AN EXAMINATION OF WORK PRACTICES AND TOOL USE
IN HIGH RISK ENVIRONMENTS

by

Nicole Forsgren Velasquez

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A Dissertation Submitted to the Faculty of the

Committee on Business Administration

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY
WITH A MAJOR IN MANAGEMENT

In the Graduate College

THE UNIVERSITY OF ARIZONA

2008

THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the Dissertation Committee, we certify that we have read the dissertation

prepared by Nicole Forsgren Velasquez

entitled "An Examination of Work Practices and Tool Use in High Risk Environments"

and recommend that it be accepted as fulfilling the dissertation requirement for the

Degree of Doctor of Philosophy

_____ Date: 6/27/2008
Suzanne P. Weisband

_____ Date: 6/27/2008
Jay F. Nunamaker

_____ Date: 6/27/2008
Alexandra Durcikova

Final approval and acceptance of this dissertation is contingent upon the candidate's
submission of the final copies of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and
recommend that it be accepted as fulfilling the dissertation requirement.

_____ Date: 6/27/2008
Dissertation Director: Suzanne P. Weisband

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SIGNED: Nicole Forsgren Velasquez

ACKNOWLEDGEMENTS

First and foremost, I would like to sincerely thank my advisor, Suzie Weisband, for her enthusiasm, encouragement, and support throughout my graduate studies. I am lucky to have found in her not only an advisor, but also a colleague, a confidant, and a friend. Her feedback, guidance, and cheering were instrumental in the completion of this dissertation and I'm thankful for all she has taught me.

My thanks also go to the members of my dissertation committee. Alexandra Durcikova always had time to offer advice and critiques of my research, bringing a fresh set of eyes and ideas to my work. Jay Nunamaker's unique perspective and words of wisdom helped me to see my research – and the field of MIS – in a new light. I would like to thank my minor advisor Massimo Piattelli-Palmarini for his advice and guidance in my minor studies in Cognitive Science.

I am grateful to my colleagues at IBM T.J. Watson Labs, especially Daniela Rosu, Jon Lenchner and Claudio Pinhanez, for their friendship and insights. I am thankful for the opportunity to work with them and see the research side of Big Blue.

Finally, I would like to thank my family for their love and support through this adventure. I am forever grateful to my husband Xavier for his love, understanding, encouragement, support, and document formatting. Thank you to my parents for their love and cheers through all of my academic pursuits.

DEDICATION

To my dad,

Vance B. Forsgren,

who always knew I could.

Sorry you missed the party.

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ABSTRACT

This research presents an in-depth investigation and description of a single user group, system administrators. Following an overview of these computing professionals and their complex, risky work environment, system administrator work practices were investigated using data collected from previous experience, interviews, a usability study, and the literature. This research contributes to existing knowledge by presenting an analysis of system administrator work practices and identifying them as broker technicians. As such, many of the findings of this study may apply to other broker technicians.

Because the work of system administration is so dependent upon technology and the way sysadmins access and control that technology, investigations of tool use were then studied. Through an analysis of work practices related to tool use, attributes important to system administrator work practices were identified. These attributes fell into two categories: information quality (currency, completeness, accuracy, format, logging, and verification) and system quality (reliability, flexibility, integration, accessibility, speed, scriptability, credibility, situation awareness, and monitoring).

This research proposes the use of Wixom and Todd's (2005) integrated user satisfaction model in the context of system administration. This theoretical model provides an opportunity to link the identified characteristics with system administrator beliefs and tool usage. This research contributes to existing knowledge by identifying

information and system quality attributes important to system administrators, and

empirically testing the modified user satisfaction model in the untested context of system

administration. The user satisfaction model was found to be significant and predictive of

system administrator tool use behaviors, with two information quality attributes

(accuracy and verification) and two system quality attributes (reliability and credibility)

significant.

CHAPTER 1.   INTRODUCTION

"A programmer is much like a virtuoso musician. They know their instrument extremely well. They may know, and occasionally play other instruments, but tend to focus almost exclusively on one.   A sysadmin is more like the conductor. They have to know about all the instruments, the characteristics of each, how they play and sound together and in contrast with others. Then [they] need to understand the timing, the sound characteristics of the hall, etc. and make everything work together. For fun, they may occasionally beat the kettledrum or pluck a banjo. They may even sound pretty good at it and enjoy it." – Survey respondent

With the growing complexity of computing infrastructures (J. Bailey et al., 2007; Barrett et al., 2004; Patterson et al., 2002), the maintenance and management of these systems is becoming increasingly important (IBM, 2006). The professionals charged with the upkeep and optimization of these systems are generally referred to as system administrators (sysadmins), though their specializations and official job titles may vary (SAGE, 2006). Responsibilities of system administrators include configuration, maintenance, troubleshooting, and data backup and replication (SAGE, 2006). Their work requires knowledge of operating systems, hardware components, databases, networking, and complex interrelationships among system components (J. Bailey et al., 2007; Barrett et al., 2003; Barrett et al., 2004; Haber & Kandogan, 2007a; Patterson et al., 2002; SAGE, 2006).

The financial implications of system administration are catching the attention of many companies (E. Anderson, 2002; SunMicrosystems, 2006). While the costs of actual hardware components are falling, studies indicate the cost of administering these systems

is increasing and surpassing component costs (IBM, 2006; Kephart & Chess, 2003; Patterson et al., 2002). Furthermore, system administrators are in demand and commanding salaries that increase 5% - 10% each year (E. Anderson, 2002; SAGE, 2006).

Even with this practical need and industry attention to system administrators, little academic emphasis has been placed on this unique and important group. Only a few universities offer coursework in system administration (E. Anderson, 2002; SunMicrosystems, 2006), and few research projects have explicitly focused on system administrators (notable exceptions include Barrett et al., 2004; Botta et al., 2007; Hrebec & Stiber, 2001).

As experts and power users, system administrators are very different from the novice computer users that most tools are designed for (S. Bodker, 1989). Bannon stated, "there needs to be a better understanding among researchers, and among many system designers too, about the "users" of computer systems and the settings in which they work" (Bannon, 1991, p. 25). By examining the work practices of system administrators, this research aims to better understand their work practices and their tool needs in light of those work practices. This approach gives the work practices of system administrators a central position in the design process (Greenbaum & Kyng, 1991b).

1.1. Research Objective

Because of the lack of research on system administrators in general, this work will focus on system administrators of all specialties, experience levels, and work environments. The main research questions are:

What do system administrator work practices tell us about their occupation?

What can system administrator work practices tell us about their tool needs?

The research presented here serves three related purposes. First, it describes the work environment and work practices of system administrators, classifying them as an occupational ideal-type. Second, it investigates and empirically tests implications for tool design based on the analysis of their work practices. Third, it enables future research on system administrators by identifying possible research directions.

This chapter continues with a definition and an overview of system administrators, including information on their demographics, background and training, and a brief discussion of their responsibilities and job tasks.   This chapter also presents their work environment as one that is complex and risky.

Chapter two describes the work practices of system administrators. Although an extensive ethnography of system administrators was conducted by IBM Almaden Research Center (described later), these users have not yet been classified or compared to other occupations. Through a description and analysis of system administrator work practices, these users are identified as broker technicians. The chapter also describes the tool use of system administrators and concludes with the assertion that because the work

of system administration is so dependent upon technology and the way sysadmins access and control that technology, investigations of tool use and tool choice are especially relevant with this user group.

Building on a tool-focused analysis of system administrator work practice, Chapter 3 presents a discussion that sheds light on system attributes needed by system administrators to do their job, followed by a model of user satisfaction that provides actionable guidance and an integration of attributes. The model proposed in this chapter and tested in Chapter 4 represents the first time tool attributes and their impact on system use have been empirically tested in the context of system administration. Chapter 4 describes the methodology and data collection procedures, and Chapter 5 follows with an analysis of the data. Chapter 6 concludes with a discussion of this research and presents research and practical implications, limitations, and future directions.

1.2. System administrators

Most of what is known about system administrator demographics, job titles, responsibilities, and standards come from information collected and published by their two main professional associations, SAGE and LOPSA. The System Administrator's Guild (SAGE) is a special interest group sponsored by USENIX, which is itself an association for professionals involved in advanced computing. The League of Professional System Administrators (LOPSA) is a nonprofit corporation with worldwide membership. These organizations collect membership dues and serve the system administrator community through conferences, training, technical information, and online

communities. SAGE conducts a yearly survey about system administrator roles, job titles, responsibilities, ages, salaries, and work schedules (named the annual "Salary Survey") and provides an analysis of the results to its members. SAGE sponsors various LISA (Large Installation System Administrators) conferences each year and publishes white papers and the magazine *:login;*. SAGE and LOPSA hold their own regional training sessions and host online forums. SAGE and LOPSA also collaborate on projects that benefit system administrators; for example, together, they composed the System Administrators' Code of Ethics (SAGE & LOPSA, 2008). Much of the demographic information about system administrators found in this study is gathered from SAGE and LOPSA websites and publications, such as the SAGE Annual Salary Survey (SAGE 2006).

System administrators are the information technology professionals who execute the system administration tasks for their organization, even though their job titles may not designate them as such. System administration may be their sole responsibility or it may be just one of the line items in their job description. They can work alone or in teams and often have broad and overlapping responsibilities. The majority of system administrators report job duties that include working independently with general management guidance, planning for the future of the facility, managing the work of junior system administrators and engineers, establishing or recommending system use and service policies, managing computing infrastructures, and evaluating components for purchase (SAGE, 2006).

Most system administrators are men (91.6%), though trends show this percentage gradually declining (SAGE, 2006). A single system administrator can support anywhere from a single end user to over 16,000 end users, though most support approximately 80 (SAGE, 2006). The average workweek for a system administrator is 44.7 hours per week, but 22.5% of system administrators report working more than 50 hours per week (SAGE, 2006). To compensate for the long hours, many system administrators telecommute, with 40% working at least 8 hours from home every week (SAGE, 2006).

System administration research has been largely regarded as a topic for computer science and as such, focuses on algorithms and aspects of the system being managed (e.g., E. Anderson, 2002). With the institutionalization of technical support work (Pentland, 1991, 1997), system administrators are an equally important part of the equation. Following a discussion of the methodology used in this research, the chapter discusses how system administration is learned and the work environment of system administrators.

1.3. Method

Work practices of system administrators were examined utilizing a multi-method approach. The narrative of work contained in this study is based on personal experiences both as a system administrator and as a consultant working closely with system administrators. While some of this work was done with small companies, most of the author's experience lies with a Fortune 500 company. This study utilized semi-structured

interviews and an analysis of existing ethnographic and work practice studies of system administrators.

These narratives are also augmented with responses from interviews. Semi-structured interviews were conducted to investigate system administrator work practice and important tool characteristics. Interview participants included both junior and senior system administrators whose work responsibilities included the administration of networks, storage, operating systems, web hosting, and computer security. Six interviews were conducted with system administrators at a location convenient to the sysadmin, with two conducted in person at the sysadmin's place of work and four conducted over the phone. Three of the sysadmins interviewed worked for a Fortune 500 services computing company, while the other three worked in an academic setting, one for a large university and the other two for a college within the same university. The average length of time as a system administrator was 14 years (ranging from 8 years to 25 years) and the average age was 39 (ranging from 30 to 58 years old). Most of the study participants (83%) were male, consistent with demographics reported by SAGE (91.6%) (SAGE, 2006). The interviews were conducted at the convenience of the sysadmin and addressed the work they did, how they did their work, the tools they used, and reasons why they personally would use or not use a given tool in their jobs. Due to security and privacy concerns, interviews were not audio taped and recorded responses were limited to copious notes taken by the researcher. Interview notes were reviewed and expanded immediately following the interview to make sure all responses and relevant information were

captured. These documents were then coded for characteristics important to and/or necessary for the system administrator.

Ethnographic and work practice studies of system administrators in the literature were also analyzed to enrich the study. The largest of these studies is an ethnography of system administrators conducted by IBM Almaden Research Center (ARC), spanning four years and six sites. Both qualitative and quantitative data were collected through videotape, interviews, a diary study, surveys, observations, and artifact collection. More specifically, six field studies were conducted with at least two researchers observing, taking notes, and videotaping. These researchers followed one sysadmin per day and collected artifacts throughout their site visits. Twelve interviews were conducted with sysadmins, managers, and team leads, focusing on work issues and concerns and were conducted in their offices. One system administrator logged his daily activities for ten months, identifying tasks such as meetings, problem solving, and planning, and details such as task collaborators. Finally, two surveys were conducted as part of the study, one pilot survey to better define the domain of system administration, and a more extensive survey to collect information on collaboration practices and tool use (J. Bailey et al., 2003; J. Bailey et al., 2007; Barrett et al., 2003; Barrett et al., 2004; Barrett et al., 2005; Haber, 2005; Haber & Bailey, 2007; Haber & Kandogan, 2007a, 2007b; Kandogan & Haber, 2005; Kandogan & Maglio, 2003; Maglio & Kandogan, 2004; Maglio et al., 2004; Takayama & Kandogan, 2006). The research from this ethnography (referred to as the ARC ethnography) provides detailed, accurate, and contextual narratives of system administrator work practices and is used to augment the data collected for this study.

Finally, a survey was used to collect data about the tools that system administrators use. This survey is described in detail in Chapter 4 and the results are presented in Chapter 5, though responses to open-ended questions are referenced throughout this thesis.

1.4. Learning system administration

It is helpful to begin with a discussion of how system administrators learn the skills necessary for their profession. Most system administrators have no formal education or formal training directly related to system administration. One third of sysadmins report having no certifications and 59% report having a college degree (SAGE, 2006). Of those that do have degrees, most are in technical fields, such as computer science (SAGE, 2006). Many system administrators report starting to work in their field almost by accident: by stepping in and fulfilling a need when their organization asked for volunteers. As one system administrator said, "many of us are cases of programmers having to do some [system administration] work because they have the skills and someone needed to get the job done." Because of the lack of academic instruction directly related to system administration (E. Anderson, 2002), the majority of learning happens informally. Over 85% of system administrators attribute their knowledge to on-the-job training or self-instruction (SAGE, 2006), similar to the training style reported by other professions, such as emergency medical technicians (EMTs) (Nelsen, 1997).

It is interesting to note that while much of western culture has a tendency to value formal, theoretical knowledge over experience or contextual knowledge (Nelsen, 1997), this opinion is not shared within the system administrator community. Given the on-the-job learning and technological specifics needed for this profession, this opinion may make sense when relating to formal education and college degrees, but the opinion even extends to specialized certifications. In fact, many system administrators don't think highly of certifications (SAGE, 2006), citing the common requirement to merely pass a written exam (Couch, 2007). As Alva Couch stated, "I can testify from personal experience that it is possible to pass a written test on system administration and not have the slightest clue about how to function as a system administrator" (Couch, 2007, p. 14). Essentially, certification exams may test a person's knowledge while missing any kind of validation of that person's skills in the area.

It is clear that in the work of system administration, technical skill – that is, the ability to perform the tasks needed to maintain and manage a computing infrastructure or system – is valued above any formal training or certifications. Skill is a component of technical work (Scarselletta, 1997) and is more than just knowledge; it is the ability to do something well (Attewell, 1990; Vallas, 1990). Skills are highly context dependent and rely on tacit knowledge often learned by doing (Barley & Bechky, 1994; Collins, 1974; Scarselletta, 1997). Indeed, system administrators are technical experts and power users, differentiating them from regular computer users (S. Bodker, 1989). Interestingly, technical skill is often not the focus of an organization's specialized job training for its technicians (Orr, 1996).

But what skills are needed? Any specific answer will depend on the situation and computing environment, but many skills are fairly universal. For example, a "Unix shop" (slang for an organization whose infrastructure is supported using primarily servers running a Unix operating system) will recruit system administrators with a Unix background, while sysadmins reported that same Unix background would offer little operating system knowledge in a "Windows shop." Beyond these vendor- or operating systems-specific requirements, the system administrators that were interviewed identified many of the same skills needed: a technical background, the desire to learn, some programming ability, creativity, and a good "sense" of the system and any problems that may arise. When probed further about acquiring the intuition needed, the answer was always very similar to, "I don't know; you can't learn it. Some people just have it and you pick it up along the way."

Indeed, most system administrator skills are learned on the job or by personal investigation and experimentation. This is apparent in the response of a sysadmin when asked about having a particular skill: "No, but only because I haven't ever needed to use it yet. The first time I do, I'll learn it." All of the system administrators that were interviewed started their careers under the guidance and direction of a mentor, much like an apprenticeship. This on-the-job training imparts practical knowledge under the guidance and direction of an experienced mentor (Carr-Saunders & Wilson, 1933). Much like the advancement within occupational communities, system administrators move through stages of skill proficiency (van Maanen & Barley, 1984). However, unlike traditional apprenticeship models, the technically diverse and dynamic work environment

of system administration does not cultivate professionals who are experts in the entire

field of system administration. Instead, a junior sysadmin will continue to gain

knowledge and eventually specialize in one particular aspect of system administration,

such as operating system administration or web server administration, more closely

resembling the guru[1] model of workplace learning (D. Bailey et al., 2004).

For example, the work of system administration requires knowledge and skills

that are local and dynamic. Emerging technologies result in frequent system changes and

upgrades, which dictate the learning required of the organization's system administrators.

In the case of an addition or upgrade of a server made by a familiar vendor, the system

administrator most familiar with that vendor's products would most likely assume – or be

assigned – responsibility for this new component and remain the local expert. In the case

of the installation of a new system component that no one on the team has experience

with, one sysadmin will likely be sent to a class to learn about it, becoming the new guru

for that component through local responsibility with that component. Additionally, a

recent college graduate may be familiar with the latest version of a database system and

therefore be regarded as a colleague and the guru of that particular database system. The

rapid pace of technological change requires knowledge and skill updates that work

against traditional models of apprenticeship and result in the dynamic allocation of guru

status among team or community members (D. Bailey et al., 2004). This also explains

the collaborative nature of the work of system administration: by assigning the

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[1] In fact, a yearly technical conference hosted by SAGE, a professional system administrator association, hosts "Guru Is In" sessions where system administrator experts impart knowledge on topics of interest to the professional community.

responsibility of a skill set to a particular team member, the cognitive load is reduced for the rest of the team.

In summary, while many system administrators list formal training and certifications on their resumes, the technical skills required in the work of system administration are most often learned *in situ*. Junior system administrators often learn much of the craft during internships or in workplace settings where they are mentored, similar to early stages in the apprenticeship model. The dynamic and technologically diverse work environment, however, results in expertise and respect allocated across a team, which more closely resembles the guru model of workplace learning.

1.5. Work environment

We will close this chapter with a description of the environment in which system administrators work. Today's business infrastructures are comprised of multiple components (e.g., database management servers, application servers, and web servers) residing on hundreds of servers distributed across many networks and running on multiple operating systems. Disaster recovery and backup systems add complexity to the environment and the requirements for data availability have amplified both the importance of continuously available data and the cost of system downtime. Because this infrastructure must be managed nearly flawlessly, the industry has seen system management costs exceed system component costs (IBM, 2006; Kephart & Chess, 2003; Patterson et al., 2002). Though many companies are exploring automated system

management (HP, 2007; IBM, 2006; SunMicrosystems, 2006), system administrators are still ultimately responsible for the management and coordination of the entire system and often represent the single point of failure. System administrators are responsible for maintaining an infrastructure that is comprised of multiple components (e.g., database management servers, application servers, and web servers) residing on hundreds of servers distributed across many networks and running on multiple operating systems.

