WHAT IS THE DECISION-MAKING PROCESS OF COMPUTER SERVICE TECHNICIANS IN THEIR ROUTINE WORK?

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This study describes the computer service technicians' decision-making process. The investigator observed the decision-making process in computer service technicians' routine work and compared it to a general decision-making process model. Results show that the decision-making process of computer service technicians basically fits into the general decision-making process model, but does have some specific characteristics. The model includes understanding symptoms, reproducing symptoms, gathering information, diagnosing problems, setting goals, thinking of alternatives, consulting with customers, repairing and confirming solutions. Experience and group discussion play an important role in their decision-making process. Computer service technicians obtain experience from previous work, the Internet and colleagues.

Headings:

Decision-making

Problem solving

Computer service

Table of Contents

1. Introduction

The decision-making process has been studied for a long time. The domains of decision-making process studies include business, medicine, judgment, and education.

Computers have been a part of people's lives for more than 50 years, however there are no studies of computer service, even though it is an important part of our life of today. In this paper, a study of computer service technicians' decision-making processes is presented.

In section 2, the background of the decision-making process is reviewed; most researchers have considered decision-making to be clearly related to problem solving. A traditional model of the decision-making process includes five basic steps: define the problem, set goals, think of alternatives, think of actions, and monitor the implementation of the action (March, 1994; Sanders, 1999; McNamara, n.d.). The complex skills and behaviors that people exhibit when they solve problems are determined by the human cognitive process, however, this study examines the applications of these skills and not the underlying psychological procedures. The world of computer service is reviewed, focusing on the function of the computer service department in the small /medium computer businesses. Computer services install new personal computers and networks, trouble-shoot personal computer systems, make repairs, and sometimes educate the customers about hardware and software. Computer service technicians are the people who perform all the above duties.

In section 4, the results of a qualitative investigation into the decision-making processes of nine computer service technicians at five computer businesses are presented based on the observation of fifteen repair cases. During interviews, the computer service

technicians were asked questions related to their computer service training and experiences. During observation of the cases, the computer service technicians were prompted to explain their thoughts and actions by asking about their decision-making process.

Section 5 analyses the decision-making process of the computer service technicians. Nine steps were commonly seen in computer service technicians' routine work: understanding the symptoms, checking obvious objects, reproducing symptoms, gathering information and diagnosing problems, confirming problems, consulting with customers, fixing, and confirming the solutions. A model of the computer service technicians' decision-making process is proposed based on the common pattern of the observed cases. Finally, this model is compared to a previous model of the decision-making process in other fields.

2. Background

2.1 Decision-Making

2.1.1 Decision-making process

The decision-making process has been studied for a long time, but what is it? Some scientists have considered "decision-making" to be just another term for " problem solving". Edmund (2000) and Huitt (1992) describe decision-making and problem solving as containing the same steps. Huitt's (1992) steps include:

1) Input phase in which a problem is perceived and an attempt is made to understand the situation or problem,

2) Processing phase in which alternatives are generated and evaluated and a solution is selected,

3) Output phase which includes planning for and implementing the solution, and

4) Review phase in which the solution is evaluated and modifications are made.

Therefore, he used the term decision-making and problem solving interchangeably, when studying their processes (Huitt, 1992). Other researchers have treated decision-making and problem solving as slightly different phenomena. Kelly & Armstrong (n.d.) considered problem solving to be a broader process that involves recognizing, interpreting and analyzing the problem, generating and evaluating alternatives, selecting the most appropriate and then implementing it within a context of adequate monitoring and control. In their view, decision-making is part of problem solving, focusing on choosing among alternatives.

In this research, the processes of decision-making were studied during computer service technicians' routine work, and the two concepts of decision-making and problem solving were treated as being the same. During the observations, it seemed that the decision-making process of computer service technicians was their working process, including diagnosing and solving problems. Therefore, I have used the broad definition of decision-making, including the activities in recognizing and analyzing problems, choosing alternatives, setting goal, and taking actions throughout this paper, thus treating the two terms as names for the same concept.

It should come as no surprise that over the years the word *problem* has accumulated several definitions in the literature. As its first and preferred definition, the *American Heritage Dictionary of the English Language (1992)* defines *problem* as " a

question to be considered, solved or answered." The *Shorter Oxford University Dictionary(1989)* likewise labels it as " a difficult question posed for a solution." These definitions highlight the idea that one can think of a problem in terms of "something being solved". I will use this definition throughout this paper.

It is also important to clarify the distinction between problems and symptoms. Symptoms are observable events, and problems are the characteristics of the situation that cause the symptoms. A problem is known to exist because symptoms are noticed. For example, the fact that a printer does not work is a symptom, and the problem causing the symptom is that it is not plugged in.

Many people have contributed insightful observations to research on decision-making. For example, Andriole (1983) described the decision-making process as a process comprised of a set of interrelated analytical steps, which always involves an assessment of tools, the performance of decision-makers' tasks, problem categorization, and solution documentation and defense. Ackoff (1978) discussed decision-making by focusing on the study of the nature of problems. Ackoff described problems as having five types of components, including the decision-makers, the controllable variables, the uncontrolled variables, the constraints imposed from within or without on the possible values of the controlled and uncontrolled variables, and the possible outcomes. Solving a problem entails making at least one choice or decision.

2.1.2 The decision-making process

People have different ways of making decisions, however a common pattern of steps can be determined. The general model of the decision-making process that follows

was adapted from March (1994), Sanders (1999), and McNamara (n.d.).

1. Define a problem.

Problem finding or problem identification is not the same as problem solving. One must find out what is wrong before trying to do anything about it. There may be underlying hidden issues that must also be identified in the context of the more obvious problem features. These hidden issues may not be obviously related to the problems, but do affect the problem situation. For example, a customer brought in a computer system for repair. The symptom was that it could not boot up. The customer said he had changed everything he could think of, such as CPU, main board, memory, even the power, but still could not find the problem. He was right about everything, but there was a hidden issue; lightning had damaged the modem, resulting in the freezing of the system. The problem could only be solved after this hidden issue was discovered.

Problem definition can occur in four steps (McNamara, n.d.)

a) Define the problem by recognizing the symptoms of the problem, noticing the circumstances of the problem, such as time and places, and looking for the causes of the problem.

If the problem is still not clear, it may be broken down into more manageable pieces by repeating a), until the descriptions of several related problems have been delineated.

b) The problem may be verified by conferring with colleague or expert.

c) If several related problems exist, prioritize their solution.

d) The decision-maker's role in solving the problem must be determined. This may be an individual or shared duty.

2. Set goals.

The second step in problem solving is to set goals to be accomplished in solving the problem. Different goals lead to different decisions, thus different results. Many goals can be set at first, but some of them may have to be eliminated because they are unrealistic and others may have to be modified. Goals may be mutually exclusive, in which case the decision-makers can pursue one or the other but not both.

3. Think of possible solutions.

The third step involves thinking of possible solutions (also known as "brain-storming"), and weighing each. Ideally, all alternative paths from the initial unwanted conditions to the ideal goal state should be considered. However, people cannot consider all the possible alternatives before making decisions in real life. Logic leads decision-makers first to survey the information pool stored in their brain, then divide, aggregate and arrange that information into some logical patterns. Visualization of the outcome of each alternative is another important part of decision-making.

