December 4, 2008

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Abstract: *National and global collaboration in research and development (R&D) is becoming increasingly important in creating the knowledge that makes research and business more competitive. Multinational enterprises have increased their research and development (R&D) investment in different countries. These multiple sites encourage the development of more ideas, due to the varied international backgrounds in global networks and the knowledge spillovers. In order to secure the viability of business processes, services and products R&D teams need to access and retrieve information from as many sources as possible. From the other perspective virtual teams are important mechanisms for organizations seeking to control scarce resources across geographic and other boundaries. Moreover, virtual collaboration has become vital for most organizations. This is particularly true in the context of designing new product and innovative services. In this paper all the major aspects of Virtual R&D team are discussed in technical terms. The paper provides an integral definition and characterization of virtual R&D team. The potential value that is created by virtual R&D teams for new product development is explored. Lastly, pertinent practical guidelines and implications are presented.*

Keywords: *Virtual R&D team, NPD, Technology management*

1. INTRODUCTION

Organizations are currently facing important and unprecedented challenges in an ever dynamic, constantly changing and complex production and service environments (Rezgui, 2007). Major trends like globalization and high demand fluctuation force companies and supply chains to innovate new business models to gain and maintain competitive position. Networking, outsourcing, and information and communication technology are considered as general tools and means to respond to these challenges (Salmela and Lukka, 2004). As a consequence multinational companies (MNCs) have increased their research and development (R&D) investment in foreign countries (Reger, 2004). While the outsourcing activities of the MNCs was highly concentrated in a handful of economies by the beginning of the global R&D wave, the offshore outsourced R&D activities have now been more geographically dispersed and this indeed reveals the increasing value of networking and networks. These multiple sites encourage the development of more ideas, due to the varied international backgrounds in global networks (Richtne´r and Rognes, 2008).

In different point of view innovation is becoming the most important key issue for company's success in the 21st century (Sorli et al., 2006). From the other direction to surviving in the highly competitive industry, requires strategies to collaborate with or compete with suitable firms within a network in the new product development (NPD) process (Chen et al., 2008b). Firms rely heavily on NPD to successfully compete in increasingly competitive global markets (Batallas and Yassine, 2004). Sooner or later, many firms expand their geographic scope from domestic to foreign markets (Lu and Beamish, 2006). Information technology is providing the necessary infrastructure to support the development of new organization forms. Virtual teams represent one such organizational form, one that could revolutionize the

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workplace and provide organizations with unprecedented level of flexibility and responsiveness (Powell et al., 2004). Moreover, information and communication technology (ICT) has brought about significant changes in organizations and produced important benefits, including in the areas of marketing and innovation. Many works highlight the importance of ICT as a key element in integrating marketing into the NPD process (Vilaseca-Requena et al., 2007). The employed Web Services technology, although very popular nowadays but is still not mature enough, so dealing with it can bring new findings (Witczynski, 2006). Considering that R&D teams need to access and retrieve information from as many sources as possible (Kafouros et al., 2008), virtual teams are important mechanisms for organizations seeking to leverage scarce resources across geographic and other boundaries (Munkvold and Zigurs, 2007).

The global competition and accelerated improvements in basic technologies demand organizations to develop the ability to manage efficient NPD projects that yield innovative products (Naveh, 2005). It's a widely held belief that the modern work-world is dominated by computer-mediated communication, and this communication is the bread and butter of virtual teams (Walvoord et al., 2008). In other words advancement in technologies and management skills has blurred firm boundaries (Acs and Preston, 1997). Now global communication is so much accessible, faster and cheaper, therefore managing and integrating geographically dispersed R&D has considerably increased (Hegde and Hicks, 2008). Many R&D projects already addressed the issue of computer supported source networks (Witczynski, 2006).

