RISK ANALYSIS OF THE 9-1-1 SYSTEM USING FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

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(ABSTRACT)

More than twenty-five percent of the risk of failure for the 9-1-1 system can be contributed to blocked lines. The second major failure mode is unhelpful or improperly trained telecommunicators. The quick dispatch of emergency response teams in the event of any disaster or accident through the use of the 9-1-1 system is crucial to the well-being of the public. These potential failure modes prevent desperately awaited help from arriving as soon as possible. Therefore, the reliability and effectiveness of the system must be evaluated.

The objective of this report is to identify failure modes of the 9-1-1 system, calculate their criticality, prioritize them in order of risk, and propose economical and feasible alternative solutions.

Failure mode, effects, and criticality analysis (FMECA) is an evaluation tool that proves extremely useful when a system is desired to be kept highly effective and reliable. In this report, it is applied within the Systems Engineering Process to analyze areas of weakness throughout the New Jersey 9-1-1 system. FMECA is widely used throughout the military and commercial industry. It illustrates the interrelationships between causes and effects of failure modes, and helps to focus attention on high risk areas so that proper precautions may be taken.

First, the use of FMECA is reviewed. The step-by-step procedures are next illustrated, and it is noted that FMECA must be tailored to each system relative to its characteristics and desired application. The New Jersey 9-1-1 system is analyzed in detail and is found to be an effective emergency communications network. However, technology has not yet provided solutions to all possible failures. In fact, technology adds to the failure possibilities. Possible future areas of development are included.

This is dedicated to the memory of my grandfather, Charles Bienkowski. His strong will, motivation, and hard work was inspiring to all who knew him.

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I would also like to take this opportunity to thank New Jersey's Berlin Borough Chief of Police Dennis T. Chance and Camden County E9-1-1 Coordinator Henry J. Birkenheuer for all of their help and effort that they have given in order to aid me in the completion of this project.

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ACRONYMS

AHA - American Heart Association

AIN - Advanced Intelligent Network

ALI - Automatic Location Identification

AMS - Address Management Systems

ANI - Automatic Number Identification

APCO - Associated Public-Safety Communications Officers, Inc.

ARC - American Red Cross

ARP - Aerospace Recommended Practice

CAD - Computer-Aided Dispatch

CC - Control Center

CIM - Computer-Integrated Manufacturing

CLEC - Competitive Local Exchange Carrier

CNA - Customer Network Address

CO - Central Office

CPAS - Cellular Priority Access Service

CR - Criticality Ranking

DACS - Digital Access Cross-Connect System

DDP - Design Dependent Parameters

DFM - Double Failure Matrix

EMS - Emergency Medical Service

ESN - Emergency Service Number

ESZ - Emergency Service Zone

ETNS - Emergency Telephone Number System

FHA - Fault Hazard Analysis

FMEA - Failure Mode and Effects Analysis

FMECA - Failure Mode, Effects, and Criticality Analysis

FTA - Fault Tree Analysis

ID - Integrated Definition

$IDEF_0$-TD - Triple-Diagonal Technique

INB - Instantaneous Network Backup

IPSAP - Integrated Public Safety Answering Point

LEAA - Law Enforcement Assistance Administration

MSAG - Master Street Address Guide

NCS - National Communications System

NENA - National Emergency Number Association

NJB - New Jersey Bell

NNA - Network Node Address

NRC - National Resource Center

NSTAC - National Security Telecommunications Advisory Committee

OETS - Office of Emergency Telecommunication Services

PACA - Priority Access and Channel Assignment

PBX - Private Branch Exchange

PHA - Preliminary Hazard Analysis

PSAP - Public Safety Answering Point

PSCS - Public Safety Calling System

PSDP - Public Safety Dispatch Point

PSTN - Public Switched Telephone Network

QFD - Quality Function Deployment

RCF - Remote Call Forwarding

RPN - Risk Priority Number

SAS - Switched Access System

SCX - Specialized Communications Exchange

SPEN - Statewide Police Emergency Network

SR - Selective Routing

SRI - Stanford Research Institute

TDD - Telecommunications Device for the Deaf

UPS - Uninterruptible Power Supply

CHAPTER 1

INTRODUCTION

Any system important to the safety and well-being of our public must be evaluated for risks that may occur. Reliability and effectiveness of the system should be maximized. In order to do this, all weaknesses of the system must be identified. Failure mode, effects, and criticality analysis (FMECA) is a tool that not only identifies these weak points, but allows one to view them along with their causes and effects. Because FMECA prioritizes failures by their criticality, the failure modes having the largest impact in the community can be concentrated upon and alternatives or countermeasures can be derived. The basic concepts underlying FMECA that the military and most of commercial industry use, are based upon MIL-STD-1629A [26]. Therefore, much of this report is fashioned after this standard.

1.1 OBJECTIVE

The objective of this report is to identify the failure modes of the 9-1-1 system. These failure modes will be evaluated for their criticality and prioritized. Countermeasures to as many modes as possible will be determined and their economic impact will be evaluated.

The main tool used in this evaluation is FMECA. FMECA is useful in determining optimum points for improving and controlling product quality or process effectiveness. It provides guidelines/check sheets that are available for assistance and are easily understood. Not only does FMECA provide risk assessments of failures, it provides a mechanism to be exhaustively thorough in identifying potential single-point failures and their consequences. A single-point failure is one in which an accident could

result from one component loss, human error, or other single untimely and undesirable event.

Hopefully, this report will uncover some hidden high risk areas of potential failure in the operation of a 9-1-1 system. Also, it is desired that this report provide alternative solutions to improve the effectiveness of New Jersey's 9-1-1 system and provide a guide for those who may want to enact a 9-1-1 system in their community.

1.2 ORGANIZATION OF THIS REPORT

This report contains eight chapters. The information in this chapter pertains to introductory material and the objective of this report. Systems Engineering and FMECA's systems context is described in Chapter 2.

Chapter 3 is a literature review of FMECA. Previous uses of FMECA at different companies and the different analyzers are presented here.

Chapter 4 discusses the main methodology, FMECA, used in this report to evaluate the selected system. The background and step-by-step procedures of FMECA are provided in Chapter 4.

Chapter 5 gives insight into the operation and design of the 9-1-1 system. Its need, history, legislation, and implementation are addressed. Features of the 9-1-1 system in comparison to previous seven-digit number systems are briefly touched upon.

Using the systems engineering process, the 9-1-1 system is analyzed in Chapter 6. Its need is defined and operational requirements and a maintenance concept are detailed. Also, functional flow of the system is discussed and resources are allocated.

Chapter 7 yields the results of performing the FMECA on a 9-1-1 system. Severity, frequency, and probability rankings are listed. A Pareto analysis is presented here for the calculated risk priority numbers (RPNs) and for the cost of the derived countermeasures.

Finally, Chapter 8 concludes this report with an overall view of the 9-1-1 system and the main results of applying FMECA in a Systems Engineering framework. Recommendations are made for future research and additional study.

CHAPTER 2

SYSTEMS ENGINEERING

Systems engineering is the integration of all system components to achieve maximum overall system effectiveness. System effectiveness is the degree of efficiency, reliability, and capability that a system demonstrates in performing its intended function. In general, a system is a composite of man (people), machine (tools), materials (supplies), and methods (procedures) that are used to perform a specific task in a specific environment. A system may be simple or complex. It will normally be defined in terms of the task or function it performs. That is, it is task-oriented. In addition, the components of a system and its environment are interrelated, and a failure in any part can affect the other parts. [30]

2.1 SYSTEMS ENGINEERING PROCESS

System design and development are accomplished through the systems engineering process. This process begins with recognizing that the system is being designed for its entire life cycle. Starting with the system's conception, this process carries through to the design, development, production, operation, and disposal phases of the system's life. A maintenance concept is also "designed in" from the beginning. The process is tailored to each system in order to reach various objectives and satisfy specific requirements. A generic diagram of the system life-cycle process is illustrated in Figure 2.1.

The need for the system first arises from a deficiency. Then, a feasibility study is made in order to establish operational requirements. Operational requirements stem from

