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Virtual Teams: What are their Characteristics, and Impact on Team Performance?*

SZE-SZE WONG AND RICHARD M. BURTON
The Fuqua School of Business, Duke University, Durham, NC 27708-0120, USA
email: ssw2@mail.duke.edu
email: rmb2@mail.duke.edu

Abstract

To date, efforts to understand virtual teaming have been largely anecdotal and atheoretical. Therefore, drawing from the extant research in the groups domain, we attempt to ground the definition of a virtual team in well-established group-level constructs, and design a simulation study to investigate the impact of different virtual team characteristics on team performance. Essentially, we argue that the virtual team is defined by three key characteristics—the virtual team context, the virtual team composition, and the virtual team structure. Using the VDT computational discrete event simulation model as our experimental platform, we simulated different virtual team models, and examined their impact on various team performance dimensions. We found that virtual team characteristics have different effects on different aspects of team performance. The virtual context team had a lower rework volume but higher coordination volume and longer project duration than the virtual composition team. Interestingly, we also found that the virtual structure team performed better than the software development team baseline model in all aspects of team performance. Based on these results, we proposed strategies to improve performance in different types of virtual team. Specifically, we propose (1) increasing the ease of communication and availability of routines in the virtual context team; (2) clarifying role expectations and fostering a team culture in the virtual composition team; and (3) implementing a lateral structure in the virtual team. Our results also suggest that firms should consider situational demands, specifically tolerance for errors and coordination volume, when considering the design of virtual teams.

Keywords: virtual team, virtual organization, simulation, coordination, rework, project duration, team performance

1. Introduction

As organizations expand their operations geographically and engage in inter-organizational alliances, the formation of work teams with physically distributed, culturally and organizationally diverse members is going to be increasingly prevalent. Enabled by advances in network technologies, many organizations are exploiting the diverse capabilities of individuals by teaming up employees from different countries and cultures as well as individuals from other organizations. This has led to an evolving new form of organization, frequently described as the virtual organization (Nohria and Berkley, 1994; Hedberg et al., 1997).

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In recent years, the virtual organization has received wide currency in the popular business press (Davidow and Malone, 1992; McDonald, 1995; Barner, 1996). Even though there has yet to appear a definitive characterization of virtual organization, it is often described as one that is internally structured with virtual teams that are assembled and dissembled according to need (Lipnack and Stamps, 1997), with those teams consisting of inter-organizational participants and culturally diverse employees who are physically distributed (Clancy, 1994). Specifically, this new form of organizing has been purported to increase flexibility (McDonald, 1995; Simons, 1995) by exploiting the diverse capabilities of individuals who are geographically dispersed, functionally differentiated and from different organizations (Ancona and Caldwell, 1987; Bleecker, 1994; Mowshowitz, 1994).

Despite the prevalence of virtual organizing, it has not been subjected to systematic investigation and analysis. Therefore, questions of how to best structure a virtual organization, when communication has to transcend the boundaries of space, time and culture, for efficient and effective coordination remain unanswered. Even though there has been research in the area of computer-mediated communication in organizational settings (Kraut, 1987; Fritz et al., 1998), virtual organizing is more than understanding the pattern of communication using information technology such as electronic mail. The added complexity of virtual organizing is that it frequently involves participants who are from different organizations and cultures, a context where team history is low, and a tendency to work on non-routine tasks. Understanding how each virtual characteristic impacts coordination is likely to aid us in suggesting strategies to manage virtual structures.

In this paper, we are focusing on the characteristics of a virtual team, and their consequent impact on team performance. A virtual team is, in fact, a form of virtual organization. A virtual organization is frequently viewed as a collection of virtual teams (McDonald, 1995; Simons, 1995; Lipnack and Stamps, 1997). Therefore, aside from the absence of consideration of inter-team coordination and integration issues, the virtual team is *a* simplified form of the virtual organization. Essentially, the complexities of the virtual organization apply equally to the virtual team. Like the virtual organization, the virtual team is characterized by members who are physically dispersed, and are both culturally and organizationally differentiated. Like the virtual organization, the virtual team is characterized by communication structures with lateral, but typically weak relationships. As such, the lessons learnt about virtual organizing in the team will be applicable to virtual organizing in the larger context.

In the remainder of this paper, we develop and explore models of the virtual team in order to explicate the influence of different virtual characteristics on team performance. First, we develop the concept of virtual team, particularly, the characteristics the team has to manifest to qualify as “virtual”. Second, we describe an actual virtual team, which performs software implementation in banks, and then specify that team as a baseline model in the Virtual Design Team (VDT) computational discrete event simulation model. Third, we manipulate the parameters in the simulation software to represent the different characteristics of team virtuality, and conduct experiments on the different virtual models. Finally, we discuss the results of and propositions from the variational simulation experiments, and review the general implications of our study.

2. Background

Lipnack and Stamps (1997) described a virtual team as a group of people who interact through interdependent tasks guided by common purpose that works across space, time and organizational boundaries with links strengthened by webs of communication technologies. Frequently, virtual teams are project-focused—they are formed when the need arises and disbanded when the task is complete (Grenier and Metes, 1995; Simons, 1995). Such dynamic teaming implies that there is not only little prior team history, but also that the work roles and responsibilities of team members change with each virtual team they are assigned to. The research on virtual organizations suggests that their structures are typically non-hierarchical and decentralized (Savage, 1996). In other words, virtual members primarily rely on lateral and informal information exchange to perform their work.

Drawing from the existing conceptualizations of the virtual team, we argue that it manifests the following characteristics: (1) a set of *culturally and organizationally differentiated* members, who are (2) grouped together *temporarily*, are (3) *physically dispersed*, (4) connected by *weak lateral ties*, and (5) engaged in performing *non-routine tasks*. However, few pure virtual teams exist today. Some teams consist of members who are geographically dispersed, but are culturally and organizationally homogeneous. Other teams may contain members who transcend cultural and organizational boundaries, but are physically co-located. Hence, whether a team is virtual maybe more in degree than in kind (DeSanctis et al., 1999). In this regard, we created three characteristics of team virtuality: (1) virtual team context; (2) virtual team composition; and (3) virtual team structure.