Virtual teams are important mechanisms for organizations seeking to leverage scarce resources across geographic and other boundaries. Moreover, virtual collaboration has become vital for most organizations. This is particularly true in the context of designing new product and service innovation. Such collaboration often involves a network of partners located around the world. However at the R&D project level, dealing with such distributed teams challenges both managers and specialists. Virtual teams reduce time-to-market of newly developed products and based on some evidence collaboration between geographically distributed engineers at manufacturer and supplier sites yields some mutual benefits in terms of better quality, reduced costs and a reduction in the time-to-market between 20 to 50 percent for a new product (May and Carter, 2001). The decision to use a virtual team is often a necessity and not a choice; being 'virtual' is in most cases not a strategy but an operational reality (Gassmann and Von Zedtwitz, 2003b). Despite numerous studies on the topic in recent years (virtual, distributed, dispersed, R&D teams and new product development), there still appears the need to a vision what a virtual R&D team is and how it can impact the NPD process. In addition, elaborate and comprehensive responses should be given to questions such as "do R&D project managers have specific knowledge of collaboration in a distributed environment" and, "are the collaborative processes still fraught with difficulties?"

In this paper the following aspects - comprehensive definition of virtual R&D teams, new product development and virtuality, how virtual R&D team impact on NPD processes, trends in organizing virtual R&D teams, benefit of application of virtual teams, R&D collaboration in distributed environment, and web base collaborative system are discussed in technical terms. Details of pertinent practical guidelines and implications for R&D managers are also discussed.

2. COMPREHENSIVE DEFINITION OF VIRTUAL R&D TEAMS

In this era popularity for virtual team structures in organizations is growing (Walvoord et al., 2008). Martins et al. (2004) in a major review of the literature on virtual teams, conclude that 'with rare exceptions all organizational teams are virtual to some extent.' Organizations have moved away from working with people who are in our visual proximity to working with people around the globe (Johnson et al., 2001). Although virtual teamwork is a current topic in the literature on global organizations but it has been problematic to define what is 'virtual' means across multiple institutional contexts (Chudoba et al., 2005). The concept of a "team" has been described as a small number of people with complementary skills who are equally committed to a common purpose, goals, and working approach for which they hold themselves mutually accountable (Zenun et al., 2007). It's a widely accepted fact that innovation is better achieved by working in team (Sorli et al., 2006). A majority of successful innovations is developed through the collective efforts of individuals in new product development teams (Akgun et al., 2006). All teams and virtual teams in particular, must develop mechanisms for sharing knowledge, experiences, and insights critical for accomplishing their missions (Rosen et al., 2007).

It is a worth mentioning that virtual teams are often formed to overcome geographical or temporal separations (Cascio and Shurygailo, 2003). Virtual teams work across boundaries of time and space by

utilizing modern computer-driven technologies. The term "virtual team" is used to cover a wide range of activities and forms of technology-supported working (Anderson et al., 2007). Virtual teams are comprised of members who are located in more than one physical location. This team trait has fostered extensive use of a variety of forms of computer-mediated communication that enable geographically dispersed members to coordinate their individual efforts and inputs (Peters and Manz, 2007). (Gassmann and Von Zedtwitz, 2003b) defined "virtual team as a group of people and sub-teams who interact through interdependent tasks guided by common purpose and work across links strengthened by information, communication, and transport technologies." Another definition suggests that virtual teams are distributed work teams whose members are geographically dispersed and coordinate their work predominantly with electronic information and communication technologies (e-mail, video-conferencing, telephone, etc.) (Hertel et al., 2005). Different authors have identified diverse areas. From the perspective of Leenders et al. (Leenders et al., 2003) virtual teams are groups of individuals collaborating in the execution of a specific project while geographically and often temporally distributed, possibly anywhere within (and beyond) their parent organizations. Lurey and Raisinghani (2001) defined virtual teams - groups of people who work together although they are often dispersed across space, time, and/or organizational boundaries. Amongst the different definitions of a virtual team the following concept from which the term employed in this paper is one of the most widely accepted definition: (Powell et al., 2004), ''virtual teams are as groups of geographically, organizationally and/or time dispersed workers brought together by information technologies to accomplish one or more organization tasks ''