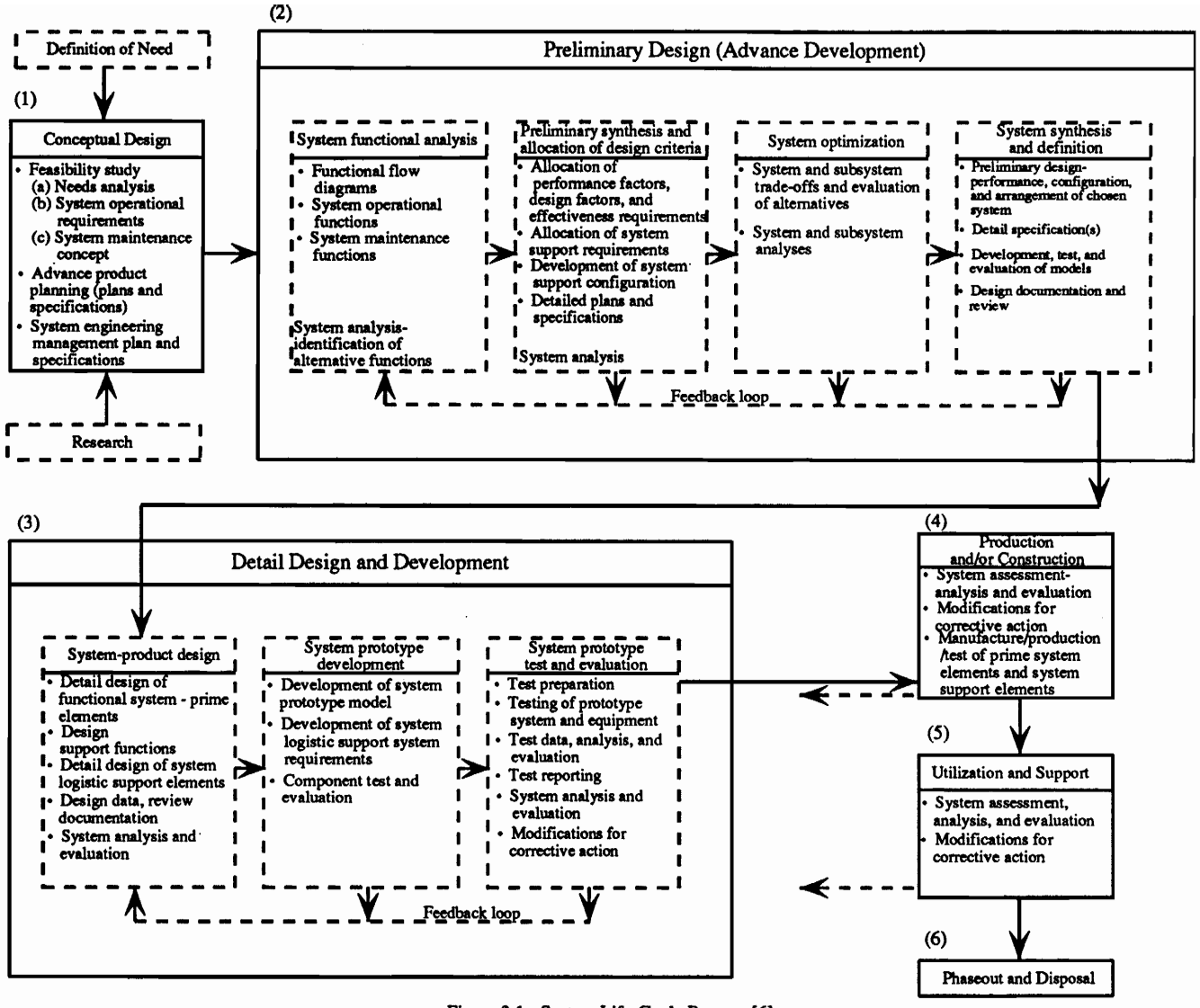


Figure 2.1 - System Life-Cycle Process [6]

performance and physical parameters, use requirements, operational distribution, operational life cycle, effectiveness factors, and the environment.

A maintenance concept is derived from the operational requirements for the upkeep of the system's performance. Levels and responsibilities for maintenance support, overall repair policy, elements of logistic support, effectiveness requirements, and the maintenance environment are defined.

Functional analysis then provides an initial description of the system and serves as a baseline for later requirements. Allocation of the system's resources is made so that the product or process may be developed by the design engineer with compatibility to the system's requirements. Alternative approaches are identified, assessed, and compared. Then, justification of the final design that is chosen can be demonstrated. The system is tested and evaluated to determine if all objectives have been met. [6]

2.2 CONTEXT WITH FMECA

This process requires the appropriate application of scientific and engineering efforts to ensure that the final product is operationally feasible. One of the most significant factors that needs to be considered in operational feasibility is reliability. As mentioned above, reliability is also a measure of system effectiveness. Reliability is defined to be the probability that a system will perform a designated task in a satisfactory manner for a given period of time when used under specified conditions.

Systems usually fulfill most expectations when operating, even when they are highly sophisticated. At times, however, these systems are inoperable and require extensive maintenance and the expenditure of scarce support resources. Unreliable systems cannot fulfill their intended mission. Therefore, it is essential that reliability be considered as a major system parameter during the design phase. [6]

FMECA helps to view the overall reliability of a system. It focuses on single events that will cause the system to exist in a state of unreliability. Specifically, it attempts to find those components that are most important to this state of unreliability. These components are called critical components. By performing a FMECA, one can observe that the components together with their modes of failure will each result in different impacts on the reliability of a system.

FMECA has numerous applications in the systems approach including reliability, logistics, maintainability, and safety. From a system reliability view, FMECA evaluates system design in terms of component application, hardware interfaces, stresses, etc., with regard to operational modes and the mission. The objective is to identify weaknesses and their criticality. Failures are studied at the basic component level and their impact is evaluated at the system level.

Diagnostics and troubleshooting are a major area of interest, with regards to maintainability. When failures occur at the system level, it is desirable to rapidly identify the faulty component with ease and precision. The system is evaluated in terms of overall supportability through the monitoring of task times, maintenance tasks, test and support requirements, etc. Here, FMECA helps to distinguish the failure detection methods and develops troubleshooting approaches.

When considering system safety, FMECA addresses both personal and equipment safety by identifying the consequences and criticality of failure. In reference to logistics, not only is FMECA used to evaluate system supportability for a given design, but the results, in many instances, specify corrective maintenance requirements and the need for additional logistic support resources. [4]

CHAPTER 3

LITERATURE REVIEW OF FMECA

FMECA and FMEA (failure mode and effects analysis) are used by many companies in various industries to improve their products and processes by identifying potential failure modes and taking preventive measures. FMECA is an extension of FMEA designated to include the criticality of failures. This chapter will explain who some of those companies are and how they interpret FMECA from MIL-STD-1629A.

3.1 FORD, GM, AND CHRYSLER

These companies have collaborated in an effort to introduce and use FMEA in their industry. Their goal is to continually improve quality, and using FMEA helps them to identify and eliminate potential concern. They claim that studies have shown that a fully implemented FMEA program would have prevented many vehicle campaigns. They use a team of knowledgeable individuals to prepare the FMEA with timeliness. That is, this is performed "before -the event" and not "after-the fact." In their *Potential Failure Mode and Effects Analysis* Instruction Manual [17], they use two types of FMEA, design and process.

Design FMEA is mostly utilized by the Design Responsible Engineer/Team to verify that all failure modes and their causes have been considered, and has supported their design process by reducing the risk of failure. It has aided in the evaluation of design requirements and alternative, and the initial manufacturing design and assembly requirements. The probability that potential failure modes and effects on vehicle operation have been considered during the design/development process has been increased.

A priority system for improvements within design and testing has been provided. Design test and development programs are able to be planned efficiently. Recommending and tracking risk reducing actions yields an open format. The FMEA serves as a future reference to aid in analyzing field concerns, evaluating design changes, and developing advanced designs.

The process begins by establishing the design intent. A FMEA form is filled out and evaluated. The Design Responsible Engineer carries the responsibility for assuring that all recommendations are implemented.

The process FMEA is used by the Manufacturing Responsible Engineer/Team for analysis in their area. Here it identifies potential product related process failure modes, assesses the effects of the failure on the customer, identifies potential manufacturing or assembly process causes and helps to focus controls for reduction in its frequency of occurrence. It is a document that reflects the latest level of design and actions even past production.

3.2 FEDERAL-MOGUL CORPORATION

Federal-Mogul Corporation in their Blacksburg plant also uses process FMEA. Their *Process FMEA Training Manual* [43] outlines the steps for conducting FMEA. This way, in their material transformation processes, they are able to eliminate undesired aspects of a process or compensate for them through a preventive maintenance program. The goal in performing FMEA on their processes is to increase productivity and improve quality.

3.3 OTHERS

The Reliability Analysis Center recommends FMECA to guarantee personnel and equipment safety [32]. MIL-STD-785 "Reliability Program for Systems and Equipment

Development Production" [23] requires the performance of FMECA. FMECA is also mandated in MIL-STD-1543 "Reliability Program Requirements for Space and Launch Vehicle" [25], and NASA NHB 5300.4 "Reliability Program Provisions for Aeronautical and Space Contractors" [27]. None of these references dictate how FMECA is to be performed. It needs to be tailored to each individual system.

According to Syan [40], formal techniques should be used to ensure that there is a consistent approach to problems throughout the organization. Even with less experienced engineers and designers, a minimum quality level will be reached. Figure 3.1 illustrates the use of FMECA and other formal techniques in the product development process.

It can also be seen from Figure 3.1 that FMECA is beneficial when used proactively. Its use early in the design phase helps to isolate problems by finding high risk areas. Fault Tree Analysis (FTA) can be used on those failures with a high RPN so that a remedy can be determined. Attention then moves to the next design consideration. A target cost analysis can then be performed.

However, FMECA must also be iterated over the life-cycle of the system. Not only should it be used in the design of a new system, but it should be implemented to evaluate existing systems as well. This reactive approach is used throughout this report with regards to the 9-1-1 system.