In order to select the best solution for a problem, a few factors are usually considered, such as:

Which solution is the most likely to solve the problem for the short or long term?

Which one is the most realistic to accomplish now?

What is the risk?

What is the cost of this solution, including money, time and labor?

4. Take action.

This is the most important step in the decision-making process, and may involve many individual actions. In general, a plan that covers the goals, arrangement of the time

and labor, and cost of the action is made before taking any actions. Various information related to the planned action(s) is collected. And then the work is started.

5. Monitor the implementation of the plan.

People often think step 4 is the final step in the decision-making process. However, solving a problem also provides an opportunity for learning how to avoid the problem in the future, or how to solve it better the next time it occurs. In addition, monitoring the situation allows evaluation of the success or failure of the solution.

2.1.3 Group decision-making

Group decision-making is the process of arriving at a solution based upon the feedback of multiple individuals. Such decision-making is a key component in the functioning of an organization, because organizational performance involves more than just individual actions. Decision-making models can be used to establish a systematic means of developing effective group decision-making. Four group decision-making models can be identified, each possessing distinct advantages and disadvantages. These four models are known as the rational, political, process, and garbage can models.

The rational model is based upon an economic view of decision-making. It is grounded on goals and objectives, alternatives, consequences and optimality. The model assumes that complete information regarding the decision is available and a correct conception of a problem can be determined (Allison, 1971; Cheshire & Feroz, 1989; Lyles & Thomas, 1988).

The political model considers the preconceived notions in the decision process. In contrast to the preceding model, the individuals involved do not accomplish the decision

task through rational choice in regard to objectives. The decision makers are motivated by and act on their own needs and perceptions (Allison, 1971; Cheshire & Feroz, 1989; Lyles & Thomas, 1988; Schneider, Shawver & Martin, 1993).

In contrast to the political model, the process model is more structured. With the process model, decisions are made based upon standard operating procedures, or pre-established guidelines within the organization. (Cheshire & Feroz, 1989; Allison, 1971).

In the garbage can model**,** an opportunity to make a decision is described as a garbage can into which many types of problems and solutions are dropped independently of each other by decision-makers. The problems, solutions and decision makers are not necessarily related to each other. The decision-makers move from one decision opportunity to another in such a manner that the solutions, the time needed and the problems seem to rely on a chance alignment of components to complete the decision. These components are the combination of options available at a given time, the combination of problems, the combination of solutions needing problems, and the external demands on the decision makers (Cohen, March & Olsen, 1972; Lovata, 1987; Schmid, Dodd & Tropman, 1987).

2.1.4 Simplifying decision-making

Simplification of decision-making should reduce the people's labor and cost for a case; therefore it would be desirable to simplify people's decision-making. Harris (1998) listed several decision simplification techniques. They may or may not be usable in every decision-making process, but they provide decision-makers with some ideas of how to simplify the decision-making process.

These techniques include:

1) Criteria Filter: establish a fixed set of criteria, which all alternatives must meet. Potential alternatives, which fail to meet even a single criterion, are excluded from the pool of alternatives.

2) Best of few: limit the number of alternatives to only a few. For example, if a person wants to buy a toaster, he probably does not have time to examine every brand. Rather than attempt to investigate every brand, he may choose just three or four to consider.

3) Cursory exclusion: a potential alternative is rejected on the basis of a single flaw.

4) Routinization: many decisions are made along the lines of previous decisions.

5) Satisfying: the first satisfactory alternative is chosen rather than the best alternative.

6) Delegation: let others do the research, consider the alternative, and make the decision.

7) Random choice.

8) Conformity: follow the crowd, do what others do.

9) Reaction: go against the crowd, do the opposite of the majority.

10) Feelings: follow the heart, go with the emotions.

11) Idleness: do nothing, let circumstances decide.

2.1.5 Mistakes in decision-making

Mistakes mean an unexpected result, which exacerbates the problem situation,

rather than improving it. People make mistakes for many reasons: prejudices or biases, information overload, or lack of understanding. Anderson (n.d.) listed some common mistakes made in the decision-making process.

- relying too much on an " expert",
- overestimating the value of information received from others,
- underestimating the value of information received from others,
- only hearing what one wants or hear or seeing what one wants to see,
- under-confidence, or not giving the proper value to one's own knowledge or intuition, and
- overconfidence.

2.2 Computer Service System

This research focuses on small-to-medium sized computer companies who provide computer repair service as one of their business functions.

The service process begins when a customer brings a computer system into the computer shop, or calls for on-site service, and describes the symptoms to the computer technician. The computer service technician tests, diagnoses, and fixes the system.

The service department is often one of the major units of a small-to-medium sized computer business. The satisfaction of customers for these businesses, at some level, depends on the service that the business provides. One reason that some people go to a small-to-medium sized computer business is their belief that it provides better service than a big one. Therefore, the role of the service department in the business's success can be significant.

The services provided by technicians may include three kinds of activities.

Consulting services provide professional opinions and assistance to the clients. They provide configurations and price quotations of new computer systems or network systems for customer purchasing. They also provide technical explanations to the customers when they repair a system.

Education services include any interactions with customers, ranging from general training for first time users on the basic operations all the way up to a specific training session for a specialized piece of equipment.

Technical support services provide customers with professional solutions to specific problems, like trouble-shooting hardware systems and installation of new systems. They also provide immediate response to meet all types of emergency conditions.

The computer service system creates a nice environment in which to study the decision-making process. First, the decision-making process of computer service technicians is not overly complicated, but it does present a complete process, since the decision-making of computer service technicians begins with a set of symptoms and ends with a solution. Second, the computer service technicians' actions are observable because they must manipulate physical objects in order to solve the problems.

This section closes with a very brief tutorial on personal computers, since they are the focus of the study, and these terms and concepts are used in the case study descriptions.

A personal computer is composed of two parts: hardware and software. Hardware is the physical equipment itself. Software is the term used to describe the instructions

that tell the hardware how to perform a task, such as device drivers and online programs. Without software, hardware is useless. Basic hardware includes:

1) Computer essentials: computer case, power supply, system board, central processing unit (CPU), memory.
2) Communication system: Network Interface Card (NIC), modem.
3) Storage system: hard drive.

All the problems reported in these cases happen on these parts.

3. Methods

The work of computer service technicians presents a complete decision-making process, and their actions are observable. Thus, the goal of this project is to observe the actions of the computer service technicians, have them report their thoughts during their decision-making processes by using the thinking-aloud method, and as much as possible, ask them to display the evidence that supports their decision-making. By means of these techniques, a model of the decision-making process of computer service technicians will be drawn and compared to the traditional model, presented in section 2.1.2.

Five small-to-medium sized computer businesses were visited. Nine computer service technicians were interviewed. After I introduced myself to them, and they agreed to participate in the research (see the consent form in Appendix A), I asked questions related to their training and experience, and their perception of what helps them do their work. Appendix B shows the list of questions.

I observed 15 cases of the technicians' work. While they worked, I asked questions related to their decision-making, asked them to explain their thoughts and

observed evidence that supported their decisions. For three of the cases the technicians allowed me to tape-record the observation session; I took notes for the rest.