Virtual Team Context. One oft-cited advantage of the virtual team is that its members can be assembled quickly to exploit emerging opportunities, and then dissolved when the job is done (McDonald, 1995; Lipnack and Stamps, 1997). This continuous configuring and reconfiguring of *ad hoc* teams implies that the team members have not previously cultivated a history of collaboration. In other words, it is a 'zero-history' team. Leveraging the diverse knowledge and capabilities of people both within and outside the organization, virtual teams are formed around market opportunities that emerge. As such, the tasks and responsibilities undertaken by the virtual team members tend to be non-routine, and completed under time-pressured environments. The members of the team are also often not physically co-located (Clancy, 1994; Barner, 1996; Lipnack and Stamps, 1997). Rather, they are distributed throughout the world, connected only through an array of interactive technologies. *Therefore, we argue that the virtual team context is characterized by low team history, novel tasks, and physically distributed members.*

Virtual Team Composition. Group composition is concerned with the characteristics of the members in a group (Moreland and Levine, 1992). Based on the existing conceptualization of the virtual team, its team composition is often comprised of culturally and organizationally diverse members. With advancements in information technology and increasing formation of external alliances, more organizations are forming teams that connect participants from different countries and organizations. The knowledge and talents of these members, rich in their unique cultural and organizational perspectives, are pooled together to maximize the potential of the team to exploit market opportunities (Lipnack and Stamps, 1997). *Therefore,* *we argue that virtual team members are characterized by the heterogeneity in their cultural and organizational backgrounds*.

Virtual Team Structure. The structure of a group describes the nature and the strength of patterns of relationships among individuals in work groups (McGrath, 1984). In virtual teams, the relationships between members tend to be lateral but weak. Due to the physical dispersion and the nature of the work that virtual team members are typically engaged in, they are often connected by lateral communication ties. The lateral structure ensures efficient information flow so that members are able to coordinate their task activities, despite the physical distance between them. In Granovetter's (1973) research on the strength of weak ties, he argued that the strength of a tie depends on the combination of the amount of time, the emotional intensity, the intimacy, and the reciprocal services, which characterize the tie. We argue that the ties connecting virtual team members tend to be weak because the lack of face-to-face interactions, the span across cultural and organizational boundaries, and the lack of a history of cooperation prevent the time, the mutual confiding and the emotional support required for the formation of strong ties. The presence of weak ties will, in turn, imply that virtual team members are more likely to treat one another formally, and less likely to reciprocate requests from one another. In sum, *the relationships connecting virtual members are likely to be lateral but weak*, due to both the lack of a prior relationship, and the cultural and organizational barriers.

Depending on where a team falls on the virtuality characteristics, the coordination dynamics within the team will differ. The distributed nature of a virtual context yields communication misunderstandings due to the lack of face-to-face interaction. Existing research in modality of communication found that richer media are required when the information exchanged is ambiguous and complex (Daft and Macintosh, 1981). Communication channels with greater bandwidth provide the social information and context cues that facilitate involvement and comprehension (Sproull and Kiesler, 1986). Electronically mediated communication in virtual teams may hinder understanding and efficiency of knowledge transfer, especially when information is equivocal. In addition, the lack of physical co-location prevents the opportunities of chance encounters and informal discussion, which are often valuable to the development of relationships and coordinated activities (Kraut and Streeter, 1995).

A virtual team composition is also likely to run into coordination problems because of team heterogeneity. Even though advocates in the group diversity literature have argued that diversity is an asset, yielding groups with flexibility, improved group performance, and innovative behaviors (Wiersema and Bantel, 1992; Fernandez, 1993), there is research evidence that group diversity results in greater group conflict, lower group cohesion and lower psychological attachment (O'Reilly et al., 1989; Tsui et al., 1992). In a related vein, the member heterogeneity in culture and organizational affiliations in virtual teams can not only lead to higher group conflict, but also greater difficulties in achieving coordinated behaviors.

The direction of the impact of the virtual team structure on coordination is less clear. The horizontally differentiated ties may improve speed of communication, but the weak ties may hinder mutual confidence and reciprocity (Granovetter, 1973; Krackhardt, 1992). Even though weak ties play an important role in the diffusion of information, strong ties "have greater motivation to be of assistance and are typically more easily available" (Granovetter, 1982: 113). Therefore, the weak ties connecting virtual team members may disrupt coordination when team members are less motivated to help, or respond to information requests from other members.

Coordination dynamics are further complicated when the different virtual characteristics overlap on one another. For instance, a team that is only virtual on the context characteristic (e.g. the formation of a team comprising of plant managers from the firm's operations in the US, Europe and Asia, for the purpose of transferring best practices) will have different coordination problems and bottlenecks from a team that is only virtual on the team members' characteristics dimension (e.g. when the firm brings in external consultants to work with a racially diverse internal group on improving cycle time in its production plant). The former is likely to experience coordination problems arising from delays and misunderstandings due to the lack of face-to-face interaction, while the latter's coordination mishaps are likely to be attributed to conflicts caused by racial and organizational differences. By comparing the performance results and tradeoffs of different virtual aspects of a team, we hope to draw inferences of how those virtual characteristics impact coordination and communication within the team. Equipped with this understanding, we aim to propose strategies for designing virtual teams.

3. Modeling an Actual Virtual Team

In order to approximate reality as closely as possible, we created a baseline simulation model from the actual workflow of a real-life software project team. We deliberately chose a software design team as the setting because such teams rely on the collective skills of their members and their efforts to coordinate with one another to build the software program. Social processes of communication and coordination are central in software development because the scope of the project typically requires the collective efforts of team members. Therefore, such a setting is ideal for explicating how software team members work together in virtual teams. We interviewed an experienced systems analyst to specify the team structure (the hierarchy within the team, the tasks allocated to each member, how each member allocates his time to his different responsibilities, etc.) and workflow (the type of tasks, the interdependencies between tasks, etc.). He was involved in a project team to customize and install a banking software system that processes commercial and corporate loan accounts for a bank.

Figure 1 displays the baseline model: the team structure and workflow of the banking software project. The design and programming tasks in this team are divided into four separate modules—fee processing, interest processing, online design and other batch design. Members of the team are allocated to each of the four modules, each module being a distinct part of the overall product that must be integrated seamlessly together at the end. Therefore, even though each module may be a distinct segments, they have to be tightly integrated into one overall system. Hence, interdependencies are tightly coupled, and team members have to work closely with one another. This represents a typical organizational design for software design projects, especially in the development of commercial software products, which can involve more than one million lines of code.