The complexity of managed infrastructures was apparent in interview responses. Interviewees from the Fortune 500 Company reported network responsibilities that included seamless interfacing with the networks at their organization's other worldwide centers and the organization's global intranet. Academic interviewees reported network responsibilities that included interfacing with networks at the university and college levels. All interviewees reported that disaster recovery and backup systems add complexity to their environment and that requirements for extended data availability have increased both the importance of continuously available data and the cost of system downtime, echoing findings of previous studies (Patterson 2002; Patterson, Brown et al. 2002). Though many aspects of this system are automated, the system administrators in this environment are still ultimately responsible for the management and coordination of the entire system. Interviewees stated that unexpected downtimes are not tolerated by their organizations and that any loss of data could impact the efforts of many different teams and is considered unacceptable.

Hardware and software additions to the network, firmware updates, and usage fluctuations contribute to the complex environment. As one interviewee stated, his work

required that he manage "an incomprehensibly complex system through many layers of abstraction, automation, and analysis." This continually evolving environment results in new situations and contexts every day, making even "routine" tasks a new challenge. As pioneers, system administrators do work that is more difficult simply because it is often the first time it is being done (Pinch et al., 1997). Much of the difficulty in supporting this complex infrastructure lies in simply locating the source of an error. Because so many things can go wrong, much of a system administrator's time is spent defining the problem and debugging it. For example, if a system error is detected following the upgrade of a software program, there are many possible causes, including a failed or incomplete upgrade, incompatibility between the upgraded software and another infrastructure component, or even an unrelated error elsewhere in the system that was coincidentally discovered following the software upgrade. A system administrator must not only perceive the error, but also identify and attempt to correct it by process of elimination – checking each possible cause and solution. This is an involved process of researching possible causes and solutions and trying each until the system is restored.

This impact of this dynamic environment was apparent in the work practices of system administrators. The workdays spent with sysadmins were started with a plan of tasks to accomplish, but these plans were quickly interrupted and changed. System errors with higher priority forced other tasks to wait and many tasks were started and left numerous times before completion. Similar findings are reported in ethnographies of system administration (e.g., Barrett et al., 2004). Research participants also noted that the work of system administration is one that is constantly marked with interruptions and

multitasking. In one typical period, sysadmins were seen simultaneously checking the

status of an earlier system problem in a problem list, talking on the telephone with a

hardware vendor about a new system error, and checking on the wiring of a server that

was experiencing intermittent downtimes.

This complexity only adds to the risk inherent in managing these systems (Barrett

et al., 2004). Six dimensions of risk have been identified in the literature (Jacoby &

Kaplan, 1972; Roselius, 1971): financial, performance, physical, social, psychological,

and time. All of these dimensions of risk are relevant to the work of system

administration. Complex infrastructures must be managed nearly flawlessly, with any

downtime resulting in significant *financial* loss to the company (Barrett et al., 2004;

Patterson, 2002) and overall system *performance* degradation (E. Anderson, 2002).   The

physical location of system servers and infrastructure components is often secured to

prevent theft of components or data. Significant system failures can lead to a loss of

employment, accounting for *financial, social, and psychological* risks for the system

administrator personally. Even simple mistakes can require hours to correct, a *temporal*

risk that adds work to already busy days (E. Anderson, 2002; Halprin, 1998).

The complex and risky work environment of system administration is also

apparent in the description of their job responsibilities. The Fortune 500 sysadmins that

were interviewed reported more stringent requirements for data security and data

availability than did the sysadmins in an academic setting. In their work, service level

agreements (SLAs) assign specific and costly consequences to any system downtime

outside of predetermined change windows. Any loss of data would cause significant

customer impact and was considered unacceptable. The academic environment offered more flexibility in system downtime, but data security remained a concern and the distributed organization often introduced more infrastructure complexity because of the variety of services and products supported at different levels of university organization. For example, continuity and compatibility were less common issues at the Fortune 500 Company, because hardware and software purchase decisions were made with the seamless integration of the overall network in mind. In contrast, networks maintained in the academic setting conformed only to the rules of the sponsoring organization. That is, the university would plan and configure their network to suit its needs, while the college would plan and configure their network to suit its needs. In addition to supporting the department's infrastructure, department-level system administrators had the added responsibility of maintaining compatibility between the university network and the department network. Although industries in which system administrators work have their differences, it is clear that they work in complex and risky environments.

1.6. Summary

This chapter has introduced and outlined the research contained in this dissertation: system administrators, their work practices, and their tool use. System administrators were described and their learning styles were discussed, showing their jobs are learned through some formal training and education, but primarily through on-the-job experience. Aspects of their learning are similar to the apprenticeship model, where

junior sysadmins learn and are mentored by senior sysadmins. Other aspects of their

learning are similar to the guru model, where different team members specialize in

different technologies or components of the system, resulting in expertise allocated across

teams. Finally, the work environment of system administrators was described and

identified as one that is complex and risky due to the high number of system components

(e.g., hardware, software, operating systems) that must interoperate seamlessly in a

dynamic environment.

CHAPTER 2.   SYSTEM ADMINISTRATOR WORK PRACTICES

When examining workplace culture for system design, Bodker and Pedersen (1991) state that the most useful things are physical and material artifacts, verbal symbols, and work practices. With system design in mind, this research focuses on the work practices of system administrators. A discussion of work practices is presented. This study extends existing research of system administrator work practices by analyzing and classifying system administrators as broker technicians.

2.1.   Work practice

Work practices include not only the tasks executed but the ways in which people organize and perform their work (Greenbaum & Kyng, 1991a; Suchman, 1987) and includes work routines, modes of cooperation, gestures, and rituals (K. Bodker & Pedersen, 1991). Work practices are not always visible to outsiders (Suchman 1995), often because of the proficiency with which it is done (R. J. Anderson, 1994). That is, "the better the work is done, the less visible it is to those who benefit from it" (Suchman 1995, p. 58). Such is often the case with the work of system administration. The organizations and people that benefit from their supported computing infrastructures often view this work as a black box, not worrying about how or what is done while depending on and utilizing the services provided (E. Anderson, 2002).

But what is the difference between work and work practice? An example

explains this best. Technical documentation for performing a software upgrade provides

detailed step-by-step instructions for upgrading a software application on a server. This

procedural instruction represents an item of *work* of system administration. The *work*

practice of upgrading a software application, however, includes much more than just the

prescribed steps taken to install the upgrade. In one case, a system administrator was

given a routine software upgrade as a training task. Before proceeding, he had to ask the

team lead for the username and password for the hardware that housed the software

application. The team lead gave him the information and joked that after he used the

password, he should forget it because this "wasn't [his] box," meaning he was no longer

allowed access to the server following the upgrade. Halfway through the install process,

a warning screen appeared that was not included on the set of instructions. Unable to

find the team lead in the lab or on his instant messaging client, the sysadmin started

reciting facts about the box state and current network configuration to himself, recalling

as best he could the detailed system status before beginning the upgrade. Once he was

confident that the warning message did not apply to him, he clicked on the 'Okay' button,

noting that even if it wasn't okay, there was no option to cancel. After exchanging DVDs

for the next phase, the instructions stated the data transfer and software install would take

approximately 30 minutes to complete. This information prompted the sysadmin to leave

the lab and go back to his desk to concentrate on a troubleshooting task he was working

on earlier in the day. After spending 45 minutes researching this error and trying possible

solutions, the sysadmin returned to the server to check his installation status. Although

the monitor showed no confirmation of completion, the optical drive was ajar, which communicated to the system administrator that the DVD was no longer needed and the installation was complete. He then executed a few command line interface (CLI) commands to confirm the successful installation of the software upgrade and the healthy status of the box.

It is clear from this example that while technical documentation may be written as explicitly as possible, the work practice of system administration is revealed in the situated context of the work. The detailed, step-by-step instructions spurred one manager to comment on the perceived ease and straightforwardness of sysadmin work. Observations here, however, show that even in this case of "straightforward" tasks, not every situation and variable can be captured in documentation. The system administrator had to collect information from his team lead to access the hardware and had to make a decision based on his interpretation of an unexpected warning message in light of his computing environment. A portion of the install task that didn't require user input allowed him to leave the server and attend to other tasks. Upon returning to the server, environmental cues (i.e., the partially open optical drive) communicated to him the completion of the installation, which was then confirmed by executing CLI commands.

2.2. System administrators as technicians

The importance of skills in the work of system administration presented earlier suggests these workers are technicians. Indeed, Pinch et al. stated, "skill is a component

of technical work" (Pinch et al., 1997). As technical professionals that span the worlds of blue-collar and white-collar workers, system administrators typify the technician occupation class defined by (Barley, 1996) and (Barley & Orr, 1997). This section provides evidence of system administrators as technicians.

Barley and Orr (1997) identified four traits that can be used to identify or define technicians. The first, a "centrality of complex technology to the work" (p. 12), is apparent in the job description of system administration. The primary job responsibility of sysadmins is the installation, configuration, and maintenance of emerging technological components (Barrett et al., 2004; Halprin, 1998). The second trait is the importance of contextual knowledge and skill, a characteristic among sysadmins that was described earlier. System administration cannot be entirely taught or learned in classrooms; system administrators report that hands-on instruction and tinkering are required to attain the skills needed to do the job (SAGE, 2006). The third trait is the importance of theories or abstract representations. The work of system administration requires a mental representation of the hardware and software components that make up the system, linked by an understanding of the underlying computing theories (Haber & Kandogan, 2007b; Hrebec & Stiber, 2001). The final trait identified by Barley and Orr is the existence of a community of practice. Evidence of a system administrator technical community is apparent in the associations they organize, the conferences they host, and their efforts to define and "advance the practice of system administration" (LOPSA, 2008). Like many technician professions, system administrators have developed occupational societies (e.g., LOPSA and SAGE, described earlier), conferences (e.g.,

LISA and USENIX Technical Conference), and journals (e.g., *;login:*). It is clear from these criteria that system administrators are technicians.

When defining these workers, Barley (1996) identified two types of technicians: buffer technicians and broker technicians. Buffer technicians translate physical and material aspects of their work into symbolic representations, which are then passed onto a professional, who utilizes these symbolic representations in their work. That is, buffer technicians act as a buffer between the material realm and the professionals who need symbolic information about that material realm and speak the same "language" about that realm. An example of a buffer technician can be seen in medical technologists, whose job exists between a physician (the professional) and a patient's tissue or blood samples (the materials), creating and passing along un-translated symbolic information about the samples, which is used by the physician in diagnosis and treatment.

In contrast, broker technicians have been described as buffers that stand between technology and society (Barley, 1996; Barley & Orr, 1997). These technicians do not share a language or occupational similarities with the professionals they support. Additionally, the professionals supported by broker technicians do not rely on any symbolic representations of the systems they work with, but rather depend on the systems themselves. The next section will describe system administrators as broker technicians through descriptions of their work practices.

2.3. System administrators as broker technicians

System administrators bridge two communities, the end users they support and their own technical community (see Figure 1). System administrators provide support for organizations that are in many fields, including finance, academia, research, government, and non-profit (SAGE 2006). In maintaining computing infrastructures, system administrators create artifacts that are meaningless to the users they support, but which are important to their understanding of the system and meaningful to other system administrators in their technical community, activities identified by Whalley and Barley (Whalley & Barley, 1997). The users supported by system administrators rely on the computing infrastructures that are maintained, but do not understand the physical or symbolic components of system administrator work, often viewing the technician's work as a black box.

Translation

| Technical Community | Information, Query → ← Query, Feedback | Technician's Work | Restatement → ← Requirement | Users |
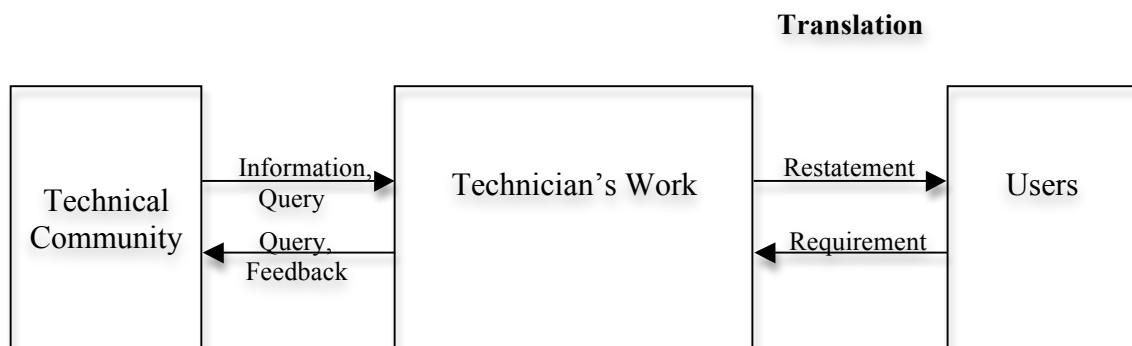
Figure 1.   Broker technicians (adapted from Barley 1996)

The ARC ethnography, described earlier, reported the breakdown of system administrator work activities (Haber & Bailey, 2007). System administrator diary reports indicated that almost a quarter of the day was spent in meetings (Haber & Bailey, 2007), echoing reports from Dijker (1998). The rest of the workday was spent on planning (21%), system maintenance (19%), troubleshooting (11%) and installation (8%) (Barrett et al., 2004). Each of these activities will be used to describe system administrators as broker technicians through the aspects of broker technician work: translated communication with the supported users, technician work activities, and un-translated communication with the technical community.

Meetings were referred to as a "necessary evil" by our interviewees; they expressed annoyance at having to leave their work duties to attend meetings, but agreed they were necessary for communication with their supported users and within the team. The translation aspect of system administrator work is apparent in meetings with supported users, where future computing needs of the organization and system status are discussed. In these meetings, future computing needs were gathered to be translated into technical specifications, which would become work items for the system administrator and his or her team. These meetings were also used to communicate system status back to the supported users, representing a translation of technical details. For example, detailed work completed, such as the installation of software patches and firmware updates would be communicated in broad terms, such as, "servers have been updated to support our growing database needs." Meetings were also held with sysadmin co-

workers as part of their technical work to communicate business requirements, coordinate work activities, and disseminate technical knowledge.

System planning is a proactive component of system administration that spans all aspects of broker technician work and includes system forecasting, component planning, system design, and implementation. As an example, system administrators are often responsible for the upgrade and maintenance of network hardware. High-level business needs are gathered from management and translated into technical specifications, generally understood only by the system administrator technical community. Up-to-date information about current hardware and software releases and issues is gleaned from the Internet and discussed with the technical community through messageboards and online forums. This knowledge is then applied to the context of their computing environment and new components are purchased, installed, and configured. At the conclusion of the upgrade work, the system administrator must then communicate the work that was done and its relative contribution to the organization's computing goals back to their end users in language and terminology they understand.

System maintenance is a continual process that includes monitoring system state and troubleshooting any problems that arise. The request for system maintenance from supported users is often implied in their job description. An example of this requirement as communicated to a system administrator might be to "maintain servers and systems to support the organization's day-to-day operations." The sysadmin then translates this requirement into tasks and activities needed to maintain current system state. These tasks and activities represent their work and may include server performance tuning and data

backup tasks. When questions arise or problems occur that sysadmins cannot solve alone,

they often consult others in their technical community and use this feedback in their

work.   Status and information of the system administrator's work, such as overall

system state, is collected and restated to the supported users using terms and language

they understand.

Troubleshooting is an on-demand aspect of system administrator work seen in

both system maintenance and system planning that can involve all aspects of broker

technician work. This work is initiated by system errors and often discovered by

monitoring tools. In one case, an organization's database was no longer accessible and

users told the system administrator that the database "wasn't working." This was

interpreted by the sysadmin as a problem with a certain database application residing on a

specific server. The system administrator and his coworkers began their technical work

by collecting information such as error messages, network connections to the database

server, and system logs and dumps[2] to generate a list of possible causes. The system

administrator then searched for information and possible solutions on a sysadmin

messageboard and posted a question in an online forum, using messageboard information

and forum feedback to identify and rank probable solutions. Each potential solution was

executed in a trial-and-error fashion, with the sysadmin issuing CLI commands to check

the current system state and see if the last action corrected the error. Once the error was

solved, the system administrator updated his online forum post to communicate his

[2] A system log contains a historical list of previous events and status messages for a given
hardware or software component. This list can include system actions and error
messages. A system dump is a more detailed and inclusive (often called "verbose") list
of system events and messages that generally must be requested by a user.

findings back to the technical community and an email was sent to users telling them that the database was "up and working."

Installation activities typically involve sysadmin technical work and interactions with the technical community. Installations include hardware or software additions to the network and may be done proactively as part of a planned system upgrade or reactively as a fix to a current network issue. An example of a software installation work practice was described earlier and involved performing work, communicating with a coworker, and engaging the technical community. Interactions may occur with sysadmins in the same organization and queries may be made to the technical community, but communication with supported users is rare and usually limited to status reports.

This section has used narratives of common system administrator activities – meetings, system planning, system maintenance, troubleshooting and installation – to provide evidence of their role as broker technicians. Much of the technical work of system administration lies in the middle of the broker technician model, but interactions with supported users and with their technical community are important in their work. Communication with supported users, however, is very different from communication with the technical community because of the language differences between the groups. Messages received from supported users must be translated into to technical requirements, while messages conveyed to supported users must be restated using terminology understood by a different profession. Communication between system administrators and their technical community, however, can leverage a common vocabulary.

2.4. Similarities to other technicians

Because they share an occupational ideal-type, system administrators share characteristics with other technicians, which are described here. Whalley and Barley (Whalley & Barley, 1997) describe engineers as technicians, having jobs that are learned both formally (i.e., in university classes or training seminars) and on the job. Similarly, system administrators may learn aspects of their profession through formal training or earning certifications, but they also employ context-specific skills learned through mentoring and on-the-job training, as described earlier. Engineers are described as technicians who span the professional white-collar world and manual blue-collar world, performing both mental and manual labor (Whalley & Barley, 1997). Mental engineering work includes duties tightly tied to science and mathematics, such as performing calculations. Manual labor done by engineers involves designing, working with, and repairing physical artifacts. Similarly, the work of system administration involves data, numbers, and artifacts typical of knowledge work, yet they must remain tightly entwined with the physical aspects of their system, for example, when positioning hardware and laying cable to connect components.

Another group of technicians identified in the literature are microcomputer technicians described by Zabusky (Zabusky, 1997) having work duties that were termed reactive and proactive. Reactive job duties involved status meetings, troubleshooting sessions and debugging, and were done as a response to either user requests or system failures. The reactive work of system administrators involves responsibilities that focus on maintaining the systems in the organization to a level acceptable to the users and also

includes status meetings, troubleshooting sessions, debugging, server repair, and system maintenance. Proactive work of microcomputer technicians includes development tasks, which included system planning and installations. Proactive work in system administration can involve planning, installations, development, and product evaluations and is done with future computing goals, scalability, and sustainability in mind.

Technicians are often organizational outsiders (Barley, 1996; Whalley & Barley, 1997). Microcomputer technicians were reported to regard their careers as a profession in an occupation rather than as a player in an organization (Zabusky, 1997), a sentiment shared by the sysadmins that were interviewed. This may be because system administrators, like other technicians, typically work in organizations that are dominated by members of another occupation (Whalley & Barley, 1997). Indeed, system administrators support a computing infrastructure used by many end users of different professions, such as finance, manufacturing, and government. As occupational outsiders, system administrators are often physically separated from others in their organization; anecdotal evidence and past experience shows that sysadmins are often housed "out of the way," in corners or basements and host their own business functions and parties.