3. NEW PRODUCT DEVELOPMENT AND VIRTUALITY

The life cycle of a product/good becomes shorter every year. Today, leading-edge firms can exploit global asset configurations to customize the existing products and services. They also have the ability to combine their resources with an expanding knowledge-base to create a continuous stream of new products and services (Miles et al., 2000). With the needs to respond quickly to dynamic customer demands, increasing complexity of product design and rapidly changing technologies, the selection of the right set of NPD is critical to a company's long-term success (Chen et al., 2008b). Also, combination of factors such as ever changing market needs and expectations, rough competition and emerging technologies among others, challenges being faced by industrial companies to continuously increase the rate of new products to the market to fulfill all these requirements (Sorli et al., 2006). The ultimate objective of all NPD teams is to acquire superior marketplace through new products (Akgun et al., 2006). In light of the above, product innovation is the central force in securing a firm's competitive advantage in international markets (Jeong, 2003). Therefore, NPD is vital and needs to be developed both innovatively and steadily (Chen et al., 2008b).

A multidisciplinary approach is needed to be successful in launching new products and managing daily operations (Flores, 2006). In NPD context, teams developing new products in turbulent environments encounter quick depreciation of technology and market knowledge due to rapidly changing customer needs, wants, and desires, and technological know-how (Akgun et al., 2007). ICT helps establish and maintain communication and cooperative relationships both inside and outside the organization, and makes NPD processes quicker, simpler and less risky (Vilaseca-Requena et al., 2007). ICT enhance the NPD process by shortening distances and saving on costs and time (Vilaseca-Requena et al., 2007). Various studies also offered a large number of examples from the industry showing how firms have been using the Internet in their NPD activities (Ozer, 2004, Ozer, 2000). Moreover, several recent studies specifically dealt with the development of new technologies and their impact on new product development among globally dispersed teams (McDonough et al., 2001, Jeong, 2003). Competitive strategies are forcing companies to deploy their NPD resources globally and, thus making collocated NPD teams prohibitively expensive and logistically difficult to manage (Susman et al., 2003).

4. VIRTUAL R&D TEAMS AND ITS ROLE IN NPD PROCESSES

Research and Development (R&D) is an ongoing process for forward thinking technology-based companies. Development of existing products is advisable to keep ahead of advances that competitors may be making. Further, when a potential customer approach is received, a firm outlining its requirements for a product - R&D may be required to fulfill the request (Lawson et al., 2006). The market success of a company's R&D effort is strongly related to the uniqueness of the product, both in terms of product functions and technical aspects (Kratzer et al., 2005). In order to ensure future sustainability, large amount of money is spent all over the world on R&D (Precup

et al., 2006). However, research is an investment, not an expense. Investment in commercial R&D usually involves a high-risk with a deferred payoff. Return can also be tremendously attractive (Boer, 2005). From different point of views the increasing complexity and inter-disciplinary nature of the R&D process in turn has increased the cost of research. Therefore, research become less attractive without partners to share the cost (Howells et al., 2003).

The success of R&D initiative is generally conditional on the stipulation of soft technology and the interdisciplinary character of the R&D itself (Zhouying, 2005). Technological change is a highly dynamic process that may quickly relocate to take advantage of optimum conditions for growth (Hegde and Hicks, 2008). Firms which appear to be approaching the technology frontier need to engage in new product development, backed up by R&D into new materials, processes and future product design options (Hobday et al., 2004). In a virtual R&D group, contributing information may substitute for more traditional methods of establishing credibility, usually found in co-located groups (Ahuja et al., 2003). The use of virtual teams, especially in international R&D projects, seems well established and is likely to continue (Gassmann and Von Zedtwitz, 2003b). For most R&D teams, being virtual is a matter of degree (Leenders et al., 2003). (May and Carter, 2001) in their case study of virtual team working in the European automotive industry have shown that enhanced communication and collaboration between geographically distributed engineers at automotive manufacturers and suppliers sites make them acquiring benefits in terms of quality, reduced costs and a reduction in the time-to-market (between 20% to 50%) for a new product.