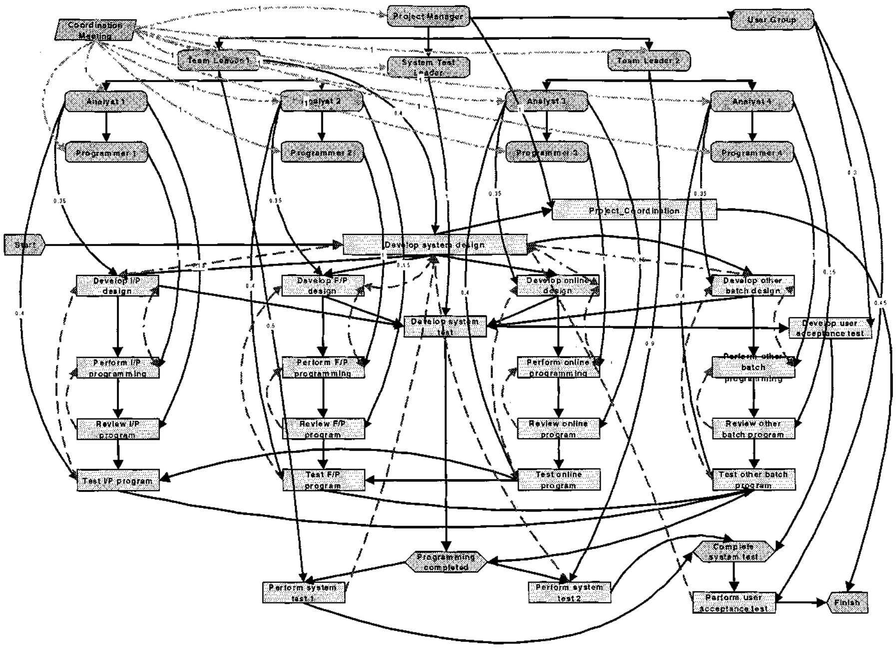


Figure 1. Workflow of the baseline simulation model (software project team).

There are 13 actors in this model—one project manager, two team leaders, four system analysts, four programmers, one system test leader and a user group (depicted as one actor in this model). The project manager oversees the coordination of the entire project and is responsible for the delivery of the system. Two team leaders are responsible for the overall design of the customization of the software and the review of the programming work of the team. They are each in charge of two pairs of system analyst and programmer, who are allocated responsibility for one of the four modules. For instance, analyst 1 and programmer 1 are responsible for the programming of the interest-processing module, while analyst 3 and programmer 3 are responsible for the programming of the online design module. Each analyst has to design the detailed customization of his module and supervise the programming that is performed by the programmer. After the module is completed, the system analyst has to test the program to ensure that it is working. During testing, any errors detected will be routed back to the analyst for diagnosis, and then the programmer for rework. After the rework, the system is re-tested. Before this testing stage, the development of each module will progress fairly independent of one another. But in the system testing stage, coordination is complicated by the precedence relationships among the four modules. For instance, the testing of other batch program can proceed only when the testing of online, fee-processing and interest-processing have taken place. After the separate testing of each module, all the modules are combined to form the integrated software system. Now, the integrated product has to be tested as an overall system. A system test leader designs the overall system test, which is executed on the integrated product by the two team leaders.

Once the system test is completed, the user group performs a user acceptance test. If the system passes the criteria of the user group, the system is deemed ready for live conversion. The team will then be disbanded.

3.1. Virtual Team Simulation Model

We used the commercial software version of the VDT computational discrete event simulation model—VITÉ—developed by the researchers at the Center for Integrated Facility Engineering at Stanford University, to simulate our virtual team models. The main premise of this simulation model is that organizations are information-processing and communication structures, and their behavior has been validated extensively for internal consistency and external validity (Levitt et al., 1994; Jin and Levitt, 1996). The inputs to the simulation model include the task structure and its interdependencies, and the descriptions of the actors in the team, while the output is a prediction of the processing time, coordination volume, and rework volume.

According to Burton and Obel (1995), computational models can be used to address research questions in organizations, as long as a balance of the research question, the experimental design and the computational model is achieved. A balanced design results in a valid computational model that is effectively appropriate to the research intent. For our present research purpose, which is to examine the implications of virtual team characteristics on performance, the VDT model represents an appropriate experimental laboratory. By manipulating the work activity, communication and actor characteristic parameters in the model, we are able to create simple computational models that meet the requirements of our virtual team characteristics, and thus, address our research question in this paper.

Specifically, we created the virtual context by varying the functional error rate of the team, the degree of team experience, the level of noise in the team, frequency of team meetings and frequency of information exchange between members. The virtual team composition is modeled by manipulating the project error rate of the team and the degree of formality in information exchange between members. Finally, virtual team structure is created by varying the degree of centralization in the team and the tendency of team members to reciprocate information requests.

Table 1 displays the simulation parameters that are used to represent the different virtual characteristics. We argue that the level of distraction is high, the frequency of team meetings is low, and the frequency of information exchange between members is high in the virtual context because of the geographical barriers. The formation of virtual teams according to need also implies that team experience will be low. The functional error rate, that is the likelihood for an actor to make an error while working on his tasks, also tends to be higher in virtual contexts because of his engagement in non-routine tasks. The heterogeneity in the virtual team composition suggests lower cohesion and greater conflict, which implies that members are more likely to treat each other at greater social distance and more likely to run into misunderstandings. As such, we increased the project error rate (likelihood of rework in activities that are dependent on the driver activity) and formalization in communications to represent the virtual team composition. The lateral relationships and weak ties in a virtual team structure are modeled by decreasing the level of centralization within the team and

Table 1. Principal parameters of the simulation model and features of the virtual team they represent.

In a virtual team	In the model
Context	Parameters that characterize virtual context
Physical dispersion	High noise
	Low face-to-face meeting frequency
	High levels of information exchange
Temporary team	Low team history
Non-routine tasks	High functional error rate
Team composition	Parameters that characterize virtual team members
Diversity (culturally and organizationally)	High project error rate
	High levels of formalization
Team structure	Parameters that characterize virtual team relationships
Lateral relationships	Low levels of centralization
Weak relationships	Less likelihood of responsiveness in information exchange

lowering the likelihood that team members will reciprocate information requests from other members.

We will focus here on three dimensions of team performance: days-to-completion, rework volume, and coordination volume. The primary purpose is to examine how team performance is affected by different characteristics of virtuality in the team. Does team performance decrease monotonically with additive increases in virtuality or are performance tradeoffs involved with different virtuality characteristics? To pursue this objective, we simulated team models with different aspects of virtuality and compared their results with one another.

