DISTRIBUTED ENGINEERING TEAMS AND THEIR ORGANIZATIONAL ASPECTS

Carlos Acosta, Efrén Moreno

Universidad de las Américas Puebla, México

Abstract: In the present, the trend of local engineering team work to become global and the trend of developing products in a distributed fashion are of great interest for the industry. The organizational aspects of doing distributed engineering are presented in both trends. Two aspects that are fundamental in the organization of distributed work are the cultural and the technological ones. This paper deals mainly with those aspects and presents some advising on how to overcome the challenges when organizing distributed teams for international engineering projects.

Keywords: Distributed work, Distributed engineering, Team work, Global manufacturing, Controlling remote collaboration.

1. INTRODUCTION

The concept of "distributed engineering" is analogous to "doing geographically dispersed engineering work". In this new engineering trend more aspects and new methodologies for solving its challenges are involved. Those aspects must be taken into account for preparing the next generation of engineers who will be dealing with the globalization effects and handling the difficulties of working at distance to develop products worldwide accepted.

This paper consists on a presentation of the most relevant aspects and/or problems involved within a process of distributed work (taken from previous experiences or projects) and recommendations based on up-to-date theory. The concepts presented here were inspired by direct participation in the Dojyo project, whose main objective was the intercultural learning and the gain of experience in simultaneous group work looking to overcome the challenges of internationalization and globalization. This project was funded by the Japanese Ministry of Education. The core idea, was to establish virtual learning environments, in which students from different countries and cultures conjoin via the internet to work on a specific task of common relevance and academic and educational interest. The team met twice during a period of one year; the first meeting to clarify the conditions of cooperation, establish a team spirit, and develop a common vision of the Dojyo; the second one to jointly discuss, optimize and present the results. Ten students were chosen to participate. The whole team was arranged by professors and students from TUM, University of Siegen, University of Magdeburg, Tokyo Institute of Technology, Tsukuba University, Universidad de las Américas, Puebla (UDLA) and Stanford University.

The development of a Computer Supported Cooperative Sports Device (CSCS) was chosen as the task.. Into more detail, the task meant the development of (a) input/output devices which require physical activities in a challenging way (force, balance, coordination) and (b) a game or an animated setting which allows the cooperation and/or competition between different players via the internet. Being a distributed team was not an easy task because it was impossible to stay together in the same geographical place for long time. One of the main problems to solve in order to be able to work at distance was communication. Germany, United

States, Mexico and Japan are completely dispersed countries in the globe; far from each other.

Some other engineering schools are addressing the problems faced by distributed engineering teams, for instance, the University of Michigan (2005) is offering a Global Product Development course. In this course academic participation in global classroom interactions teaches students to understand and benefit from the multicultural environment that globalization introduces. Mechanical and industrial engineering, industrial design and business MBA´s students from University of Michigan, University of Oxford, Technical University of Berlin and Seoul National University participate in a case-study format of instruction and cooperate to develop and build a global product.

2. OBJECTIVES

To present the organizational aspects involved on doing internationally distributed engineering work. To list the problems of distributed engineering and to suggest alternative solutions. To introduce a process for organizing distributed teams.

3. BACKGROUND

3.1 Reflexive innovation.

Reflexive innovation attempts to redefine the general goals and assumptions of traditional innovation. (Ito, Moritz, Ruth; 2003). Some assumptions that have been reconsidered are: the difficulty to plan for innovation, innovation needs the joint work of different disciplines, knowledge, experience and cultural backgrounds, innovation needs to be adaptive to the product, and the local and the global cannot any longer be separated, local niches are disappearing and cannot be protected against global influences. Local decisions have to reflect on global implications. The globalization of production and markets and the worldwide webs of communication enforce the tempo and the risks of technological innovation. A new coordination mechanism is wanted to avoid the disadvantages and to combine the advantages of markets and organizations. Networks seem to have this reflexive capacity. They are based on negotiation and trust relations. Strategic networks among corporations nowadays are initiated to start joint ventures in highly uncertain fields and at the same time to compete in the conventional fields (Rammert 2000). Innovation is becoming an integrated networking process on which different actors work to fulfill requirements and simultaneously take into account ecological, social, economical, technological and cultural goals. These actors will be part of an innovation community therefore, in order to get a good performance, aspects like communication, cooperation, knowledge, skills and experience should be reinforced.