3.4 CONTEXT

3.4.1 Tailoring

The most accepted procedures by the military and throughout commercial industry for FMECA are described in MIL-STD-1629A "Procedure for Performing a Failure Mode, Effects, and Criticality Analysis" [26]. However, FMECA is tailored to fit

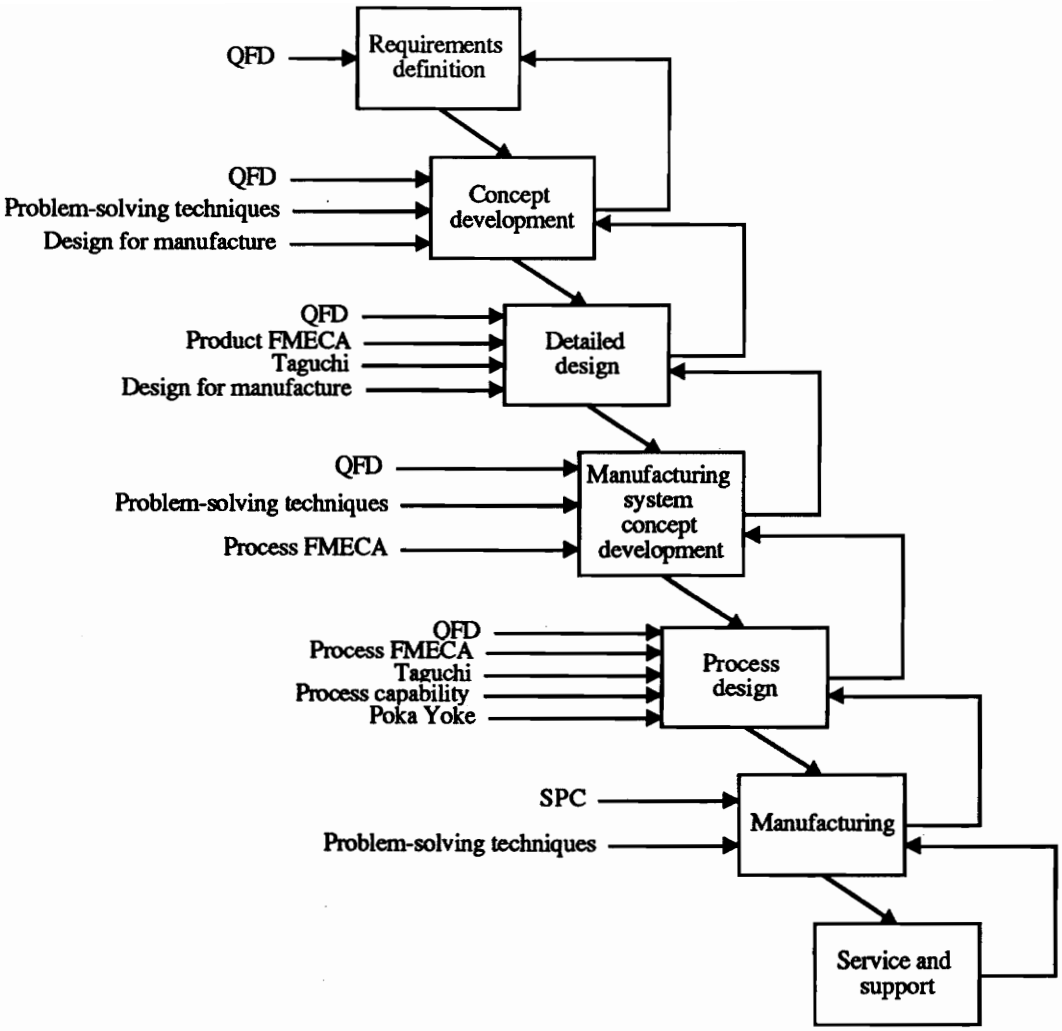


Figure 3.1 - Formal Techniques [40]

the characteristics of each system, company, product, or process. This gives way for a large variety of systems on which FMECA would be appropriate to use.

Because FMECA is an excellent way to identify potential failure modes before they occur and can be tailored to fit each system that it is used on, FMECA is an appropriate analysis tool for use with the 9-1-1 system. Also, all of the applications of FMECA mentioned above dealt with reliability and human safety, two of the biggest concerns dealt with by 9-1-1 operators. This is why the 9-1-1 system could greatly benefit from FMECA.

3.4.2 Cause And Effect

Ishikawa's cause-and-effect diagrams, also known as fishbone diagrams, can serve as a checklist for consideration and are generic in their application. Knowledge about possible causes of variation or some other problem is summarized. These causes are organized into logical categories. A cause-and-effect diagram is a valuable tool for organizing efforts to improve a process because it helps a team to stay focused on different possible causes.

In order to construct an effective diagram, using a team helps to cover all aspects. Generate a potential cause list by brainstorming. Then build the diagram. Place the problem statement on the right. Draw and name three to six major cause categories. Look for causes that appear repeatedly. Use expert knowledge from the team and reach a consensus for which causes need the most attention. Keep the diagram updated. An Ishikawa diagram based upon the causes and effects of the 9-1-1 system FMECA is illustrated in Figure 3.2 [42]. This diagram will help to identify the causes to be used later in the FMECA.

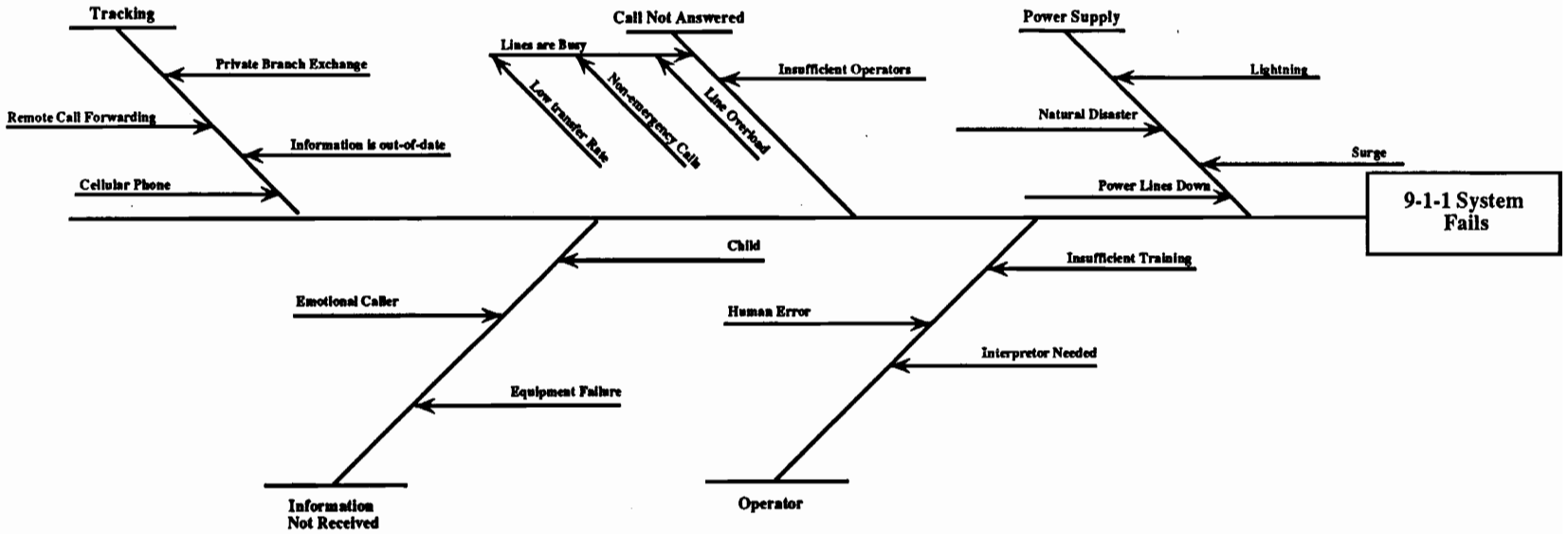
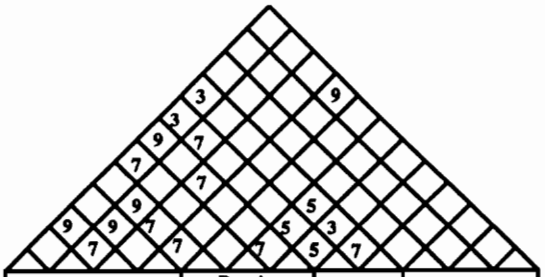


Figure 3.2 - Ishikawa Diagram of 9-1-1 System

3.4.3 Quality Function Deployment (QFD)

QFD originated in 1972 at Mitsubishi's Kobe shipyard. It is a tool that aids in the translation of customer requirements into a set of design requirements. Also termed the "House of Quality," QFD is beneficial because of its customer-focused product development, shorter system development cycles, enhanced early system design efficiency, and effective early system design tradeoffs. Production start-up problems, start-up costs, and deployment and support costs are also lowered [15]. QFD is an important part of the analysis throughout the system's life-cycle as was demonstrated in Figure 3.1.

To construct a "House of Quality", customer requirements are first determined and assigned a relative importance weight. Then, design dependent parameters (DDP) or engineering characteristics are listed. The correlation of customer requirements and engineering characteristics is classified and the relationship matrix is filled in. Next, the matrix is checked for any empty rows or empty columns. An empty row signifies unaddressed customer requirements and an empty column implies unnecessary engineering characteristics. The roof is filled in displaying the relationship between engineering characteristics [45]. A partial QFD model can be found for the 9-1-1 system in Figure 3.3.