4. The Experiment: The Effects of Virtuality of Performance

We first simulated a baseline team model that is absent of all three characteristics of virtuality. Based on the workflow, task interdependencies, and number of man-hours involved, the estimated days-to-completion for the critical path model[1] is 516 days. The simulated days-to-completion of the baseline model is 562 days. While the total work volume is 402 days, the rework volume is 55 days and the coordination volume is 32 days.

Next, we simulated a team model that contains all three characteristics of virtuality—virtual team context, composition and structure. Not surprisingly, the simulated days-to-completion, rework volume, and coordination volume escalated upwards. The days-to-completion increased to 740 days, representing an increase in 178 days over the baseline model (32 percent increase). At the same time, rework volume increased to 253 days (360 percent increase), and coordination volume increased to 103 days (222 percent increase). The basic result is that a combination of all three characteristics of virtuality compounds coordination problems by creating bottlenecks from distance and communication problems arising from cultural differences and weak ties.

Table 2. A comparison of different characteristics of virtuality on team performance.

Days	Baseline	Maximum virtuality	Virtual context	Virtual team composition	Virtual team structure
CPM[a] duration	516	516	516	516	516
Simulated duration	562	740	690	663	553
Rework volume	55	253	168	192	45
Coordination volume	32	103	123	68	22

[a]Critical path model.

In order to isolate the nature of the coordination problems caused by different characteristics of virtuality, we simulated 3 team models, each manifesting one aspect of virtuality. Table 2 and figure 2 show the simulated results of the 3 team models, as well as the baseline model and the model with maximum virtuality as bases of comparison. As reflected in the findings, the escalation of coordination difficulty did not inhere in all aspects of virtuality.

Interestingly, the model that is virtual only in structure has not only the fastest simulated days-to-completion (553 days), but also the lowest rework (45 days) and coordination (22 days) volume. It is unexpected that the virtual team structure, with horizontally differentiated but weak ties, performed better on all three performance dimensions than the baseline model. Even though we expected the lateral relationships to improve information sharing, and thus result in better performance, we expected the weak ties to exert a detrimental effect on

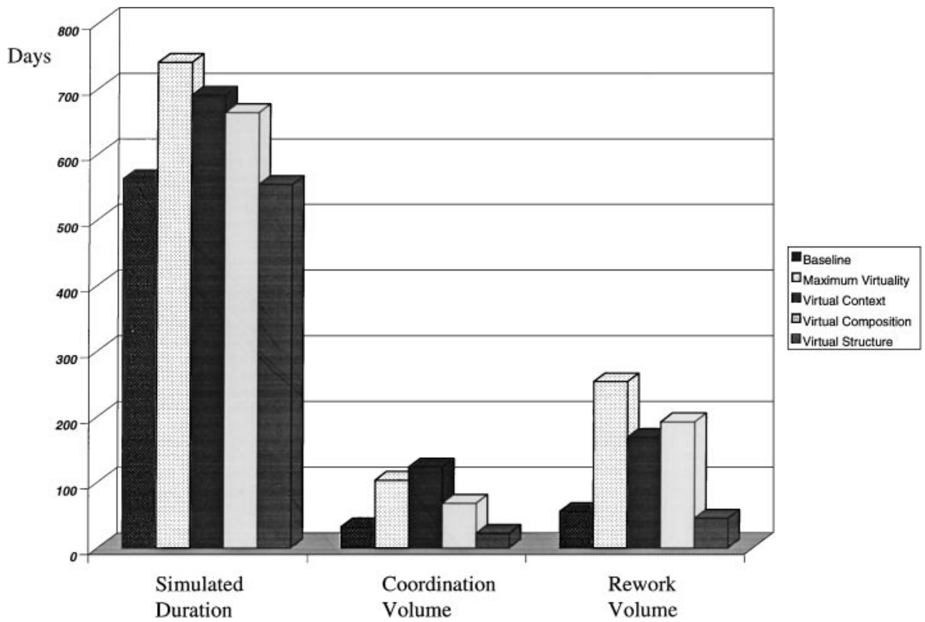


Figure 2. Comparison of baseline model with the virtual team characteristics.

team performance. Did the lateral relationships mask the negative impact of weak ties? In order to explicate the independent effect of each type of ties on team performance, we simulated two additional models—one with solely weak ties, and another with solely lateral ties. Results indicate that a team with weak ties requires 563 days to complete their tasks, and coordination and rework volume of 33 and 55 days respectively. A team with lateral ties takes only 552 days to complete the work, with a coordination volume of 20 days and a rework volume of 43 days. Recall that a virtual team structure (i.e. a lateral structure combined with weak ties) encounters 553 days-to-completion, 22 days of coordination and 45 days of rework. Therefore, when weak ties are added to a lateral structure, days-to-completion increased by one day, and both coordination and rework volume increased by 2 days. Clearly, the weak ties counteract the *positive* impact of the lateral structure, but their negative effects are, surprisingly, minor.

Compared to the team model with maximum virtuality, the model that is virtual only in team context has lower simulated days-to-completion (690 days) and rework volume (168 days). But its coordination volume (123 days) is higher. The team that is only virtual in composition also has a lower simulated days-to-completion (663 days), rework volume (192 days), and coordination volume (68 days). With the exception of the team that is virtual only in structure, there is no clear performance advantage between a team that is only virtual in terms of context and a team that is only virtual in terms of composition. The former is advantageous in terms of relatively lower rework volume, but the latter is more efficient in terms of faster days-to-completion and coordination volume. Therefore, the findings indicate that different characteristics of virtuality have different effects on different aspects of team performance. In addition, the pattern of findings suggests that there may be interactions between the different characteristics of virtuality. The team that manifests all three characteristics of virtuality experiences lower coordination volume than the team that is virtual only in context. When this finding is juxtaposed with the higher performance of the team that is only virtual in structure, it points to the possibility of positive synergistic effects between the different aspects of virtuality.

Therefore, in the next section, we examined the interactive effects of different combinations of virtuality in teams.

4.1. *Interactive Effects of Virtuality*

In order to explicate the potential synergistic effects, we simulated 3 different team models, each with different pairs of virtuality characteristics. Table 3 displays the simulation results, and figure 3 shows the comparison between the different combinations of team virtuality on simulated duration, coordination volume and rework volume. As reflected in figure 3, when teams with only virtual context or virtual team composition are each combined with virtual group structure, the simulated days-to-completion, rework volume, and coordination volume dropped. When the virtual structure is imposed on the virtual team context, the simulated duration decreased to 645 days, the coordination volume dropped to 61 days, and the rework volume lowered to 107 days. Similarly, when the virtual structure is combined with the virtual team composition, the simulated duration declined to 650 days, the coordination volume decreased to 45 days, and the rework volume reduced to 175 days. In contrast,

Table 3. An analysis of the interactive effects between different characteristics of virtuality.

