Association for Information Systems
AIS Electronic Library (AISeL)

AMCIS 2002 Proceedings

Americas Conference on Information Systems (AMCIS)

December 2002

OPERATOR PERFORMANCE WITH A SAFETY-CRITICAL WIDE AREA NETWORK

Tuncay Bayrak
Western New England College

Martha Grabowski
LeMoyne College

OPERATOR PERFORMANCE WITH A SAFETY-CRITICAL WIDE AREA NETWORK

Tuncay Bayrak
Western New England College

Martha Grabowski
Rensselaer Polytechnic Institute and
LeMoyne College
grabowsk@mail.lemoyne.edu

Abstract

There has been a considerable amount of research in the area of network performance evaluation. However, little of the research focused on the evaluation of real-time safety-critical WANs. Previous research evaluated WANs in terms of their quantitative aspects using quantitative performance models such as queuing theory, simulation and statistical distributions. However, this research proposes a more comprehensive approach, incorporating technical approaches such as mathematical models, statistical models, and communication models, as well as human-oriented approaches such as business models, psychological and sociological models that address the technical, sociological and organizational needs of WANs in safety-critical large scale systems.

Research Objectives

By definition, safety-critical real-time WANs need to be high-speed, accurate, dependable, and reliable. Thus, determining appropriate performance measures and evaluation criteria for safety-critical WANs is important. Similarly, since the performance of a network also influences how human users use and interact with the network, performance evaluation of operators with safety-critical networks presents challenges in terms of defining and utilizing appropriate performance metrics.

Examples of such safety-critical wide area networks include distributed battle management systems (Mosher, 1997), intelligent transportation systems (Andrisano et al., 2000), distributed health care networks (Yamamoto et al., 2000), global oil and gas exploration and research networks (MacIntyre, 1999), and aviation traffic monitoring systems (Cheng et al., 2000).

Most large-scale networks depend on hardware, software, and human operators to function correctly. Failure of any of the network elements can bring the entire network down and in safety-critical settings, the consequences can be disastrous. A well-known example of such failure is the 1990 nationwide AT&T network failure (Kuhn, 1997). This example is not an isolated one: according to the Federal Communication Commission (FCC), network failures in the United States with impact on more than 30,000 customers happen on the order of one every two days and the mean time to repair them is on the order of five to 10 hours (Demeester, et al., 1999).

Previous work evaluated WANs in terms of their quantitative aspects using quantitative performance models such as queuing theory, simulation and statistical distributions. However, this research proposes a more comprehensive approach, incorporating technical approaches such as mathematical models, statistical models, and communication models, as well as human-oriented approaches such as business models, psychological and sociological models that address the technical, sociological and organizational needs of WANs in safety-critical large scale systems.

Theoretical Foundations

Over the years, networks have been evaluated by different disciplines from different perspectives. Mathematical models based on queuing theory, Markov analysis and using well-defined metrics such as throughput, response time, and utilization have been used in many network performance evaluations (Haverkort, 1998; Bolch, et al., 1998; Higginbottom, 1998). Other metrics utilized include network traffic performance (Adie, et al., 1998; Banerjee, et al., 1997), circuit overhead of switches (Niehaus, et al., 1997; Da Silva, et al., 1997), and equipment used and network conditions (Da Silva, et al., 1997).

Statisticians frequently use statistical distributions to evaluate communication networks as distributions allow prediction of system performance measures to a reasonable degree of accuracy (Akar, et al., 1998). Technical communication models often consider network traffic over switches, routers, bridges and repeaters (Khalil, et al., 1995). Social and organizational communication models consider networks of organizations, their patterns of behavior and communication strategies, and organizational structures (Monge, et al., 1998; Orlikowski, et al., 1995).

Large-scale system models evaluate networks in terms of two important concepts, reliability and survivability. Survivability is defined as the percentage of total traffic surviving some network failure in the worst case (Myung, et al., 1999). Reliability is a measure of the system's ability to provide deterministic and accurate delivery of information (McCabe, 1998). In other words, reliability is the likelihood that a system will remain operational (potentially despite failures) for the duration of a mission (Somani and Nittin, 1997).