In the three cases where the technicians were working on more than one system at a time, only one system and its repair was the focus of my attention. Six cases were completed and the problem successfully solved during the observation period; they will be described in the results section. Four cases were stopped on the customers' request. Another five cases were not finished during the observation time, either because new parts need to be ordered, or because the customers could not be reached for consultation.

Finally, a model of the decision-making process of computer service technicians is developed, and compared to the general theory of decision-making.

4. Results

4.1 Technicians' Training and Experience

Several questions asked about the technicians' preparation for and experience in their jobs.

Information about the computer service technicians' education, experience, and certifications is summarized in Tables 1 thorough 3.

Among nine technicians, one has a High School diploma as the highest level of formal education. Five hold the Bachelor degree with a computer science or information science major. Two hold the Bachelor degree with another science as their major. One has the Bachelor degree with a non-science major, and one has a Masters degree with a major in information management.

Degree	Number of Technicians
High School Diploma	1
B.S in Computer or Information Science	5
B.S in other Science	2
B.A	1
M.S in Information Management	1
Total	9

Table 1. The highest education level of computer service technicians

Experience	Number of Technicians
<2 years	3
3-7 years	5
>7 years	2

Table 2. Years of experience in computer service

Certification	Number of Technicians
A+	4
MCSE	2
UNIX	1
CCNA	1

Table 3. Certifications held by the technicians

Three of the technicians have less than two years experience in the computer service field, five have between 3 and 7 years of experience, and two have more than 7 years experience.

These nine technicians have different certifications. In computer service, a certification indicates that an individual has passed the tests that cover a specified area of knowledge. Certification may be administrated by a corporation or a professional organization.

Four have A+ certification. A+ Certification is a CompTIA-sponsored testing program (http://www.comptia.org/certification/aplus/) that certifies the competency of entry-level (6 months experience) computer service technicians. Two exams are necessary for Certification - the Core/Hardware Exam and the DOS/Windows Exam, which are endorsed by major computer hardware and software vendors, distributors, and resellers.

Two have MCSE certification on Windows 2000. The Microsoft Certified Systems Engineer (MCSE) (http://www.microsoft.com/traincert/mcp/mcse) credential is the premier certification for professionals who analyze business requirements and design and implement the infrastructure for business solutions based on the Microsoft Windows® 2000 platform and Microsoft NET Enterprise Servers. Four operating system exams, one design exam and two elective exams need to be passed to get the MCSE Certification.

One has UNIX Solaris Operating System certification. The Solaris UNIX certification is based on operating system version like Solaris (http://suned.sun.com/US/certification/); a certification that never expires or requires

re-certification. However, they are of little value when the associated version of the operating system is no longer used. Two certification tracks are available: the System Administration certification requires passing two exams, however starting with Solaris 8 a single upgrade exam can be taken instead. The Network Administration certification requires passing one exam.

Another technician has the CCNA certification. The CCNA certification (Cisco Certified Network Associate) (http://www.cisco.com/warp/public/10/wwtraining /certprog/lan/programs/ccna.html) provides a foundation in and apprentice knowledge of networking for the small office/home office (SOHO) market. CCNA certified professionals can install, configure, and operate LAN, WAN, and dial access services for small networks (100 nodes or fewer), including but not limited to use of these protocols: IP, IGRP, IPX, Serial, and AppleTalk.

4.2 Technicians' Perceptions of What Helps Them in Their Work

In addition to information on the technicians' education and experience, I also asked questions to gather some preliminary information about the technicians' general thoughts about what helps them in their decision-making process (see Appendix B). Results are shown in Figure 1.

First they were asked how important they thought education was in their work. Seven technicians said that education was important. According to the technicians, their education helped them better understand the complete system, find resources, and consult with customers.

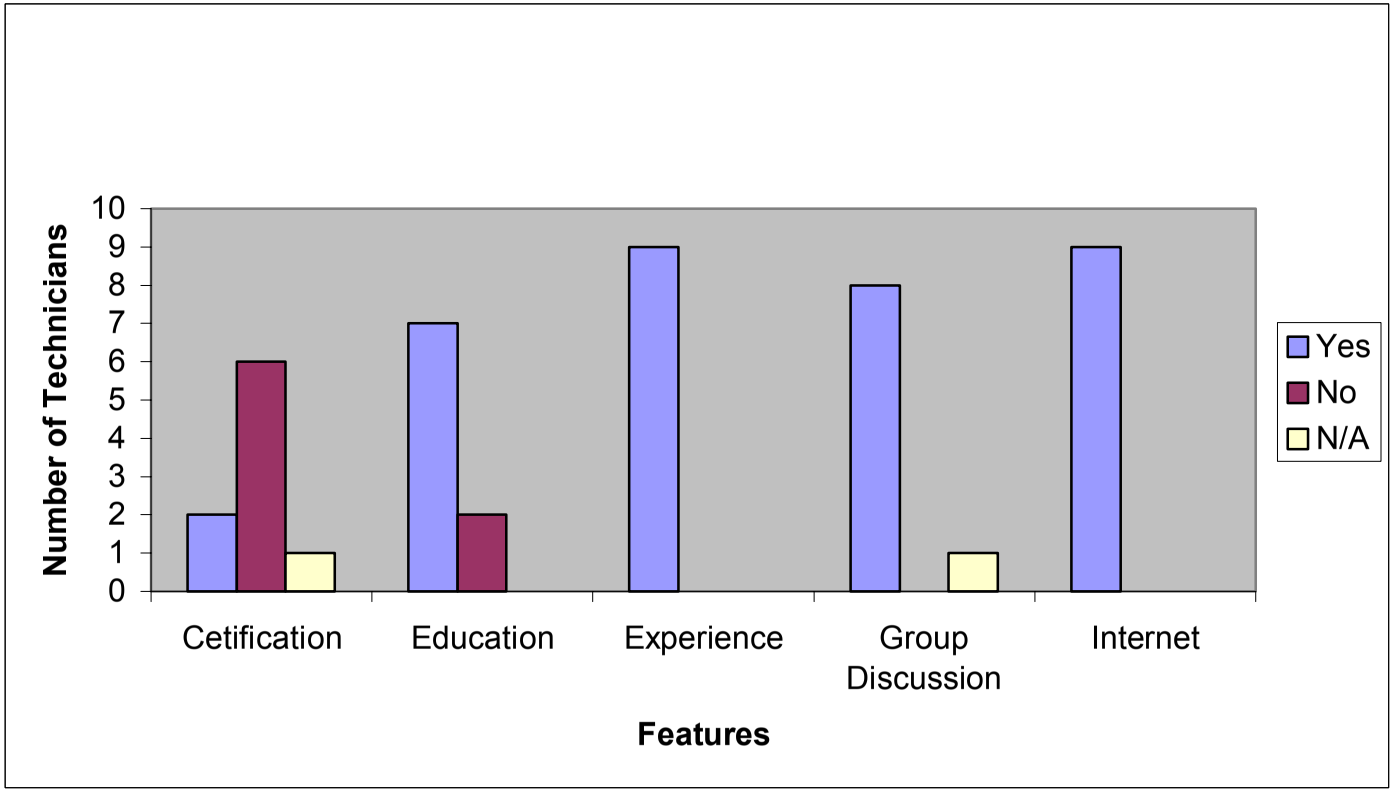

Figure 1: Computer service technicians' perception of the importance of certification, education, group discussion and the Internet in their decision-making process.