Finally, as members of an occupational rather than organizational community, technicians belong to and participate in their technical community (Barley 1996; Whalley and Barley 1997). Similarly, system administrators participate in a community that extends beyond the bounds of a single organization or a single project. System administrators utilize discussion listservs, online forums, online support groups, and IRC

chat to share stories, describe problems and discuss solutions. System administrators have developed their own professional organizations (e.g., SAGE and LOPSA, described earlier), which define the profession and create foundational documents. For example, to alleviate confusion associated with ambiguous job titles – one organization's system architect might be another's senior administrator – SAGE has defined job levels and responsibilities that system administrators can then use in communications with fellow sysadmins (SAGE, 2006). Professional conferences, such as LISA and the USENIX Annual Technical Meeting, give members the opportunity to gather in person and strengthen social ties while gaining technical knowledge. For example, many sysadmins attend the LISA conference every year and make sure to attend the "hallway track," or the informal discussions that occur in the hallway during technical presentations.

2.5. Differences from other technicians

System administrators do differ from the technician ideal-type defined by Barley and Orr (1997) in two ways. One, technicians are traditionally defined by a technical professionals, such as lab technicians, who are defined by the medical and biological professionals they support (Keefe & Potosky, 1997). System administrators, however, act independently of their management and do very different work from others in their employing organization. Two, technicians are often considered an extension of a profession. An example of a professional extension would be emergency medical technicians (EMTs), who act in the place of physicians until a patient reaches a hospital

and who hold no authority independent of a physician's medical license (Nelsen, 1997).

System administrators, in contrast, do not work under the authority of a licensed

professional and are responsible for all aspects of the work performed.

Differences can also be seen when sysadmins are compared to software support

line technicians described by Pentland (1992). First, the work practices of these software

support workers were described as collaborative, but engaging only members of their

organization. This makes sense because knowledge relating to the support of a

proprietary software product would only exist within the organization. System

administrators, however, support computing environments that are comprised of products

from external vendors used in many organizations, and so knowledge of such products

exists outside of their organization. Second, the work tasks of software support

technicians is also described as serial, with the work for each support task completed or

transferred before moving on to the next. The work of system administration, however,

is full of multitasking and diversions, as seen in the software installation example earlier.

In the middle of the installation, the sysadmin left the server room and returned to an

earlier troubleshooting task. Third, software support technicians participate in only

maintenance activities, with future planning assigned to the software development team.

Sysadmins, however, have been shown to participate in both system maintenance (e.g.,

monitoring and troubleshooting) and system planning (e.g., forecasting and design).

Finally, software support techs only need to know information directly related to the

software component they specialize in. In contrast, regardless of their area of expertise,

each sysadmin was expected to have a constant understanding of both general (e.g.,

current system state) and specific (e.g., the names, locations and IP addresses of "their"

data backup servers) system information.

Despite these differences, system administrators are a good example of the

technician ideal-type defined by Barley (1996). Their work includes activities

traditionally classified as both blue- and white-collar work, and they broker information

between their technical community and the many end users they support. System

administrators identify themselves as members of their occupation rather than members

of their employing organization.

2.6. Tools used in the work of system administration

In addition to the identification of system administrators as broker technicians,

this research aims to study the work practices of system administrators with system

design in mind. Many studies have shown the relevance of work practice for design

(Button & Harper, 1996; Greenbaum & Kyng, 1991a; Karasti, 2001; Suchman, 1987,

1995) and investigations of work in context have shown that people often perform work

tasks differently than assumed by the design team (Suchman, 1995), forcing them to

adapt their interactions with technology to support their work practices (Button & Harper,

1996; Suchman, 1987). Agre states that systems provide more functionality to users by

including end user work practices and behaviors in system design (Agre, 1994). Through

an examination of system administrator work practices, this research aims to identify and

empirically test tool attributes that support the work practices of system administrators.

This extension beyond attribute identification to the identification and empirical testing of a model that measures attribute impact on tool use in the context of system administration is an important contribution of this study.

Throughout the time spent working with system administrators, it was obvious that many of the tools available were not always practical in the work environment. Command line interfaces (CLIs) were preferred to check system state because of their guarantee of current system information, while graphical user interfaces (GUIs) were used when complicated – yet often inflexible and system defined – graphical reports were needed. When asked if he preferred CLIs to GUIs, one interviewee answered that he would use whatever tool would get him what he needed the fastest, whether it be a report (in this case, a GUI tool) or the execution of a system task (in another example, a custom CLI script).

Monitoring activities were automated by a number of tools that continually watch for changes in the system, such as component performance or disk utilization, and generate notifications when predetermined thresholds are reached. These notifications appeared on a server monitor or were emailed to a member of the team. Even with the availability of a monitoring function in some tools, other tools did not contain this functionality and many of the interviewees reported checking system status either manually (usually using the command line) or by scripting a tool to fill this need.

System administrators use many tools in their work, and the interview participants often commented on the high number of tools needed to do their job. These tools can be developed in house or provided by vendors and third parties (Barrett et al., 2004) and can

be GUI or CLI. When analyzing system information, sysadmins used the tool that was uniquely suited the problem or task at hand. For example, when checking on system utilization, one sysadmin stated his preference for a GUI reporting tool because it presented the information quickly and in an easy-to-understand format. However, when checking other system statistics, he stated that GUI tools were too slow to present the information and he preferred the flexibility of CLI commands. Many teams of system administrators maintain system information in spreadsheets and in organizational-supported knowledge bases.

Interview responses echoed similar opinions about the number and types of tools available. Some participants thought the amount of tools available to them was "about right," while others thought they needed too many tools to do their jobs. Interviewees primarily used IM and email to collaborate with other sysadmins on their teams, increasing the number of software applications used in their job. While many stated a preference for CLI tools, this was explained as an underlying need for tools that were fast (both in speed of execution and speed of information gathering), used little system memory, and were scriptable. Great importance was placed on reliability of tools, with one sysadmin noting, "If it doesn't work once, it's out," and he'll find another tool to do that particular task. Indeed, one sysadmin remarked that "something always breaks" with the addition of a new component because of the unknowns introduced into the system, and that similar unreliable behavior is not tolerated in tools.

2.7. Summary

This chapter has shown how examinations of work practice can provide insights into the situated work of end users and shed light on implications for tool design. A narrative of the work practices of system administrators was presented, describing them as broker technicians and comparing them with other technicians. The chapter concluded with a brief discussion of the tools used in system administration, which will be continued in the next chapter. Because the work of system administration is so dependent upon technology and the way sysadmins access and control that technology, investigations of tool use and tool choice are an effective way of studying system administrators.

CHAPTER 3.   THEORY AND MODEL

Previous chapters have shown that system administrators are broker technicians. As skilled workers in complex and high-risk environments, this unique user group may have requirements of the systems and software they use that differ from the requirements of regular computer users, i.e., users who are not experts and power users. An examination of system administrator work practices sheds light on the system attributes and characteristics they need to do their jobs. Through previous experience, interviews, and a review of system administrator studies, information and system quality attributes that appear to be important to system administrators are presented. Following a discussion of these attributes, a model of user satisfaction that provides actionable guidance to system designers and an integration of the attributes is presented. The chapter closes with a discussion of the theory and model presented.

Research question: *What do system administrator work practices reveal about the tools they use?*

In addition to the semi-structured interviews described earlier, an exploratory study was done to observe system administrators and their interactions with a GUI software tool using audio and video data from a Fortune 500 usability study (Velasquez & Durcikova, forthcoming). The usability study targeted a single system administration tool (pre-beta code release) used to setup, configure, and monitor various data replication tasks. The audio and video analysis examined information availability and information

seeking behavior observed during the use of this tool to perform routine data replication tasks. This analysis expanded the definition of task completion to include both task execution and subsequent task verification and focused on the information seeking behaviors of system administrators during the verification stage of task execution. The study found a positive relationship between task complexity and the need for information that repeated the outcome of previous actions, which was termed verification information. The complex work environment of system administrators suggests the need for verification information in the tools they use.

3.1. Implications for tool design

It is clear from the description presented earlier that the work environment and work practices of system administrators both influence and are influenced by the tools they use. For example, the delay in software installation caused the system administrator to leave the server room and return to a previous task. Furthermore, because of the technical nature of their work, it is impractical to study system administrators without also studying the tools they must use to interact with their computing infrastructure and do their jobs. Indeed, Suchman makes the argument that in order for computer systems to be practically used in context, their design must be in line with the underlying work practices of those who use them (Suchman, 1995).

To augment the observations and findings from the interviews and data described above, a review of previous system administrator studies was conducted. The review

process is described below, followed by a discussion of the findings and the implications

that these finding have on tools designed for system administrators.

3.1.1. Review of System Administrator Studies

To complete the analysis, a review of the relevant literature was conducted.

Selected publications were limited to journals and conference proceedings, excluding

articles in trade magazines. Studies included were those that met the following criteria:

1. The subjects of the study were exclusively system administrators, including

   web administrators, network administrators, security administrators, etc.

   Studies of system administration concepts with end users or students as

   subjects were excluded.

2. The study focused on the work, work practices, and/or tools of system

   administrators. Studies that focused on other issues, such as algorithms or

   computing environments, were excluded.

Because research involving system administrators is relatively recent, no date

range limitations were used and studies were added to the sample iteratively.   The

literature reviewed was selected from CHIMIT 07 and an ACM search on the keywords

"system administrator" and "system administration." Papers from the first CHIMIT

(Computer Human Interaction for the Management of Technology) conference (CHIMIT

07) were selected because of the conference's emphasis on system administrators and

ACM publications were selected because of their known existing system administrator

literature content. A forward search of these publications was then conducted using

Google Scholar (Google, 2008) to expand the search to include studies published outside of ACM.

Twenty-nine studies were identified in the search for relevant literature. Each study was coded for characteristics important to system administrators. Because the goal of this classification was to identify system characteristics useful to system administrators, a characteristic was attributed to the study if 1) the characteristic was identified as an existing, useful aspect of the system(s) being used, or 2) the characteristic was identified as a missing aspect of the system, with the assumption that the missing characteristic was specifically identified by the authors because of an observed need for that characteristic. A full list of the papers included in the analysis and the coding can be found in Appendix A.

3.2. Findings

The technical expertise of system administrators is apparent in the narratives of their work and in the review of previous studies. The earlier description of a system administrator's work environment shows that it is one that is complex, risky, and large scale. Studies of aircraft and air traffic control systems show that complex environments require *flexible* systems that are capable of as much variety as their systems support (Dalcher, 2003). Flexible systems are those that can adjust to new demands or conditions. As an example, a study of IT security administrators cited the need for flexible reporting (Botta et al., 2007), wherein users can specify sets or subsets of data to

include and modify the output format to suit their changing environment and changing needs.

The large size of today's computing infrastructures presents a practical need for tools that can *scale* to meet the requirements of systems that continually grow and change. This need for tools that scale was identified in the ARC ethnography (Barrett et al., 2004; Haber & Bailey, 2007) and was named by system administrators themselves as a limitation of current tools (Verdoes, 1997). An example of this need was depicted in a commercial for a storage and services company. Small business owners were shown launching their first website. These owners shared congratulations as their Internet traffic and online sales increased. However, this excitement quickly turned to concern and then panic once the product was featured on television and their infrastructure crashed under the load of surging Internet traffic.

System *monitoring* activities were seen during system maintenance, with scripts, flashing screens, and email notifications used to alert the system administrator when certain predefined events occurred or thresholds were reached. Without monitoring capabilities, sysadmins must check various aspects of system and subsystem state at regular intervals as part of their system maintenance responsibilities. A common example of a monitoring function can be seen with automated emails that are sent when server capacity reaches a predetermined level. This email notification allows the sysadmin to focus on other aspects of the computing infrastructure he is supporting until the server capacity requires his attention.

As keepers of massive infrastructures, it is perhaps impossible for sysadmins to have a complete understanding of every component in their system (Hrebec & Stiber, 2001). However, a mental picture of the overall state of the system, or *situation awareness*, has been identified as a requirement in the work of system administration (J. Bailey et al., 2003) and a survey conducted by Hrebec and Stiber (2001) found that system administrators report a poor understanding of the computing infrastructures they support. Systems that can convey an understanding of overall system state while providing the ability to also access system details is important in the complex and dynamic infrastructures supported by system administrators. For example, when installing an operating system patch on a server, the sysadmin must know IP address and port information for the server (details) while also knowing where the server fits in the rest of the system and the overall system state.

A related system requirement can be found in the need for *accurate* and *current* information. An accurate understanding of one's system relies on accurate information, and many sysadmins reported relying on CLI commands because they reported information stored and calculated by the operating system and known to be accurate. For example, some sysadmins reported using tools in the past that reported incorrect I/O (input/output throughput) information, which was discovered only after noticing discrepancies and then confirming with detailed and time-consuming research. Current information is also a requirement in system administration, a need that was communicated by a system administrator that participated in the usability study. When asked to report on the status of the background data replication, the participant completed

the task using the web-based GUI tool being tested, but then commented that he would also want to confirm the status using a CLI command. When asked why he would use a CLI command, he expressed concern that the GUI information might be cached but that the use of a CLI command would ensure current status information.

Many study participants reported the use of custom tools to monitor system state, configure components, and perform many other maintenance tasks, suggesting the need for *scriptability*. The ability to program, or script, portions of system administration work was apparent in two general situations: 1), when the automation of oft-repeated or complex functions generally executed through the command line, and 2), when the sysadmin wished for an api (a scriptable interface to a program) to automate some GUI tasks that took too long and required navigating multiple screens. The ability to script work processes has also been identified as an important attribute in previous studies (e.g., Haber & Bailey, 2007).

Troubleshooting activities illustrate the use of *logging information* while gathering information about the problem and *verifying* the outcomes of commands issued. The use of system logs was seen in the work of system administrators, particularly when executing long sequences of CLI commands or when returning to a task that was started, left, and then returned to later. In these cases, system logs were helpful to determine the last command issued or, in the case of verification information, to determine the outcome of the last command issued. The latter information was often used following installations or configurations as a way to verify action completion and assure the sysadmin that the task was complete. The need for additional information in complex

and risky work is also supported in the literature. A study of government workers and

their information seeking behavior done by Bystrom and Jarvelin (1995) suggests that as

tasks increase in complexity, users are more likely to seek additional information

(Bystrom & Jarvelin, 1995). Marketing research suggests that consumers use the search

for additional information as a risk-reducing strategy (Murray & Schlacter, 1990). The

complex and risky work environment of system administrators suggests a greater need for

information, seen the need for logging information and verification information.

One interviewee reported the use of a local installation of Bugzilla because it was

an easily *accessible* central repository of system information. Originally created by

Mozilla, Bugzilla is a free software application that is traditionally used to support

software development by managing software bugs. The system administrator

interviewed used his group's installation of Bugzilla to track system errors, outages, and

component status. He reported his preference for Bugzilla over the corporate-sponsored

knowledge base because of the ease with which he could access and edit information.

A study by Takayama et al. (2006) found that *credibility* was an underlying factor

in user interface choice. Based on comments from study participants, this research

suggests that credibility may also be a factor in tool choice, regardless of user interface

type. For example, many system administrators reported their preference for a given tool

because they had used it for a long time or because himself or a respected peer had

programmed the tool. When asked to elaborate on this motivation for tool use, many

sysadmins identified the length of use and knowledge of the programmer as an indication

of their confidence and trust in these tools.

The large number of information sources used by system administrators suggests that *data integration* could be useful. For example, a sysadmin troubleshooting a system error was seen accessing data from server logs, monitor notifications, vendor documentation, online forums, and Google searches. At one point, the sysadmin remarked that it "would be handy" to be able to access more than one piece of information from a single screen or application.

Additional characteristics that emerge in the discussion of tools used include *complete* information that is presented in a *format* that is easy to understand. One clear example of these two needs was seen when a sysadmin was trying to gain a better understanding of system usage. The sysadmin issued five CLI commands, stating he wanted to see "everything" on the screen and his GUI tool didn't report every metric he needed to access. After seeing the output from these commands, he switched to his GUI tool (that he had just avoided because of its lack of complete information) for its formatted reports and a graphical representation of the data he had just viewed. After asking why he used both tools, he responded that the CLI command gave him the detailed information he needed and the GUI tool provided him with a better overall picture of the system through formatted reports and graphical representations.

Given the hectic, multi-tasked nature of the work involved, it wasn't surprising to hear many of the participants report a preference for "whichever tool will get me what I need *fastest*." In fact, many system administrators expressed a preference for CLI tools simply because of their speed of tool start up and command execution. One sysadmin remarked that the only problems with his favorite GUI tool were the long start up time

(which prompted him to rarely exit the program) and the system "hang" or delay that occurred when he was performing complex tasks.

3.3. Important Characteristics

The strength of this focused investigation of technology-in-use lies in its ability to identify realistic solutions and guide potential designs (Button & Harper, 1996). By examining the work practices of system administrators, the following list of attributes that appear to be important to system administrators was generated. Note that many attribute definitions were refined throughout the project, referencing the attribute definitions provided by Wixom and Todd (2005).

1. Flexibility: the way the system adapts to changing demands of the system administrator

2. Scalability: the ability of a system to scale to large and/or complex computing environments

3. Monitoring: the ability to monitor for certain events or conditions

4. Situation Awareness: the ability of a system to provide information about the overall state of the system

5. Scriptability: the ability to script add-ons or automate tasks provided by the system.

6. Logging Information: information that echoes or repeats previous actions taken

7.   Accessibility: the ease with which information can be accessed or
        extracted from the system

8.   Accuracy: the user's perception that the information is correct

9.   Integration: the way the system allows data to be integrated from various
        sources

10.   Information Completeness: the degree to which the system provides all
        necessary information

11.   Information Format: the user's perception of how well the information is
        presented

12.   Information Currency: the user's perception of the degree to which the
        information is up to date

13.   Speed: the degree to which the system offers timely responses to requests
        for information or actions, including the speed of tool start up/initiation.

14.   Reliability: dependability of system operation

15.   Verification Information: information that echoes or repeats the outcomes
        of previous actions taken

16.   Trust: the credibility of a system and its output

Upon further inspection, these characteristics fall into categories of attributes
pertaining to attributes of the information supplied by the system and attributes of the
system itself. This classification of characteristics can be seen in Table 1. (See
Appendix A for the supporting literature for each attribute identified.)

Information Attributes	System Attributes
Logging	Flexibility
Accuracy	Scalability
Completeness	Monitoring
Format	Situation Awareness
Currency	Scriptability
Verification	Accessibility
	Integration
	Speed
	Reliability
	Trust

Table 1.   Classification of characteristics

3.4. Model and Theory

Although the above list of characteristics important to system administrators is interesting, it does little more than summarize observations and offer untested guidance to designers. Without evidence that these characteristics will influence a system administrator to use a particular tool, practitioners will be reluctant to invest the time and money needed to implement these features. The goal of this study is to understand the link between these characteristics and their impact on system administrator perceptions and ultimately, use of the system.

When evaluating user perceptions of information technology (e.g., DeLone & McLean, 1992), theories of technology acceptance (e.g., Davis, 1989; Venkatesh, 2000) and user satisfaction (e.g., J. Bailey & Pearson, 1983; Shneiderman, 1997) are often cited, and each has its strengths and limitations. The strength of technology acceptance theory lies in its ability to link behavioral attitudes and beliefs about the system (i.e., ease of use

and usefulness) to users' system usage behaviors. That is, technology acceptance

theories have high predictive ability. A limitation of technology acceptance theories,

however, is the lack of system feedback that can be easily translated into design

guidelines. For example, feedback regarding a system's ease of use and usefulness offers

no concrete information about what attributes and features to include in system design.

However, these theories offer little practical guidance on system design. The opposite is

true of user satisfaction theories. The strength of user satisfaction theories lie in the

measured impact of system attributes, such as information format and system

accessibility, on user satisfaction. That is, system attributes that are found to be

significant indicators of user satisfaction can be addressed in the design of the system.