In engineering and business models, WANs have been evaluated from the customer point of view, using such criteria as cost, connectivity, bandwidth/speed, data integrity, availability, reliability, and security (Hemrick, 1992). Business models consider network performance as a means of enhancing the performance of an enterprise (Yang et al., 2001) because network managers are interested in fully functional, high performance, and secure networks that provide resilient services (Rudd, 2000). High-performance enterprise networks can help an enterprise operate more efficiently and improve its competitive capability. Thus, economic aspects are always important (Yang et al., 2001).

From an organization's point of view, however, networks are seen as an investment. Jurison (1996) argues that success measures of interest to managers are those that can be measured and expressed quantitatively, especially in monetary terms, because such measures can be used for justifying information technology investments. Finally, psychological and sociological models of network performance assess optimal communication structures, improvement of decision making, the impact of communication networks on organizations and their performance, and distribution of decision making rights over the network using such metrics as the time taken to correctly solve a problem, the number of messages used for each problem, and the number of errors (Jehiel, 1999; Mackenzie, 2000).

It seems obvious that the performance of a network might influence how human users use and interact with the network. For instance, decreased network reliability may be associated with decreased user satisfaction, decreased user confidence, decreased communications over time and increased user workload. In an early network evaluation study, Zimmer (1981) argued that telecommunication networks should be evaluated from the user's point of view as well as from technical point of view, and that a user's satisfaction should be defined by means of quality parameters such as reliability, availability and the projected ability of the communication network. Nokes (1978) followed a similar route and evaluated computer communications networks with respect to user satisfaction and two important reliability metrics, the mean time between failures and the mean time to repair of interruptions. Nokes found that service interruptions and excessive response times, not surprisingly, played an important role in defining user satisfaction with a communication network. In recent work, Ingvaldsen et al., (2000) identified wide area network end-to-end delay as a significant parameter affecting users' satisfaction with applications. All of these studies suggest that decreased network reliability may have a negative impact on user confidence, which may lead to other user problems such as satisfaction, stress and fatigue.

Networks can increase collaboration among individuals in an organization, allowing employees to share their knowledge and expertise. However, if the reliability of the network is questionable, communication in an organization can be dampened as users become frustrated (Heesock et al., (1999). Network reliability is thus critical to effective communication in an organization.

Although Kanungo (1998) suggests that, in general, the higher the system usage, the higher will be the level of satisfaction with the computer system, increased use of a network may also be associated with negative effects for operators. For instance, the more frequently users utilize a network, the more operator workload increases. In some safety-critical networks, operators monitor the network, provide maintenance and 24x7 operational support. Higher system usage can also lead to problems in sustaining operator vigilance, and lead to decreased vigilance due to fatigue. Vigilance is defined as a state of readiness to detect and respond to certain small changes occurring at random time intervals in the environment (National Research Council (NCR), 1997). Parasuraman (1987) indicates that when vigilance failures in complex monitoring occur, they may result either from a vigilance decrement or from a low overall vigilance level. These findings suggest that in general, prolonged network monitoring under monotonous conditions can decrease the vigilance of human operators and his/her performance of the monitoring task. The longer an operator spends time using a network, the more he/she may experience difficulty sustaining vigilance. Human performance with a network, particularly in a monitoring task, is impacted by the tendency for vigilance to degrade within 30 minutes of task inception, which is the well-known vigilance decrement (Teichner, 1974). Nevertheless, a network operator needs to maintain his/her vigilance continuously in order to take control and corrective actions when and if the network fails. In contrast to vigilance, workload, generally referred to as mental workload, is the load associated with the mental process of the human operator, rather than (or in addition to) the operator's physical workload (NRC, 1997). An operator may have to take over when a system fails, thereby putting an operator under unexpected workload. To an operator, unexpected system failures can mean unexpected workloads. At the same time, users expect uninterrupted and high quality services in networked systems. Degradations and interruptions can be reasons that users are not satisfied with and lose confidence in networks. These findings suggest that no matter how many precautions are taken to increase reliability, networks may still fail unexpectedly, and system operators may have to be trained for such cases.