Days	Virtual context and structure	Virtual composition and structure	Virtual context and composition	Virtual context	Virtual composition	Virtual structure
CPM duration	516	516	516	516	516	516
Simulated duration	645	650	793	690	663	553
Rework volume	107	175	352	168	192	45
Coordination volume	61	45	202	123	68	22

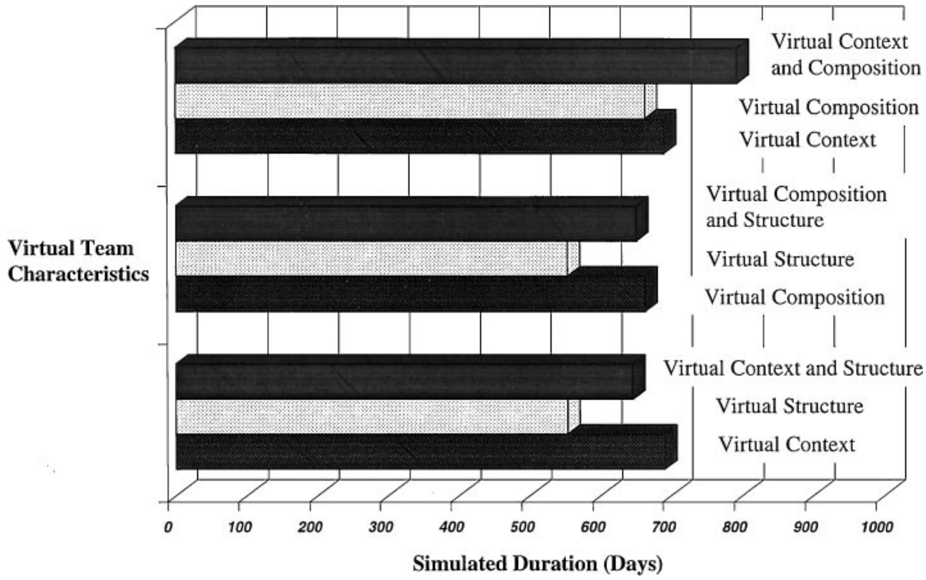
when virtual context is combined with virtual composition, there is a dramatic increase in all aspects of the team performance indicators.

Clearly, the findings suggest that the virtual team structure maybe effective in overcoming some of the coordination and communication problems caused by virtual team context or virtual team composition. Even though lateral ties are often perceived to increase communication and facilitate coordination, it is surprising that the weak ties can improve coordination as well. This finding appears to be in contradiction to existing beliefs, which posit that strong ties are essential to fostering a cooperative culture in virtual settings (Handy, 1995; Jarvenpaa and Leidner, 2000).

However, there is a possibility that the high performance of the team with only virtual team structure is situation-specific. In other words, the relatively low number of task interdependencies between members responsible for different modules in our simulated model may have attenuated the negative impact of weak ties on team coordination difficulties. Therefore, we randomly increased the number of task interdependencies between all the team members, so that the need for information exchange is increased. As the basic structure of the workflow is changed, the estimated days-to-completion for this critical path model is changed to 586 days. The simulated duration is 642 days. This represents an increase of 10% over its critical path model, which is comparable with the 7% increase of our original virtual structure model. Surprisingly, even though simulated duration increased, rework volume (42 days) and coordination volume (21 days) decreased. Thus, the lower task interdependencies may have attenuated the negative impact of weak ties on days-to-completion, but it also appears to attenuate the positive impact of weak ties on coordination and rework.

5. Discussion

Based on these findings, it is clear that despite the potential flexibility and productivity gains from a virtual team, the coordination within the team to reap these gains is fraught with difficulties. In situations of maximum virtuality, that is when a team manifests all three team virtual characteristics, days-to-completion, coordination and rework volumes escalate. Further, as we expected, different characteristics of virtuality led to different effects on team performance. Specifically, there are performance tradeoffs between teams with different types of virtuality, suggesting that different patterns of interaction and communication seem to inhere in different aspects of virtuality.



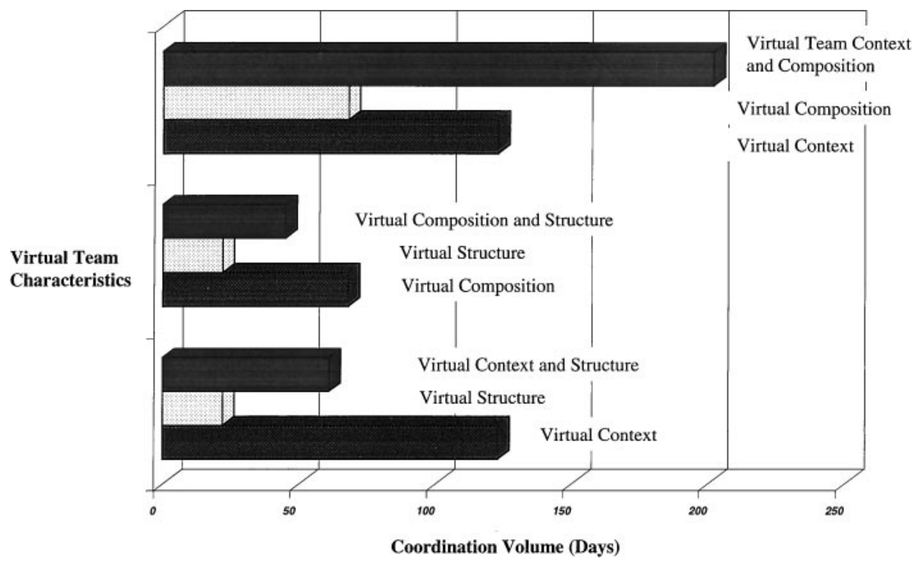


Figure 3. Comparison of interactive effects of virtual characteristics on simulation duration, coordination volume and rework volume.