3.2 Shared mental models and coordination in distributed teams.

Teams and individuals that work simultaneously on large-scale projects require a great coordination to get high quality products on time. This often involves collaboration from more that one location and makes coordination more difficult to accomplish. Espinosa (2002) proposes two ways of managing the difficulties of coordination: (a) teams coordinating explicitly by the use of programming mechanisms or by communication, and (b) teams coordinating implicitly through team cognition mechanisms, which are based on shared knowledge among team members.

3.3 Concurrent engineering and global manufacturing

Concurrent engineering relates to distributed work in the need to have good means of communication and the awareness of the coordination factor. Concurrent engineering embodies team values of cooperation, trust, and sharing (CERG 2004). This can be achieved through teams on which every participant of the product life cycle is involved into the product development process. Global manufacturing premises relate to distributed work in a way that they involve international work, distance communication, technology exchange and cultural adaptation. Models of global enterprises (Acosta, Leon, Villalobos 2004) should be studied to learn from their approaches applicable to distributed engineering.

4. ORGANIZATIONAL ASPECTS AND CHALLENGES OF DISTRIBUTED ENGINEERING TEAMS

Distributed work is the coordinated activities of work teams whose members are geographically dispersed. The challenges of working in a distributed team include all of the challenges of a team that works together at one location, plus the added variables of distance, time and environment. Table 1 shows some advantages and disadvantages of distributed teams from the managers' point of view and from the team members' point of view. To select and construct a work team is not an easy task and depends on the needs of the product to be developed. It is important to take into account aspects like: what fields (professions) should be included? What ethnic and culture backgrounds shall people have? What degree of expertise is required? How big the team will be? Which tasks will each of them be developing? Then a variety of challenging arises: the geographic distance among members, the way team members

Table 1. Advantages and disadvantages of a distributed team (Haywood, 1998)

Managers (adv.)	**Team members (adv.)**
• Access to a grater and less expensive labor pool • Reduced office space • Greater utilization of employees • Round-the-clock work • Greater access to technical experts	• Increased independence, less micro management • Larger pools of jobs to choose from • Greater flexibility • Opportunity for travel
Managers (dis.)	**Team members (dis.)**
• Team building • Cultural issues • Cost and complexity of technology • Process and workflow	• Communication • Technical support • Recognition • Inclusion vs. isolation • Management resistance

communicate, the organization in a distributed team, the leadership, the planning of work, the work-cycle synchronicity and the appropriate management of human, social and cultural aspects.

One important aspect of distributed teams is the philosophy of the team. This is a strong platform on which all the activities of the team as well as the way of working is based. The philosophy of the team may be taken from an already existing way of thinking or may be formulated by common agreement and idea contributions from all the members of a team. Building a distributed team is not an easy task. In a team there will always be task interdependence, shared responsibilities, shared processes, relationships and trust (Haywood, 1998). When building a virtual team, it is necessary to think of the infrastructure (technology, software, hardware, etc). Besides of building a team, one should take into account the problem of predicting if a person will be effective in a distributed team fashion and the cost of projects, cost of technology, cost of development processes, cost of human resources and so on.

Once a distributed team is conformed the issue of belongingness-to-a-team becomes relevant. The need of belongingness is stronger when distance is present; there is no direct physical contact, there is no face-to-face communication, there is no watching of daily real context and it becomes harder for team members to get along with the others. Face-to-face meetings are always necessary while working at distance to build and keep strong relationships among team members. The cultural aspect relates in that the best way to reach other cultures and learn from them is to have a direct contact with them and face-to-face meetings make this possible having foreign team members to get in touch with the culture from others.