An increased number of tasks processed in a real-time network may be associated with decreased operator accuracy and decreased operator reliability. In large-scale networked systems, continuous access to data and information is crucial to make decisions on time and execute tasks that may be interest to many participants. The number of tasks executed successfully is usually a good performance measure (Ujita et al., 1995). However, the more operators focus on the number of tasks processed, the more likely it is that accuracy and reliability will be decreased. While an operator is concerned with the number of tasks performed within specified times, the accuracy of tasks may be deemed questionable. Eventually, inaccurate results can introduce significant errors in decisions made by an operator or user. These studies suggest that when an operator has to deal with an increased amount of tasks, he/she may sacrifice accuracy and reliability without even noticing. This may be due to stress, limited time available to process a task, and fatigue.

Operator performance may also be associated with WAN network reliability. To assess user performance, many studies have been undertaken. Korilis et al., (1995) focused on methodologies to improve both network and user performance. In their view, adding link capacity to a network without considering the fact that users make control decisions that optimize their individual performance measure might lead to degradation of user performance. Ujita et al., (1995) suggest that operator performance can be evaluated by an error rate. Heeseok et al., (1999) argue that while replacing standalone applications with corporate networks such as LAN or WAN enhances system reliability and flexibility, the problems with network reliability such as transaction delay, communication delays may frustrate users and may degrade user-related performance. In terms of evaluating operator performance, a variety of methods are used including real-time monitoring on the job, specially designed simulation exercises, checklists, and annual written performance appraisals (NRC, 1997). These findings suggest that in networked organizations, operators may be idle when the network is not operational; hence, network reliability and operator performance can be related.

Operator performance may also be associated with ease of use of the WAN interface. Such interfaces would also differ by levels of response required, in emergency situations, in situations requiring immediate user response, and for informational display. Eurich-Fulcer and Schofield (1995) argue that one problem with existing WANs is a lack of user friendliness. These studies suggest that the easier to master the user-to-network interface is, the higher is user performance.

Thus, network evaluation has been considered in different ways by different disciplines over the past forty years. Many of these evaluations focus on network technical performance, or an organization's performance when using a network, or individual users' performance when using a network. Few evaluations, however, consider both social and technical impacts of network performance, both of which are key in safety-critical large-scale systems. Because humans and technology cooperatively perform tasks in network-centered safety-critical large-scale systems, the model proposed in the next section for performance evaluation of safety-critical WANs in real-time settings encompasses both social and technical dimensions. We now describe the model and its theoretical underpinnings.

Theoretical Model

The different literatures surveyed illustrate that network evaluation has been considered from several perspectives --technical, social, organizational, psychological and commercial. In safety-critical settings, where network failures can have catastrophic effects and networks provide an important social and technical infrastructure, utilizing performance criteria that reflect the differing requirements that such networks must meet is important [So and Durfee 1996]. For instance, real-time safety-critical WAN's must meet stringent response, availability, reliability, survivability, accuracy and redundancy requirements; thus, use of technical performance criteria can provide some measure of the network's ability to meet those requirements. Similarly, real-time WAN's in safety-critical settings must also meet critical communication, decision-making, problem-solving and organizational effectiveness requirements; as a result, social, psychological and organizational network performance criteria can also be used to measure the social and organizational effectiveness of the network infrastructure. Finally, in many cases, real-time WAN's in safety-critical settings must also satisfy demanding commercial and economic requirements, as befitting their industrial hosts. Thus, commercial and economic performance criteria can provide measures of the network's ability to satisfy its economic and resource requirements. These requirements suggest important performance criteria for use in evaluating real-time WAN's in safety-critical settings. In such evaluations, technical, social, organizational, psychological, commercial and economic evaluation criteria provide a means of measuring the performance of the network, and of addressing the social, technical and economic challenges faced by real-time WAN's.