Customer Attributes	Engineering Characteristics	Costs				Receive calls			Timing		Design		
		Training	# of trunks	# of operators	Maintainance	Keep lines clear	Obtain correct/ sufficient information	Communication	Route call	Dispatch	Number not taken	Simple, short, standard	Conversion process
Minimum total time on phone	Short transfer time	5	7	7		9			7	7			
	Short answer	5	5	9									
	Information retrived quickly	7				9		9	3	7			
Easy	Can remember number											9	
	Easy to dial											9	
	No coins needed				7						7		9
Gain hope/ be calmed	Not transferred or have to repeat information					5	5	9					
	Easy to communicate /pleasant operator	9						9		7			
	Quick help arrival						7	7	7	9			
Costs	Taxes	9	5	5	9								9

Correlation

9	Very strong
7	Strong
5	Weak
3	Very weak
1	Some

Figure 3.3 - QFD Model

CHAPTER 4

METHODOLOGY

As the design of a system takes place, it is possible to analyze how the final system will operate, the problems that may be encountered during its operation, the failures that may occur, and the hazardous conditions that may exist. There are many methods of reliability analysis such as fault tree analysis (FTA), preliminary hazard analysis (PHA), fault hazard analysis (FHA), and double failure matrix (DFM) [35]. The form that is concentrated upon herein is FMECA. A failure mode is the exact manner in which an item can fail, whereas a failure is designated to be the condition of not achieving the desired end.

Reliability is the probability that a system or product will perform its designated function in a satisfactory manner for a given period of time when operated under specified conditions. Probability is a quantitative expression representing a fraction or percent specifying the number of times that one can expect an event to occur in a total number of trials. FMECA was developed by reliability engineers so that they could predict the reliability of complex systems. In order to accomplish this, it was necessary to establish how and how often components of a system would fail. Failure mode and effects analysis (FMEA) was then introduced.

This technique was first used in the development of flight control systems in the early 1950's. The Society of Automotive Engineers in Aerospace Recommended Practice (ARP) 926 made an extension to this in order to include criticality, which is the magnitude of risk associated with a given hazard. It combines the measurements of hazard severity and hazard probability. A hazard is a condition that is prerequisite to a mishap - an unplanned event or series of events resulting in death, injury, occupational

illness, or damage or loss of equipment or property, or damage to the environment. This extension of FMEA was designated FMECA. FMECA is used extensively in safety analyses. It attempts to find those components that are most important to the state of unreliability of the system.

FMECA identifies the possible problems of a design that could develop as a result of system failures. Its objective is to determine rapidly the ways a system can fail, the effects of such failure on other components of the system, and the criticality of these failures, with accuracy and ease. FMECA is applicable within systems or at the sub-system interfaces, and can be applied at the system, subsystem, component, or part levels. Overall, FMECA is a visibility tool that provides a mechanism for a thorough and exhaustive analysis.

4.1 BOTTOM-UP/INDUCTIVE APPROACH

The process of analyzing failure modes falls into one of three categories: (1) bottom-up, (2) top-down, (3) a combination of up-down and bottom-up. The bottom-up method first analyzes the failure modes of the basic components. The failure modes of the successively more complex units are then analyzed until the entire system is completed. The basic tool of the bottom-up method is FMECA. FMECA needs to be initiated as early as possible in the design phase of a system and should be repeated throughout its life cycle in order to provide feedback for the designer. The result is an improvement in the quality of the system. If performed in a timely manner, FMECA will have a meaningful and cost-effective influence on the design.

Inductive reasoning is a systematic evaluation of the parts or elements of a given system or subsystem to determine the characteristics of interest. Therefore, FMECA is an inductive tool. In this bottom-up approach one would ask "What would happen if ...?". The other type of reasoning is deductive - logical reasoning from a defined unwanted

event or premise to its causative factors. In this top-down approach, the question "How could it happen?" is asked.

4.2 PREPARATION

In order to define the scope and boundaries of the system to be assessed, pertinent data relating to the system must be gathered. This includes requirement specifications, descriptions, drawings, components and parts list, etc. The interface control specifications and the system environmental specifications are also important in establishing the boundaries and definitions for the system hardware and functions to be used in the evaluation of failure effects. The budget, schedule, and allocated resources for the analysis must be determined with management. The considered mission phases need to be established. The system should be categorized into advantageous and reasonable elements including subsystems, assemblies, subassemblies, components, and piece parts. This can be accomplished in conjunction with functional flow analysis. Functional flow diagrams are employed to identify subsystem, assemblies, subassemblies, components, and parts. These determine the interrelationships between the units and the system, and the units among each other.

This is similar to $IDEF_0$ (integrated definition) function modeling. After taking each function to its basic level, cost and time drivers are quantified. The resources that are required by each function are assigned to that function in the chosen units. Major cost drivers are emphasized graphically. Because much data is generated that overly complicates sorting and assimilation therefore not allowing the process to be seen as part of the larger CIM (computer-integrated manufacturing) system, the triple-diagonal technique ($IDEF_0$-TD) was devised. Diagrams of information, control, and material flow systems comprise its three main components. This technique illustrates the total

integration of a factory by developing these components sequentially, then approving, layering, and quantifying them. [39]

4.3 ORGANIZING INFORMATION

Valuable resources to be protected should be identified such as personnel, facilities, equipment, productivity, test objectives, environment, etc. These resources are targets. Next, the levels of acceptable risk that have been predetermined and approved by management are observed. Accepted (assumed) risk/loss is a risk/loss that is specified, identified, analyzed, and quantified to the maximum practicable degree and accepted by the right level of management after proper evaluation. The scope and resources required to perform a FMECA can be reduced without benefit or loss by answering the following question:

- Will the system failure render an unacceptable loss?

If not, the analysis is complete. Document the results. If the answer is yes, proceed to each subsystem followed by assembly followed by subassembly, followed by component, followed by part, and ask the question of each. Whenever the answer is no, the analysis is complete. When finished, the results must be documented. Whenever the answer is yes, proceed forward. [12]

Take the TWA Flight 800 explosion for example. The cause of the explosion is yet to be determined. However, suppose FMECA was being performed on the aircraft before its flight and a defect in the fuselage was found. The question is asked if this system failure will render an unacceptable loss. Obviously, if that defect was the reason for the explosion, the answer would have been yes and corrective measures would have hopefully been taken. If the explosion was caused by outside forces such as a bomb, the answer to that question may have been no.

4.4 PROCEDURE

The basic methodology used is shown in Figure 4.1. For each failure that would render an unacceptable loss, determine the failure modes and the effects of each failure mode on each target. Effects may range from complete system destruction to partial system operation. The cause of each failure should be described. Assess worst-credible case severity and probability for each failure mode, effect, and target combination. The severity of failure can be classified as minor, major, critical, or catastrophic. Severity may also be ranked on a scale of 1 - 10. The risk of each failure mode is assessed. Each identified risk is categorized as acceptable or unacceptable. If the risk is unacceptable, then countermeasures are developed. The risk is then reevaluated with the new countermeasure intact. When new countermeasures are introduced, it needs to be determined if they will present new hazards or diminished system performance. If they do, new countermeasures are once again needed and risk should be reevaluated. All information should be documented on a worksheet. The implementation of the FMECA process is demonstrated in Figure 4.2.

4.5 CRITICALITY

Since some units of a system may be especially critical to the system's mission, they should be given special notice and analyzed in greater detail. One criticality system established by the military consists of four classifications of criticality. They are as follows:

- **Category 4 - Minor Failure** - Any failure that does not degrade the overall performance and effectiveness of the system beyond acceptable limits. May result in excessive unscheduled maintenance.