Certification is an outward sign of a professional, but the computer service technicians did not think it was that important. Only two technicians said that certification was important, six said it was not, and one was not sure. Those who said it was not important felt that "book knowledge" was much less useful than experience from actual practice.

Eight technicians said that group discussion was important and all nine of them agreed that the Internet is an important resource. Group discussion is a good means of getting new knowledge, "tricks of the trade", and more. They indicated that the Internet is even more helpful; they could download useful programs, and drivers, they could get help or resources from a chat room, and take advantage of others' experience in problem-solving.

All nine of the interviewed technicians, regardless of their own level of experience, said that experience was very important. The more cases they have seen, heard about or fixed, the more experience they gain and the more confident they feel. They felt that the more experience they gained, the more their work improved.

4.3 Case Observations

Among the cases that were observed, only the complete and successful cases are described below. The first case is presented in detail and five other cases are presented more briefly. From the first case, a preliminary list of steps performed by the computer service technicians is summarized. At the end of this section the comparisons of the other cases with this preliminary outline is described. In each case, T represents the Technician, C the Customer, and Co the Company. All companies have the customer fill

out a service request form that asks for contact information and a description of the symptoms. An example form is shown in Appendix C.

Case study 1:

In the service department of Co1, there were 4 technicians working in the room. A customer (C1) had brought in a Dell Dimension XPS r400 system the evening before. On the service request form, the symptoms were described as: “system freezes when boot up the computer, cannot access the operating system”. The technician (T1) has a B.S. in computer science. He has 4 years computer hardware service experience and A+ certification.

T1 said that first of all he needs to know the symptoms from the service request form. But the information from the form is usually far less than enough to figure out the problem. Therefore, in addition to the information from form, he needs to ask more questions of the customer, such as when did it happen, what had happened before this problem, and had anything been changed before it happened. If the customer is not in the store, he contacts him or her later when more information is needed.

T1 started by opening the case and checking the hardware connections, making sure they were tight. After connecting the keyboard and mouse, power cord, and monitor, T1 turned on the computer. The computer passed through the first system information detecting, then the Windows 98 startup picture appeared, and then the system froze there.

T1 said that the symptoms were obvious. He needs to diagnose the problems based on the symptoms. This is a hard step according to T1. He said there are many reasons that cause this problem, such as damage to the CPU, system board, memory or

even the case. Therefore he must find out what causes this symptom, in other words, dig out the real problem behind the symptoms. Since there was not much information on the customer's service request form, T1 decided to call the customer to obtain more information.

T1 obtained information by calling the customer. This problem happened right after he downloaded an old version of anti-virus software. After getting this information, T1 said he already knew that the cause of the symptom might be the anti-virus software, based on his experience. He has met countless cases where anti-virus software causes the same symptoms.

T1 continued, that he was going to try boot up Windows operating system in safe mode first, because he wanted to let the computer operate only under its basic setting, without loading any of the drivers and programs, in which case the anti-virus software would not run. T1 explained that if the anti-virus software was the problem, the machine would run normally in the safe mode. The computer did indeed start up in safe mode, thus confirming the underlying anti-virus problem.

After diagnosing and confirming the problem, T1 decided to call the customer to discuss the current situation. The store has a policy that the customer must be kept informed about the repair process, including what the problem is, how it is going to be handled, what may happen to the computer after the repair, etc, because the computer is not just a piece of hardware, it may also contain useful or even vital information for the customer. T1 told the customer that he thought the anti-virus software might be the problem. Because it was too old to tell the difference between useful programs and viruses, it blocked or damaged useful programs. As for the solution, T1 said he would

delete the anti-virus software under the safe-mode of Windows 98. Doing this might solve the problem, but might also cause an even worse problem; the computer might not startup from safe mode at all. After getting the customer's permission, T1 fixed the problem by uninstalling the anti-virus software in the safe mode of Windows 98, checking the system setting, then rebooting the system. After this, the computer system worked normally.

After completing the actions, T1 checked to see if there were any viruses in this computer by using a newly updated anti-virus software from the vendor's web site. Finally, T1 said: "I still need to run the computer for a while to make sure there are not any other problems."

From this initial case, we can identify some preliminary stages in the working process of the technician.

1. Understanding the symptoms, including the circumstances before and after the problem happened, and what the customer did before and after the problem, from the service request form and/or the customer.

2. Checking some obvious objects, such as the connection of mouse, keyboard, the power, and connection of hardware inside the case.

3. Reproducing the symptoms, especially since the customers may not know how to describe the symptoms or may give unclear or misleading information.

4. Gathering more information and diagnosing the problems. Often there are several possible causes of one particular symptom, thus the technician needs to gather more information to eliminate the possibilities.

5. Confirming the problem. After diagnosis and gathering more information, T1 confirmed the problem by working around it.

6. Consulting with the customer. The role of the customer cannot be ignored, because the technician needs to cooperate with him or her. The decision of what to do to the computer is a joint decision between the technician and the customer.

7. Fixing the problem. It is the action process leading to the final results of the decision-making process.

8. Confirming the solution. Check the outcome of the actions to confirm the problem is solved and no new problems are caused.

Case study 2:

Customer C2 brought his computer to the service department front desk of Co2. Technician T2 came to help C2. After filling in his contact information, C2 told T2 that his Windows 98 would not shut down properly after an Ethernet card was installed in the computer; he had to cut the power off to shut down the computer. He had already tried to uninstall Windows operating system and reload it, but could not solve the problem. T2 let C2 wrote down those symptoms on the service request form, and told C2 leave the computer in the service department and he would contact him after finding the problem. T2 has a high school diploma, 8 years computer service experience, and no certification. He is currently the manager of the service department.

T2 checked every connection, and found the symptom was obvious: Windows 98 froze after an Ethernet card was installed. T2 told me he has met a few similar cases before. One was because the BIOS version was too old, but this was not the problem in

this case. Another one happened around 6 months ago and it took him more than two days to identify the problem. Finally he figured it out by using a discussion forum on the Internet, which indicated that the Ethernet card was a likely candidate. Therefore, according to T2's experience, the Ethernet card made trouble again this time. After searching the Internet he diagnosed the problem: the Ethernet card was 3com xxx. According to the Microsoft web site, the 3com xxx Ethernet card may cause the Windows shut down problem when running Windows 98. T2 downloaded the update program from Microsoft, and the problem was fixed.

Case study 3:

Technician T3 was helping the customer C3 at Co3. C3 had an IBM generic system that she bought 6 months ago through the Internet. She could not find the invoice to request the RMA (Return Merchandise Authorization) service from the original company, so she brought it in for service. C3 also brought a piece of paper, on which she had written down the symptoms: Windows 2000 showed an error when she started the system. After the Windows 2000 picture shows up, the system goes to blue screen with the error message: STOP: 0x0000007B Inaccessible Boot Device … After having her fill in the service form and contact information, T3 asked questions regarding the time, situation and changes before and after the symptom appeared.

T3 has a Bachelor degree of computer science, and 5 years experience working on system repairs and upgrades. He has A+ certification and MCSE certification on Microsoft Windows 2000.