Figure 1 illustrates the proposed evaluation approach. Three types of performance are of interest in evaluating WANs in real-time safety-critical settings: the performance of the network P (N); the human performance of those using the network --both operator and user-- HP (N); and the performance of the system and organization P (S), as seen in Figure (1). Real-time networks interact with humans, the environment, and other technologies, and interactions between these different elements may contribute to network failures. Hence, in addition to traditional technical performance considerations, the Figure 1 WAN evaluation model considers human factors and environmental considerations. This is because human error and acts of nature are among the major sources of failures in networks (Kuhn, 1997).

As discussed earlier, technical variables (T), such as network reliability, accuracy, response time and utilization, certainly impact network performance P (N), as do social, psychological and organizational variables (S), commercial and economic variables (E), or system and environmental variables (SE) such as hardware failures, software failures and acts of nature, and interactions (I_N) between the network and its working environment (Figure 1). Network performance, therefore, is a function of technical variables such as reliability, accuracy, response time and utilization; social, psychological and organizational variables such as communication type, frequency, and timeliness of decisions; commercial and economic variables such as cost and security; as well as a function of system and environmental variables, such as acts of nature or power failures; and interactions between the network and its physical and execution environment. Network performance can be assessed using a variety of mathematical, statistical, engineering system, large-scale system, and business models, as explained in Section 2, and the relationships between the network performance factors can be expressed in the following way:

$$P\,(N) = f\,(T, S, E, SE, I_N)$$

where P(N) = performance of the network,
T = technical network variables,
S = social, psychological and organizational variables,
E = commercial and economic variables,
SE = system and environmental variables, and
I_N = interactions between the network and its working environment.

Note that in Figure 1, technical variables (T) also influence commercial and economic variables such as cost and social, psychological and organizational variables (S), such as accuracy, communication and system usage. These are indirect effects on network performance P(N), and the impact vectors in Figure 1 for these variables are shown as dotted lines.

In turn, network performance P (N) influences human performance with the network HP (N) as well as the performance of the system that the network serves P (S). Individual (I_H) and group (G) variables such as user knowledge and skills, vigilance and workload, also influence human performance with the network HP (N), as seen in Figure 1.

Human performance with a network is thus influenced by the network's performance as well as by individual and group variables such as individual or group's knowledge or skills, workload, stress, experience with networking, and /or fatigue. These relationships can be expressed as:

$$HP\,(N) = f\,(P\,(N), I_H, G)$$

where HP(N) = human performance with a network,
P(N) = performance of the network,
I_H = individual performance variables, and
G = group performance variables.