The limitation of user satisfaction theories is seen in their poor predictive ability. That is,

a user's satisfaction of a system has been shown to be a poor predictor of their actual

system usage behaviors (e.g., Davis, 1989; Wixom & Todd, 2005).

To take advantage of the strength of both the technology acceptance and user

satisfaction theories, Wixom and Todd (2005) presented a modification of DeLone and

McLean's original user satisfaction model (1992) that links system and information

satisfaction with the behavioral predictors found in technology acceptance literature,

perceived ease of use and usefulness. They argue that the object-based attitudes and

beliefs expressed in system quality, information quality, system satisfaction, and

information satisfaction affect the behavioral beliefs that are captured in ease of use and

usefulness. These behavioral beliefs, in turn, influence a user's behavior (i.e., their use or

non-use of a system). Essentially, this new model represents a theoretical integration of

user satisfaction and technology acceptance theories. The strength of the model lies in its

ability to guide IT design and development and predict system usage behaviors. System

and information quality antecedents offer concrete attributes important to the user that

can be addressed and tested throughout the system development lifecycle. (See Figure

2.)

Characteristics important to System	Object-based beliefs	Object-based attitudes	Behavioral beliefs	Behavioral attitude
Information attributes	Information quality	Information satisfaction	Usefulness	Intention
System attributes	System quality	System satisfaction	Ease of use	Attitude
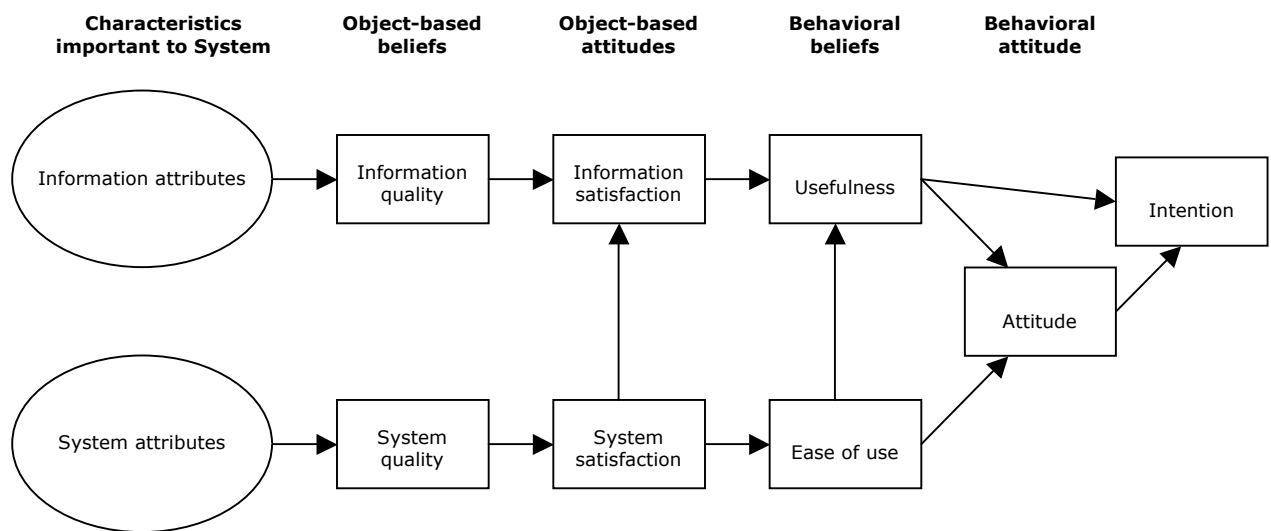
Figure 2.   Integrated user satisfaction model (Wixom and Todd 2005)

This model also provides a solid foundation for investigations into software

characteristics that might be more or less important to specific user groups, such as

system administrators. Because system administrators are still computer users in the

general sense, the overall theoretical model is expected to hold. Their unique work

environment, technical background and work practices, however, suggest that they may

have different needs when using computers or software applications to do their jobs.

Previous studies (e.g., J. Bailey & Pearson, 1983; Baroudi & Orlikowski, 1988; Doll &

Torkzadeh, 1988; Ives et al., 1983) have focused on a relatively small number of

characteristics that, although telling in their underlying structure (Wixom & Todd, 2005),

have been criticized for investigating arbitrary system attributes (Galletta & Lederer,

1989). The analysis of system administrator work practices above identifies system and

information quality attributes (i.e., antecedents) that are meaningful and important to

system administrators.

	Information Attributes	System Attributes
Wixom & Todd	Completeness Accuracy Format Currency	Reliability Flexibility Integration Accessibility Speed (Timeliness in W&T)*
Additional attributes identified in this study	Log Information Verification Information	Scriptability Scalability Situation Awareness Monitoring Trust

* Not significant in W&T study
Table 2.   Information and system attributes

Wixom and Todd (2005) identify information and system quality antecedents

through a decomposition and integration of factors used in prior user satisfaction studies.

The authors suggest that while the antecedents used in their study are generally

applicable, the importance of each may be dependent upon the specific settings and

systems studied. Building on this assertion, this research suggests that the unique

environment, technical ability, and work practices of system administrators may introduce additional attributes. In fact, many of the system and information quality attributes uncovered in the examination of system administrators and their work practices have been identified by Wixom and Todd (2005) (see Table 2).

Aside from the newly identified attributes, one difference (timeliness, marked with an asterisk in Table 2) should be discussed. Wixom and Todd's study of data warehouse users found timeliness to not be a significant indicator of system quality. These findings are supported by work done by Bodker (1989), which found that the speed of an information system was not important to novices. The inclusion of speed when studying system administrators, who are skilled workers, is supported by the same research, which found that speed was important to skilled workers. Because the speed of a system was a recurring theme in previous experience and interviews with system administrators and they are skilled workers, speed was included in the model.

In summary, the unique context and work practices of system administration suggest information and system attributes presently missing from user satisfaction research. The model presented in this paper links design system attributes to system usage and identifies tool attributes important to system administrators.

3.5. Portion of model tested

Although organizations may play a role in tool purchase, interviews and previous experience indicate that system administrators primarily use a self-selected suite of tools to do their work. Interviews showed that many system administrators within the same

organization and even on the same team use different tools and different sets of tools to perform the same tasks. Given this variability of tool choice and use, the difficulty in gathering survey responses from hundreds of system administrators on one particular tool was apparent. As such, the survey was administered to sysadmins of all types (e.g., network administrator, operating system administrator, web administrator, etc), and each participant was asked to identify the tool they used most often in their jobs and complete the survey with that one particular tool in mind. Because the surveys were completed for a tool used most often by the participants, their intention to use the tool is implied; as such, the survey instrument tested all aspects of the model leading up to the sysadmin's behavioral attitude of the tool. This portion of the model can be seen in Figure 3.
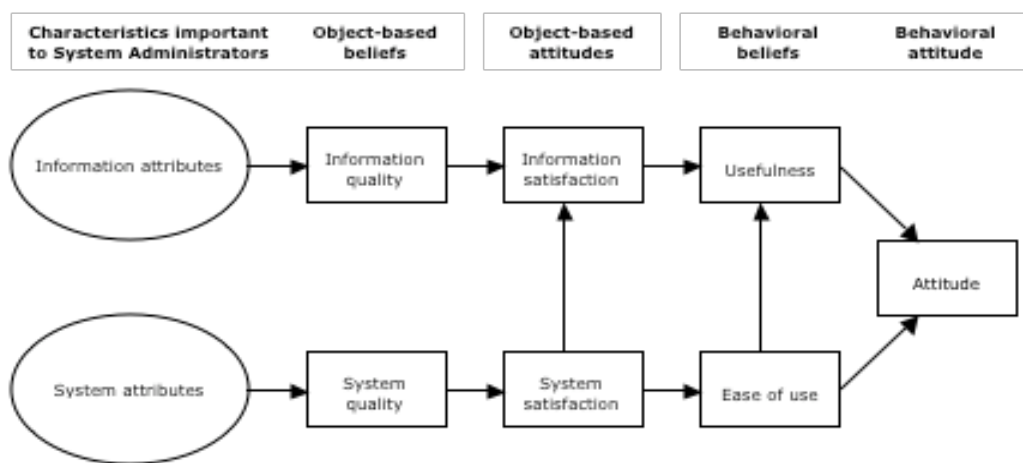
Figure 3.   Research model tested

3.6. Theory and Model Summary

This study presents the work practices of system administrators. As skilled workers and power users responsible for large computing infrastructures, their work is fast-paced and is characterized by interruptions and multitasking. The complex and risky work environment in which they operate distinguishes them from regular computer users. System administrators require absolute attention to some details while maintaining a general understanding of the overall system. These factors indicate that system administrators may be unique users with information system requirements that are different from the requirements of regular computer users.

Our analysis of system administrator work practices and environment has implications for tool design and suggests that tool development specific to this unique user group is appropriate. The study identified system and information quality attributes that are new and differentiate this unique user group. Log information, verification information, monitoring, situation awareness, scalability, scriptability, and trust have not been previously identified as important tool attributes and appear to be important to the work practices of system administrators. For example, regular computer users rarely require scripting abilities in the systems they use or rely on system logs, while system administrators require support for these activities in their work.

Finally, a modified user satisfaction model that links system design attributes to end user satisfaction and system use was presented, offering an opportunity to measure the impact that these identified attributes have on system administrator beliefs and tool usage. This study provides researchers guidance for adapting existing user information

satisfaction models for tools used by system administrators. An empirical test of the

model is presented next.

3.7.   Model hypotheses

The Wixom and Todd integrated user satisfaction model (2005) was selected

because of its ability to link actionable design guidelines (found in system and

information quality antecedents) to end user behavioral beliefs and attitudes. These

behavioral attitudes, in turn, affect a user's intention to use a tool. Beginning with

information and system quality antecedents, the hypotheses in the model are listed.

3.7.1.   Information quality characteristics

Information and system characteristics are core elements in information success

research (DeLone & McLean, 1992) and shape the beliefs a user has about the

information a system provides (Ajzen & Fishbein, 1980). The antecedents of information

quality important to system administrators were identified in Chapter 5, based on

researcher experience, interviews, and a review of the literature.

> *Hypothesis 1-1: Information currency positively affects the perceived information quality of a system.*

> *Hypothesis 1-2: Information completeness positively affects the perceived information quality of a system.*

> *Hypothesis 1-3: Information accuracy positively affects the perceived information quality of a system.*

Hypothesis 1-4: Information format positively affects the perceived information quality of a system.

Hypothesis 1-5: The availability of logging information positively affects the perceived information quality of a system.

Hypothesis 1-6: The availability of verification information positively affects the perceived information quality of a system.

3.7.2. System quality characteristics

Information and system characteristics are core elements in information success research (DeLone & McLean, 1992) and shape the beliefs a user has about the system (Ajzen & Fishbein, 1980). The antecedents of system quality important to system administrators were identified earlier, based on researcher experience, interviews, and a review of the literature.

Hypothesis 2-1: Reliability of a tool positively affects the perceived system quality.

Hypothesis 2-2: Flexibility of a tool positively affects the perceived system quality.

Hypothesis 2-3: Information integration provided by the system positively affects the perceived system quality.

Hypothesis 2-4: The accessibility of information positively affects the perceived system quality

Hypothesis 2-5: Speed positively affects the perceived system quality

Hypothesis 2-6: Scriptability positively affects the perceived system quality.

Hypothesis 2-7: Scalability positively affects the perceived system quality.

Hypothesis 2-8: Credibility positively affects the perceived system quality.

Hypothesis 2-9: The support of situation awareness positively affects the
perceived system quality.

Hypothesis 2-10: Monitoring positively affects the perceived system quality.

3.7.3. Integrated user satisfaction model

Object based beliefs. The beliefs a user has toward a system's information quality

and system quality are shaped by the system's attributes (Ajzen & Fishbein, 1980).

Social psychology research on attitude and behavior state that a user's beliefs about an

object affect their attitude toward the object (Ajzen & Fishbein, 1980). In the context of

information systems, a user's beliefs about information and system quality affect their

information and system satisfaction, respectively (Wixom & Todd, 2005). These theories

are expected to hold for system administrators, resulting in the following hypotheses:

Hypothesis 3-1: Information quality positively affects perceived information
satisfaction.

Hypothesis 3-2: System quality positively affects perceived system satisfaction.

Object-based attitudes. Research in social psychology has shown that object-based attitudes can predict behavioral intentions by framing information about that behavior (Eagly & Chaiken, 1993; Fazio & Olson, 2003). These attitudes reflect a user's satisfaction with the object (Wixom & Todd, 2005), which influence the user's beliefs about using the object (Ajzen et al., 2005). Rephrased in the context of information systems, attitudes about a system (that is, object-based attitudes) frame a user's beliefs about that system, which can affect their beliefs about using the system (Ajzen & Fishbein, 1980). Similar relationships are expected among system administrators and the systems they use, resulting in the following hypotheses:

Hypothesis 3-3: System satisfaction positively affects information satisfaction

Hypothesis 3-4: System satisfaction positively affects perceived ease of use.

Hypothesis 3-5: Information satisfaction positively affects perceived usefulness.

Behavioral beliefs. Technology acceptance theory provides predictions of system usage by linking behavioral beliefs and behavioral attitudes that are consistent in time, target, and context (Adams et al., 1995). This research states that external factors can influence one's beliefs regarding the outcomes of performing a behavior. Technology acceptance theories have been empirically tested and validated numerous times (e.g., Davis, 1989), demonstrating the strength of the underlying theory. At its core, technology acceptance research predicts that perceived ease of use affects the perceived usefulness of the system, and that together, perceived usefulness and perceived ease of

use affect a user's attitude toward system usage. Similar predictive relationships are expected in the context of system administrators, resulting in the following hypotheses:

Hypothesis 3-6: Ease of use positively affects perceived usefulness.

Hypothesis 3-7: Usefulness positively affects attitude.

Hypothesis 3-8: Usefulness positively affects attitude.

3.7.4. Hypotheses Summary

The modified user satisfaction model links system design attributes to end user satisfaction and system use. Attributes unique to system administrators are presented and hypothesized to positively influence perceived information and system quality when controlling for user interface type. The remainder of the model, as proposed by Wixom and Todd (2005), is expected to hold for these users and relationships are hypothesized. The following chapters outline the methodology and results of the model proposed.

CHAPTER 4.   METHODOLOGY AND DATA COLLECTION

Previous chapters have presented system administrators and their work practices, showing that this user group may have needs different than those of regular computer users. Through personal work experience of the researcher, semi-structured interviews, and a review of the literature, system characteristics that appear to be important to system administrators were identified and a modified user satisfaction model was presented. This theoretical model provides an opportunity to link the identified system characteristics with system administrator beliefs and tool usage. Most importantly, this research contributes to existing knowledge by 1), identifying information and system quality attributes important to system administrators and 2), testing the modified user satisfaction model in the untested context of system administration.

The goal of this chapter is to operationalize these characteristics and test the modified user satisfaction model. Interviews were conducted to investigate system administrator tool use and preferences. A survey methodology was utilized to collect both quantitative and qualitative data; sampling and data collection procedures will also be described.

Once the constructs were identified, corresponding measurement items were researched. When possible, previously validated measures were used. Paper-based surveys were created with input from the dissertation advisor and IT colleagues. Next, the instrument was pre-tested with three system administrators. While some wording was

edited for clarity, no major issues were reported with the survey instrument. An online version of the survey instrument was then pre-tested by 24 system administrators.

The chapter proceeds with a detailed discussion of the items used to measure each construct, with the final measurement instrument presented in Appendix C. Section 4.7 presents the sampling and data collection procedures used. All constructs were measured on a seven-point Likert scale, with 1="very strongly disagree" and 7="very strongly agree." The chapter concludes with an analysis of the data collected and a discussion of the findings.

4.1. Object-based beliefs and antecedents

Object-based beliefs about information quality and system quality are shaped by their antecedents, which were derived in Chapter 4, following the assertion by Wixom and Todd (2005) that the "importance of [attributes] is contingent on a specific system and setting" (p. 90). This section describes the constructs and corresponding items that were used to measure system quality and its antecedents and information quality and its antecedents.

4.1.1. System quality

The Wixom and Todd (2005) measurement instrument for system quality was adapted to measure users' perceptions of system quality for the tool identified. Only two items were included for system quality to reduce redundancy. All constructs adapted from the Wixom and Todd (2005) instrument are listed and defined in Table 3.

4.1.2. System quality antecedents

System quality attributes, include both existing constructs and newly developed constructs. Measurement items for the existing constructs (i.e., reliability, flexibility, integration, accessibility, and speed) were modified from the Wixom and Todd (2005) instrument and are included in Table 3.

Measurement items for the new constructs (i.e., credibility, scalability, scriptability, situation awareness, and monitoring) were developed following Churchill's methodology (Churchill, 1979). Items were created based on construct definitions and components identified in the literature. Next, a sorting task was used to determine face and discriminant validity. Each measurement item was written on a 3x5 note card and all cards were shuffled. Three professional system administrators were asked to sort the cards into logical groups and name each group. Each sysadmin sorted the items into the five groups and specified similar identifying terms[3]. Based on participant feedback, the wording on some items was slightly modified. All new constructs are shown in Table 4.

4.1.3. Information quality

The Wixom and Todd (2005) measurement instrument for information quality was adapted to measure users' perceptions of information quality for the tool identified. Only two items were included for information quality to reduce redundancy. The construct definitions are shown below in Table 3.

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[3] One construct, situation awareness, was identified as "system awareness" or "system state awareness" by all system administrators. As such, the term "system awareness" was used in importance rankings in Section 1.6.

4.1.4. Information quality antecedents

Information quality attributes include both existing constructs and newly developed constructs. Measurement items for the existing constructs (i.e., completeness, accuracy, format, and currency) were modified from the Wixom and Todd (2005) instrument. Existing construct definitions are shown below in Table 3.

Measurement items for the new constructs (i.e., logging and verification) were developed following Churchill's methodology (Churchill, 1979) described earlier. Items were created based on construct definitions and components identified in the literature and were modified based on system administrator feedback. These new constructs are shown below in Table 4.

4.2. Object-based attitudes

4.2.1. System satisfaction

System satisfaction is an important object-based attitude that contributes to both information satisfaction and ease of use. System satisfaction is influenced by users' object-based beliefs of system quality, which are in turn influenced by system attributes. The Wixom and Todd (2005) measurement instrument for system satisfaction was adapted to measure users' perceptions of system satisfaction of the tool identified. The construct definition is shown below in Table 3.

4.2.2. Information Satisfaction

Information satisfaction is an important object-based attitude that contributes to perceived usefulness. Information satisfaction is influenced by users' object-based beliefs of information quality, which are in turn influenced by information quality attributes. The Wixom and Todd (2005) measurement instrument for information satisfaction was adapted to measure users' perceptions of information satisfaction of the tool identified. The construct definition and two items are shown below in Table 3.

4.3. Behavioral beliefs and behavioral attitude

A user's satisfaction with a system and the information it provides impacts their behavioral beliefs about using the system and includes measures of perceived ease of use and user satisfaction. These behavioral beliefs affect a user's attitude toward using the system. These constructs are defined in Table 3.