T3 checked the whole system, while he was telling me that from questions he'd asked, he knew that the symptom was not caused by a hardware upgrade, power failure, or new program having been loaded. After confirming the symptoms by turning the computer on, T3 searched the Internet. Upon being asked why, T3 said: "Searching Internet gives me a lot of help. I would say Internet is the most helpful tool for all computer technicians. We get the drivers and useful programs from Internet, also discuss over Internet, provide opinions and share our experiences. Although Internet is super powerful, it's not like everything you can depend on it".

The Internet search showed 8 reasons that often cause this error, but T3 had already eliminated some of the possibilities based on the questions he asked C3. T3 decided to check for a virus infection, because the customer was browsing the Internet before the symptoms happened and T3's experience told him that the computer might get a virus from the Internet.

While he was using the Norton anti-virus program to scan the customer's hard drive another problem appeared. The first partition could not be accessed by Norton, but the second partition was good and had no virus infection.

T3 explained that viruses could change the setting of a partition or physically damage the hard drive, but the fact that the customer's second partition was good and accessible told him it was not a virus problem. T3 backed up the customer's data and decided to use an application tool program to check the hard drive.

T3 used the tool program to scan the entire hard drive and the scan failed at 10%. Then T3 used a low-level format program to format the entire hard drive. This program helps clean viruses that may physically change the hard drive and recover some of the

hard drive. This process lasted about 2 hours. After checking, it turned out that some clusters on the hard drive were bad, and had lost the boot information, which led to the boot up error.

T3 gave the customer a call, and told her the story. The customer decided to change to a new hard drive, and reload Windows 2000 operating system to her system again.

T3 said he is sometimes misled by initial information, but he obtains more experience from every single false start. He probably will put this case on the Internet, so his experience can help others.

Case study 4:

Customer C4 brought his computer and monitor to the service department of Co4. Technician T4 first let C4 fill out a service record form with his contact information and description of the computer symptoms. C4 told T4 that when he turned on the computer this morning, there was nothing showing on the monitor. T4 decided to turn on the computer to see what happened. So he connected everything and turned on the computer. The power fan and processor fan worked, but there was no beeping sound or other noise. Then T4 asked C4 the following questions:

When was the last time it was running ok?

Had the customer installed any hardware before that?

Was there any power failure or lighting damage happened in customer's house?

C4 told T4 that the computer had run fine the night before, he did not install any hardware before the problem happened, and there was no power problem. T4 told C4 to

leave the computer and monitor in the service department for a while, so he could check it. T4 has a B.S with a biology science major and computer science minor, 6 years of experience on computer hardware service and no certification.

T4 said this is a general symptom that may be caused by various reasons, such as a power supply failure, video card failure, processor failure, or a power shortage. Lightening damage happens a lot in this season and in this area. Also, customers often damage the computer when they install hardware. His questions helped eliminate some causes of the trouble.

Since this was a problem related to video, T4 double-checked the video card and memory chips, but still found no clue. T4 told me he was expecting some beeps of sound, because the main board always first detects the basic set up of the devices, called BIOS and if it cannot find the right devices, it generates some noise. For example, a long beep may mean "checking memory", and a short continued beep may mean "checking video card". No noise means the system did not go through the checking up steps. This step narrowed the problem to the main board, CPU or a PC speaker. Since a PC speaker is a very stable part, T4 decided to start working from the main board.

The CPU was a socket-7 processor, made by AMD, model k6-2 450MHz, with a 100 MHz front side bus. T4 installed the customer's processor onto a new socket-7 main board and it worked well. T4 then knew the problem was caused by the motherboard. T4 mentioned that in the past, technicians actually diagnosed and repaired the main board. They would read the electronic menu of the motherboard and check all those chips on the board, because the main board was quite expensive at the time (several hundreds of

dollars). They do not do the main board repair now, since the cost of a new motherboard is under one hundred dollars.

After discussing the situation with customer, getting his permission to do so, T4 changed to a new main board and the computer operated normally.

Case study 5:

C5 brought his computer and printer to the front desk of Co5. T5 let the customer fill in the service request form. C5 described the symptoms as: the printer stopped working yesterday, it worked fine before. T5 told the customer that he would need at least couple hours to check the system, and would call C5 after he found the problem or if he had further questions. Before C5 left, T5 asked some questions about what the customer was doing before and after the symptom happened. T5 has a Bachelor Degree in telecommunication, with 2 years experience in computer hardware service and no certification.

T5 decided to check the printer first, because the printer itself could cause trouble. The self-test of the printer was good.

T5 checked BIOS and port setting in control panel, because in his experience, sometimes customers changed the parallel port setting and IRQ from BIOS, and then parallel port would conflict with other port and stop working. But there was no sign of this having occurred.

T5 changed another IEEE bi-directional parallel cable, and the same symptom appeared.

Next T5 used his testing computer to test the printer again and successfully print files. This confirmed the fact that something was wrong with the customer's computer, not the printer.

Then T5 uninstalled the printer from the printer setup, and restarted the computer. This time the computer did not detect any new hardware. T5 said it might be a hardware problem, but the customer had not touched the hardware at all. He could not figure out the problem.

T5 went to the service department manager to get suggestions. After listening to the story and checking the computer briefly, the manager said: "Call the customer again, ask him how did he turn on the computer and the printer?" The customer responded that he turned on the computer first and printer later.

The manager had discovered the mystery. He explained that there is an I/O chip on the main board, which charges all I/O devices (keyboard, mouse, parallel port and serial port etc). It is very sensitive, and can easily be damaged by improper input power. What the customer had done would burn out the I/O chip or part of it and cause the problem. The chip is not hard to find, but it is integrated on the main board, it would take at least 2 hours to change it, so he would suggest to the customer that they install a new main board or a secondary parallel port card which may cost less.

After discussion with the customer, C5 decided to change a new main board. T5 installed a new main board and the computer worked properly. After finishing this case, T5 told me that he always talks with his co-workers, or managers because he does not have too much experience. Sometimes they discuss technical problems as a group, which

really helps. They could learn new techniques and tricks from group discussion, and also learn from other technicians' experience.

Case study 6:

T6 began to work on a computer that had been brought to his department this morning. The customer left the service request form with his contact number and the symptom description: Windows would not boot up after deleting some programs last night. The system would stop after the Windows98 picture displayed on screen. T6 has a Master degree of Information Management, with 6 years of experience on computer hardware service. He has MCSE certification on Windows 2000 and certification on UNIX system.

T6 thought it was possible the deletion messed up the Windows boot up. When the customer deleted files, he might have deleted the system files, which are necessary for the computer's boot up.

T6 checked the connections, turned on the system and the symptoms showed as the customer had described. Then T6 restarted system under safe mode, but it still did not work. Finally T6 started the computer under the DOS system, and found the files and data.

T6 said there were couple ways to solve this problem. Since Windows98 does not support multiple boot up selection, and it does not support system recovery either, he could reload the Windows98 operating system, this would mean he had to format the hard drive, but all data would be lost. A second choice would be to load Windows 2000 or Windows XP, because these operating systems support multiple boots up, and thus he

could keep this Windows 98 operating system, files and all the data. This would be more expensive because the customer would need to purchase the new operating system.