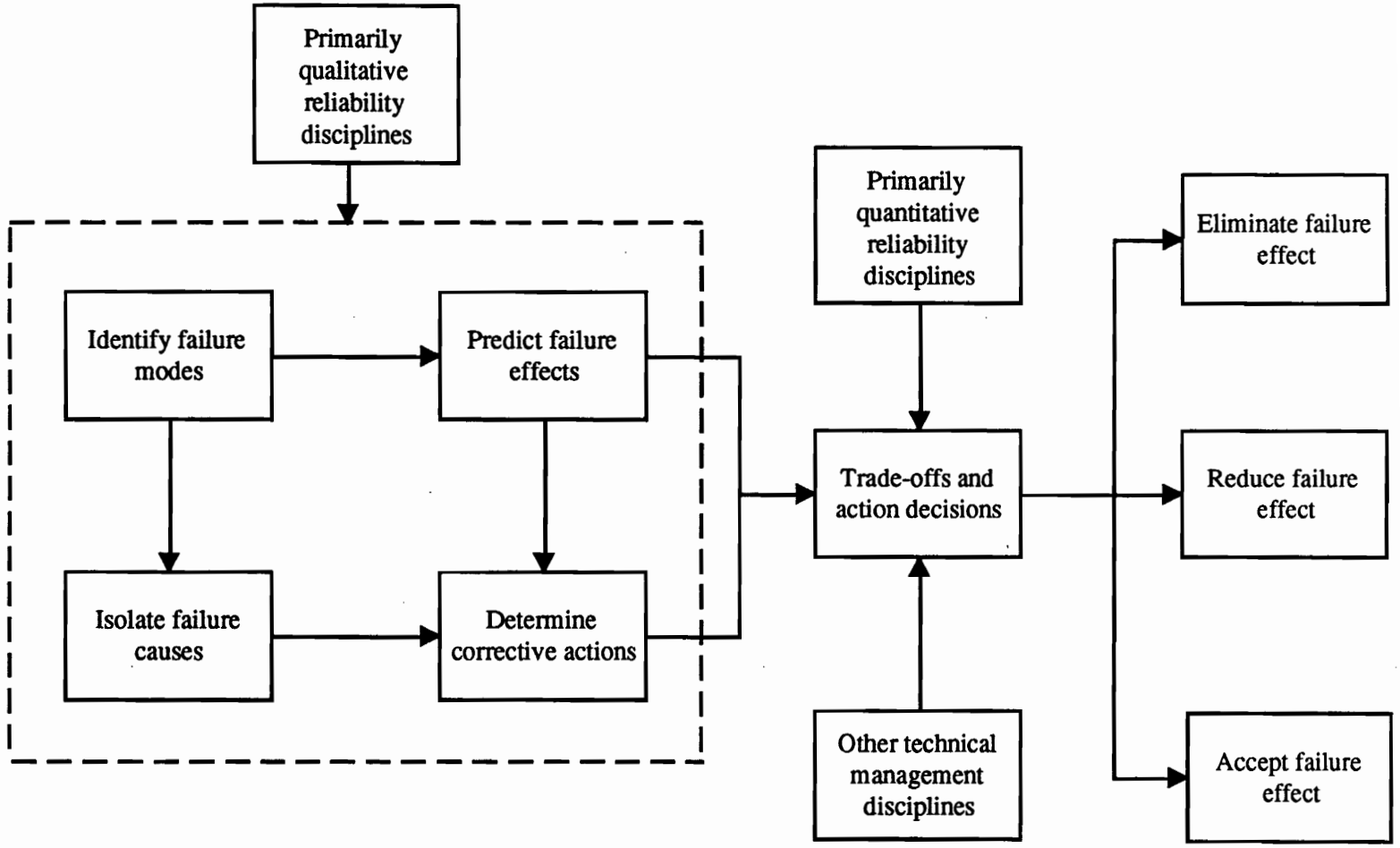


Figure 4.1 - FMECA Methodology [38]

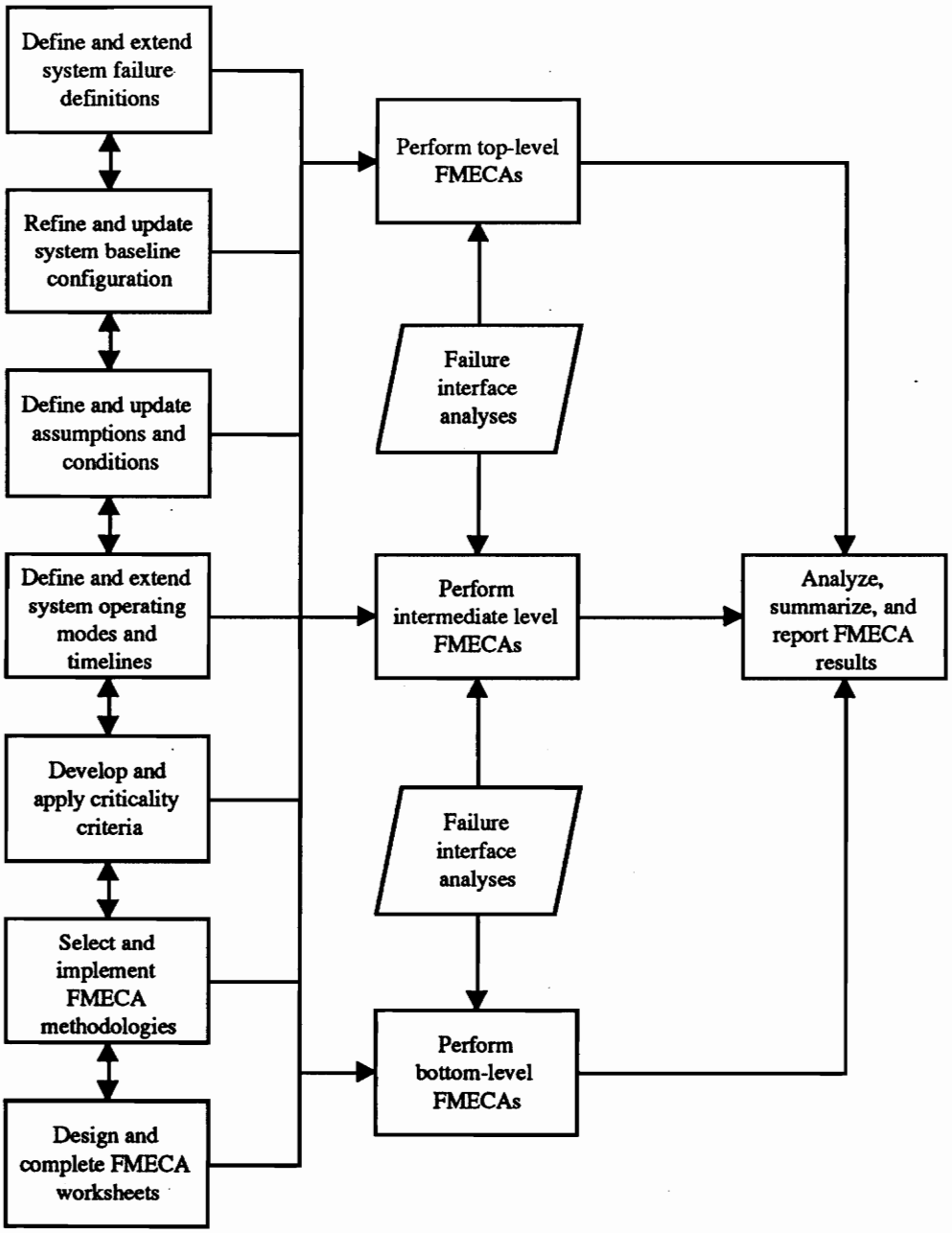


Figure 4.2 - Implementation of FMECA Process [18]

• **Category 3 - Major Failure** - Any failure that will degrade the system performance and effectiveness beyond the acceptable limits, but can be controlled. May result in delay or loss of operational availability.

• **Category 2 - Critical Failure** - Any failure that will degrade the system beyond acceptable limits and could create a safety hazard if immediate corrective action is not initiated. May result in mission failure.

• **Category 1 - Catastrophic Failure** - Any failure that could result in significant system damage, such as to preclude mission accomplishment, and could cause death, personnel injuries, system loss, or severe environmental damage. [24]

Criticality rankings are usually expressed as probabilities, but may be indicated in other ways such as on a scale of 1 to 10 or as letters starting at the beginning of the alphabet. A simple way of calculating criticality is to multiply the probability of the occurrence of failure by the severity of the damage that could be generated. Also, the criticality ranking (CR) can be determined by:

$$CR = P_L \times Q \times F_R \tag{4.1}$$

where P_L = probable damage resulting from a specific failure mode;

Q = probability of component failure (1 - reliability);

F_R = ratio of occurrence of a specific failure mode.

A specific unit may have more than one failure mode. Only certain ones may have the possibility of causing damage or injury. F_R is the ratio of those failures that could generate a specific damage level to the total number of possible failures. [14]

Risk priority numbers can also be assigned as another way of demonstrating the failure mode's criticality. They are computed in a similar manner to Eq. (1). The modification to the previous equation is:

$$RPN = F \times S \times P_d \tag{4.2}$$

where S is the severity of the effect of the failure, F is the frequency of the cause, and P_d is the probability of detection of the failure. This is the equation used later in the report to assess the 9-1-1 system. A high RPN indicates a high failure risk.

Once criticality rankings are assigned they may be used to determine:

- Which items should be studied more intensively to eliminate a hazard that has the potential for failure and for "fail safe" design, failure rate reduction, or damage containment.
- Which items require special attention during production, require tight quality control or require protective handling at all times.
- Special specification requirements for suppliers concerning design, performance, reliability, safety, or quality assurance.
- Acceptance standards to be established for components received from subcontractors and for parameters that need to be tested more intensively.
- Where accident prevention efforts and funds could most effectively be applied.
- When special procedures, safeguards, protective equipment, monitoring devices, or warning systems should be provided. [14]

4.6 WORKSHEETS

All information during the FMECA analysis is documented on a worksheet. A basic outline of a worksheet is shown in Figure 4.3. The worksheet records the results obtained at each step of the analysis and should be tailored to fit the needs of each analysis level. The following are some basic elements of a typical FMECA worksheet: identification number; failure mode; failure effect; failure cause; frequency of failure, severity of failure; probability of detection; RPN; countermeasures.

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS

ID	Failure Mode	Failure Cause	Failure Effect	Risk Assessment				Countermeasure
				Severity	Probability	Frequency	RPN	

Figure 4.3 - Sample Worksheet

The worksheet should be analyzed and summarized to extract and report significant information. It should address the implementation of the plan, contain the purposes and objectives, specify all assumptions, identify all single points of failure, and present conclusions and recommendations that identify the elements of the system with the most significant failure modes and effects.

4.7 ADVANTAGES

There are many advantages and benefits that can be derived from performing FMECA. FMECA is useful in the comparison of designs, can be easily understood, and is flexible in terms of scope and depth of analysis. It determines optimum points for improving and controlling product quality or process effectiveness. FMECA is a visibility tool that identifies weaknesses in the design of a system [10]. The systematic procedure that FMECA employs provides guidelines/check sheets that are available for assistance. Not only does it provide risk assessments of failures, it provides a mechanism to be exhaustively thorough in identifying potential single-point failures and their consequences.

Potential high risk areas impacting cost, customer satisfaction, regulations, etc. are identified, along with maintenance requirements. FMECA also helps to develop monitoring, test, evaluation, and diagnostic capabilities within the system. The results can be used to maximize reliability, maximize effectiveness of the design, incorporate "fail safe" features into the system design, obtain satisfactory operation using equipment of "low reliability", and guide in component and manufacture selection. When completed, it can be used for record keeping, illustrating safety provisions that have been enacted.