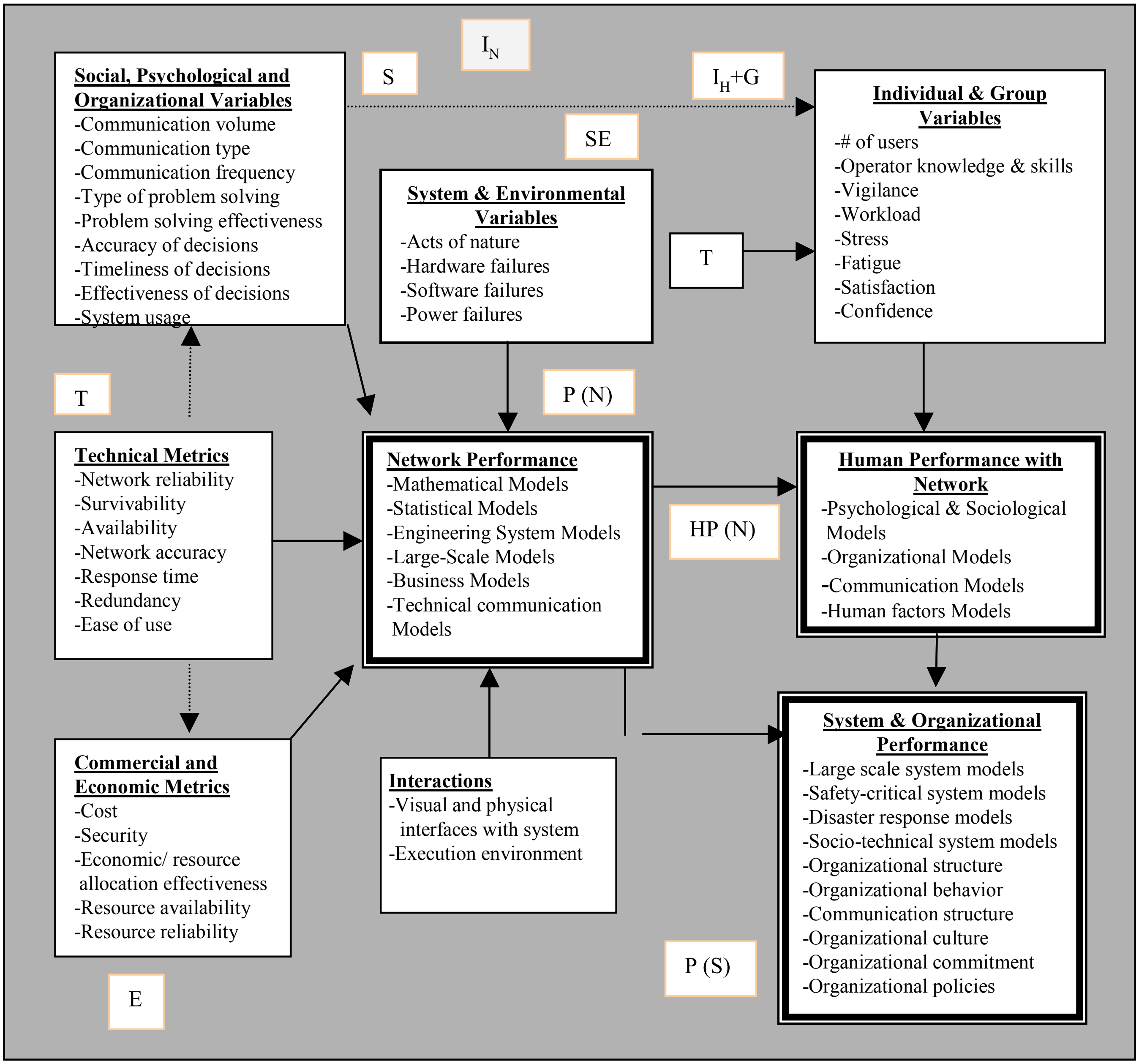

Figure 1. Proposed Model

Similarly, in Figure 1, social, psychological and organizational variables (S) influence individual (I_H) and group (G) variables such as workload, stress, and fatigue. Finally, overall system performance for the systems that host real-time WANs is influenced by the performance of a network P(N) as well as by human performance with the network HP(N), as in

$$P(S) = f(P(N), HP(N)),$$

where P(S) = performance of the system,
P(N) = performance of the network, and
HP(N) = human performance with a network.

System performance can be assessed using large-scale, socio-technical and safety-critical system models, as well as by examining the system and organizational structures, policies, performance, behavior and culture. In the following section, we describe use of the Figure 1 model in evaluating an operational real-time WAN.

Research Methodology

The purpose of the operator performance evaluation was to determine how technical variables such as network reliability and response time and individual and group variables such as workload and vigilance level influence operators' performance with the network under study.

Research Vehicles

There are two sets of subjects for this research: an operational wide area network (WAN) for the network performance evaluation, the operators who utilize the network for the human performance evaluation.