5. TRENDS IN ORGANIZING VIRTUAL R&D TEAMS

Based on interviews with 204 R&D directors and project managers in 37 technology-intensive multinational companies, Gassmann and Von Zedtwitz (2003b) have concluded five trends in organizing virtual R&D teams, which are:

1. Continued internationalization of R&D will further increase the importance of and reliance on virtual R&D teams.
2. Virtual R&D teams will better integrate talent in newly industrialized countries.
3. Advances in information and communication technologies will further enhance the functionality of virtual teams.
4. Relative costs of running virtual R&D projects will decrease due to learning curve effects.
5. Highly decentralized virtual R&D teams will gain importance in open system architectures such as internet-based applications.

In next section some benefaction of applying virtual teams will be described.

6. BENEFIT OF APPLYING VIRTUAL TEAMS

Anderson et al.(2007) suggest that the effective use of communication, especially during the early stages of the team's development, plays an equally important role in gaining and maintaining trust. Virtual teams often face tight schedules and a need to start quickly and perform instantly (Munkvold and Zigurs, 2007). Virtual team may allow people to collaborate more productivity at a distance, but the tripe to coffee corner or across the hallway to a trusted colleague is still the most reliable and effective way to review and revise a new idea (Gassmann and Von Zedtwitz, 2003a). Virtual teams reduce time-to-market (May and Carter, 2001). Lead time or time to market has been generally admitted to be one of the most important keys for success in manufacturing companies (Sorli et al., 2006). In a virtual team environment, collaborative and competitive conflicting behavior is positively linked with performance (Powell et al., 2004), depending on the degree of virtuality (Ortiz de Guinea et al., 2005) and team connectivity (Ortiz de Guinea et al., 2005). As drawbacks, virtual teams are particularly vulnerable to mistrust, communication break downs, conflicts, and power struggles (Rosen et al., 2007). Table 1and Table 2 summarize some of the main advantages and disadvantages associated with virtual teaming respectively.

Table 2: Main advantages associated with virtual teaming

Advantages	**Reference**
Reduce relocation time and costs, reduced travel costs, Greater productivity, shorter development times.	(McDonough et al., 2001, Rice et al., 2007, Bergiel et al., 2008, Cascio, 2000, Fuller et al., 2006)
Virtual teams reduce time-to-market	(May and Carter, 2001)
Ability to digitally or electronically unite experts in highly specialized fields working at great distances from each other	(Rosen et al., 2007)