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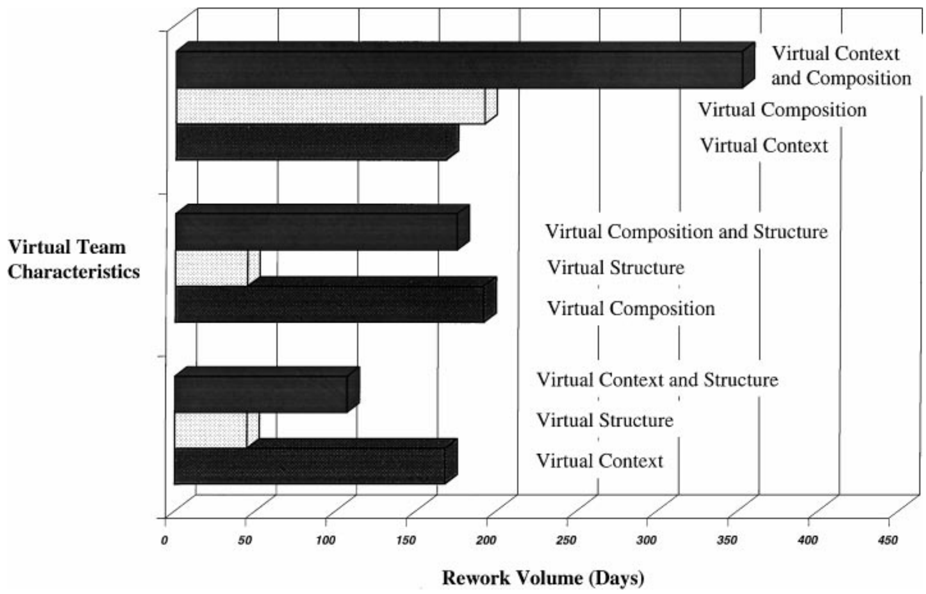

Figure 3. (*Continued*).

When a team is virtual solely in terms of virtual context, it experiences a lower rework volume, but higher simulated duration and coordination volume than a team that is virtual only in team composition. This implies that when software development team members are from a “zero-history” team, physically distributed and involved in designing novel software, they are not as likely to run into problems of errors that require rework, but are more likely to take more time coordinating with one another and completing the project, than a team that is composed of heterogeneous team members. The greater time expended in coordinating and in completing the project can be attributed to the use of electronically mediated communication in physically distributed teams (DeSanctis and Monge, 2000), the lack of prior working experience which hampers the ability of the team to coordinate efficiently, and the greater information requirements demanded in non-routine tasks (Gladstein, 1984; Jehn, 1995).

In contrast, a software team that is virtual in terms of team member heterogeneity is more likely to encounter problems of rework. This implies that when a software design team is comprised of members from different cultures and organizations, there is likely to be a higher incidence of errors (e.g. programming errors) and thus, a higher rework volume. When team members are culturally and organizationally diverse, their belief structures and work norms may diverge due to their different working experiences and culture (Hambrick and Mason, 1984; Walsh, 1988). Confusion and misunderstandings are thus more likely to emerge between team members because information that is communicated from one’s unique perspective may not be understandable from another’s cultural and/or organizational perspective. As such, errors are more likely to ensue, thus resulting in greater rework volume.

The comparatively lower performance of a virtual context team on coordination and simulated duration suggests that its performance may be improved by increasing the *ease of communication and availability of routines* within the team. Ease of communication can be enhanced through the use of rich and collaborative electronic communication tools. For instance, videoconferencing and electronic bulletin boards can be used to augment email in computer-mediated communication. In addition, geographically dispersed members can be brought together at critical junctures (e.g. at scheduled milestones) so that face-to-face interaction can be used to thrash out problems and/or decide key future plans. Availability of routines improves virtual team performance by guiding coordination in a "zero-history" team. By routines, we do not mean rigid standard operating procedures imposed by the organization (March and Simon, 1958), but a well-understood set of behavioral repertoires jointly created by the team members (Gersick, 1988). Given that the team task is novel and members have no history of working together, the virtual team must create a shared way of operating early in its inception. Examples of enabling routines include the use of milestones, information-processing procedures, and problem-solving processes.

In the case of a team that is only virtual in terms of team composition, its high rework volume signals the need for social processes that improve mutual understanding and reduce the incidence of errors. This may be achieved by *clarifying the role expectations of team members and the cultivation of a common team culture* that de-emphasize their differences arising from diverse cultural and organizational backgrounds. Clarification of role expectations builds shared understanding of one another's responsibilities and hence, alleviates uncertainties resulting from having heterogeneous teammates. In order to minimize any misunderstandings or confusion arising from differing perspectives, it is important that the team creates expectations of how team members—both as an individual and as a group—should behave. In a related vein, the cultivation of a team culture minimizes cultural and/or organizational differences by creating a common frame of reference—shared knowledge about the group, group members, and work (Levine and Moreland, 1991). Specifically, we suggest that a virtual composition team should engage in team-building exercises (Lipnack and Stamps, 1997) such as mutual self-disclosure and exchange of social messages in the early stages of the team inception.

Proposition 1. *The greater the ease of communication and the availability of routines, the higher the performance of virtual teams with low team history, and whose members are physically distributed and engaged in novel tasks.*

Proposition 2. *The greater the clarification of role expectations and the cultivation of a common team culture, the higher the performance of virtual teams with culturally and organizationally diverse members.*

What is most surprising in our simulation results is the favorable performance of the software team that has a virtual structure (lateral and weak ties). Its performance even exceeded the baseline model. Even though we expected the lateral ties to improve communication and coordination between the software designers and programmers, we expected the weak ties to exert a negative impact on their effectiveness and efficiency. Although the negative effect of virtual team structure on simulated duration is reinforced when the interdependencies between members are increased, its positive effects on rework and coordination increased! We suspected that the positive effects of the lateral communication might have masked the negative effects of the weak ties. Therefore, we simulated two additional models, one with only lateral ties and one with only weak ties. Not surprisingly, weak ties exerted a negative impact on the lateral structure, but their negative effects were minor. This finding is counter to the widespread belief that strong ties are required for collaborative performance in socially impoverished contexts (Handy, 1995; Cohen, 1997).

In particular, it questions the past emphasis that has been placed on the need for strong relationships in virtual teams. Moreover, our simulation findings indicated that when the virtual team structure is juxtaposed with virtual context and virtual team composition, it improved each team's performance. These findings appear to suggest that even when team members are physically distributed or heterogeneous, the weak relationships between members do not adversely impact team performance. The heavy emphasis on strong ties may have overestimated the importance of reciprocity and underestimated the risk of information overload.