The real-time WAN is known as the Continuous Operational Real-Time Monitoring System (CORMS), which was designed and built by the U.S. National Oceanic and Atmospheric Administration (NOAA). CORMS was implemented in April 1998 and takes input from two NOAA systems, the Physical Oceanographic Real Time System (PORTS) and the National Water Level Observation Network (NWLON). PORTS collects data from San Francisco, New York, Tampa Bay, Houston/Galveston, Chesapeake Bay, Narragansett Bay, and Soo Locks. NWLON, which collects water-level data, is comprised of 189 water level gauges located around the coastal United States, including Alaska, Hawaii, and U.S. territories in the Pacific, and Great Lakes [NOAA, 1999].

Subjects for the operator performance assessment were 6 CORMS watchstanders who stand rotating watches of 12 hours each on a 24x7 basis. The subjects work in the CORMS watchstation located within the NOAA complex in Silver Spring, MD. There must be a person physically present, on duty, at all times. Since the present design of the watch is to have one person on duty, turnovers of the watch usually involve just two people. During the shift changeover, the person on duty briefs the oncoming shift person on anything that could affect future actions of the new shift. The actual briefing takes about five minutes; however, in some cases, it takes as long as necessary. The list of CORMS operators' responsibilities includes but is not limited to monitoring the CORMS system displays, monitoring the operational status of PORTS, data acquisition systems (DAS), and NWLON systems as well as the sensor systems themselves, monitoring the MCI connections to the PORTS, monitoring the status of the data processing and acquisition system (DPAS), monitoring the status of the system being used to run nowcast and forecast models, and monitoring the CORMS system itself.

Since a technical baseline was established by (Bayrak & Grabowski, 2002), this paper focuses on network monitoring watchstanders monitoring a Visual Display Terminal and responding to the information displayed and behavioral patterns of 24x7 watchstanders.

Experimental Design

Metrics associated with operator performance such as vigilance, workload, satisfaction, and operator error rate were evaluated by utilizing survey techniques, real-time observations, interviews and questionnaires. Currently, the CORMS network is monitored continuously in 24x7 mode by the operators. Each operator signed a consent form and voluntarily participated in this research. Such well-known tools as the NASA Task Load Index (TLX), and the Stanford Sleepiness scale (SSS) were the two primary metrics used to measure the operator workload and vigilance level in this study. Other dependent variables such as operator satisfaction level with and operator confidence level in the network performance, and operator satisfaction with the network interface were measured using structured questionnaires. In each questionnaire, a five point Likert-type scale was used.

Method

Currently, the CORMS network is monitored by 6 operators, all of whom were asked if they would participate in the study, and each of whom agreed to participate in the first survey. However, in the second survey, only 4 out of 6 operators agreed to participate. Although the small number of subjects in this study is regrettable from an experimental design viewpoint, it is a difficulty often encountered in empirical field research.

Subjects were briefed about the purpose of the study by Mike Connolly, CORMS manager, and by the researcher. Each questionnaire, along with its purpose, was explained in great detail. The NASA Task Load Index and Stanford Sleepiness Scale tests were explained step by step and questions asked by the operators were answered. Subjects were informed that the conduct of the study would require them to fill out questionnaires, and they were asked to fill out the questionnaires twice- one in April 2001 and one in November 2001. Subjects were told that questionnaire completion would require about 45 minutes. However, the Stanford Sleepiness Scale test required them to mark their vigilance level on Stanford Sleepiness

Scale every hour, thus requiring 12 hours' attention. In April 2001, six subjects filled out questionnaires over 7 days. 3 of those 6 were on day watch (6am-6pm) and the other 3 operators were on night watch (6pm-6am). Each and every questionnaire was administrated by the researcher. In November 2001, 4 operators participated in the study and filled out the same set of questionnaires over 7 days. 2 of those 4 operators were on day watch and the other 2 operators were on night watch. In November 2001, subjects were briefed again by Mike Connolly, CORMS manager, about the purpose of the study and were told that the same questionnaires would be re-administrated. Having been briefed by the CORMS manager, each operator filled out the same set of questionnaires.