Construct	Definition
System Quality	The user's perceptions of the system itself and the way it delivers information.
Reliability	The dependability of system operation.
Flexibility	The way the system adapts to changing demands of the user.
Integration	The degree to which the system allows data to be integrated from various sources.
Accessibility	The ease with which information can be accessed or extracted from the system.
Speed	The degree to which the system provides timely responses to requests for information or action, including the speed of tool start up / initiation.
Information Quality	The user's perception of the quality of the information included in the system.
Completeness	The degree to which the system provides all necessary information.
Accuracy	The user's perception that the information is correct.
Format	The user's perception of how well the information is presented.
Currency	The user's perception of the degree to which the information is up to date.
System Satisfaction	The user's perception of their satisfaction with respect to the system and the mechanics of interaction.
Information Satisfaction	The user's perception of their satisfaction with the information produced by the system.
Ease of use	The degree to which a person believes that using the system would be free of effort.
Usefulness	The degree to which a person believes that using the system would enhance his or her job performance.
Attitude	The user's positive or negative feelings about using the system.

Table 3.   Constructs adapted from Wixom and Todd (2005).

Construct	Definition
Credibility	The credibility of the system and its output.
Scalability	The ability of a system to scale to large or complex computing environments.
Scriptability	The degree to which the system provides the ability to script add-ons or automate tasks.
Situation Awareness	The degree to which the system provides information about the overall state of the system.
Monitoring	The degree to which the system provides the ability to monitor for certain events or conditions.
Logging	The degree to which the system provides information that echoes or repeats previous actions taken.
Verification	The degree to which the system provides information that echoes or repeats the outcomes of previous actions.

Table 4.   New constructs and definitions.

The reader is referred to Appendix C for the final survey instrument.

4.4.   Importance of antecedents

Because some tools may not have all of the characteristics generally important to

system administrators, the survey began by asking participants to rate the importance of

each attribute in the suite of tools they use to do their job with the following instructions:

Of the tools you use most often, how important are the following

attributes. Please keep in mind that while not every tool will have every

attribute, we are interested in what attributes are important to you across

your suite of tools. That is, while one particular tool may not have a

certain attribute, you may still find it important in other tools.

Survey respondents were asked to rate the attributes on a scale from 1 = "Not important"

to 5 = "Very important."

4.5. Demographic information

Participants' demographic information was collected using single-item questions.

The scale and items used are shown below in Table 5.

Scale	Items
Position	What is your official job title?
Tenure	How many years of experience do you have as a system administrator in your current organization? How many years of experience do you have as a system administrator in total?
Gender	What is your gender?
Age	What is your age?
Education	What is the highest level of education you have attained?
Organization	What industry do you currently work in?

Table 5.   Items to measure demographic information

4.6. Tool choice and use information

Information regarding participants' tool use and choice of tools was solicited

through open-ended questions. The items used are shown below in Table 6.

Items
What five (5) tools do you use most often?
Briefly, what do you like about these tools that makes you use them?
Briefly, what do you NOT like about these tools?
Are there any tools you WISH you could use, but you currently do not? What are these tools and why do you not currently use them?
What role does your company play in your selection of tools? That is, does your company select every tool you use in your job, or do you choose all of your tools yourself?

Table 6.   Items to collect tool choice and use information.

4.7.   Sampling and data collection

A web-based survey method was selected because of ease of distribution and data collection and the targeted respondents' access to the Internet and familiarity with web-based applications and tools. The population of interest is system administrators, including network administrators, operating system administrators, web administrators, etc, who identify themselves as system administrators or the work they do as system administration.

Before implementing the survey, it was pilot tested using professional system administrators. The survey was advertised through professional system administrator association (e.g., LOPSA and SAGE) message boards and notifications were sent via email when requested. Twenty-four surveys were completed, and participants were invited to email the researcher with any suggestions or modifications not included in their

survey responses. Each newly developed construct showed reliability with Cronbach's alpha levels of 0.70 or greater (Nunnally, 1978).

To obtain final survey participants, an announcement was posted on professional system administrator association message boards (e.g., LOPSA and SAGE) and emailed to participants as requested (see Appendix B). In order to reach as many system administrators as possible, participants were also invited to refer fellow system administrators to the study. Message board notices were posted in December 2007, and reminder notices were posted in early spring 2008. Data collection was stopped March 31, 2008. Email notices were sent as requests were received, up to the data collection stop date. All surveys were confidential, no identifying information was required and all questions were optional.

4.8. Summary

This chapter presented the methodology used in this research study. Constructs were listed and defined. The data was collected from professional system administrators via a web-based survey. The final survey instrument can be found in Appendix C.

CHAPTER 5.   DATA ANALYSIS AND RESULTS

Survey respondents were professional system administrators who were solicited through professional association message board postings. Research study notifications with the online survey's URL were posted in late December 2007 and late February 2008. Data collection was stopped late March 2008. After removing incomplete responses, 126 surveys were fully completed. Following Podsakoff et al. (Podsakoff et al., 2003), mono-method bias was considered by performing a factor analysis and testing for a common method influence across all responses. A factor analysis of all items extracted 12 factors explaining 74% of the variance, with no single factor accounting for significant loading (at the $p < 0.10$ level) for all items. The average time to complete the survey was 23 minutes. Overall information about survey completion rates is shown below in Table 7.

Viewed	517
Started	364
Completed	129
Completion Rate	35.44%
Drop Outs (After Starting)	235

Table 7. Survey statistics

5.1.   Demographic information and descriptive statistics

This section describes the demographic information of the survey respondents as well as descriptive statistics of all of the constructs used in the research study. Of the survey respondents, 91% were male and 9% were female. The age of respondents ranged

from 21 to 62, with an average age of 37.5. Participants reported working at their current

organization for an average of 5 years (ranging from 3 weeks to 26 years) and reported

working as a system administrator for an average of 12.1 years (ranging from 2 years to

29 years). Participant demographics were similar to those found in the 2005-2006 SAGE

Salary Survey (SAGE, 2006), considered the most comprehensive survey of system

administrator personal and work demographics. These similarities suggest the survey

sample is representative of all system administrators. Demographics that were available

(or those that could be approximated from available information) for direct comparison

are shown below in Table 8.

Measure	Study Statistics	SAGE Statistics
Total years as system administrator (mean)	12.39	10.8
Total years as system administrator (std dev)	6.01	5.84
Age (mean)	37.5	35[1]
Male respondents	91.2%	91.6%
Female respondents	8.8%	8.4%
Attained undergraduate degree	53.6%	59%

[1] Age was approximated from available data

Table 8.   Current study vs. 2006 SAGE Salary Survey

Almost half of the survey participants worked for for-profit organizations and

companies (49.6%), including manufacturing, high tech, and finance. The next largest

number of respondents (38.4%) worked in academic settings, while others worked for

non-profit organizations (5.6%), government agencies (5.6%), or in research (.8%).

	Mean	Std. Deviation
Currency	5.62	1.12
Completeness	5.04	1.14
Accuracy	5.84	0.87
Format	5.14	1.33
Logging	4.40	1.69
Verification	4.74	1.62
Reliability	6.09	0.94
Flexibility	5.83	1.04
Integration	5.20	1.47
Accessibility	5.77	1.06
Speed	5.81	1.11
Scriptability	5.67	1.38
Scalability	6.17	0.92
Credibility	5.47	0.82
Situation Awareness	5.09	1.22
Monitoring	4.80	1.51
Information Quality	5.83	1.08
System Quality	6.07	0.98
Information Satisfaction	5.72	1.04
System Satisfaction	5.93	1.07
Usefulness	5.98	0.86
Ease of Use	5.33	1.10
Attitude	5.45	1.22

Table 9.   Mean and standard deviation of constructs

Table 9 above, displays the descriptive statistics for the constructs used to test the

modified user satisfaction model. As these numbers show, there is enough variability in

each construct so there are no restrictions of range issues. Descriptive statistics are also reported in Table 10, below, for the *importance* of each attribute, as reported by the participants. Attribute ratings were measured on a scale from 1 to 5.

	Mean	Std. Deviation
Accuracy	4.74	.506
Accessibility	3.98	.762
Completeness	3.74	.870
Credibility	4.57	.700
Currency	4.23	.709
Flexibility	3.92	.947
Format	3.58	.900
Integration	3.50	.947
Logging	3.62	.982
Monitoring	3.78	.906
Reliability	4.68	.576
Situation Awareness	3.72	.876
Scalability	3.79	.927
Scriptability	4.12	.993
Speed	3.66	.782
Usefulness	4.31	.745
Verification	3.38	.904

Table 10.   Mean and standard deviation of attribute importance.

5.2.   Measurement model

To begin the analysis, the reliability and validity of each construct in the model was tested. The reliability of a construct is its internal consistency and was assessed with Cronbach's alpha and composite reliability. While Cronbach's alpha is traditionally used to measure reliability, Chin et al (Chin et al., 2003) show that composite reliability provides more accurate reliability estimates, especially in an SEM context. Additionally, Cronbach's alpha has been shown to be biased against short scales (Carmines & Zeller,

1979), and many of the constructs are measured with two or three items. Both measures should be greater than 0.70 (Chin et al., 2003; Nunnally, 1978). In the initial analysis, all constructs are above the recommended level of 0.70 for composite reliability, and most constructs are above the recommended level of 0.70 for Cronbach's alpha. Constructs not meeting alpha = 0.70 are Completeness, Accuracy, Accessibility, and Credibility.

The validity of a construct is the degree to which inferences can be legitimately made from the operationalization of a construct, and is comprised of convergent and discriminant validity. Convergent validity is used to show that measures that should be related are related, while discriminant validity is used to show that measures that should not be related are not. Two measures were used to assess validity of the constructs: average variance extracted (AVE) and items loading on constructs. AVE is an indicator of convergent validity and measures range from 0 to 1; adequate validity is found in AVE measures above 0.50 (Fornell & Larcker, 1981). For satisfactory discriminant validity, the square root of AVE for each construct should be greater than the correlations with other constructs (Chin, 1998).

Factor analysis was used to identify items that needed to be dropped from a construct. Items that loaded below the 0.70 level (Carmines & Zeller, 1979) were dropped from their construct. The revised reliability measures for the constructs are found below in Table 11. The refinement of the measurement instrument increased the reliability of the Credibility construct to adequate levels. The remaining constructs not meeting Nunnally's suggested Cronbach's alpha level of 0.70 (Nunnally, 1978) are

Completeness, Accuracy, and Accessibility. It should be noted, however, that the

composite reliability measures favored by Chin et al (Chin et al., 2003) remain above the

suggested level of 0.70 and in the case of Accuracy, increases due to its refinement.

Furthermore, Cronbach's alpha can be biased against short scales (i.e., two- and three-

item scales) (Carmines & Zeller, 1979); therefore, composite reliability is more

appropriate as a measure of reliability (Chin et al., 2003). The composite reliability

measures for Completeness, Accuracy, and Accessibility, meet the 0.70 cut-off value for

composite reliability and therefore are reliable. All other constructs meet both the

Cronbach's alpha cut-off of 0.70 (Nunnally, 1978) and the composite reliability cut-off of

0.70 (Chin et al., 2003) and therefore are reliable.

	# of Items	Cronbach's Alpha	Composite Reliability	AVE	Sqrt (AVE)
Currency	2	0.77	0.90	0.81	0.90
Completeness	2	0.55	0.82	0.69	0.83
Accuracy	2	0.63	0.84	0.73	0.85
Format	3	0.94	0.96	0.90	0.95
Logging	2	0.90	0.95	0.90	0.95
Verification	2	0.85	0.93	0.87	0.93
Reliability	3	0.90	0.94	0.83	0.91
Flexibility	3	0.80	0.88	0.71	0.84
Integration	2	0.80	0.91	0.83	0.91
Accessibility	2	0.69	0.87	0.76	0.87
Speed	2	0.81	0.91	0.84	0.92
Scriptability	3	0.86	0.91	0.78	0.88
Scalability	3	0.78	0.87	0.70	0.84
Credibility	2	0.81	0.91	0.84	0.92
Situation Awareness	3	0.78	0.87	0.65	0.81
Monitoring	2	0.79	0.88	0.78	0.88
Information Quality	2	0.84	0.93	0.86	0.93
System Quality	2	0.88	0.94	0.89	0.94
Information Satisfaction	2	0.86	0.94	0.88	0.94
System Satisfaction	2	0.91	0.96	0.92	0.96
Usefulness	3	0.77	0.87	0.69	0.83
Ease of Use	2	0.72	0.87	0.78	0.88
Attitude	2	0.88	0.94	0.89	0.94

Table 11.　　Revised reliability analysis

As stated earlier, discriminant validity is adequate when the square root of AVE for a given construct is greater than the correlations between the construct and other constructs. Table 12 shows the correlation matrix, with correlations among constructs and the square root of AVE on the diagonal. In all cases, the AVE for each construct is larger than the correlation of that construct with all other constructs in the model.

	Accuracy	Accessibility	Attitude	Completeness	Credibility	Currency	Ease of Use	Flexibility	Format	Integration	Information Quality	Information Satisfaction	Logging	Monitoring	Reliability	Situation Awareness	Scalability	Scriptability	Speed	System Quality	System Satisfaction	Usefulness	Verification
Accuracy	**0.85**																						
Accessibility	0.51	**0.87**																					
Attitude	0.55	0.58	**0.94**																				
Completeness	0.59	0.64	0.50	**0.83**																			
Credibility	0.63	0.51	0.66	0.37	**0.92**																		
Currency	0.63	0.34	0.25	0.59	0.29	**0.90**																	
Ease of Use	0.47	0.59	0.72	0.48	0.54	0.27	**0.88**																
Flexibility	0.37	0.42	0.54	0.34	0.56	0.10	0.34	**0.84**															
Format	0.54	0.58	0.43	0.63	0.29	0.52	0.47	0.05	**0.95**														
Integration	0.21	0.46	0.37	0.33	0.27	0.13	0.35	0.54	0.22	**0.91**													
Info Quality	0.70	0.63	0.72	0.52	0.75	0.45	0.59	0.46	0.48	0.38	**0.93**												
Info Sat	0.60	0.73	0.73	0.53	0.68	0.37	0.61	0.46	0.49	0.43	0.85	**0.94**											
Logging	0.22	0.15	0.24	0.33	0.13	0.21	0.15	0.37	0.25	0.33	0.17	0.12	**0.95**										
Monitoring	0.27	0.34	0.23	0.27	0.26	0.29	0.19	0.28	0.15	0.32	0.30	0.27	0.14	**0.88**									
Reliability	0.62	0.43	0.63	0.34	0.80	0.27	0.51	0.48	0.27	0.20	0.67	0.59	0.18	0.23	**0.91**								
Sit Awareness	0.30	0.44	0.32	0.41	0.35	0.32	0.25	0.39	0.20	0.43	0.42	0.46	0.16	0.56	0.28	**0.81**							
Scalability	0.43	0.22	0.44	0.27	0.59	0.13	0.33	0.49	0.07	0.19	0.44	0.38	0.11	0.17	0.57	0.22	**0.84**						
Scriptability	0.21	0.15	0.36	0.09	0.37	-.02	0.15	0.77	-0.10	0.49	0.23	0.21	0.46	0.16	0.32	0.22	0.39	**0.88**					
Speed	0.46	0.38	0.54	0.34	0.54	0.20	0.43	0.43	0.12	0.22	0.52	0.43	0.18	0.21	0.62	0.15	0.42	0.34	**0.92**				
Sys Quality	0.59	0.46	0.71	0.30	0.80	0.21	0.57	0.60	0.27	0.33	0.74	0.66	0.24	0.23	0.78	0.25	0.53	0.46	0.57	**0.94**			
Sys Sat	0.65	0.60	0.85	0.47	0.77	0.31	0.66	0.57	0.41	0.35	0.81	0.78	0.23	0.22	0.75	0.34	0.50	0.37	0.55	0.83	**0.96**		
Usefulness	0.45	0.58	0.67	0.40	0.63	0.19	0.55	0.60	0.30	0.40	0.60	0.67	0.16	0.31	0.49	0.47	0.42	0.42	0.42	0.57	0.64	**0.83**	
Verification	0.15	0.18	0.28	0.27	0.16	0.13	0.17	0.33	0.23	0.33	0.22	0.16	0.77	0.22	0.18	0.27	0.11	0.41	0.21	0.20	0.21	0.20	**0.93**

Table 12.   Correlations of Latent Variables. Diagonals are square root of AVE.

Correlations greater than 0.22 significant at *p* < 0.01 level.
Correlations greater than 0.18 significant at *p* < 0.05 level.

The validity of constructs can also be assessed using item loading on constructs. These loadings, shown in Appendix D, shows that all items load more highly on their associated construct than on any other constructs. Combined with each construct's AVE values greater than 0.50 and their square root of AVE values greater than the correlation of the construct to any other constructs, one can conclude that the constructs used in this research study have good discriminant and convergent validity.

Some interesting correlations can be observed in Table 12. Not surprisingly, attitude towards use was highly correlated with ease of use, information quality, information satisfaction, system quality, system satisfaction, and usefulness. Attitude is also highly correlated the two system quality attributes found significant in this study (reliability and credibility), but is not highly correlated with the information quality attributes found significant in this study (accuracy and verification).

Although logging was not found to be significant in this study, it is highly correlated with verification information, which is significant. This correlation makes sense, because verification information is generally found in system logs. Another interesting correlation lies between flexibility and scriptability, because the ability to modify one's tools is one aspect of a flexible system.

Monitoring and situation awareness were highly correlated. Many interviewees reported maintaining a "feel" for the system through their automated alerts and monitoring capabilities. Surprisingly, situation awareness was not highly correlated with

logging or verification, two other information types that are reported to help maintain a view of the computing infrastructure.

5.3. Results

The research model was tested using partial least squares (PLS), a structural modeling method that is suitable for complex predictive models and avoids problems of multi-collinearity (Barclay et al., 1995; Chin, 1998; Lohmoller, 1989). Smart PLS version 2.0 (Ringle et al., 2005) was used for the analysis, and the bootstrap resampling method (using 200 samples) was used to determine the significance of the paths in the structural model. Similar to linear regression, PLS examines the significance of construct relationships and provides R^2 measures (Gefen et al., 2000). Path coefficients can be used to test hypotheses and indicate the strength and significance of relationships between constructs. Together, the R^2 and the path coefficients (with their significance and loadings) indicate how well the data support the hypothesized model. PLS was used in this research study because it is well suited for theory building, analyzing predictive models, and small data sets (Chin, 1998). A rule-of-thumb for PLS sample size is ten times the number of items or indicators in the most complex construct in the model (Barclay et al., 1995; Gefen et al., 2000); in this case, System Quality has 10 indicators. The sample size of 126 meets this minimum requirement and results in statistical power of 0.83 (effect size f^2 = .15, alpha error prob = .05) as measured by G*Power 3 (Faul et al., 2007).

The model tested in this research study is captured by 24 hypotheses, shown in Table 13. The R^2 values for each predicted construct are shown in Table 14. R^2 values report the model's ability to predict. For example, the model explains approximately 54% of the variance in Information Quality. User interface type (purely GUI, purely CLI, or a combination of GUI and CLI), years of experience and gender were used as control variables and were linked to both Information Quality and System Quality. A significant relationship between years of experience was found to both System Quality (path = 0.33, $p < 0.01$), and Information Quality (path = 0.30, $p < .01$).

In testing attributes important to system administrators, only four paths were significant. Hypotheses 1-3 and 1-6 were supported, suggesting that Accuracy and Verification are important to Information Quality. Hypotheses 2-1 and 2-8 were supported, suggesting that Reliability and Credibility are important to System Quality. Hypotheses 3-1 through 3-8 were supported showing the rest of the modified user satisfaction model is supported in the context of system administration.

Figure 4, below, shows the results of the test of the hypothesized structural model. In summary, Usefulness (path = 0.39, $p < 0.001$) and Ease of Use (path = 0.51, $p < 0.001$) both had a significant influence on Attitude, accounting for 63% of the variance in the measure. Information Satisfaction (path = 0.55, $p < 0.001$) and Ease of Use (path = 0.22, $p < 0.01$) had a significant influence on Usefulness and accounted for 48% of the variance in Usefulness. System Satisfaction (path = 0.67, $p < 0.001$) had a significant influence on Ease of Use and accounted for 44% of the variance in Ease of Use.