After consulting with the customer, T6 could not use either of these solutions, because the customer wanted to save the data, but not purchase a new operating system.

Facing this situation, T6 decided to boot the system from DOS mode, save the data from DOS commands, transfer the data to floppy disks, and then reload the operating system. That method worked well, and the customer was very satisfied.

We proposed a brief outline of steps from the first case. Does this outline describe events in other cases?

In every case, the technician started by understanding the symptoms described by the customers. Similarly, the steps of checking obvious matters, reproducing symptoms and diagnosing problems occurred in every case. The diagnosis step was always the most time- and labor-intensive step. In cases # 2, 3 and 6 the technicians did not confirm the problems, either because there was no way to do so, or it was not necessary. Consultation with customers occurred in every case, and the technicians each said that this was the company policy. Fixing, of course, is the major part of every case. And the final step, confirmation of the solution occurred in every case. The technicians agreed that this step was important, because some other problems might happen after the original ones have been solved.

5. Discussion

The decision-making process has been studied in different domains, such as business, medicine, career, and education. This paper addresses the work and decision-

making process of computer service technicians for three reasons. First, computer technologies have been changing rapidly and computer service is becoming more and more important, and thus the work of computer service technicians is playing a role in more people's lives. Second, the computer service technicians' routine work presents a complete decision-making process. Their work starts with a declaration of the symptoms, followed by reproducing and confirming the symptoms, diagnosing problems, repairing the systems, and then concludes with their monitoring of the results. This presents a complete process from knowing the problems to solving the problems. Third, their decision-making process is observable. The symptoms are observable, as illustrated in case 1, where the symptom was that the computer system could not boot up. Computer technicians can describe their thoughts, their actions can be observed, the evidence of their decisions can be displayed and the results of the actions can be viewed. However since this decision-making process has never been studied before, it is unclear whether technicians follow the traditional decision-making process, whether they have their own process, or whether their decision-making process fits into the traditional model but with some additional features.

Figure 2 shows a model of computer service technicians' decision-making process drawn from the case observations and conversations with the computer service technicians. This structure is compared with the general model of decision-making process described in Section 2.1.2.

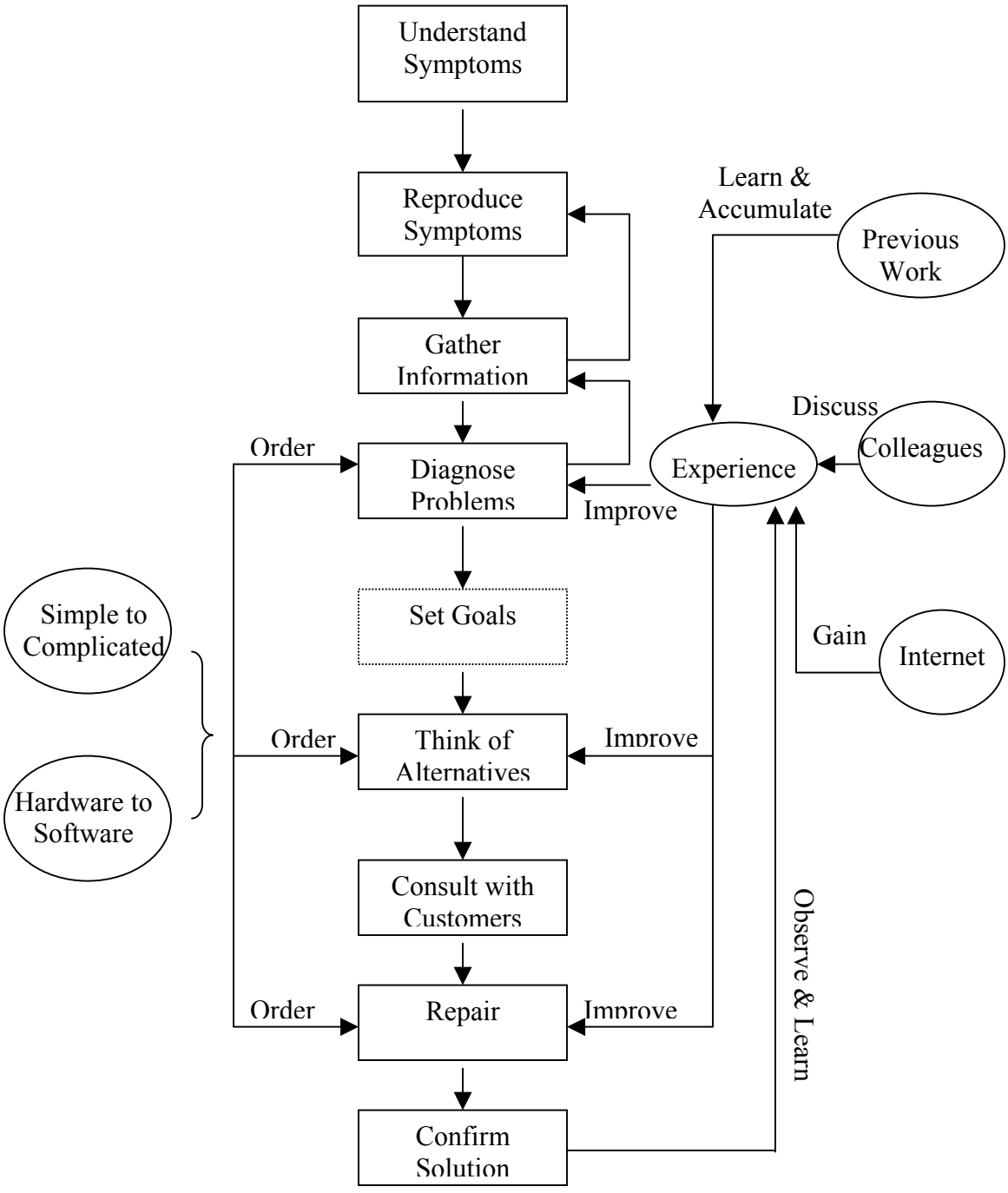

Figure 2: The basic structure of computer service technicians' decision-making process in their routine work.

Understanding symptoms is the first required step. The computer service technicians obtain the symptoms either from the service request form or directly from the customer. This is similar to medical doctors treating patients; they have to know the symptoms first. People only know there is a problem because of the symptoms. The symptoms provide two kinds of information; they let people know there is a problem and they provide clues as to the nature of the problem.

After checking some obvious objects, such as the hardware connections, the computer service technicians reproduce the symptoms based on their own checking and observation. In each case, the technicians reproduced the symptoms to see whether they matched the symptoms that the customer described.

The third and fourth steps in this model are gathering more information and diagnosis of the problems. Most technicians thought that diagnosis was the most complicated step. There are often many possible causes for a single symptom. In case 1 and case 4, for example, the symptoms were simple and obvious: the computer froze or nothing showed on the screen of the monitor, but there were many possible problems behind those symptoms. When they diagnosed the problems as well as when they considered alternatives and made repairs, the technicians usually started from simple to difficult, and from hardware to software. These ordering constraints are shown in the two bubbles on the left of the diagram. These orders come from the technicians' experience. Computer service technicians think working in this order makes their work easier and faster. In case 5, for example, the technician started by checking the connection between the computer and printer, and the printer itself, because that was the easiest part to check for the origination of the problem.