Table 3: (Continued) Main advantages associated with virtual teaming

Advantages	**Reference**
Have more effective R&D continuation decisions, Most effective in making decisions.	(Cummings and Teng, 2003) (Hossain and Wigand, 2004)
Ability to tap selectively into center of excellence, using the best talent regardless of location, Allow organizations to access the most qualified individuals for a particular job regardless of their location.	(Criscuolo, 2005, Cascio, 2000, Samarah et al., 2007, Fuller et al., 2006) (Gassmann and Von Zedtwitz, 2003b) (Munkvold and Zigurs, 2007) (Hunsaker and Hunsaker, 2008)
Greater degree of freedom to individuals involved with the development project	(Ojasalo, 2008)
Producing better outcomes and attract better employees	(Martins et al., 2004, Rice et al., 2007)
Provide flexible working hours for the employees, Create and disperse improved business processes across organizations, Do a good job and finish their work on time. Resistance to change is reduced. Faster response times to tasks Provide a vehicle for global collaboration and coordination of R&D-related activities.	(Johnson et al., 2001), (Paul et al., 2005), (Precup et al., 2006)
Useful for projects that require cross-functional or cross boundary skilled inputs	(Lee-Kelley and Sankey, 2008)
Teams can be organized whether or not members are in proximity to one another	(Kratzer et al., 2005, Cascio, 2000)
Provide organizations with unprecedented level of flexibility and responsiveness	(Powell et al., 2004, Hunsaker and Hunsaker, 2008)
Perform their work without concern of space or time constraints	(Lurey and Raisinghani, 2001)
Self-assessed performance.	Chudoba et al. (2005)
Optimize the contributions of individual members toward the completion of business tasks and organizational goal	(Samarah et al., 2007)
reduce the pollution	(Johnson et al., 2001)
The ratio of virtual R&D member publications exceeded from co-located publications	(Ahuja et al., 2003)
Extent of informal exchange of information is minimal	(Pawar and Sharifi, 1997)
Can manage the development and commercialization tasks quite well	(Chesbrough and Teece, 2002)
Facilitate transnational innovation processes	(Gassmann and Von Zedtwitz, 2003b)
Respond quickly to changing business environments	(Bergiel et al., 2008)
Improve communication and coordination, and encourage the mutual sharing of inter-organizational resources and competencies	(Chen et al., 2008b)
Team communications and work reports are available online to facilitate swift responses to the demands of a global market. Employees can be assigned to multiple, concurrent teams; dynamic team membership allows people to move from one project to another. Employees can more easily accommodate both personal and professional lives.	(Cascio, 2000)
Cultivating and managing creativity	(Leenders et al., 2003)
Sharing knowledge, experiences	(Rosen et al., 2007, Zakaria et al., 2004)
Improve the detail and precision of design activities	(Vaccaro et al., 2008)
Enable organizations to respond faster to increased competition	(Hunsaker and Hunsaker, 2008, Pauleen, 2003)
Better team outcomes (quality, productivity, and satisfaction)	(Gaudes et al., 2007 , Ortiz de Guinea et al., 2005)
Higher team effectiveness and efficiency	(May and Carter, 2001, Shachaf and Hara, 2005)

Table 4: Main limitations associated with virtual teaming

Disadvantages	**references**
Sometimes requires complex technological applications	(Bergiel et al., 2008)
Face-to-Face collaboration (FFC) appears to be better developing a conceptual understanding of a problem (lack of physical interaction)	(Rice et al., 2007) (Cascio, 2000, Hossain and Wigand, 2004)
Decrease monitoring and control of activities	(Pawar and Sharifi, 1997)
Everything to be reinforced in a much more structured, formal process	(Lurey and Raisinghani, 2001).
Vulnerable to mistrust, communication break downs, conflicts, and power struggles	(Rosen et al., 2007, Cascio, 2000)
Challenges of project management are more related to the distance between team members than to their cultural or language differences	(Sanchez et al., 2006).
Challenges of determining the appropriate task technology fit	(Qureshi and Vogel, 2001, Ocker and Fjermestad, 2008)
Challenges of managing conflict	(Hinds and Mortensen, 2005, Ocker and Fjermestad, 2008)
Cultural and functional diversity in virtual teams lead to differences in the members' thought processes. Develop trust among the members are challenging	(Paul et al., 2005)

7. R&D COLLABORATION IN DISTRIBUTED ENVIRONMENT FOR NPD

According to (McDonough et al., 2001), as many organizations will become increasingly more reliant on geographically dispersed NPD teams in the future, companies will need to understand how to implement most effectively and utilize collaborative technology. Firms need to collaborate with internal and external parties in order to enhance the success of their new products (Ozer, 2004). Networked R&D management emphasizes both internal and external collaboration. Internal coordination and collaboration are still major challenges, and cross-functional in-company collaboration must be enhanced e.g. by setting up cross-functional teams, external R&D networks include collaboration and integration with complementary corporations between suppliers and customers and research centers (Blomqvist et al., 2004).

Grinmaldi and Tunzelmann (2002) classified the benefits of R&D collaboration from companies point of view and extracted the following benefits:

- Economies of scale and scope in research;
- Reducing product or process costs;
- Acceleration of R&D;
- Avoidance of unnecessary duplication of research;
- Risk management;
- Financial support for costly projects or equipment;
- Technology and knowledge transfer, assimilation and utilization;
- Hiring university students or graduates;
- Enhancement of reputation.