A high tendency on the part of each team member to reciprocate information requests and engage in information sharing behaviors may result in dense information flow, which can lead to increasing equivocality and potential for conflict (Nohria and Berkley, 1994). Strong norms for reciprocation can not only rapidly create a burdensome obligation to respond to all information requests, but also potentially create a huge volume of electronic information that has to be tracked and filtered. When this happens, teams have to expend considerable time and resources to managing the electronic information created (Hiltz and Turoff, 1985). In retrospect, we examined the plausibility of information overload by comparing the communication required of team members when they are only virtual in context, and when they are virtual in both context and structure. The simulation findings show that the communication required is 560.9 messages when the team is only virtual in context, and decreases to 460.7 messages when the virtual structure is added to the team. The high communication required in the virtual context team appears to support our claim that information overload is present, which is alleviated when the virtual structure is overlaid on the team.

In addition, to the extent that team members fail to discriminate between creditable and superfluous information requests, each member runs into information overload, which results in stress, confusion and reduced performance (O'Reilly, 1980; Rader, 1981). Therefore, the benefit of weak ties may lie in their influence on team members to be more discriminatory. For instance, in Constant, Sproull and Kiesler's (1999) study on the practice of strangers, they found that weak ties between distant employees resulted in greater provision of useful advice. Despite weak ties between virtual team members, ensuring lateral communication maybe adequate for effective virtual team performance. In terms of implementation, lateral communication in both virtual context and composition teams can be increased by reducing the hierarchical structure of the team (i.e. a flatter reporting structure and/or decentralization) and the use of enabling computer-mediated communication tools.

Proposition 3a. *Lateral communication among weakly tied team members with low team history, and who are physically distributed and performing novel tasks, improves team performance.*

Proposition 3b. *Lateral communication among weakly tied members who are culturally and organizationally diverse, improves team performance.*

In sum, we argue that technological factors—computer-mediated communication tools and enabling group routines—and social factors—role expectations, team culture and lateral communication—are critical to determining successful performance in virtual teams. They improve virtual team performance by providing some "structure" within which members operate. Having routines, clear expectations and team culture ensure that members can collaborate efficiently and effectively in an otherwise very loosely-coupled team. At the same time, by not imposing strict operating procedures from above and allowing routines and expectations to be jointly created by members, the virtual team retains the autonomy and flexibility, within broad limits, to proceed with its work. Threats to control, a theme pervasive in virtual settings, are also alleviated by the presence of shared expectations that reduce uncertainty and increase predictability. Coordination, a critical determinant of virtual team performance, is enhanced by increasing lateral communication and using rich electronic communication tools. To the extent that coordination in virtual teams is hampered by heterogeneous members and physical dispersion, both lateral communication and collaborative computer tools improve performance by facilitating rapid information-sharing and rich interactions.

5.1. Virtual Team Design Implications

Drawing from the performance tradeoffs between different types of virtual teams, we propose a typology for the design of virtual teams. Table 4 displays the typology. Despite the potential positive implications of virtual teams on flexibility and adaptability, there are situational constraints that firms have to consider when designing virtual teams. The two situational constraints of interest here are the team's (1) *tolerance for errors* and (2) *tolerance for coordination volume*.

Tolerance for Errors. In organizations where interdependencies are tightly coupled and maintenance of reliability is highly critical (Perrow, 1984), tolerance for errors may be extremely low. The activities to be performed are inherently risky and therefore, the capacity of the system to absorb errors is extremely low. Examples include firefighter teams, disaster

Table 4. A typology of situational considerations and virtual team design.

Tolerance for coordination volume	Tolerance for errors	
	High	Low
High	Maximum virtuality[a]	Virtual context, with a virtual structure
Low	Virtual team composition, with a virtual structure	Non-virtual team

[a]Maximum virtuality refers to a team that contains all three virtual dimensions—context, composition and structure.

management teams, and air traffic control teams. In such cases, small errors can propagate into grave consequences, and hence, risk mitigation procedures are essential to ensure the organization's survival. Under such circumstances, high reliability organizations (Roberts, 1990; La Porte and Consolini, 1991) are required to carry out its operations.

Tolerance for Coordination Volume. In other organizations, tolerance for coordination volume may be extremely low due to the nature of their tasks. For instance, in software development, the design and programming of the software is typically broken down into different modules, and allocated to different individuals in the team. Each sub-team is responsible for one module, which is later assembled into the final software product. Due to the complexity of its design and development (especially in the case of commercial software), the tolerance for coordination volume is extremely low. By segmenting its development, the interdependencies between team members are reduced, and the potential overlapping and complicated recursive interdependencies are greatly simplified. Instead of enormous time and effort spent in aligning one's programming with one another, coordination is reduced to specific and identifiable points in time. This not only results in less time spent in mutual monitoring and communicating, but also allows different sub-tasks to proceed in parallel. Therefore, in situations where the slack set aside for coordination is low, there may be a need to design a team where coordination volume is kept to a minimum.

Under conditions where tolerance for both errors and coordination volume are low, imposing maximum virtuality (that is, one that manifests all three characteristics of virtuality) may have potentially drastic consequences. To mitigate against the potential high rework volume, coordination volume and days-to-completion, a non-virtual team maybe more appropriate. For instance, in firefighter teams (Weick and Roberts, 1993), where reliability is extremely crucial and time to be spent in coordinating is low, implementing a virtual team is not advisable. In contrast, when the incidence for errors and coordination breakdowns are minor considerations but flexibility is the critical concern (e.g. consulting teams), designing a team with virtual context, members and structure maybe optimal.

But where there is high tolerance for errors but low tolerance for coordination volume, a team with virtual composition and structure is feasible. In these situations (e.g. software design), the organization can institute a lateral communication structure in its teams and exploit the diversity advantage of heterogeneous team members. The culturally and organizationally diverse team members may experience greater errors and therefore, rework (possibly due to misunderstandings) but less time is spent in coordinating with one another. When the reverse is true, that is when the situation calls for low error rates but tolerates high coordination volume, a virtual team context overlaid with a virtual structure is more suitable. In other words, where the nature of the task allows for high coordination among team members but demands high reliability (e.g. teams of doctors, nurses, radiologists and pharmacists), an organization can assemble temporary teams of physically distributed members who communicate laterally with one another.