Proximity refers to the physical distance among people measured in units such as meters, miles or inches. Some interesting conclusions stated by Kiesler and Cummings (2002) about the effects of proximity are: it can be stated that being proximate is beneficial for attention purposes and causes an impact. A very close distance might go from being beneficial to disturbing. A face-to-face interaction develops and maintains group culture, authority and norms; it is healthy for cooperation and group identity. Sharing social settings shows two aspects: influences the likelihood of establishing a shared territory but also the tendency to establish local territories may interfere with coworkers. Proximity always promotes having spontaneous communication. In Fig. 1 one notices how time intervals of communicating diminish as the distance among people increases. Social and background proximity is important as well. Diversity in skill or technical background does not always boost performance in groups, but management often believes that a mix of expertise increases creativity and know-how devoted to the task. However to integrate this diverse expertise, the group must resolve differences in opinion, perspective and expectations. Certainly groups are less likely to try when they begin as strangers or with a strong sense of social distance. Communication problems are generally due to factors like the verbal communication style of every member, the distance interaction technologies, the level of familiarity with electronic communication devices, time available, time difference and others (Moreno, 2004).

An important aspect of distributed engineering is CAD. What CAD tools (software applications and hardware platforms) are available? Is there a common data-interchange format? What tools are available for documentation? Acosta et al (1998) (2002) studied the case of four automotive companies working together in a global environment to design, assemble, test and produce a power train for a vehicle. They investigated the problem of CAD data exchange among these companies (use of different platforms) and its consequences. Acosta concludes that CAD incompatibility needs to be addressed from the early stages of project formulation.

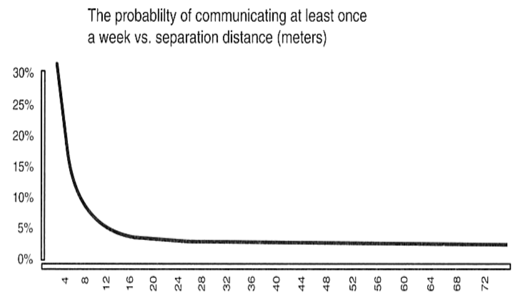

Fig.1. Distance and communication (Haywood,1998).

Other two aspects of the problematic of distributed collaborative engineering are the elaboration of conceptual designs and the elaboration of prototypes. Regarding the first, there are many activities that engineering teams can make separately, but conceptual designs are part of the innovation process and the best way to accomplish good results is working face-to-face on this task, getting all team members together to take every necessary decision. One problem experienced in the Dojyo project was that the selection of a final concept for the product was too fast so the team could not achieve a very clear idea of the solution at the end of the first face-to-face meeting; that leaded to a series of conflicts later on (Acosta, Moreno, Moritz 2004). The operating of mechanical devices can often not be preconceived intellectually. An engineering team needs to use different types of prototypes as early as possible. Teams should decide, depending on their needs, either to build local prototypes (several prototypes located at strategic places or to develop prototypes in one place only that would be under the supervision of one group or individual. Here the need to develop virtual prototypes is highlighted. In the worldwide product development process one technique that has been used among engineers over the past years is to work following the sun or around the clock to gain time instead of loosing it (e.g., from the east to the west). This technique works pretty well for the optimization process and teams can gain valuable hours.