External-technology integration plays an important role in many operational activities, including new product and new process development (Stock and Tatikonda, 2004). New ideas and insights do not occur in isolation; they are the result of collaboration. Indeed, the innovation era ultimately unfolds knowledge, which is its key asset. Collaboration may render meta-capability by which knowledge will be exploited to drive innovation and reap its economic benefits (Miles et al., 2000). The use of collaborative technology that requires users to categorize the comments they received from others result in increased information processing, which in turn lead to better decisions and more satisfied participants (McNamara et al., 2008). In high-risk areas, R&D collaboration can be used as an optional strategy for risk sharing, where small stakes in risky projects enable further investments and it is a major motivators for R&D collaboration (Blomqvist et al., 2004). Narula (2004) by analyzing European technology firms found that both large and small firms have similar motives to undertake inter-firm R&D collaboration. The primary motivation for both groups of firms was not considered to be the reduction of risks or costs, but the reduction of innovation time span, and the access to complementary technologies.

8. WEB BASE COLLABORATION

The internet, incorporating computers and multimedia, has provided tremendous potential for remote integration and collaboration in business and manufacturing applications (Lan et al., 2004). But it is still hard to allocate funding and to design infrastructures and software to support virtual team working (Chudoba et al., 2005). Despite computers' widespread use for personal applications, very few programming frameworks exist for creating synchronous collaborative applications (Holloway and Julien, 2006). A web-based collaborative product design platform enables authorized users in geographically dispersed locations to have access to the company's product data such as product drawing files stored at designated servers and carry out product design work simultaneously and collaboratively in any operating systems (Zhan et al., 2003).

9. MCDM APLICATION

Since new product development can be evaluated according to different aspects and criteria, the multi-criteria decision making (MCDM) approach is suitable to evaluate the virtual R&D teams for new product development. The idea behind MCDM methods is not to find the optimal solution but rather try to determine what solution is the closest to be "optimal" in regards of several criteria or among existing solutions. To collect the data, decision-makers need to express their preferences by evaluating the alternatives and weighting the criteria (Ondrus et al., 2007). Future research after building a MCDM model and the hierarchy and network relevance systems (by DEMATEL AHP/ANP/fuzzy integral) should able to evaluate processes. An empirical case which is ongoing would help for achieving aspired/desired level of virtuality in new product development.

10. PRACTICAL GUIDELINES AND IMPLICATIONS FOR R&D MANAGERS

The globalization and the new waves of global trends in economy, services and business along with advances in telecommunications technology have paved the way for the formation and the performance of virtual teams. This paper provides a brief dealing with virtual R&D team, based upon recent articles, mostly on virtual teams. Despite the enormous benefaction of virtual R&D team and virtual publicity, the application of virtual team to upgrade and enhance business operation by most enterprises, is still at its infancy. While reviewing the previous study, it is believed that the advantages of working on the basis of virtual teams far outweigh the disadvantages.

Virtual teams bring about knowledge spillovers within enterprises bridging time and place, reduce time-to-market, reduced travel costs, ability to tap selectively into center of excellence, using the best talent regardless of location, greater degree of freedom to individuals, shorter development times, provide flexible hours for the employees the working hours, creates and disperses improved business processes across organizations, provide organizations with unprecedented level of flexibility and responsiveness, reduce resistance to change, reduce the pollution, optimize the contributions of individual members toward the completion of business tasks and organizational goal, facilitate transnational innovation processes, respond quickly to changing business environments, employees can be assigned to multiple, concurrent teams and finally higher team effectiveness and efficiency. Therefore the decision on setting up virtual teams is not a choice but a requirement. Global market requires short product development times.

Future research need to allocate funding to design infrastructures and software to support virtual R&D team working especially web base collaboration system. New business environment, attached with demands by workers for more flexibility and empowerment, suggest that dealing with virtual R&D team. Scope and challenges of managing a virtual R&D team will rise in the days to come. New ways of communicating and interacting among team members in virtual environments will necessitate being developed and implemented.

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