4.8 LIMITATIONS AND DISADVANTAGES

There are certain limitations and disadvantages of FMECA. Environmental stresses are determined from environmental conditions that cause the system to fail. However, the frequencies of their occurrence are rarely actually used. A usage factor is incorporated for the type of product application instead. Another factor is applied for the reduction of theoretical reliability that could result from the substandard manufacture of an assembly. This factor is extremely rough because some items may suffer little damage during production while others may be badly damaged and fail soon. [14]

Failure probability data is often difficult to obtain. The form may be mistaken for substance. If the project becomes a simple matter of filling out forms instead of conducting a proper analysis, the exercise will be completely futile. Hazardous characteristics of equipment created by bad design are often neglected. Hostile environments are frequently overlooked. [12]

In addition, inadequate attention is frequently given to human error because of the concentration on hardware failures. FMECA is costly in man-hour resources. It is also sometimes difficult to identify exactly which failures contribute to the occurrence of a specific catastrophe.

FMECA is limited to determination of all causes and effects, hazardous or not, and no method exists for evaluating the completeness of the analysis. The possibilities of system failures presented by coexisting, multiple-element faults within the system are not addressed. Severe system threats may be overlooked if too much concentration is on identifying and eliminating single-point failures. Because of this, it is recommended that FMECA be performed in teams consisting of members from various divisions. FTA is another tool that may be used also to prevent this from occurring. A greater number of system failures are the result of interface problems rather than the components

themselves. Finally, FMECA is heavily dependent upon the analyst's ability to discover all modes of failure.

4.9 APPLICATIONS WITH OTHER METHODS

4.9.1 Fault Tree Analysis (FTA)

The problem of identifying exactly which failures contribute to the occurrence of a specific catastrophe can to a great extent be overcome by logic methods such as FTA. FTA was developed in 1961 and quickly gained recognition as being a powerful tool for analyzing sets of events arranged in systems. Since FMECA is a single-failure-oriented method, fault trees are used for multiple-point failures. Multiple-point failures occur when two or more components in the system interact to cause an undesirable event.

In their original uses, fault trees were only diagrams that illustrated how the data developed by FMEA should be interrelated to arrive at a specific event. The reverse process is now used at times. A logic analysis establishes those events, failures, or successful operations that may contribute to an accident. A FMEA or FMECA then studies in detail those conditions that could cause failures, the modes in which failures could take place, and the preventive or safety measure to be taken. [14]

The purpose of FTA is to determine root causes failures. These are the initiating causes of the failure and may not relate directly to the system's failure. A focused picture of the causes at different levels is relayed given the kinds of failures. It lists general ways in which a process may fail. Causes and sub-causes are then derived and linked through "AND"-gates or "OR"-gates. It increases the reliability of process planning and focuses reliability work by indicating interrelationships among failure modes.

FTA's advantage over FMECA is that it directs the analyst deductively to events.

Combinations of low order events that will cause an accident are generally more important than understanding how a single component failure will impact the system. Both are visual tools and both can be used in a qualitative and quantitative sense. However, if it is desired that all potential hazards in a system be discovered, FMECA is advantageous over FTA; FTA would become too complicated to perform. It is best used to determine the cause of a failure that has already occurred.

4.9.2 Quality Function Deployment (QFD)

FMECA and QFD are complementary. The first is targeted at satisfying the customer expectations and the second is targeted at preventing failure to satisfy. As both are related and include detailed administrative tasks, computer software has been developed to automate the administrative work. FMECA is performed by product and process design engineers. It is contained in some of the matrices found in the QFD model. FMECA can be used as a filter and QFD as a means of focusing priorities. Both are used in quality planning. QFD captures the "voice of the customer". Through these tools, effort is directed away from non-priority areas towards priority ones so that proper attention can be given where it is most needed.

CHAPTER 5

THE 9-1-1 SYSTEM

The 9-1-1 system has replaced the need for people to look up and dial a special seven-digit number for their location and specific need in the event of an emergency. A fast emergency service response time is necessitated along with trained telecommunicators instead of untrained operators who answer the call when "0" is dialed. Also, too many people calling "0" at one time provides for an overload and proves the need for the 9-1-1 system.

5.1 BACKGROUND AND HISTORY

From 1937 to 1959, many countries began using various Emergency Telephone Number Systems (ETNSs). Britain used "999" ETNS, Belgium used "900" ETNS, Denmark used "000" ETNS, and Sweden used "9000" ETNS. In 1957, the National Association of Fire Chiefs advocated a single nationwide number for reporting fires. In 1967, the President's Commission of Law Enforcement and Administration of Justice recommended that a "single number should be established" in order to report police emergencies. In January of 1968, AT&T announced that the digits available for emergency telephone service in its serving areas would be "9-1-1". Soon after, other telephone companies also provided 9-1-1 in their serving areas.

In March of 1973, President Nixon issued a national policy statement addressing the benefits of 9-1-1. He encouraged its quick adoption and established a Federal Information Center on 9-1-1. The Federal Emergency Medical Service Act of 1973 required 9-1-1 or definitive plans for its implementation before grant funds for improvement of emergency medical services would be released. Many other agencies

and associations have endorsed the 9-1-1 emergency number concept such as the Federal Law Enforcement Assistance Administration (LEAA), the National League of Cities, and the Associated Public-Safety Communications Officers, Inc. (APCO).

The first municipal use of 9-1-1 was recorded in Atlantic City in 1972. The New Jersey Legislature's County and Municipal Study Commission in 1976 recommended that municipalities throughout the state strive to place their fire and emergency services on the 9-1-1 system. The first countywide 9-1-1 system was installed in Hunterdon County Communications Center in February of 1977. The Attorney General then appointed a Statewide Police Emergency Network (SPEN) Task Force to evaluate all police telecommunications in New Jersey. From its findings, the Task Force suggested that implementation of 9-1-1 throughout the state be strongly encouraged. In June of 1984, the Atlantic Chapter of APCO appointed the APCO Ad Hoc New Jersey 9-1-1 Committee which drafted 9-1-1 legislation calling for the Emergency Response System Study Commission.

In May of 1985, the first Enhanced 9-1-1 system was installed in the Gloucester County Communications Center. Enhanced 9-1-1 refers to the new emergency system that contains many features intended to improve its effectiveness. These features are discussed further in Section 5.3. In January of 1986, the Emergency Response System Study Commission recommended the enactment of legislation to create a statewide, Enhanced 9-1-1 emergency telephone system in New Jersey.

On January 18, 1989, a proposal was enacted that required the implementation of a New Jersey statewide enhanced 9-1-1 emergency telephone system within three years from the date of enactment. The 9-1-1 Act also created the New Jersey 9-1-1 Commission and the Office of Emergency Telecommunication Services (OETS), in the Department of Law and Public Safety.

Twenty-six members comprise the 9-1-1 Commission including two members of the Senate, two members of the General Assembly, seven ex-officio members from state agencies, and fifteen members appointed by the Governor with the advice and consent of the Senate. The State 9-1-1 Commission and OETS are responsible for setting specifications for the statewide network and the Public Safety Answering Points (PSAPs), and implementation of the network. In January of 1990, the State of New Jersey adopted the 9-1-1 Emergency Number Plan. [2]

5.2 BASICS

The New Jersey 9-1-1 plan allows a person anywhere in the state to dial 9-1-1 and be automatically connected to a PSAP operator. The call can be placed without charge (dial tone first provision), on a 24-hour basis, seven days a week. Before the enactment of the Enhanced 9-1-1 System, residents of New Jersey, except those in the very few areas which had Basic 9-1-1, had to use specific seven digit telephone numbers to obtain help from the police, fire, or emergency medical services. Sometimes, a different number for each service in the same area had to be utilized. The 9-1-1 system provides a simple, easy-to-remember number to summon all services for emergencies from any telephone in the state. Response time is minimized since the operator at the PSAP receives the location of the telephone, the registered identification, and the appropriate emergency services. Even in those cases in which the caller cannot identify him/herself, the operator will automatically have that information available.

This system allows those in an emergency to dial 9-1-1 anywhere in New Jersey and be connected to a PSAP, which is the first point of reception of a 9-1-1 call. At the same time, the PSAP will automatically receive the name and address registered to the telephone placing the call and the identity of the police, fire, and emergency medical service agencies that are responsible for that particular location. The operator at the

PSAP is then able to transfer the call to the appropriate emergency service agency through single button transfer or dispatch the emergency service directly, depending on the option chosen by the localities it serves.

5.3 ENHANCED 9-1-1 SYSTEM

The Enhanced 9-1-1 system is an emergency telephone system that provides sophisticated features, in comparison with Basic 9-1-1. Basic 9-1-1 accesses and routes calls from a central office (CO) to a single staffed 9-1-1 answering point. The CO is in local telephone company facility that houses the switching and trunking equipment serving telephones in a defined area. It may handle one or more telephone exchanges and may also be referred to as the end office.

The Enhanced 9-1-1 system provides its features via computers and electronic switches so that calls can be selectively routed to one of multiple PSAP's. Selective routing is a feature that routes a 9-1-1 call from a central office to the designated PSAP based upon the identified number of the calling party, or in the case of a cellular call, a unique seven-digit identification number for each cell site, or if so configured, each sector at the cell site. When answered, the system provides an automatic location identification (ALI) and/or automatic number identification (ANI) display at the PSAP. ANI is the automatic display of the calling party's telephone number. ALI, however, not only automatically displays the calling party's telephone number at the PSAP, but also the address and any other supplementary information.