Meil and Heidling (2005) investigated on the new competency requirements in distributed work. Among several new competencies they point out that in the technical dimension what is changing is the additional requirement for system integration and monitoring the contribution from partners. This means that there is a need for a much broader range of technical know-how outside of individual specialties, or even company boundaries. In a typical car development process, different stages in a project phase correspond to diverse demands for competency needs. For instance, in an exploratory phase (concept development) a group is engaged in a process of discovery and thus openness, flexibility and creativity are called for, whereas in the series development phase the project requires the competencies to be goal oriented, to see the complete picture, to think in process terms and to obtain high performance levels from project participants under extreme time pressure

Other researches (Nof 2004) on e-work and e-manufacturing identify common challenges that emerge with collaboration: (1) greater work complexity, (2) more limitations caused by increasing interdependence, (3) issues of integrity and trust, (4) greater need for coordination, cooperation and synchronization, (5) communication challenges and failures, (6) problems of mismatch, e.g. inconsistent versions, cultural differences, etc, (7) new users training requirements and associated costs.

5. OVERCOMING THE CHALLENGES OF DISTRIBUTED ENGINEERING

Four steps are proposed for distributed engineering effective teamwork: (1) establishing a shared vision, leadership and organization, (2) creating infrastructure (technology, policies and processes), (3) selecting and assessing members, and (4) making the work experience rewarding and enjoyable. Leaders shall be no longer just traditional but relational and cultural. When handling with relationships leaders should communicate descriptively and objectively rather than evaluative; they should focus on working together for solving problems; they should be spontaneous, open and honest and encourage members to initiate communication. Absolutely necessary for building strong relationships among team members are face-to-face meetings. A face-to-face meeting gets members of a team into the right path of the innovation process and carries them to achieve the desired results. The first encounter decides the strength of the links among people, the success of their common work and the degree of compatibility and confidence. The main objective of the first face-to-face meeting is to build the team, to make the right connections and to assure constant involvement Regarding the cultural aspect it is impossible to get deep into a culture different from the own in just a little time but what can be done is to get at least some cultural clues, some pick-points about the cultures one will be dealing with (Acosta, Sanchez, Rodriguez, Leon 2003). This helps to strength the relationships between individuals and to understand better the working style of one another. In other words one becomes more open and comprehensive with the others.

Referring to the organizational aspects of distributed engineering some statements can be made as suggestions. First, leaders are in charge of the team building process but more important they must provide team members with the knowledge about distributed work. They must dedicate some time to teach them and train them on this new work methodology. In few words leaders are responsible for creating a consciousness of what distance work means and what being part of a distributed team means. Second, learning how to apply information technologies helps to have: better connectivity and ability for farther, global reach; enhanced communication and coordination; acceleration of knowledge sharing and distribution; better interactivity; flexibility, customization-ability; higher velocity of work tasks and exchanges; and reduced communication costs. Third, face-to-face meetings are the best moment to organize distributed work, to plan the activities at distance and to establish working guidelines. Fourth, having two members or more in the same region diminishes the feeling of being isolated and stimulates the work activity. Fifth, when working at distance members need a controlled freedom so they do not feel completely alone but they feel supported at any time and they feel the presence of leadership, authority and guidance.

With respect to communication infrastructure there is adequate technology that assists distributed teams to get in touch, have meetings and discussions. Some examples are e-mail, videoconferencing, audio-conferencing, shared software, computer supported cooperative work (CSCW), chat tools, distributed computing, and groupware. Haywood (1998) writes down four principles for effectively distant communication: team members´ standards for availability and acknowledgement are defined and respected, team members replace lost context in their communication, team members regularly use synchronous communication, senders take responsibility for prioritizing communication.

In the Dojyo project, the BSCW tool was created by the Siegen group. The BSCW works mainly as a virtual place where all team members can store files and information of any kind so the other members can check this information online always updated and at time they want. The information can be modified, enriched and shared among all members. It includes also a chat tool. Another important communication means was TANEWS. After TANEWS started to be issued team members became more active therefore the necessity of filing all the emerging information and work increased. Other advantages of BSCW are: there is no restriction on memory space, there is a calendar included inside, managing information and files are better organized, members can acknowledge when others are participating. BSCW provides information on which user has read the files. Email can also be handled from there. See Fig. 2. An interesting tool already developed to support groups in analyzing problem situations and in performing group decision-making tasks is the interactive computer-based Group Decision Support System (GDSS). In this system a decision room is set up in which each participant has a computer workstation, a leader coordinates de meeting, the room has a display screen that all the participants can view, computers are networked, client/server architecture is used and specialized software is available to all participants. This type of decision support tool can be a good supplement to the BCSW.