In order to make a correct and accurate diagnosis (define the real problem), the computer service technicians need information. That is why the computer service technicians always ask customers to fill out a service request form providing as much detail as possible and also ask many questions regarding the circumstances of the problem. Frequently, as in cases 1, 5 and 6, the technician called the customer while he was working on the computer in order to gather more information or to clarify a question. Experience also plays an important part in diagnosis, as shown by the bubbles on the right of the diagram.

The steps of reproducing the symptoms, gathering information and diagnosing the problem can sometimes form a loop. If there are many complicated, interconnected problems that cannot be identified in one round, then the technician must obtain more information, reproduce new symptoms and make new diagnoses, until the whole problem set is described clearly. The steps of understanding symptoms, checking obvious objects, reproducing symptoms, gathering information, and diagnosing problems correspond to the step of the defining the problem in the general decision-making model.

The second step of the general decision-making process is setting a goal. For computer service technicians setting a goal is an intrinsic part of the process. The goal for computer service technicians is always the same; to fix the computer system, satisfying both the customers and the company. Therefore, the technician does not explicitly set the goal of fixing the computer for each case. This implicit step is shown as a dotted box in Figure 2. An exception occurs if the customer decides at a later stage that the solution is too expensive, in which case the decision-making process is abandoned, and the computer is not fixed.

Next, the computer service technicians start thinking of possible solutions to the problem. The technicians performed well at this stage of thinking of as many alternatives as possible. They would evaluate each solution based on its simplicity, time and cost, and most importantly, the customer's requests.

The next step differs from that of the traditional decision-making process model. For computer service technicians, consulting with customers plays a very important role in their decision-making. In most cases, technicians and customers cooperate. The technicians are solving the problems not for themselves, but for the customers. The satisfaction of the customers is the most important criterion in the technicians' decision-making. Since the customers are valuable to the company, the satisfaction of the customers leads to the satisfaction of the company, which results in the satisfaction of the technicians. Case 6 provides a very good example. The technician has three choices of how to fix the computer: 1) format the whole hard drive, and reload the Windows98 operating system, 2) load a new operating system like Windows2000 or Windows XP, and keep the old one and all the data, and 3) save the data from the DOS system and then reload the Windows98 operating system. For a computer service technician, method number 1 is the easiest, and number 3 is the most difficult. However, the customer's request is to save the data, but not load a new operating system, because that is more expensive. Therefore, the computer service technician has no choice; he has to satisfy the customer by using the third method.

After consulting with customers, the technicians start repair. In common with the general model, they make a plan, get everything they need, and go to work. The repair

stage did not seem to be very difficult for the computer service technicians. All they needed to do was replace damaged parts, load operating systems, and configure the set up.

The final step is confirmation of the solution. Usually, the technicians accomplished this by rebooting the computer and letting it run. Monitoring the outcome of the decision-making process is an important part in computer service. Every computer business I observed had rules that the technicians must monitor a finished system, new or old, for at least 24 hours. This rule gives the computer service technicians enough time to make sure everything works normally, or to find more problems. This step provides computer service technicians with an opportunity to correct mistakes, if there are any. This is similar to the final step of the general decision-making process model. The outcome of computer service technicians' decision-making is reversible and changeable, to some extent. In contrast to it, the most decision-makings in medical field are not reversible. Once a patient takes a medication, it will function in the patient's body.

Experience plays a very important role during the steps of diagnosing problems, thinking of alternatives and making repairs. Experience helps the technicians diagnose problems faster, gives them more solutions from which to select, and helps them make better selections. In the repair stage, experience helps them complete the work faster and better.

Computer service technicians compare previous similar cases to the current case, in order to ease diagnosis and solution selection. In case 2, for example, the technician had experience with the problems caused by the Ethernet card and that gave him a very good clue to diagnose and solve the problem. It can be considered a short cut in decision-making process. However there is a potential risk behind this short cut. The normal

pattern is for the technician to examine the simple parts first, then the complicated ones, and to examine hardware first and then software. If the technician in case 3 had followed this pattern, he would have found the hard drive damage pretty easily. Instead, he followed his experience from a previous case by checking for virus infection, which is a software problem. That took extra time and labor.

Computer service technicians gain experience from their previous work, other technicians, and the Internet (Figure 2). Previous work is definitely the most common way to get experience. Through one decision-making process, a technician might see new problems, use a new technique, or learn new information. All of these become experience for next decision. As in the general theory of decision-making, observation and consideration of the outcome of the decision-making becomes information, which accumulates and can be applied to later decisions. Therefore, experience is important in computer service technicians' decision-making process, even though relying on experience may occasionally cause more trouble.

According the technicians' responses, most thought that being educated was helpful in their work and their decision-making. It is apparently not the domain content of education that is important, however, because technicians majored in a variety of subjects. The content of their education from school was not observed to have helped their work. They did obtain the abilities to learn and evaluate, to gather information, to make logical connections between symptoms and problems, and to explain problems and discuss possibilities. However, experience or natural ability may also provide these skills, since no difference among technicians was observed based on education level.

Certification is another kind of education for computer service technicians. The certification does sometimes help their work, according to the technicians, although this was not observed in these cases. Obtaining certification forces them to learn new information. But overall, they thought that hands-on experience was more important than formal education or certification.

Another factor in the technicians' decision-making is group discussion. Almost every technician thought that group discussion was helpful. When they had difficulty with a case, they talked with colleagues to get suggestions, or chatted with other technicians through the Internet to get information.

Face-to-face group discussion was not observed in this study due to time constraints. But according to the reports of the technicians, their group discussions could be described as following the rational model (Allison, 1971; Cheshire & Feroz, 1989; Lyles & Thomas, 1988). During their discussions, all participants have the same clear goal, they have faced to clarify problems, they may have enough information and they definitely have the same clarified goal to reach, which is fixing the problem. The Internet cannot be ignored. Every technician interviewed thought that the Internet was one of the most useful tools for their work. They used it to download useful programs (case 2), search help resources (case 2, 3), and chat with other technicians to get help (case 2). Computer service technicians exchange knowledge, experience, and information with colleagues. Some computer businesses have routine meetings every month to discuss important matters, which provide an opportunity for all technicians to discuss difficult cases with each other. The technician in case 5 obtained useful suggestion from his

manager. All of these events emphasize the importance of group discussion and consultation in decision-making.

Section 2.1.4 presented techniques to simplify the decisions-making process. From these observations, only one technique was used: routiniztion. There are certain routine steps summarized from previous work that computer service technicians to follow for certain problems. Whenever they meet with similar cases, they would follow the routine and thus simplify their decision-making process.

Computer service technicians make mistakes in their work sometimes. For example, in case 3, the technician was misled by the information he obtained from the Internet. This is an instance of the mistake "of relying too much on information received from others", mentioned in Section 2.1.5.

In summary, the decision-making process of computer service technicians in their routine work essentially fits into the traditional decision-making process model. The computer service technicians' decision-making process model starts with understanding symptoms, checking obvious objects, reproducing problems, gathering information and diagnosing problems. With the addition of the reproducing symptoms step, this corresponds to the problem definition stage. Thinking of alternatives, setting goals, taking actions, and monitoring the outcome of action occur in both the general model and this computer service technicians' model.