The Enhanced 9-1-1 system also includes such features as "add", a button on the ANI unit used to transfer a caller to another PSAP not assigned a preset button, fixed transfer keys, a feature that allows a PSAP to transfer an established 9-1-1 call to another specific PSAP, PSDP, or other specific location, and ringback which permits the PSAP to

ring the hung up telephone on a held circuit. The basic structure of the Enhanced 9-1-1 system is illustrated in Figure 5.1.

Other features are included in the following passage. The "cmnd" key allows a telecommunicator to request assistance from a supervisor, test the console, log in, etc. The "cncl" key, when used before dialing input is completed, cancels any form of dialing input or may be used to drop a third party on a three way conference call while retaining the connection between the caller and the first attendant. The "crank" button is used to transfer non-emergency calls to a tape recorded message suggesting that the caller consult the telephone directory. The "disc" key disconnects the telecommunicator from a Line 1 or 2 call; fixed transfer allows a PSAP to transfer an established 9-1-1 call to another specific PSAP, PSDP, or other specific location. The forced disconnect allows the telecommunicator to disconnect the call to prevent an overload. The idle-circuit-tone enables the PSAP telecommunicator to distinguish between calls that have been abandoned before they answered and calls where the caller is connected, but cannot speak. The instantaneous network backup allows a 9-1-1 call to be completed to a 7/10 digit number off the 9-1-1 network if the CO has difficulty completing the call to the network. "hold" key places and removes Line 1 from hold. "lin 2" key allows access to the outside line. "repeat" key re-polls the ALI from the remote database.

Three dedicated Rockwell SCX (Specialized Communications Exchange) tandem switches are utilized as network controllers. The Rockwell public safety calling system (PSCS) has a computer aided dispatch (CAD) system interface which uses the same technique as that of an AT&T ALI interface. The PSCS passes ALI records to the CAD system over a physical link. There are two recorded announcements in this switch system, a "redundant call" message and a "non-emergency call" message.

Each position allows a recording device to be connected on the back of the

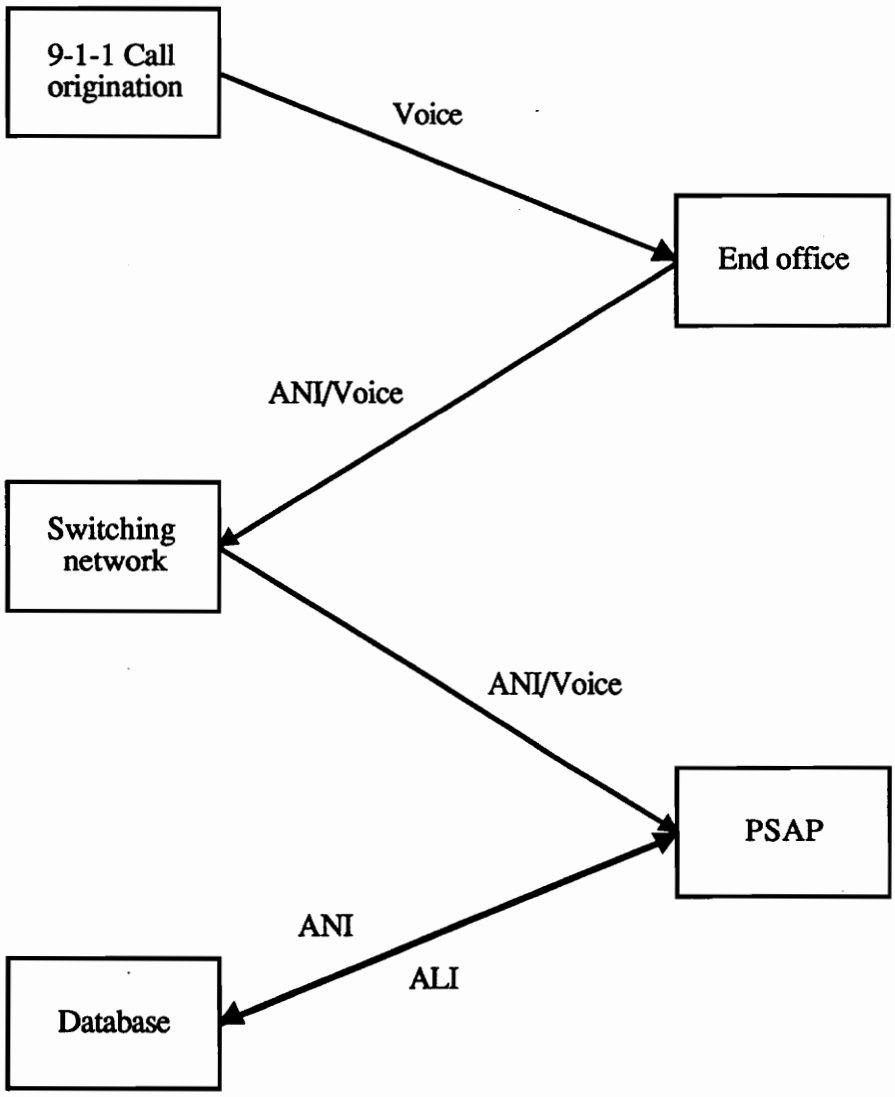


Figure 5.1 - Enhanced 9-1-1 Network

console via plug-in jack. It is controlled by console firmware which enables the device for use when the modem carrier is received at the beginning of every call. It is disabled when the call is disconnected through the use of the "disc" key. During a power loss, the recorder is turned on the entire time. The printer interface uses separate, full-duplex 1,200 bps asynchronous modems which enables the Rockwell SCX to provide printer reports and call log records to a PSAP with the Rockwell integrated PSAP (IPSAP) equipment. [2]

5.4 SAVING LIVES

9-1-1 saves lives. In 1974, the Stanford Research Institute (SRI) performed a study and reported its conclusions [2]. In emergency situations, most people call the wrong agency and are misdirected. Somewhere between twenty-four and forty percent of calls must be transferred at least twice between agencies before reaching their proper destination. Much less than half of the citizens have emergencies numbers conveniently recorded for their use or have their seven-digit emergency numbers memorized.

The study also indicated that a one minute reduction in response time results in an average residential fire loss reduction of eleven percent and an average non-residential or non-building loss reduction of two percent. Depending on the particular agency, the maximum time that can be saved by using 9-1-1 ranges from 1.5 to four minutes. Additional lives are saved by proper aid being more quickly received. The Task Force on Science and Technology of the President's Commission on Law Enforcement and the Administration of Justice in 1967 demonstrated high increases in the arrest rate when response time is below five minutes.

CHAPTER 6

SYSTEMS ENGINEERING ANALYSIS OF NEW JERSEY 9-1-1

This chapter will proceed to perform an analysis of the system's engineering process on the 9-1-1 system. A definition of the need for the system will be presented. Operational requirements and a maintenance concept will be defined. Functional analysis and resource allocation will be discussed.

6.1 THE NEED

As telephone numbers changed to seven digit identifiers and Americans continued to be extremely mobile in their living patterns, operators undertook overwhelming pressure from people who dialed "0" when they where in trouble (approximately 3,500 times a day in New Jersey). These operators were forced to act as emergency response coordinators. A single number was sought after that would be common to many communities, instead of the unique emergency numbers that were used in each of the 567 municipalities in New Jersey. This way anyone already in the community or entering the community would know how to get help. In 1968 in Los Angeles, 9-1-1 was determined to be the number that would be used. Quickly, 9-1-1 spread throughout the nation although even today, not all communities have a 9-1-1 system. [22]

The goal of the system is to have the amount of time between the receipt of a call and the time assistance arrives at the scene to be as small as realistically possible. With the use of 9-1-1, there is no time spent trying to find a telephone book, looking up the correct seven digit number, and dialing it. Much planning is required for this system in order to receive, route, and dispatch calls.

In order for the system to be successful, adequate and reliable equipment must be used and maintained. This should be done as economically as possible with as little cost to taxpayers as possible. A large expenditure of most law enforcement agencies is for telephone service. Operators must be properly trained, lines must be clear for troubled callers to get their call through, and power outages must be considered.

As the design and operation of the 9-1-1 system takes place, it is desirable to analyze how the system will operate, the problems that may be encountered during its operation, the failures that may occur, and the hazardous conditions that may exist. FMECA identifies the possible problems of a design that could develop as a result of system failures. It is a visibility tool that provides a mechanism for a thorough and exhaustive analysis. The objective of FMECA is to rapidly determine the ways a system can fail, the effects of such failure on other components of the system, and the criticality of these failures, with accuracy and ease. A failure in the 9-1-1 system has been defined to be any deviation from the standards imposed by the State of New Jersey.

An unreliable 9-1-1 system cannot fulfill its mission and leaves people in danger. Thus, an analysis tool should be implemented to ensure its reliability. FMECA focuses on single events that will cause a state of unreliability in the system [36]. Specifically, it attempts to find those components that are most important to this state of unreliability. FMECA will be utilized in order to isolate all potential hazards that may be involved.