Information Quality (path = 0.58, *p* < 0.001) and System Satisfaction (path = 0.32, *p* < 0.001) both had significant influences on Information Satisfaction, accounting for 74% of the variance in Information Satisfaction. System Quality (path = 0.81, *p* < 0.001) significantly determined System Satisfaction and accounted for 66% of the variance in that measure. Accuracy (path = 0.58, *p* < 0.001) and Verification (path = 0.23, *p* < 0.05) were significantly related to Information Quality and accounted for 54% of the variance in the measure. Reliability (path = 0.37, *p* < 0.001) and Credibility (path = 0.37, *p* < 0.001) were significantly related to System Quality and accounted for 75% of the variance in System Quality.

* p < 0.05, ** p < 0.01, *** p < 0.001
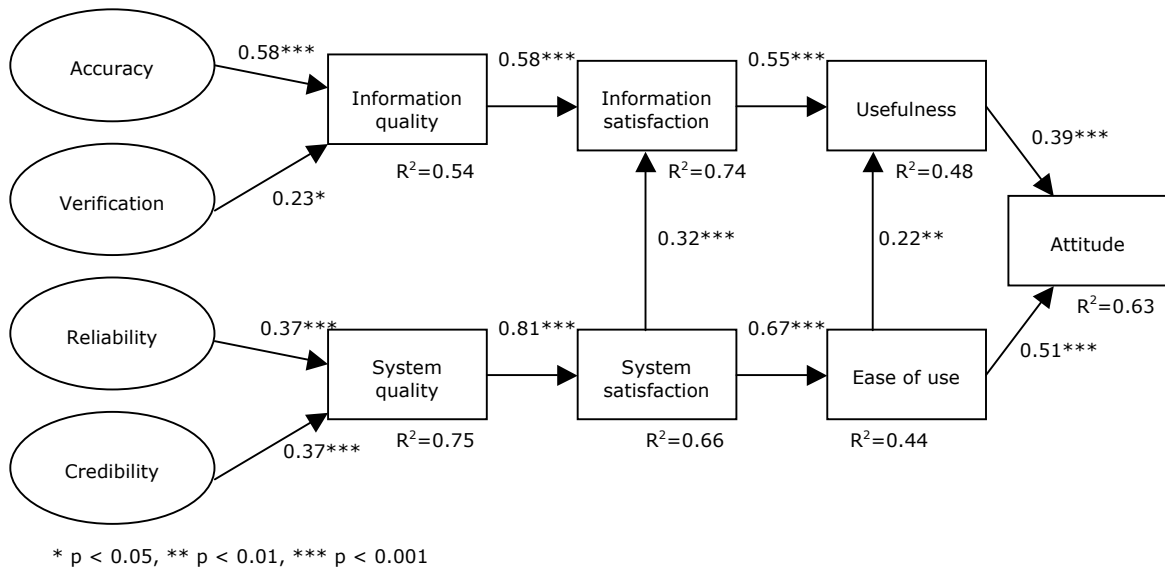
Figure 4.   Research model results

These results suggest that at the macro level, system administrators are similar to regular computer users; the user satisfaction model is significant and predictive of their attitude towards computer system use. These results also confirm that at the micro level, system administrators have needs of a computer system specific to their work practices and work environment.

Wixom and Todd (2005) found four attributes of Information Quality significant. In this study, only Accuracy was found to be supported, while Currency, Completeness, and Format were not supported. Furthermore, one new attribute was found significant, Verification. Findings show that Accuracy and Verification explain 54% of the variance for information quality.

Wixom and Todd (2005) found four attributes of System Quality significant. In this study, only Reliability was supported, while Flexibility, Integration, and Accessibility were not supported. Speed was not supported in either study. One new attribute, Credibility, was found significant. Findings show that reliability and credibility explain 75% of the variance for system quality.

H#	Hypothesis	Path Coefficient	Sig (two-tailed)	Supported?
1-1	Currency --> Info Quality	0.00	n.s.	No
1-2	Completeness --> Info Quality	0.12	n.s.	No
1-3	**Accuracy --> Info Quality**	**0.58**	***p< 0.001***	***Yes***
1-4	Format --> Info Quality	0.10	n.s.	No
1-5	Logging --> Info Quality	-0.16	n.s.	No
1-6	**Verification --> Info Quality**	**0.23**	***p< 0.05***	***Yes***
2-1	**Reliability --> Sys Quality**	**0.37**	***p< 0.001***	***Yes***
2-2	Flexibility --> Sys Quality	0.11	n.s.	No
2-3	Integration --> Sys Quality	0.04	n.s.	No
2-4	Accessibility --> Sys Quality	0.01	n.s.	No
2-5	Speed --> Sys Quality	0.05	n.s.	No
2-6	Scriptability --> Sys Quality	0.14	n.s.	No
2-7	Scalability --> Sys Quality	-0.02	n.s.	No
2-8	**Credibility --> Sys Quality**	**0.37**	***p< 0.001***	***Yes***
2-9	Situation Awareness --> Sys Quality	-0.08	n.s.	No
2-10	Monitoring --> Sys Quality	0.01	n.s.	No
3-1	**Info Quality --> Info Sat**	**0.58**	***p< 0.001***	***Yes***
3-2	**Sys Quality --> Sys Sat**	**0.81**	***p< 0.001***	***Yes***
3-3	**Sys Sat --> Info Sat**	**0.32**	***p< 0.001***	***Yes***
3-4	**Sys Sat --> Ease of Use**	**0.67**	***p< 0.001***	***Yes***
3-5	**Info Sat --> Usefulness**	**0.55**	***p< 0.001***	***Yes***
3-6	**Ease of Use --> Usefulness**	**0.22**	***p< 0.01***	***Yes***
3-7	**Ease of Use --> Attitude**	**0.51**	***p< 0.001***	***Yes***
3-8	**Usefulness --> Attitude**	**0.39**	***p< 0.001***	***Yes***

Table 13.   Path coefficients in model

Variable	R^2
Information Quality	0.55
System Quality	0.75
Information Satisfaction	0.74
System Satisfaction	0.66
Usefulness	0.48
Ease of Use	0.44
Attitude	0.63

Table 14. R^2 values

5.4.   Comparative analysis

It is interesting to compare the models for purely GUI and purely CLI tools. In order to do this, two separate models were run. Years of experience and gender were used as control variables and were linked to both Information Quality and System Quality. In the case of GUI tools, a significant relationship between years of experience was found to both System Quality (path = 0.10, $p < 0.05$) and Information Quality (path = 0.17, $p < .001$); a significant relationship with gender was also found to both System Quality (path = 0.30, $p < .001$) and Information Quality (path = 0.28, $p < 0.001$). In the case of CLI tools, a significant relationship was only found between gender and System Quality (path = -0.12, $p < 0.01$).

The path coefficients for each can be found below in Table 15. The R^2 values for both models can be found in Table 16. Differences in path coefficients between the measurement models (CLI and GUI) were calculated using the methodology described by Chin and shown below (Chin, 2000). No significant differences in path coefficients were found.

$$t = \frac{Path_{sample1} - Path_{sample2}}{\left[\sqrt{\frac{(m-1)^2}{(m+n-2)} * StdErr^2_{sample1} + \frac{(n-1)^2}{(m+n-2)} * StdErr^2_{sample2}}\right] * \left[\sqrt{\frac{1}{m} + \frac{1}{n}}\right]}$$

Figure 5.   Equation for comparison of models (t-test)

Tables 15 and 16, below, display the results of the test of the hypothesized structural model for GUI and CLI tools. In the case of GUI tools, Usefulness (path = 0.65, $p < 0.001$) and Ease of Use (path = 0.33, $p < 0.001$) both had a significant influence on Attitude, accounting for 68% of the variance in the measure. Information Satisfaction (path = 0.71, $p < 0.001$) and Ease of Use (path = 0.11, $p < 0.05$) had a significant influence on Usefulness and accounted for 56% of the variance in Usefulness. System Satisfaction (path = 0.39, $p < 0.001$) had a significant influence on Ease of Use and accounted for 15% of the variance in Ease of Use. Information Quality (path = 0.37, $p < 0.001$) and System Satisfaction (path = 0.52, $p < 0.001$) both had significant influences on Information Satisfaction, accounting for 75% of the variance in Information Satisfaction. System Quality (path = 0.85, $p < 0.001$) significantly determined System Satisfaction and accounted for 72% of the variance in that measure. Currency (path = .43, $p < 0.001$), Accuracy (path = 0.30, $p < 0.01$), Format (path = 0.28, $p < 0.001$) and Logging (path = -0.25, $p < 0.05$) were significantly related to Information Quality and accounted for 56% of the variance in the measure. Reliability (path = 0.33, $p < 0.05$), Flexibility (path = 0.36, $p < 0.01$), Integration (path = -0.20, $p < 0.01$) and Scriptability (path = 0.20, $p < 0.01$) were significantly related to System Quality and accounted for 83% of the variance in System Quality.

In the case of CLI tools, Usefulness (path = 0.39, $p < 0.001$) and Ease of Use (path = 0.49, $p < 0.001$) both had a significant influence on Attitude, accounting for 60% of the variance in the measure. Information Satisfaction (path = 0.43, $p < 0.001$) and Ease of Use (path = 0.34, $p < 0.001$) had a significant influence on Usefulness and

accounted for 47% of the variance in Usefulness. System Satisfaction (path = 0.67, $p <$ 0.001) had a significant influence on Ease of Use and accounted for 43% of the variance in Ease of Use. Information Quality (path = 0.57, $p < 0.001$) and System Satisfaction (path = 0.34, $p < 0.001$) both had significant influences on Information Satisfaction, accounting for 74% of the variance in Information Satisfaction. System Quality (path = 0.78, $p < 0.001$) significantly determined System Satisfaction and accounted for 60% of the variance in that measure. Accuracy (path = 0.64, $p < 0.001$) and Verification (path = 0.23, $p < 0.05$) were significantly related to Information Quality and accounted for 54% of the variance in the measure. Reliability (path = 0.44, $p < 0.001$), Integration (path = 0.14, $p < 0.05$) and Credibility (path = 0.44, $p < 0.001$) were significantly related to System Quality and accounted for 71% of the variance in System Quality.

H#	Hypothesis	GUI Path Coefficient	CLI Path Coefficient
1-1	Currency --> Info Quality	0.43***	-0.10
1-2	Completeness --> Info Quality	-0.06	0.09
1-3	Accuracy --> Info Quality	0.30**	0.64***
1-4	Format --> Info Quality	0.28***	0.15
1-5	Logging --> Info Quality	-0.25*	-0.16
1-6	Verification --> Info Quality	0.15	0.23*
2-1	Reliability --> Sys Quality	0.33*	0.44***
2-2	Flexibility --> Sys Quality	0.36**	0.11
2-3	Integration --> Sys Quality	-0.20**	0.14*
2-4	Accessibility --> Sys Quality	0.09	-0.03
2-5	Speed --> Sys Quality	-0.10	-0.01
2-6	Scriptability --> Sys Quality	0.20**	0.01
2-7	Scalability --> Sys Quality	0.12	-0.05
2-8	Credibility --> Sys Quality	0.07	0.44***
2-9	Situation Awareness --> Sys Quality	0.05	-0.08
2-10	Monitoring --> Sys Quality	0.02	0.00
3-1	Info Quality --> Info Sat	0.37***	0.57***
3-2	Sys Quality --> Sys Sat	0.85***	0.78***
3-3	Sys Sat --> Info Sat	0.52***	0.34***
3-4	Sys Sat --> Ease of Use	0.39***	0.67***
3-5	Info Sat --> Usefulness	0.71***	0.43***
3-6	Ease of Use --> Usefulness	0.11*	0.34***
3-7	Ease of Use --> Attitude	0.33***	0.49***
3-8	Usefulness --> Attitude	0.65***	0.39***

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 15.   GUI and CLI model path coefficients

Construct	GUI R^2	CLI R^2
Information Quality	0.56	0.54
System Quality	0.83	0.71
Information Satisfaction	0.75	0.74
System Satisfaction	0.72	0.60
Usefulness	0.56	0.47
Ease of Use	0.15	0.43
Attitude	0.68	0.60

Table 16. R^2 values for GUI-only and CLI-only models.

5.5. Summary

This chapter provided a detailed statistical analysis of the model proposed earlier using Smart PLS. The analysis indicates strong reliability and validity among existing constructs and those developed for this study. As hypothesized, the user satisfaction model was supported, suggesting that at the macro level, system administrators have tool use behaviors similar to regular computer users. Findings also support the idea that, at the micro level, system administrators may have information and system attribute requirements that differ from those of regular computer users. Accuracy and verification were identified as important information attributes, explaining 54% of the variance in information quality, and reliability and credibility were identified as important system attributes, explaining 75% of the variance in system quality. When comparing results between CLI and GUI tools, the models were not significantly different. A discussion of these results, implications, limitations, and future research directions are presented in the next chapter.

CHAPTER 6.   CONCLUSION

This research presents an in-depth investigation and description of a single user group, system administrators. Following an overview of these computing professionals and their complex, risky work environment, system administrator work practices were investigated using data collected from previous experience, interviews, a usability study, and the literature. This research contributes to existing knowledge by presenting an analysis of system administrator work practices and identifying them as broker technicians. As such, many of the findings of this study may apply to other broker technicians.

Because the work of system administration is so dependent upon technology and the way sysadmins access and control that technology, investigations of tool use were then studied. Through an analysis of work practices related to tool use, attributes important to system administrator work practices were identified. These attributes fell into two categories: information quality (currency, completeness, accuracy, format, logging, and verification) and system quality (reliability, flexibility, integration, accessibility, speed, scriptability, credibility, situation awareness, and monitoring).

This research proposed the use of Wixom and Todd's (2005) integrated user satisfaction model in the context of system administration, empirically testing the information and system quality antecedents identified in the above analysis. This theoretical model provides an opportunity to link the identified characteristics with

system administrator beliefs and tool usage. This research contributes to existing

knowledge by identifying information and system quality attributes important to system

administrators, and testing the modified user satisfaction model in the untested context of

system administration.

6.1.   Discussion of work practice findings

Narratives of common system administrator activities – meetings, system

planning, system maintenance, troubleshooting and installation – provided evidence that

system administrators are broker technicians. The technical work of system

administration lies in the middle of the broker technician model and often involves

interactions with supported users and with their technical community. Communication

with supported users, however, is very different from communication with the technical

community because of the language and terminology differences between the groups.

Messages received from supported users must be translated into technical requirements,

while messages conveyed to supported users must be restated using terminology

understood by a different profession. Communication between system administrators and

their technical community, however, can leverage a common vocabulary. Based upon

this classification, future research of system administrators may be able to utilize the

concepts and metrics used to describe the work of other broker technicians.

6.2. Discussion of survey results

Results suggest that system administrators are similar to previously studied computer users; the user satisfaction model is significant and predictive of their attitude towards computer system use. These results also confirm that system administrators have specific needs of a computer system that relate to their work practices and environment. The findings support the use of this model in the context of system administration.

6.2.1. Information quality antecedents

When looking at Information Quality, only one attribute found significant in other studies (e.g., Baroudi & Orlikowski, 1988; Wixom & Todd, 2005) was supported, Accuracy. Other attributes previously found significant (Currency, Completeness, and Format) were not. Furthermore, one new attribute was found significant, Verification. Some of these findings may be explained by the work practices of system administrators.

While information currency is an important part of sysadmin work, it may not be an important attribute of a tool because currency can be "forced" through the use of a CLI command. In fact, currency was significant only when measuring GUI tools. For example, rather than refresh a GUI screen or require constant information updates, one interviewee stated a preference for the use of a command issued through a CLI tool that queries and returns information in real-time.

Similarly, the need for and degree of information completeness may change with the task at hand, and information overload can be a very real issue for system administrators. As such, completeness was not significant for any interface type. An

interviewee cited the ability to "get [the information] I need when I need it" as a motivation for using CLI commands, giving him control over the amount and completeness of information without requiring it of a separate tool.

While the format of information from the system is important to system administrators, it was only significant in GUI tools. This may be a reflection of the information format that is expected from a given tool. An example was described earlier when the sysadmin used both CLI and GUI tools to access similar information. The sysadmin stated an expectation that information accessed through CLI commands would be detailed and unformatted, while supporting information gathered from the GUI tool would summarize information through formatted reports and graphical representations.

The use of logging information has been observed and was often reported in interviews, though it was only found to be significant in GUI tools. This is most likely due to the nature of CLI and GUI tools. A simple "ps" command, which on Unix machines brings up a report of process status, lists all commands issued on the system. Sysadmins studied were not aware of any similar functionality offered by GUI tools, but often didn't identify this as a need because of the ease of accessing logging information through their existing command line interfaces.

Findings show that accuracy and verification explain 54% of the variance for information quality when testing the model for all tools. Information accuracy is a very real need for system administrators, and was found to be significant for all interface types in this study. System planning, updating, and debugging are often done with only the

information supplied by the system; rarely is a system administrator lucky enough to have a system failure physically apparent, and thus must rely on the accuracy of the information supplied to them. Verification information was found to be a significant influence on information quality. This echoes the results of the analysis of the usability study data. While a log of previous actions taken on the system may be relatively simple to access, a list of the outcomes of previous actions may be more difficult to generate.

6.2.2. System quality antecedents

When looking at System Quality, again only one attribute found significant in other studies (e.g., Baroudi & Orlikowski, 1988; Wixom & Todd, 2005) was supported, Reliability. Other attributes previously found significant (Flexibility, Integration, Accessibility, Speed) were not. One new attribute, Credibility, was found significant.

Given the dynamic nature of the systems they manage, it is surprising to find that flexibility was only significant in GUI tools. This may be because of the structured nature of GUI tools. That is, CLI tools are very basic and scriptable, giving the sysadmin the ability to query information and configure the tool to suit his needs. GUI tools, however, provide structured interactions with the system and predefined reports, which can be difficult to change. As one sysadmin stated, "Sometimes I just can't get the [GUI] reports to work after I change the system. So I gave up and just started using [CLI] programs that I can change when I need to."

Accessibility was not found to be significant for any interface type. This finding makes sense, given the power user authority and access this group has. That is, as

keepers of their organization's data and infrastructure, system administrators reported having the ability to access any and all data (even if doing so may violate ethical or company policies).

Speed was not found to be significant, which echoed results from a study done by Wixom and Todd (2005). This finding is surprising, because system administrators are technology experts and Bodker (1989) states that expert users have a need for fast systems. Furthermore, numerous interviewees reported using "whichever [tool] can get me what I need the fastest" when the choice between tools was available. Given the qualitative findings and prior research, this attribute should be studied in the future.

The ability to script add-ons or automate tasks was only found to be significant in GUI tools, which may be a reflection of the environment in which sysadmins work. By definition and default, all CLI tools can be scripted; technically, it could be stated that every action taken through a CLI is done by entering a command or executing a small script. However, the ability to automate functions in GUI tools must be explicitly provided through scriptable interfaces or an api. Furthermore, most sysadmins studied reported automating aspects of their work and as one participant stated, "decent admins should have a fair amount of programming ability to get the job done."

While the need for scalable systems is identified in much of the system administrator literature, it did not emerge in the interviews. In previous experience, tools used in system administration were created with large systems in mind. The lack of non-

scalable tools may hide the need for scalable systems in the system administrators that were surveyed.