6. Conclusion

Despite the current excitement over virtual teams, there is surprisingly a lack of systematic research in this area. We believe that one of the contributing reasons is the lack of a definitive description of the concept of "virtual". Therefore, one of the goals of this paper is to delineate the key characteristics that comprise a virtual team. In performing a literature search on virtual teams, we noticed that the current literature on virtual teams tend to be practitioner-oriented and lacking in theoretical grounding. Therefore, in conceptualizing the characteristics of the virtual team, we drew heavily on research that has been performed in the groups domain, and grounded the concept of "virtual team" in familiar group-level constructs. Specifically, the three characteristics of the virtual team that are proposed in this paper are: (1) virtual team context; (2) virtual team composition, and (3) virtual team structure. Virtual team context refers to a temporary team with physically distributed members who are engaged in novel tasks, virtual team composition refers to a team with culturally and organizationally diverse members, and virtual team structure refers to a group structure with lateral but weak ties. By building our definition of the virtual team from research in the groups literature, we hope to provide a theoretical foundation to guide future research.

A second goal of this paper is to consider how different characteristics of the virtual team influence group processes and hence, team performance. By distinguishing between the impact of each virtual characteristic on different dimensions of team performance, this paper attempts to simplify the complex interplay between the 'virtual' phenomena and team performance. Specifically, we examined the impact of virtual context, virtual composition and virtual structure on three dimensions of team performance—days-to-completion, rework volume, and coordination volume.

Through our simulation experiment, we found that there are performance tradeoffs between teams with differing virtual characteristics. Not surprisingly, a team that possesses all three virtual characteristics performed worse on all three performance dimensions, when compared to the non-virtual team. When we simulated each virtual characteristic individually, we found that there are performance tradeoffs between the characteristics. Teams with virtual context experienced greater coordination volume, but lower rework volume relative to teams with virtual composition. These results suggest that technological factors that have a greater effect on the facilitation of coordination may have a greater performance impact on virtual context teams, and social factors that are more likely to reduce the incidence of errors may have a greater performance impact on virtual composition teams. Therefore, we propose that performance in virtual context teams can be improved by increasing ease of communication and instituting appropriate routines to facilitate coordination, and performance in virtual composition teams can be improved by clarifying role expectations and fostering a common team culture to reduce the incidence of errors.

Most importantly, the strategies we propose do not dramatically transform the inherent character of virtual teams. Members remain predominantly geographically dispersed and retain the flexibility to perform their tasks but their autonomous structure is augmented by adaptive routines, clear role expectations, shared cultural knowledge about each other and their work, and rich connective technologies. In other words, the flexibility is balanced with order created by these strategies. Under such circumstances, the virtual team preserves the autonomy to react to emerging opportunities but it also has the discipline to accomplish its tasks.

The simulated findings also suggest that lateral communication is a critical determinant of virtual team performance, but strong ties may not be as significant as we have initially thought. The norms of reciprocity in strong ties may improve rates of response between team members, but they may also result in information overload and a burden on members to respond to every information request. Based on these findings, we premise that lateral communication among weakly tied team members is likely to result in higher team performance in teams with virtual context and teams with virtual composition.

Undoubtedly, there is a possibility that our findings may be particular to the specifications of our simulation model, and the algorithms of the VDT simulation software that is used in this study. Therefore, the findings and propositions in our study should be subjected to empirical validation. However, in mitigation, the algorithms of VDT have been validated extensively for internal consistency and external validity by its designers (Levitt et al., 1994) and our simulation model is modeled closely after real-life software design and development processes. In addition, to increase the robustness of our findings, we performed several additional simulation models to probe results that were surprising and unexpected.

Extrapolating from our findings of performance tradeoffs, we also propose a typology relating to the design implications of virtual teams. Specifically, we argue that the design of a virtual team is dependent on two situational requirements: (1) tolerance for errors; and (2) tolerance for coordination volume. Where there are low tolerance for both errors and coordination volume, non-virtual teams are the most appropriate. Virtual teams that manifest all three characteristics of virtuality should only be used when there are high tolerance for both errors and coordination volume. In situations that demand high reliability but tolerate high coordination volume, a virtual team context, combined with a virtual structure can be used. However, in circumstances where low coordination volume is called for but requirement for low incidence of errors is secondary, an organization can implement teams with virtual composition and virtual structure.

In sum, when organizations are considering the formation of virtual teams, they should not only pay attention to the need for a sophisticated electronic networking infrastructure, but should also be aware of the coordination complications that typically result in virtual teams. The added complexities of virtual teams are the complex interplay of task-oriented coordination behaviors and social relationships across space, time and cultural boundaries. In designing virtual teams, organizations need to take into consideration the implications of the impact of different characteristics of virtuality on team performance. In view of the increasing prevalence of virtual teams, the examination of the design of virtual teams to optimize performance represents a growing and exciting area of research. As it currently stands, there are also intriguing and unexplored research opportunities in the impact of learning in virtual teams, the development of virtual teams over time, and their influence on performance. Understanding how efficient and effective virtual teams are created and maintained will, no doubt, remain an important research inquiry. Our paper represents an initial step towards that direction.

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Note

1. Critical path model refers to predicted duration of the project, assuming that all the actors have unlimited time to perform the task activities. The predicted duration does not include time spent on rework, coordination, time waiting and idle time.

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Sze-Sze Wong is a doctoral candidate in Management at the Fuqua School of Business, Duke University. She is interested in examining collective learning processes in teams, the collective cognition and behavior that emerge as a result, and the team conditions that foster these learning processes. Her other research interests are virutual organizing and knowledge management. She is currently engaged in research on collective learning in teams, and the management of knowledge depth and breadth in organizations.

Richard M. Burton is Professor of Business Administration, The Fuqua School of Business, Duke University where he teaches and researches organizational design issues. He has served as the Program Director for the Health Services Management program and the area coordinator for Management and Organization Behavior. He joined the Duke faculty in 1970 and has been visiting Professor, Institute d'Adminstration des Enterprises, Universite d'Aix-Marseille, France and visiting Professor, Odense University, Denmark. He has a BS, MBA and DBA from the University of Illinois, Urbana.

Professor Burton's research and teaching is in organizational design and the application of computational approaches in organization theory. Recently, he completed a book with Professor Obel, Odense University, STRATEGIC ORGANIZATIONAL DIAGNOSIS AND DESIGN: DEVELOPING THEORY FOR APPLICATION, Kluwer Academic Publishers. They are the co-developers of the ORGANIZATIONAL CONSULTANT software—a knowledge based expert system for decision support in the design of organizations. Previously, he has published six books and some fifty articles and book chapters on organizational design, strategy and management science.

With Professor Obel, he is editing a new series, INFORMATION AND ORGANIZATION DESIGN FOR THE NEW CENTURY, Kluwer Academic Publishers. He serves on editorial board of various journals and was the Department Editor for MANAGEMENT SCIENCE in Organizational Analysis, Performance and Design. He consults on strategy and corporate organizational design.