Current Status

The literature review is concluded, and the proposed model, hypotheses, dependent variables, and their operationalizations to evaluate subjects have been defined. Currently, data collection and survey administration are in progress, as is analysis of the collected data. Results will be available for conference presentation.

References

Adie, R. G., Zukerman, I., and Neame, T. D. Broadband Traffic Modeling: Simple Solutions to Hard Problems, *IEEE Communications Magazine,* (36:8), 1998, pp.88-95.

Akar, N., Oguz, N.C., and Sohraby, K. TELPAC: An Advanced Teletraffic Analysis Package, *IEEE Communications Magazine*, (36:8), 1998, pp.84-87.

Andrisano, O., Verdone, R., and Nakagawa, M. Intelligent Transportation Systems: The Role of Third-Generation Mobile Radio Networks, *IEEE Communications Magazine,* (38:9), 2000, pp.144-151.

Banerjee, S., Tipper, D., Weiss, B.H.M., and Kahlil, A. Traffic Experiments on the vBNS Wide Area ATM Network, *IEEE Communications Magazine*, (35:8), 1997, pp.126-133.

Bayrak, T. and Grabowski, M. Safety-Critical Wide Area Network Performance Evaluation. In *Proceedings of the European Conference on Information Systems*, June 6-8, 2002, Gdansk, Poland.

Bolch, G., Greiner, S., de Meer, H., and Triverdi, K.S. *Queuing Networks and Markov Chains, Modeling and Performance Evaluation with Computer Science Application*, John Wiley &Sons, New York, 1998.

Cheng, A. Y., Liu, R. Y., and Luxhoj, J. T. Monitoring Multivariate Aviation Safety Data by Data Depth: Control Charts and Threshold Systems, *IIE Transactions*, (32:9), 2000, pp.861-872.

DaSilva, L. A., Evans, J.B., Niehaus, D., Frost, V. S., Jonkman, R., Beng O. L., Lazarou, G.Y. ATM WAN Performance Tools, Experiments, and Results, *IEEE Communications Magazine*, (35:8), 1997, pp.118-124.

Demeester, P., Wu, T., and Yoshikai, N. Survivable Communication Networks, *IEEE Communications Magazine*, (37:8), 1999, pp.40-42.

Eurich-Fulcer, R., and Schofield, W. J. "Wide-area Networking in K-12 Education: Issues Shaping Implementation and Use", *Computers & Education*, (24:3), April 1995, pp.211-220.

Haverkort, B, R. *Performance of Communication Systems, A Model-Based Approach*, Wiley, Chichester, NY, 1998.

Hemrick, C (1992). Building Today's Global Computer Inter-networks, *IEEE Communication Magazine*, (30:10), 1992, pp.44-49.

Heeseok, L., Jongwon L., Sufi M. N., Yong S., and Justin S., Managing User Performance for a Corporate Network, *Information & Management*, (35:5), May 1999, pp. 251-263.

Higginbottom, G.N. *Performance Evaluation of Communication Networks*, Artech House, Boston., 1998.

Ingvaldsen, T., Klovning, E., and Wilkins, M. "Determining the Causes of End-to-End Delay in CSCW Applications," *Computer Communications*, (23:3), February 2000, pp.219-232.

Jehiel, P. Information Aggregation and Communication in Organizations, *Management Science*, (45:5), 1999, pp.659-669.

Jurison, J. The Temporal Nature of IS Benefits: A Longitudinal Study, *Information & Management*, (30:2), 1996, pp.75-79.

Kanungo, S. "An Emperical Study of Organizational Culture and Network-Based Computer Use," *Computers in Human Behavior*, (14:1), January 1998, pp. 79-91.

Khalil, K., Hand, J.C., Mariswamy, M., and Obaidat, M.S. Methodologies for Characterizing Traffic in Wide Area Networks: Analysis and Benchmarking, *International Journal of Communication Systems*, (8:2), 1995, pp.117-127.