The importance of support for situation awareness in system administrator tools was reported in the ARC ethnography (J. Bailey et al., 2003; Barrett et al., 2004; Haber & Bailey, 2007), and Hrebec and Stiber (2001) found that sysadmins report having a poor understanding of their system. However, situation awareness was not found to be significant in this study. This finding was unexpected, given the complexity of systems managed and comments from an interviewee about the difficulty of "keeping a good picture of the system in [his] head." The ability of tools to provide information about overall system state would benefit from further investigation.

Findings show that reliability and credibility explain 75% of the variance for system quality when testing the model for all tools. The reliability of a system is of utmost importance; downtime in a large system can cost $500,000 per hour (Patterson, 2002). It should come as no surprise that the tools used to manage, configure, and monitor those systems need to be just as reliable. The credibility of a tool was also found to be significant. Similar results were reported by Takayama et al. (Takayama & Kandogan, 2006), whose survey found that trust was an underlying factor in system administrator user interface choice. Indeed, many sysadmins reported the use of tools they had used for a long time or that had been programmed by peers, citing their "trust" in the tool.

6.3. Research implications

This study presents three implications for research. First, this study empirically tests the Wixom and Todd (2005) integrated user satisfaction model in the context of system administration, providing a test of information satisfaction models in new contexts, a research need cited by Rai et al. (2002). System and information quality antecedents important to system administrators were identified while confirming the significance of the overall model in a new context, extending the generalizability of the model.

Second, this study developed new measurement instruments for the information quality antecedents Logging and Verification and for the system quality antecedents Scriptability, Scalability, Credibility, Situation Awareness, and Monitoring. These measures were found to be reliable and have convergent and discriminant validity.

Most importantly, this study presents system administrators as broker technicians who perform their work while interacting with their technical community and the users they support. Furthermore, they work in high risk and complex environments that are dynamic and often at the bleeding edge of technology. This occupational categorization provides a foundation for future studies of system administrators.

6.4. Practical implications

This study presents two implications for practice. First, companies now have a way to assess information quality and system quality characteristics and link those characteristics to system administrator perceptions of usefulness, usability, and ultimately, user attitude towards use. This will allow companies to evaluate tools and identify those most useful to system administrators. For example, when considering two very similar GUI tools, the one that provides for automation and scripting will be better suited to system administrators.

Second, this study provides designers of system administration tools guidance about characteristics important to their audience: system administrators. By focusing their efforts on information and system features most important to this unique user group, they will be better able to develop tools that will be useful. Accurate information and verification information were significant indicators of information quality. Information accuracy may be difficult to "show," but developers can account for this need through careful programming and rigorous testing of their product. Companies may also capitalize on this need by including it in marketing materials. Verification information can be provided through the inclusion of easily accessible execution result logs. Reliability and credibility were significant indicators of system quality. Again, tool reliability may be difficult to show, but developers can account for this need through careful programming (e.g., be careful to avoid memory leaks, which may cause systems to hang or crash) and rigorous testing of their product in many different environments. Companies may also explicitly state this attribute of their tool in marketing materials.

Credible tools were those with a good track record and known developers. Companies with well-known and well-liked tools already on the market will benefit when introducing new applications. New companies may increase the credibility of their tools through beta testing and testimonial marketing.

Among GUI tools, currency, format, logging, flexibility, and scriptability were also significant. Information currency may be a "hard sell" in GUI tools, as many interviewees reported the assumption that all GUI tools had a poor screen refresh rate, resulting in "old" data. Advanced programming methods may allow for screen refreshes at smaller intervals. Another solution may be the inclusion of a timestamp, which would communicate to the sysadmin the "age" of the data, so they could determine if they needed more recent information. While many sysadmins reported their acceptance of unformatted data in CLI tools, they expected more of their GUI tools. Information formatting can be added to GUI tools by taking advantage of its graphical capabilities and presenting data in a logical, formatted manner. Logging information can be added to GUI tools through the inclusion of easily accessible execution logs. Flexibility can be included in GUI tools through configurable interfaces and user-defined reports. Finally, support for scripting can be included through built-in programming interfaces (e.g., macros) or by including apis that allow system customization through external scripts that can access system data and functions.

6.5. Limitations

The limitations to this study should be noted. Limitations regarding the survey population exist. Although efforts were made to recruit system administrators of all specialties and experience levels, respondents may not be representative. Additionally, while respondents were recruited through organizations with primarily North American, Australian, and European membership, there is no way to ensure survey respondents were not from countries with different work cultures, such as China and India. Furthermore, all survey respondents cannot be guaranteed to be professional system administrators. These challenges were minimized by examining demographic and work information and examining the data for any outliers in response or completion time.

Second, there is a potential for non-response bias. Because system administrators self-selected into the study and were not required to complete the survey once it was started, the respondents might not be representative of all system administrators. For example, the survey took an average of 23 minutes to complete, which may have excluded participation from extremely busy system administrators. However, good variance in respondent experience level and in the tool identified for survey responses indicate heterogeneity, suggesting that the results reported here are relatively robust.

Third, further development and refinement of measurement items are needed. This research study utilized previously validated measures and developed new measures. Most of the constructs used short scales and though the measures were found to be reliable and valid, they could be improved.

Fourth, this research focused on system administrators and the tools they use most often in their work. The findings may not be generalizable outside of the context of system administration. If one assumes that system administrators most often use tools of their choosing, the findings may not be generalizable when evaluating non-volitional tools.

Finally, this study collected measures at a point in time with a tool used most often, and therefore, a tool the sysadmins were very familiar with. A longitudinal study may provide insights for tools at various levels of implementation and familiarity. For example, specific antecedents may have different importance at different times.

These limitations are difficult to overcome outside of highly controlled environments, such as a lab experiment; however, this examination in context provides more generalizable findings. Even with these limitations, the study provides insights into the work practices and tool use of a rarely studied population.

6.6.   Future directions

This research suggests many promising areas for future research. First, it would be beneficial to understand the relative contribution of education, training and experience to skill acquisition among system administrators. An examination of their learning could further theories of the structure of learning and teaching *in situ* (D. Bailey et al., 2004).

Second, a study should be conducted to assess the need for verification information among system administrators. The exploratory study conducted as part of this research offers insight into their information needs and information seeking behaviors and should be expanded to include more system administrators and tasks with higher perceived risk (Velasquez & Durcikova, forthcoming). The need for verification information could also be explored among users in other high risk, complex environments, such as air traffic controllers or nuclear power plant operators.

Third, gender differences should be explored. Although females represent a small portion of system administrators, they may exhibit differences worth investigating. For example, studies of engineers suggest there may be differences in gender work practices, with female engineers preferring to interact with colleagues (Perlow, 1995) and a having a higher likelihood of performing "invisible" work (Fletcher, 1994). Given the categorization of engineers as technicians (Barley, 1996), these findings may apply to system administrators as well.

Fourth, a longitudinal study of system administrators and system use and usefulness could shed light on the relative importance of attributes throughout the implementation lifecycle of a system.

Fifth, the integrated Wixom and Todd (2005) model should be used to evaluate information systems among other broker technicians and in other complex, risky environments. This investigation could uncover common system and information quality attributes important to broker technicians or important to working environments.

Sixth, system administrator collaboration should be studied. Collaboration is an important part of system administration and its potential importance as a tool characteristic has been identified in previous sysadmin studies (e.g., Barrett et al., 2004); however, it was not included in this study because research participants noted that they preferred it to be done using separate tools. One interviewee stated a preference to "stick to one [collaborative tool] and leave the rest alone." Furthermore, collaboration may differ when interacting with the supported users or the technical community.

Finally, the full Wixom and Todd (2005) model should be evaluated to include intention to use and non-volitional systems. System administrator tool usage may differ when examining a single tool across sites or tools that their organizations have chosen for them.

6.7. Conclusion

The main goal of this study was to investigate the work practices of system administrators. In this endeavor, sysadmins were identified as broker technicians. Work practices were also analyzed with tool use in mind, which generated a list of information and system quality attributes important to the work practices and environment of system administrators. This research has shown that an integrated model of information satisfaction and technology acceptance is significant in the context of system administration. Tool attributes important to system administrators were explored and two information quality attributes (Completeness and Verification) and system quality

attributes (Reliability and Credibility) were identified and found to be significant. This thesis presents the empirical test of a model in the unexplored context of system administration and identifies future research streams that will shed light on system administrators.

APPENDIX A.   A REVIEW OF SYSADMIN LITERATURE

To augment the analysis and investigation described in Chapter 5, a review of the relevant literature was conducted. Selected publications were limited to journals and conference proceedings, excluding articles in trade magazines. Studies included were those that met the following criteria:

1. The subjects of the study were exclusively system administrators, including web administrators, network administrators, security administrators, etc. Studies of system administration concepts with end users or students as subjects were excluded.

2. The study focused on the work, work practices, and/or tools of system administrators. Studies that focused on other issues, such as algorithms or computing environments, were excluded.

3. If a similarly titled journal article and conference proceeding written by the same authors emerged in this search, only the journal article was included in this study[4].

Because research involving system administrators is relatively recent, no date range limitations were used and studies were added to the sample iteratively.   The initial literature was selected from two sources:

1. The First Symposium on Computer Human Interaction for Management of Information Technology (CHIMIT07). This conference was selected because of

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[4] The only duplicate was (Maglio & Kandogan, 2003)

its unique and focused emphasis, resulting in an increased likelihood of usability-related system administrator research.

2. The ACM Digital Library. Results to article abstracts and keywords searches of the terms "system administrator" or "system administration" were included. In an effort to extend the selected papers beyond those published under the umbrella of ACM, a forward search of all papers collected in steps one and two above was conducted using Google Scholar (scholar.google.com). Subsequent forward searches were conducted on all papers added to the selection until no new papers emerged.

Twenty-four studies were identified in the search for relevant literature. Each study was coded for each of the system and information quality antecedents identified through the coding of system administrator interviews and those used in the Wixom and Todd (2005) study. Because the goal of this classification was to identify system characteristics useful to system administrators, a characteristic was attributed to the study if 1) the characteristic was identified as an existing, useful aspect of the system(s) being used, or 2) the characteristic was identified as a missing aspect of the system, with the assumption that the missing characteristic was specifically identified by the authors because of an observed need for that characteristic. Additional characteristics that emerged during the coding process were added to the working list of attributes and any coded papers were re-coded for the new characteristics. A detailed table of the papers included in the study and their information and system attributes found in each paper can

be found in Tables 17 and 18. A key for the papers included in the study can be found in

Table 19.

	Complete-ness	Accuracy	Format	Currency	Logging	Verification
Bailey1	✓	✓	✓	✓		
Bailey2					✓	✓
Barrett1			✓			
Barrett2	✓	✓	✓	✓	✓	✓
Barrett3	✓		✓	✓	✓	
DAmico1	✓		✓			
Haber1	✓				✓	
Haber2					✓	
Haber3	✓	✓				
Haber4		✓	✓	✓	✓	✓
Hrebec1						
Kandogan1	✓	✓			✓	✓
Kandogan2	✓		✓		✓	
Maglio1	✓				✓	
Maglio2	✓			✓	✓	
Takayama1		✓		✓		
Thompson1	✓		✓			
Botta1			✓		✓	
Fitzpatrick1				✓	✓	
Goan1	✓	✓	✓	✓	✓	
Jaffe	✓		✓	✓		
Lentz1						
Sandusky1	✓		✓	✓	✓	
Yurcik1	✓	✓	✓		✓	

Table 17.   Information quality attributes reported in the literature

	Reliability	Flexibility	Integration	Accessibility	Speed	Trust	Scalability	Scriptability	Situation Awareness	Monitoring
Bailey1	✓		✓						✓	
Bailey2		✓	✓					✓		✓
Barrett1			✓				✓		✓	✓
Barrett2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Barrett3		✓	✓	✓	✓	✓	✓	✓	✓	✓
DAmico1									✓	
Haber1		✓	✓	✓				✓	✓	✓
Haber2		✓	✓							✓
Haber3		✓	✓			✓		✓		✓
Haber4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hrebec1		✓							✓	
Kandogan1	✓		✓	✓	✓	✓	✓			
Kandogan2			✓	✓			✓	✓	✓	✓
Maglio1			✓	✓						
Maglio2									✓	
Takayama1	✓				✓	✓				
Thompson1		✓	✓						✓	✓
Botta1	✓	✓				✓		✓		✓
Fitzpatrick1		✓	✓	✓			✓		✓	✓
Goan1	✓	✓	✓	✓	✓					✓
Jaffe	✓				✓		✓		✓	✓
Lentz1		✓			✓		✓	✓		
Sandusky1	✓	✓	✓	✓				✓	✓	
Yurcik1	✓		✓		✓	✓		✓	✓	

Table 18.   System quality attributes reported in the literature.

Code	Paper
Bailey1	(J. Bailey et al., 2003)
Bailey2	(J. Bailey et al., 2007)
Barrett1	(Barrett et al., 2003)
Barrett2	(Barrett et al., 2004)
Barrett3	(Barrett et al., 2005)
DAmico1	(D'Amico & Kocka, 2005)
Haber1	(Haber, 2005)
Haber2	(Haber & Kandogan, 2007a)
Haber3	(Haber & Kandogan, 2007b)
Haber4	(Haber & Bailey, 2007)
Hrebec1	(Hrebec & Stiber, 2001)
Kandogan1	(Kandogan & Maglio, 2003)
Kandogan2	(Kandogan & Haber, 2005)
Maglio1	(Maglio et al., 2004)
Maglio2	(Maglio & Kandogan, 2004)
Takayama1	(Takayama & Kandogan, 2006)
Thompson1	(Thompson et al., 2007)
Botta1	(Botta et al., 2007)
Fitzpatrick1	(Fitzpatrick et al., 1996)
Goan1	(Goan, 1999)
Jaffe	(Jaffe et al., 2007)
Lentz1	(Lentz & Bleizeffer, 2007)
Sandusky1	(Sandusky, 2003)
Yurcik1	(Yurcik et al., 2007)

Table 19.　　Papers included in review

APPENDIX B.   CORRESPONDENCE WITH PARTICIPANTS

This section provides the text of all correspondence to the participants of the study conducted in Chapter 6. These include recruitment materials as well as interview and survey disclosures.

EMAIL/PHONE DESCRIPTION FOR INTERVIEW PARTICIPATION

[Prospective Participant],

My name is Nicole Velasquez, and I am a researcher at the University of Arizona. My colleagues and I are conducting a study about the tools the system administrators use in their work. We are particularly interested in understanding why you may use – or not use – certain tools. This study will help researchers and software developers better understand and support your needs in system administration.

Thank you for contacting me about participating in this research study. The interview will focus on what tools you currently use and what you like about them. We will also discuss tools you do not use and reasons you do not use them. The interview will last approximately 30 minutes [and will be conducted over the phone]. Participation in the interview is completely voluntary, and the only known risks associated with your participation are your confidentiality if you choose to schedule the interview during work hours and/or at your work place. Approximately 5-7 other system administrators will be participating in interviews.

[Email]: If you are still willing to participate in this study, please respond to this email with a convenient time for you to participate in the interview.

[Phone]: If you are still willing to participate in this study, can we set up a convenient time to conduct the interview?

Thank you very much!

Nicole Velasquez

MESSAGEBOARD NOTICE FOR SURVEY PARTICIPATION

Dear System Administrator,

My name is Nicole Velasquez, and I am a researcher at the University of Arizona. My colleagues and I are conducting a study to examine the factors and qualities that motivate system administrators to use or not use software applications, and we would really appreciate your help. You are being invited to participate because as a system administrator, you have a unique understanding of what makes a software application (i.e., "tool") useful in your job.

The survey asks about the tools you use in your work and will take about 20-30 minutes to complete. There are no right or wrong answers; we are interested in your opinions. Approximately 200-500 system administrators are being asked to participate in this survey. As a way of thanking you for your participation, one participant will be randomly chosen to win an iPod Nano. The survey can be accessed here: <URL for survey>

We would like to get the opinions of as many system administrators as possible, so feel free to tell fellow system administrators about the survey.

Thank you very much!

Nicole Velasquez

EMAIL DESCRIPTION FOR SURVEY PARTICIPATION

Dear [Prospective Participant],

Thank you for contacting me about participating in a research study. My name is Nicole Velasquez, and I am a researcher at the University of Arizona. My colleagues and I are conducting a study to examine the factors and qualities that motivate system administrators to use or not use software applications, and we would really appreciate your help. You are being invited to participate because as a system administrator, you have a unique understanding of what makes a software application (i.e., "tool") useful in your job.

The survey asks about the tools you use in your work and will take about 20-30 minutes to complete. There are no right or wrong answers; we are interested in your opinions. Approximately 200-500 system administrators are being asked to participate in this survey. As a way of thanking you for your participation, one participant will be

randomly chosen to win an iPod Nano. The survey can be accessed here: <URL for survey>

We would like to get the opinions of as many system administrators as possible, so feel free to forward this email to fellow system administrators.

Thank you very much!

Nicole Velasquez

SUBJECT CONSENT FORM - Interview

Title of Project: A Study of System Administrators and Their Tool Use

You are being invited to voluntarily participate in the above-titled research study. This study is being conducted to examine the factors and qualities that motivate system administrators to use or not use software applications or other tools. You are being invited to participate because as a system administrator, you have a unique understanding of what makes a software application (i.e., "tool") useful in your job. A total of 6 to 8 people will participate in interviews.

If you agree to participate, your participation will involve 1 interview about the tools you use in your job and why you use those tools as well as the tools you do not use in your job and why you do not use those tools. The interview will take place in a location convenient for you and will last approximately 30 minutes. The interview will be conducted during a time convenient for you. You may choose not to answer some or all of the questions. During the interview, written notes will be made in order to help the investigator review what is said. Your name will not appear on these notes. The interview will not be tape-recorded.

Any questions you have will be answered and you may withdraw from the study at any time. The only known risk to your participation will occur if you choose to schedule the interview during work hours and at your work site, which may compromise confidentiality. The researchers will make every effort to protect your confidentiality by removing any personally identifying information from reported interview responses.

No immediate personal benefit from your participation is expected. The broader benefits of this study include providing researchers with better insight into what factors are important in tools used by system administrators. This study will also help to advance research in the area of large-scale information systems implementation and use. There is

no cost to you except for your time and you will not be compensated for your participation.

Only the principal investigator, Nicole Velasquez, Ph.D. student, and the collaborator, Dr. Suzanne Weisband, will have access to your name and the information that you provide. In order to maintain your confidentiality, your name will not be revealed in any reports that result from this project. Interview information will be locked in a cabinet in a secure place.

You can obtain further information from the principal investigator, Nicole Velasquez, Ph.D. student, at (520) 465-9383. If you have questions concerning your rights as a research subject, you may call the University of Arizona Human Subjects Protection Program office at (520) 626-6721 or toll free at (866) 278-1455.

By participating in the interview, you are giving permission for the investigators to use your information for research purposes.

Yours truly,

Nicole Velasquez   Prof. Suzanne Weisband
Eller College of Management   Eller College of Management
University of Arizona   University of Arizona
nicolefv@u.arizona.edu   Weisband@eller.arizona.edu
520-465-9383   520-621-8303

Your Signature

By signing this form, I affirm that I have read the information contained in the form, that the study has been explained to me, that my questions have been answered and that I agree to take part in this study. I do not give up any of my legal rights by signing this form.

_____
Name (Printed)

_____   _____
Participant's Signature   Date signed

Statement by person obtaining consent

I certify that I have explained the research study to the person who has agreed to participate, and that he or she has been informed of the purpose, the procedures, the

possible risks and potential benefits associated with participation in this study. Any questions raised have been answered to the participant's satisfaction.