For predicting if a person would be effective in a distributed team project managers might want to make use of two suggested models: the alignment model and the maturity model (Haywood, 1998). Basically the alignment model is designed to help managers to select and assess people who will allow them to get the best performance with the current infrastructure. It represents every member as "blocks" consisting of four areas: goals, processes,

Fig. 2. Organizing the Dojyo in BSCW.

tools and skills; in order to fit individuals into a team they must be "aligned" in all four areas. The maturity model is about the "effectiveness" of a virtual team to meet project and organizational objectives on time and on budget. The team goes through four levels each one having specific characteristics and problems. To answer the question: how do I know team members work?, leaders are encouraged to develop some evaluation methods for instance, developing practical performance metrics, refining estimating skills of both leaders and members, increasing visibility, and defining project reporting mechanisms.

The need of belongingness on a team can be solved by means of creating the team's own identity and supplying the fun factor. The team should try fun activities that are culturally accepted, that means they contain a combination of cultural backgrounds but up to certain degree that no specific culture will trespass the boundary of the others and shade them or affect them. In other words it is an activity mediated by an equilibrated management of each culture involved (Acosta, Moreno, Moritz 2004). In the first face to face meeting of the Dojyo project several acrobatics exercises were successfully performed by the team members to demonstrate the meanings of trust, confidence, team-work and so on.

Following is a recommendation of the elements treated on this paper and how they can be accommodated systematically for doing appropriate distributed engineering. I) Setting the project, (a) Planning which includes: deciding what engineering fields will be involved, producing invitational information, getting international contacts, and setting the member selection procedure. (b) Organizing project activities. (c) Looking for sponsorship. (d) Introducing the core idea. II) Building the team, (a) Procedure: to have a shared vision, to get the infrastructure, to select and train members, to make work a nice experience. (b) Effectiveness prediction: to use the maturity and alignment models (c) Belongingness creation: to build relationships and trust, to create own identity, to have fun. III) Organizing the work, (a) To distribute and localize the work (partition and localization), (b) To establish local leadership and remote leaderships. (c) To keep a constant feedback of the activities realized. (d) To reward the work done. IV) Doing distributed work. (a) Proximity: to interact face-to-face, to have a shared social setting, to communicate spontaneously. (b) Synchronicity: to configure the communication frame, to get a work schedule, to adjust time. (b) Culture: to try mutual understanding, to acquire general knowledge, to share cultural learning. In the areas of product development and engineering an experience-based approach to work has to be strengthened to carry out distributed project work. Therefore two instruments are needed to promote the type of competency development called for in distributed work: experience-based learning methods and an appropriate organizational framework.

6. CONCLUSIONS

Working on a distributed engineering style is becoming more necessary on a globalized world. Global enterprises are adopting this way of work for many advantageous reasons. The new models for engineering innovations claim for methodologies to make this type of work an effective one. Reflexive innovation, shared mental models, concurrent engineering and global manufacturing developments study the problematic and give some solutions.

Several problems of distributed engineering have been identified and discussed such as: team selection, work philosophy, cost, team building, team belongingness, team organization, communications, CAD compatibility, conceptual design generation, use of prototypes and cultures understanding. From theory and past experiences the authors proposed several ways to overcome the many challenges of distributed engineering and suggested several steps to the establishment of successful distributed engineering teams. For the time being still very little research work has been done on this exciting arena. More methodologies are needed and will be developed as distributed engineering becomes more important for global enterprises progress. Several universities are embracing this type of work experimenting with distributed engineering courses.

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