Korilis, Y. A., Lazar, A. A., and Orda. A. "Architecting Noncooperative Networks," *IEEE Journal on Selected Areas in Communications*, September 1995, pp. 1241-1251.

Kuhn, R. D. Sources of Failure in the Public Switched Telephone Network, *IEEE Computer*, (30:8), 1997, pp.31-36.

MacIntyre, H. Linking Up to the Behemoth." *Mobile Radio Technology*, (17:3), 1999, pp.37-39.

Mackenzie, K.D. Processes and Their Frameworks, *Management Science*, (46:1), 2000, pp.110-125.

McCabe, J.D. *Practical Computer Network Analysis and Design*, Morgan Kaufmann Publishers, San Francisco, 1998.

Monge, P. R., Fulk, J., Kalman, M. E., and Flanagin, A. J. Production of Collective Action in Alliance-Based Interorganizational Communication and Information Systems. *Organization Science*, (9:3), 1998, pp.411-433.

Mosher, D. E. Grand Plans, *IEEE Spectrum,* (34:9), 1997, pp.28-39.

Myung, Y., Kim, H., and Tcha, D. Design of Communication Networks with Survivability Constraints, *Management Science*, (45:2), 1999, pp.238-252.

National Oceanographic and Atmospheric Administration (NOAA). Center for Operational Oceanic Products and Services (CO-OPS), Silver Spring, Maryland, 1999.

National Research Council (NCR), *Flight To The Future, Human Factors in Air Traffic Control,* National Academy Press, Washington D.C. 1997.

Niehaus, D., Battou, A., McFarland, A., Decina, B., Dardy, H., Sirkay, V., and Edwards, B. Performance Benchmarking of Signaling in ATM Networks, *IEEE Communications Magazine*, (35:8), 1997, pp.134-142.

Nokes, C. "Availability and Reliability of Teleprocessing Systems," *Computer Communications*, (1:1), Feb. 1978, pp. 33-41.

Orlikowski, W. J., Yates, J., Okamura, K., and Fujimoto, M (1995). "Shaping Electronic Communication: The Metastructuring of Technology in the Context of Use." *Organization Science* (6:4), 1995, pp.423-444.

Parasuraman, R., Human Computer Monitoring, *Human Factors*, (29:6), December 1987, pp.695-706.

Rudd, C. Network management of an e-business environment, based on the new CCTA, ITIL Model," *Proceedings of the 2nd International Network Conference*, 2000, p.99-106.

Shin, K.G. *HARTS: A Distributed Real-Time Architecture, Advances in Real Time Systems*, IEEE Press, 1993.

So, Y., and Durfee, H. E. Designing Tree-Structured Organizations for Computational Agents, *Computational and Mathematical Organization Theory*, (2:3), 1996, pp.219-245.

Somani, K. A., and Nitin, H. V. "Understanding Fault Tolerance and Reliability," *Computer*, (30:4), 1997, pp.45-50.

Teichner, W. H. "The Detection of a Simple Visual Signal as a Function of Time on Watch," *Human Factors*, Vol.16, pp.339-353.

Ujita, H., Kawano, R., and Yoshimura, S. "An Approach for Evaluating Expert Performance in Emergency Situations," *Reliability Engineering and System Safety*, Vol. 47, 1995, pp.163-173.

Yamamoto, K., Takada, T., Nakai, K., and Nagaoka, H. Structuring WAN and LAN for EPR Use in Community Health Care, *International Journal of Medical Informatics*, (60:2), 2000, pp.219-226.

Yang, C., Chen-Hua, F., and Yueh-Heng, T. Enterprise Traffic with a Differentiated Service Mechanism, *International Journal of Network Management*, (11:2), 2001, pp. 113-128.

Zimmer, M., Effectiveness of Telecommunication Systems Defined as a Unique Measure of Quality from User's Point of View, *Elektrotehnika*, (24:1), Jan.-Feb. 1981, pp. 59-68.