_____
Name of study personnel

_____   _____
Study personnel Signature   Date signed

SUBJECT DISCLOSURE FORM - Survey

We are conducting a study to examine the factors and qualities that motivate system administrators to use or not use software applications or other tools, and we would really appreciate your help. You are being invited to participate because as a system administrator, you have a unique understanding of what makes a software application (i.e., "tool") useful in your job. This survey asks about the tools you use in your work. Most people take about 20-30 minutes to complete this survey. There are no right or wrong answers; we are interested in your opinions. Your participation is completely voluntary, and you may withdraw from this survey at any time. Approximately 200-500 system administrators are being asked to participate in this survey.

After collecting and analyzing the responses, we will provide LOPSA and SAGE with an aggregated report of tool features important to system administrators. In this process, the confidentiality of your responses is very important to us, and we will only release aggregated data. We will NOT reveal your identity or the content of your responses to your employer or any other individual. The only foreseeable risk of participation in this survey is that the privacy of online activity while using work computers to complete the survey cannot be guaranteed by the researchers. There are no direct benefits to you as a participant. The broader benefits of this study include providing researchers with better insight into tool features important to system administrators. This study will also help to advance research in the area of large-scale information systems implementation and use.

The survey will be conducted at a time convenient to you. The only cost to you is your time.   As a way of thanking you for your participation, we will be randomly selecting 1 survey participant to receive an iPod Nano.

If you are willing to participate, please click the "continue" button at the bottom of this page to begin the online questionnaire. By completing the on-line survey, you are giving permission for the use of the data for research purposes. On the pages that follow, please answer each question to the best of your knowledge.

Your assistance in improving our understanding of how information systems are used in organizations is greatly appreciated. If you have any questions or comments please

contact us at the email addresses or phone numbers below. If you have questions about your rights as a research participant, you may call the University of Arizona Human Subjects Protection Program at (520) 626-6721 or toll free at (866) 278-1455.

Yours truly,

Nicole Velasquez	Prof. Suzanne Weisband
Eller College of Management	Eller College of Management
University of Arizona	University of Arizona
nicolefv@u.arizona.edu	Weisband@eller.arizona.edu
520-465-9383	520-621-8303

APPENDIX C. FINAL SURVEY INSTRUMENT

Construct and Item	Mean	St. dev.
Completeness *α = 0.55* *Composite reliability =0.82*		
_____ provides me with all the information I need.	5.12	1.336
_____ provides me with a complete set of information.	4.96	1.339
Accuracy *α = 0.63* *Composite reliability =0.84*		
The information provided by _____ is accurate.	5.97	1.099
_____ produces correct information.	6.13	0.861
Format *α = 0.94* *Composite reliability =0.96*		
The information provided by _____ is well laid out.	5.05	1.361
The information provided by _____ is clearly presented on the screen.	5.26	1.425
The information provided by _____ is well formatted.	5.10	1.430
Currency *α = 0.77* *Composite reliability =0.90*		
The information from _____ is always up to date.	5.62	1.216
_____ provides me with the most recent information.	5.62	1.256
Logging *α = 0.90* *Composite reliability =0.95*		
_____ keeps track of previous actions so I can retrace my steps later.	4.28	1.790
_____ allows me to see and review previous actions.	4.53	1.755
Verification *α = 0.85* *Composite reliability =0.93*		
_____ allows me to see and review the outcomes of previous actions.	4.65	1.747
_____ makes the outcomes of previous actions available to me.	4.84	1.710

Construct and Item	Mean	St. dev.
Flexibility *α = 0.80* *Composite reliability =0.88*		
_____ can flexibly adjust to new demands or conditions.	5.83	1.183
_____ is versatile in addressing needs as they arise.	5.81	1.199
_____ can be adapted to meet a variety of needs.	5.82	1.308
Integration *α = 0.80* *Composite reliability =0.91*		
_____ effectively combines data from different sources.	5.28	1.575
_____ pulls together information that used to come from different sources.	5.14	1.648
Accessibility *α = 0.69* *Composite reliability =0.87*		
_____ makes information easy to access.	5.88	1.154
_____ allows information to be readily accessible to me.	5.66	1.264
Speed *α = 0.81* *Composite reliability =0.91*		
_____ executes commands quickly.	5.80	1.178
_____ starts up and initializes quickly.	5.82	1.253
Credibility *α =0.81* *Composite reliability =0.91*		
I trust _____ because it has worked well for me in the past.	6.27	0.865
_____ is trustworthy.	6.28	0.912
Scalability *α = 0.78* *Composite reliability =0.87*		
_____ can be used in both simple and complex environments.	6.30	1.010
_____ is scalable.	5.86	1.310
_____ can be used in both small and large environments.	6.35	0.994

Construct and Item	Mean	St. dev.
Situation Awareness *α =0.78* *Composite reliability =0.87*		
_____ provides me with information necessary to predict future system state.	4.45	1.677
_____ provides me with information necessary to plan future actions on the system.	5.02	1.591
_____ helps me to understand the current state of my environment.	5.58	1.357
Monitoring *α = 0.79* *Composite reliability =0.88*		
_____ allows me to monitor system state	5.20	1.690
_____ provides monitoring capabilities	5.00	1.832
Information Quality *α = 0.84* *Composite reliability =0.93*		
In general, _____ provides me with high-quality information.	5.84	1.160
Overall, I would give the information from _____ high marks.	5.82	1.167
System Quality *α = 0.88* *Composite reliability =0.94*		
Overall, _____ is of high quality.	6.06	1.015
Overall, I would give the quality of _____ a high rating.	6.08	1.052
Information Satisfaction *α = 0.86* *Composite reliability =0.94*		
I am very satisfied with the information I receive from _____.	5.78	1.009
Overall, the information I get from _____ is very satisfying.	5.64	1.208
System Satisfaction *α = 0.91* *Composite reliability =0.96*		
All things considered, I am very satisfied with _____.	6.02	1.074
Overall, my interaction with _____ I use is very satisfying.	5.84	1.160

Construct and Item	Mean	St. dev.
Usefulness		
α = 0.77		
Composite reliability =0.87		
Using _____ improves my ability to make good decisions.	5.53	1.280
Using _____ enhances my effectiveness on the job.	6.31	0.827
_____ allows me to get my work done more quickly.	6.10	1.011
Attitude		
α = 0.88		
Composite reliability =0.94		
Overall, using _____ is a pleasant experience.	5.63	1.181
Using _____ is very enjoyable.	5.27	1.411

Table 20.   Survey items and measurement properties

APPENDIX D.   CROSS LOADINGS OF MEASURES

	Accuracy	Accessibility	Attitude	Completeness	Credibility	Currency	Ease of Use	Flexibility	Format	Integration	Info Quality	Satisfaction	Logging	Monitoring	Reliability	Situation Awareness	Scalability	Scriptability	Speed	Sys Quality	Satisfaction	Usefulness	Verification
ACC2	0.88	0.41	0.48	0.57	0.50	0.61	0.32	0.24	0.59	0.17	0.65	0.51	0.23	0.21	0.47	0.21	0.31	0.14	0.36	0.50	0.56	0.36	0.11
ACC3	0.83	0.47	0.46	0.43	0.58	0.45	0.50	0.41	0.31	0.18	0.55	0.51	0.14	0.25	0.61	0.31	0.44	0.23	0.44	0.51	0.55	0.42	0.16
ACCESS1	0.39	0.89	0.50	0.48	0.43	0.19	0.48	0.41	0.41	0.42	0.53	0.64	0.07	0.27	0.42	0.37	0.20	0.15	0.32	0.42	0.55	0.50	0.08
ACCESS2	0.51	0.86	0.51	0.66	0.46	0.41	0.56	0.31	0.63	0.39	0.57	0.63	0.19	0.32	0.32	0.40	0.19	0.11	0.34	0.38	0.49	0.52	0.24
ATT1	0.52	0.56	0.95	0.45	0.66	0.23	0.72	0.47	0.41	0.36	0.71	0.72	0.18	0.25	0.64	0.35	0.43	0.30	0.53	0.68	0.82	0.66	0.25
ATT2	0.53	0.53	0.94	0.49	0.57	0.25	0.63	0.54	0.41	0.35	0.65	0.66	0.28	0.18	0.55	0.24	0.41	0.39	0.49	0.66	0.78	0.60	0.28
COMPL1	0.58	0.54	0.52	0.82	0.39	0.48	0.45	0.39	0.43	0.22	0.42	0.44	0.24	0.24	0.37	0.30	0.35	0.18	0.35	0.33	0.46	0.37	0.20
COMPL2	0.41	0.53	0.32	0.84	0.23	0.51	0.35	0.19	0.62	0.33	0.45	0.45	0.32	0.22	0.20	0.38	0.11	-.02	0.21	0.18	0.33	0.29	0.25
CRED2	0.55	0.49	0.64	0.35	0.93	0.27	0.52	0.56	0.24	0.32	0.73	0.67	0.11	0.18	0.70	0.33	0.54	0.38	0.48	0.76	0.74	0.64	0.15
CRED5	0.61	0.44	0.56	0.32	0.91	0.26	0.48	0.45	0.31	0.16	0.63	0.58	0.13	0.30	0.78	0.30	0.56	0.30	0.51	0.69	0.68	0.51	0.14
CURR1	0.62	0.31	0.28	0.57	0.25	0.92	0.23	0.08	0.53	0.10	0.44	0.35	0.18	0.25	0.24	0.28	0.09	0.02	0.19	0.18	0.27	0.20	0.14
CURR2	0.50	0.30	0.17	0.50	0.28	0.89	0.25	0.11	0.40	0.14	0.37	0.31	0.21	0.28	0.24	0.30	0.16	-.07	0.18	0.20	0.29	0.13	0.10
EOU1	0.41	0.55	0.69	0.41	0.54	0.20	0.91	0.42	0.35	0.31	0.54	0.56	0.18	0.16	0.51	0.22	0.30	0.25	0.45	0.58	0.68	0.54	0.21
EOU2	0.44	0.49	0.57	0.44	0.41	0.28	0.85	0.15	0.51	0.31	0.50	0.51	0.07	0.18	0.37	0.24	0.29	-.02	0.28	0.42	0.47	0.41	0.07
FLEX1	0.29	0.30	0.41	0.26	0.49	0.09	0.29	0.85	0.00	0.47	0.38	0.35	0.32	0.34	0.45	0.37	0.40	0.64	0.44	0.53	0.47	0.44	0.31
FLEX2	0.39	0.42	0.43	0.40	0.45	0.24	0.31	0.82	0.16	0.41	0.45	0.47	0.29	0.16	0.34	0.29	0.38	0.53	0.28	0.47	0.51	0.53	0.16
FLEX3	0.26	0.33	0.52	0.22	0.46	-.05	0.27	0.86	-.02	0.49	0.34	0.36	0.32	0.19	0.42	0.33	0.45	0.75	0.36	0.50	0.47	0.56	0.35
FMT1	0.48	0.57	0.42	0.61	0.28	0.50	0.45	0.06	0.95	0.19	0.45	0.46	0.22	0.13	0.25	0.23	0.05	-.09	0.11	0.24	0.38	0.26	0.22
FMT2	0.51	0.56	0.41	0.60	0.30	0.46	0.47	0.06	0.94	0.19	0.46	0.48	0.24	0.20	0.26	0.17	0.08	-.09	0.10	0.27	0.38	0.31	0.22
FMT3	0.53	0.53	0.40	0.60	0.26	0.51	0.42	0.04	0.95	0.23	0.45	0.46	0.26	0.11	0.26	0.18	0.08	-.11	0.12	0.24	0.40	0.28	0.23
INT1	0.17	0.41	0.32	0.27	0.25	0.06	0.33	0.56	0.16	0.92	0.32	0.36	0.35	0.28	0.18	0.36	0.20	0.50	0.22	0.32	0.31	0.38	0.37
INT2	0.21	0.43	0.37	0.34	0.23	0.18	0.31	0.42	0.24	0.90	0.37	0.43	0.25	0.31	0.18	0.43	0.15	0.40	0.17	0.28	0.33	0.34	0.23
IQUAL1	0.70	0.60	0.68	0.52	0.70	0.45	0.57	0.45	0.45	0.33	0.93	0.76	0.16	0.26	0.65	0.36	0.45	0.23	0.55	0.71	0.76	0.53	0.19
IQUAL2	0.61	0.57	0.66	0.45	0.68	0.38	0.52	0.41	0.44	0.37	0.93	0.81	0.16	0.30	0.58	0.43	0.36	0.20	0.41	0.67	0.74	0.58	0.22
ISAT1	0.56	0.74	0.65	0.52	0.64	0.33	0.58	0.40	0.48	0.35	0.76	0.93	0.13	0.25	0.60	0.39	0.35	0.17	0.39	0.65	0.73	0.60	0.16
ISAT2	0.56	0.63	0.72	0.48	0.64	0.36	0.57	0.46	0.44	0.45	0.82	0.94	0.10	0.25	0.51	0.47	0.35	0.22	0.42	0.59	0.74	0.65	0.15

	Accuracy	Accessibility	Attitude	Completeness	Credibility	Currency	Ease of Use	Flexibility	Format	Integration	Info Quality	Info Satisfaction	Logging	Monitoring	Reliability	Sit Awareness	Scalability	Scriptability	Speed	Sys Quality	Sys Satisfaction	Usefulness	Verification
LOG1	0.23	0.15	0.24	0.34	0.15	0.24	0.15	0.38	0.22	0.32	0.19	0.12	0.97	0.10	0.21	0.14	0.11	0.45	0.20	0.26	0.23	0.16	0.70
LOG2	0.19	0.13	0.21	0.28	0.09	0.15	0.14	0.31	0.27	0.31	0.12	0.11	0.93	0.18	0.12	0.18	0.09	0.41	0.12	0.18	0.20	0.14	0.79
MON2	0.27	0.33	0.23	0.25	0.28	0.29	0.19	0.27	0.14	0.29	0.31	0.28	0.10	0.99	0.25	0.57	0.19	0.14	0.24	0.25	0.24	0.32	0.17
MON3	0.19	0.26	0.16	0.27	0.10	0.23	0.16	0.22	0.18	0.35	0.16	0.15	0.27	0.77	0.07	0.38	0.07	0.20	0.06	0.06	0.08	0.22	0.32
REL1	0.53	0.33	0.59	0.30	0.70	0.19	0.47	0.42	0.26	0.15	0.57	0.51	0.20	0.20	0.92	0.18	0.54	0.31	0.63	0.70	0.69	0.36	0.23
REL2	0.61	0.46	0.63	0.35	0.74	0.32	0.49	0.46	0.25	0.22	0.69	0.60	0.12	0.24	0.89	0.34	0.49	0.27	0.52	0.74	0.73	0.51	0.11
REL3	0.55	0.38	0.50	0.27	0.75	0.22	0.42	0.44	0.23	0.16	0.56	0.50	0.18	0.20	0.92	0.23	0.52	0.30	0.54	0.70	0.62	0.46	0.16
SA1	0.16	0.24	0.26	0.35	0.24	0.27	0.19	0.42	0.15	0.39	0.23	0.28	0.30	0.33	0.18	0.72	0.13	0.26	0.13	0.15	0.23	0.35	0.29
SA2	0.31	0.35	0.27	0.35	0.28	0.24	0.24	0.32	0.19	0.36	0.41	0.43	0.17	0.43	0.22	0.86	0.20	0.19	0.12	0.23	0.32	0.44	0.30
SA3	0.23	0.45	0.25	0.31	0.32	0.28	0.19	0.25	0.15	0.32	0.36	0.38	-.01	0.57	0.26	0.83	0.18	0.12	0.11	0.22	0.27	0.36	0.09
SCALE1	0.33	0.24	0.41	0.21	0.52	0.03	0.30	0.35	0.07	0.14	0.38	0.32	-.01	0.14	0.50	0.18	0.87	0.24	0.36	0.44	0.43	0.42	-.01
SCALE2	0.43	0.14	0.35	0.27	0.50	0.18	0.23	0.53	0.05	0.23	0.38	0.30	0.21	0.17	0.47	0.22	0.76	0.48	0.35	0.48	0.43	0.27	0.23
SCALE3	0.31	0.19	0.35	0.18	0.45	0.12	0.31	0.31	0.07	0.10	0.31	0.31	0.05	0.12	0.44	0.12	0.87	0.24	0.32	0.38	0.38	0.37	0.03
SCRIPT1	0.20	0.12	0.35	0.04	0.30	-.05	0.13	0.68	-.15	0.39	0.19	0.23	0.36	0.04	0.25	0.21	0.32	0.83	0.28	0.36	0.31	0.46	0.39
SCRIPT2	0.24	0.11	0.31	0.08	0.39	0.01	0.14	0.69	-.08	0.45	0.23	0.17	0.39	0.16	0.32	0.17	0.37	0.92	0.34	0.44	0.35	0.32	0.34
SCRIPT3	0.12	0.17	0.31	0.12	0.28	-.02	0.13	0.66	-.05	0.46	0.19	0.17	0.45	0.22	0.28	0.22	0.35	0.89	0.29	0.42	0.31	0.36	0.38
SPEED1	0.40	0.29	0.48	0.29	0.49	0.22	0.36	0.40	0.10	0.18	0.45	0.36	0.17	0.19	0.59	0.14	0.40	0.32	0.91	0.49	0.52	0.38	0.19
SPEED2	0.45	0.40	0.51	0.32	0.49	0.15	0.42	0.39	0.11	0.22	0.50	0.43	0.16	0.20	0.54	0.13	0.37	0.31	0.93	0.55	0.49	0.38	0.19
SQUAL1	0.54	0.46	0.68	0.29	0.74	0.22	0.56	0.51	0.28	0.28	0.70	0.62	0.21	0.21	0.77	0.27	0.45	0.36	0.54	0.94	0.76	0.53	0.19
SQUAL2	0.57	0.42	0.67	0.29	0.77	0.18	0.53	0.61	0.23	0.35	0.71	0.63	0.25	0.22	0.72	0.21	0.54	0.51	0.53	0.95	0.81	0.55	0.20
SSAT1	0.60	0.58	0.78	0.45	0.76	0.30	0.61	0.56	0.39	0.33	0.78	0.77	0.21	0.22	0.73	0.32	0.48	0.34	0.50	0.82	0.96	0.60	0.18
SSAT2	0.65	0.56	0.84	0.46	0.72	0.29	0.66	0.53	0.39	0.34	0.76	0.72	0.23	0.20	0.70	0.33	0.48	0.36	0.56	0.77	0.96	0.62	0.22
USEF1	0.33	0.56	0.53	0.40	0.41	0.22	0.47	0.42	0.31	0.44	0.52	0.61	0.17	0.42	0.30	0.58	0.26	0.27	0.24	0.35	0.45	0.79	0.27
USEF2	0.43	0.46	0.58	0.29	0.63	0.16	0.48	0.54	0.28	0.24	0.54	0.57	0.10	0.25	0.51	0.28	0.40	0.35	0.39	0.61	0.63	0.87	0.12
USEF3	0.37	0.41	0.54	0.29	0.51	0.08	0.41	0.55	0.15	0.30	0.40	0.48	0.12	0.08	0.41	0.31	0.39	0.43	0.41	0.46	0.50	0.83	0.11
VERI1	0.18	0.18	0.25	0.24	0.17	0.17	0.22	0.29	0.24	0.31	0.21	0.14	0.70	0.24	0.19	0.27	0.09	0.37	0.22	0.20	0.21	0.18	0.94
VERI2	0.11	0.15	0.27	0.26	0.12	0.07	0.10	0.33	0.19	0.30	0.20	0.16	0.74	0.16	0.15	0.23	0.12	0.40	0.16	0.17	0.19	0.19	0.93

Table 21. Cross-loadings of measures

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