The only real difference is the computer service technicians' step of consulting with customers. This represents the cooperative aspect of computer repair.

6. Conclusion & Acknowledgement

6.1 Conclusion

The decision-making process has been studied in many domains. This paper addresses the decision-making process of computer service technicians; their decision process was modeled in nine steps, which corresponded to a general model of decision-making. Two differences were found: the technicians need to reproduce symptoms reported by customers before trying to identify the problem, and they also need to consult with the customers regarding which solution to use.

More studies are needed in order to understand the computer service technicians' decision-making process. In particular, the role of group discussions and the Internet as sources of information and various experiences, and the need for cooperation between the customer and the technician deserve more attention.

6.2 Acknowledgement

This research was conducted at School of Information and Library Science, UNC-CH. I would like to thank my advisor, Dr. Stephanie W. Haas for her guidance and advice throughout my work, and all the faculty and staff in my department for giving me suggestions and help on my thesis writing. I also want to thank my family, for their support during my research.

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Appendix A: Consent Form

Consent Form for Decision-Making Process Study

Purpose of this Study
We are inviting you to take part in a research study on decision-making process of computer service technicians. Yuming Zhao is the Principal Investigator of this research project under the advise of Dr. Stephanie W. Haas.

The Methods Used in this Project
First of all, a few general questions related to your decision-making process in your work will be asked. Secondly, your working on a case will be observed. The think aloud method will be applied in this project. This is a method allow you to describe your think process to the investigators during your working. The whole process would either cover a single case from beginning to end, or as much of a case as can be covered in a workday.

Number of Participants
There will be approximately six to ten participants.

What will Happen During the Study
As a participant you will be asked questions regarding your decision-making during your routine work. After this your work will be observed. You will be asked to provide the explanations, like how, and why do you make decisions? Your explanation will be recorded on tape or written down on paper.

Your Privacy is Important
We will make every effort to protect your privacy. Any information obtained in the study will be recorded with a participant number, not your name, your position. Since we will be making efforts to protect your privacy, we ask you to agree that we may use any information we get from this research study in any way we think is the best for publication or education.

If you have any questions regarding this study, please contact Dr. Haas Stephanie (919-962-8360) E-mail: stephani@ils.unc.edu, or Yuming Zhao (336-722-6144) E-mail: zym27@yahoo.com

Risk and Discomforts
Basically there are no any risk and discomforts to you.

Your Rights
You are free to refuse to participate, you can choose not to answer specific questions, and you may withdraw from the study at any time, without any negative consequences.

Institutional Review Board Approval
The Academic Affair Institutional Review Board (AA-IRB) of the University of North Caroline at Chapel Hill has approved this study. If you have any concerns about your rights in this study you may contact the Chair of the AA-IRB.

Barbara Davis Goldman, Ph.D.
AA-IRB Chair
CB# 4100, 201 Bynum Hall
UNC-CH, NC 27599-4100
919-962-7761
aa-irb@unc.edu

I have had the chance to ask any questions I have about this study, and they have been answered for me.

I have read the information in this consent form, and I agree to be in the study. I understand I will get a copy of this consent form.

Signature of Participant	Date

Appendix B

Please read carefully and write or circle the right answer

PART 1:

What is your highest education level
High School Bachelor Master Higher

If you have Bachelor degree or higher, what was your major?

How many years of experience do you have in computer hardware service
None < 2years 2-5 years > 5 years

What kind of certifications do you have
A+ Unix MCSE Other

PART 2:
Questions may related to the decision making:

Do you think being educated is
Important Not important Not Sure

Do you think group discussion is
Important Not important Not sure

Do you think Internet is
Important Not important Not sure

PART 3:
Please describe your answer briefly

How do you start a case?

Which has more problems, hardware or software?

Describe your decision-making process briefly.

Appendix C
SERVICE REQUEST FORM

Warranty Service: ☐
Non-Warranty Service: ☐

Customer Name:_____ Time Received: _____
Phone Number:_____ Date Due: _____
Street Address:_____ Contact: _____
City, State:_____ Zip Code:_____ Date Purchased: _____

QTY	Item Received	Serial Number

Description of Problem: _____
_____
_____
_____

Notice to Customer:
1) ****Labor is non-refundable****
2) x company is not responsible for any software loss. Hard drives should be backed up before be send in for service.
3) Minimum $25 labor charge to repair if there is no hardware problem. Or if the problem is software or user related.
4) There is a bench-fee of minimum $15 to examine or estimate a problem or a possible upgrade
5) Company will be not responsible for any consequence resulting from testing or items left for more than 30 days.
6) Monitors and printers under manufacture's warranty may need to be shipped out for service. There will be a freight charge if they are handled by company.

Customer Signature:_____ Date:_____ Received by:_____

Work Performed:
1._____
2._____
3._____
4._____
Special Comment:_____
_____
Performed By:_____ Date:_____ Finished? Yes/No

Parts:_____ **Qty:**_____ **Price:**_____
_____ _____ _____
_____ _____ _____
_____ _____ _____
Subtotal:_____
Tax:_____
Labor:_____
Total:_____

I acknowledge that all work specified has been completed satisfactorily and I received ALL hardware AND software I left in xxxxxxx company!

Customer Signature:_____ **Date Picked up:**_____

AA –IRB Application

Title: What is the decision-making process of the computer service technicians in their routine work?

Yuming Zhao
Advisor: Dr. Stephanie W. Haas

1. Project Description
   - A The purpose of this project is to conduct a study on what is the decision-making process of the computer service technicians, and compare it to the traditional theory of the decision-making process.
   - B. This project is initiated by interviewing six to ten computer service technicians. They will be asked questions related to their decision-making process in their work. A copy of the questions is in Appendix B. Then their work will be observed, a few cases will be described. A think aloud protocol will be applied in this project to describe how do they make their decision in their work. Their description will be recorded on tapes or written down on paper. Hopefully, a pattern of decision-making process in computer service technicians will be obtained from all these observations and interviews.

2. Participants
   a. Participants will vary in age and gender. There will be approximately six to ten participants from different computer business.
   b. Participants will be chosen base on their education, experiences, and certifications.
   c. Participants will be randomly selected from service departments of 6 six local computer reseller and distributors.
   d. There is no inducement of participants.

3. Are participants at risk?

   Participants are not at risk. Investigator will interview participants during their work hours at their work place, and only ask questions that related to the topics they are working on.

4. Describe steps to minimize risk

   Not applicable.

5. Are illegal activities involved?

   Illegal activities are not involved.

6. Is deception involved?

   Deception is not involved.

7. What are the anticipated benefits to participants and/or society?

The proposed empirical studies will lead to better understand of how computer service technicians make their decisions during their routine work. There is no finical benefit to the participants till this step of this study yet.

8. How will prior consent be obtained?

Participants will be presented a written informed consent form, which will be asked to sign. A copy of this form is available in Appendix A.

9. Describe security procedures for privacy and confidentiality.

All the computer service technicians will be reported by numbers or symbols not name or their positions. The record of interviews, both on paper and on tapes, will be locked in cabinets. No identifying a subject will be associated with the stored data. The subjects' privacy and confidentiality will be secure.