6.2 OPERATIONAL REQUIREMENTS

6.2.1 PSAP

6.2.1.1 Equipment

The following are the required and recommended equipment for all PSAPs in New Jersey. [28]

1.) Each PSAP operator must have the following:

a.) A telephone which will enable the operator to use the features of the enhanced 9-1-1 system.

b.) Conference and transfer push buttons which allow the PSAP operator to perform single button transfers and conferences to other PSAPs and/or Public Safety Dispatch Points (PSDPs) as well as other telephones on the public switched telephone network. A PSDP is the location which provides the dispatch services for one or more public safety agencies.

c.) An ANI display for viewing the number from which the call was made.

d.) An ALI screen for viewing the address, telephone number, and primary police, fire, and EMS agency for the jurisdiction in which the call was made.

e.) One of two types of instant playback recorders. An instant playback voice recorder that will record and is capable of instantly playing back a 9-1-1 call or an instant playback voice/ALI screen recorder that will record and is capable of instantly replaying a 9-1-1 call and ALI data.

2.) Each PSAP must have the following:

a.) A number of fully equipped operator positions sufficient to provide a ringdown time of no more than 10 seconds for 90% of all 9-1-1 calls during the

average busiest hour of the day. Ringdown time is the length of time that a phone rings before it is answered.

b.) A number of telephone lines necessary to provide P.01 grade of service. P.01 is a grade of emergency telephone service where no more than one call in 100 attempts will be blocked during the busiest hour. A more detailed description of the method used for determining the correct number of trunks is described in Appendix A.

c.) A 9-1-1 line printer in the immediate vicinity of the PSAP operators which prints a record for each call indicating the caller's telephone number, the time the 9-1-1 telephone equipment seized the line, the time the call was answered, the time the call was transferred, the time the call was disconnected, the trunk line the call came in on, and the operator position in the PSAP.

d.) Either a telecommunications device for the deaf or speech impaired (TDD) which is available for immediate connection to the 9-1-1 network at all PSAPs or equipment that permits the PSAP operator to single button transfer the caller to a location approved by the Office of Emergency Telecommunications Services (OETS), in the Department of Law and Public Safety that is prepared to handle such calls.

e.) A logging recorder connected to each 9-1-1 line or telephone that records and time-date-stamps the time and disposition of all 9-1-1 calls. Also, if the PSAP is also a PSDP, all radio channels and other public safety emergency telephone lines should be recorded.

f.) A means of interagency communication, other than the 9-1-1 system, in case of failure or breakdown in the system.

3.) The following is not required, but is strongly recommended:

a.) Emergency generators for all critical electric circuits.

b.) An uninterruptable power supply (UPS) that has a high degree of protection from power surges and spikes and has a capacity sufficient to keep all 9-1-1 telephone equipment fully operative for a 15 minute minimum.

c.) Lightning protection. This should consist of state-of-the-art common ground with cad-welding used to the greatest extent on all earth grounds and ring-type lightning protection that will minimize catastrophic damage and downtime due to electrical storms.

6.2.1.2 Staffing

The following are the staffing requirements for all PSAPs in New Jersey.

1.) Each PSAP must be:

a.) Staffed with the number of operators necessary to permit the PSAP to answer all calls within 10 seconds, except during the average busiest hour. Then 10% of the calls should be answered within 20 seconds.

b.) Completely staffed 24 hours a day, 7 days a week.

The Poisson queuing theory equation is used in calculating the number of 9-1-1 operators required to handle an estimated busy-hour call volume. This is described in Appendix B.

2.) If the PSAP serves a municipality identified by the most recent census as having more than 5% of the population being non-English speaking, then it must have a language interpreter available at the PSAP or immediately available, under contract, by telephone conference call.

3.) Each operator position in a PSAP must be filled by an OETS certified person qualified on the basis of successful completion of a training program approved or adopted by the 9-1-1 Commission.

6.2.2 PSDP

6.2.2.1 Equipment

The following are the required and recommended equipment for all PSDPs in New Jersey.

1.) Each PSDP must be equipped with:

a.) Basic or integrated PSAP telephones which allow 9-1-1 calls to be transferred from the New Jersey Bell 9-1-1 tandem central offices by either direct connection or seven-digit transfers over the shared public network as determined by OETS in consultation with the county 9-1-1 coordinator.

b.) The number of telephone lines sufficient to permit the PSDP to answer 90% of the PSAP transfers within 10 seconds during the average busiest hour.

2.) It is the option of the PSDP to have enhanced 9-1-1 operator equipment such as ANI displays, ALI screens, and line printers, as approved by OETS in consultation with the county 9-1-1 coordinator.

6.2.2.2 Staffing

The following are the staffing requirements for all PSDPs in New Jersey.

1.) At all times, each PSDP must be staffed with the number of dispatchers necessary to permit the PSDP to comply with the level of dispatch performance established by the local governing agencies.

2.) Each dispatcher position in a PSDP must be filled by an OETS certified person qualified on the basis of successful completion of a training program approved or adopted by the 9-1-1 Commission.

6.2.3 Operator/Dispatcher Training

Operators or dispatchers with at least 320 hours of prior experience as such in a New Jersey telecommunications center prior to the implementation of the 9-1-1 system can be certified by the APCO Institute 40-Hour Public Safety Telecommunicator Basic Training Course New Jersey Edition and American Heart Association (AHA) Provider B or American Red Cross (ARC) Community Level CPR. Those with less than 320 hours of prior experience can be certified by the above and the APCO Criteria Based Institute 24-Hour Emergency Medical Dispatch Training Program, unless the PSAP directly transfers Emergency Medical Service (EMS) calls to emergency medical PSDP personnel which have the appropriate medical dispatcher training.

PSAP telecommunicators who are not certified by OETS may substitute for a certified operator/dispatcher who is scheduled for duty, but unavailable because of illness or emergency, or is providing relief for operator/dispatcher during breaks. The substitute may be certified by the U.S. Department of Transportation's "First Responders: Emergency Medical Care Training Course," or "Crash Injury Management for Traffic Law Enforcement Officers," or "EMT-A Course". They also must have had AHA Provider B or ARC Community Level CPR and an eight-hour introductory course on New Jersey's enhanced 9-1-1 emergency system which has been prepared by the local PSAP and approved by OETS.

All operators/dispatchers (substitutes included) must successfully complete annual in-service training during each year of service following completion of the appropriate training program. This program is also an eight-hour course prepared by the local PSAP and approved by OETS to recognize technical developments and improve 9-1-1 service.

6.3 MAINTENANCE CONCEPT

Each PSAP and PSDP shall maintain tape recordings produced by the logging recorder and all documents or records related to 9-1-1 calls in a secured area for no less than 31 days. A sample log report is explained in Appendix D. Also, a current listing of PSAP operators or PSDP dispatchers, which indicates the operators' or dispatchers' certification date must be available at all times. A record of each occasion when a substitute was utilized must be kept and contain the name of the substitute, the date and time of the substitution, and the reason for the substitution. This record will be kept for one year.

The main arrangement that ensures network recovery from a catastrophic switch failure within minutes of occurrence is the Network Protection Plan. In front of each Rockwell tandem switch is a Digital Access Cross-Connect System (DACS). DACS switches and reroutes emergency calls to the assigned back-up 9-1-1 tandem during a major 9-1-1 tandem failure. Emergency calls are handled by the back-up tandem normally until the failed tandem is restored. Although not probable, if the CO cannot switch the call to an alternate tandem, the system will default the call to a pre-specified seven-digit number assigned at the default PSAP. The Rockwell public safety calling system includes provisions for testing IPSAP consoles through which the sender, receiver, and modem link are tested. Lamp, keypad, and function key tests are initiated independently.

Statewide, 24 hour responsibility for monitoring the 9-1-1 system statewide falls to New Jersey Bell Telephone Company (NJB). NJB monitors and gives priority to emergency call flow from all CO's, sector tandems, and operator service positions tandems to the 9-1-1 portions of the network. This monitoring permits service restoration of a 9-1-1 carrier system failure in a time efficient manner, usually within one hour.

The New Jersey Bell 9-1-1 Control Center (CC) carries the responsibility of maintaining, repairing, and monitoring (24 hours a day) the 9-1-1 tandem switch. The CC is the central contact for all PSAP trouble reports over a toll-free "800" number (1-800-323-PSAP). For swift repair of any other 9-1-1 network components affecting the critical 9-1-1 service, the CC assumes responsibility.

The 9-1-1 Commission primarily supervises OETS in its planning, design, and implementation of the statewide 9-1-1 system. The 9-1-1 Commission approves actions proposed by OETS such as training programs for PSAP and PSDP telecommunicators, public education programs, and advertising of 9-1-1 when required to do so by the 9-1-1 Act.

In order to plan, design, and implement the system, OETS consults with other telephone companies and the Board of Public Utilities. OETS also obtains assistance from the Office of Telecommunications and Information Systems in the Department of Treasury. OETS is able to enter contracts with other telephone companies for provisions of the Enhanced 9-1-1 network. Any device connected to the New Jersey 9-1-1 network by any vendor, manufacturer, or installer must be approved by OETS. County 9-1-1 plans are reviewed by OETS to assure the satisfaction of requirements of the 9-1-1 Act, the State 9-1-1 Plan, and implementing regulations. OETS notifies counties of their approval in writing. Most essential to maintaining the 9-1-1 system are PSAP inspections. Theses are performed initially and periodically by OETS to conclude requirement fulfillment.

6.4 FUNCTIONAL ANALYSIS

A functional flow graphically represents the overall process. Diagrams are developed in order to relate process requirements into functional terms [6]. Figure 6.1

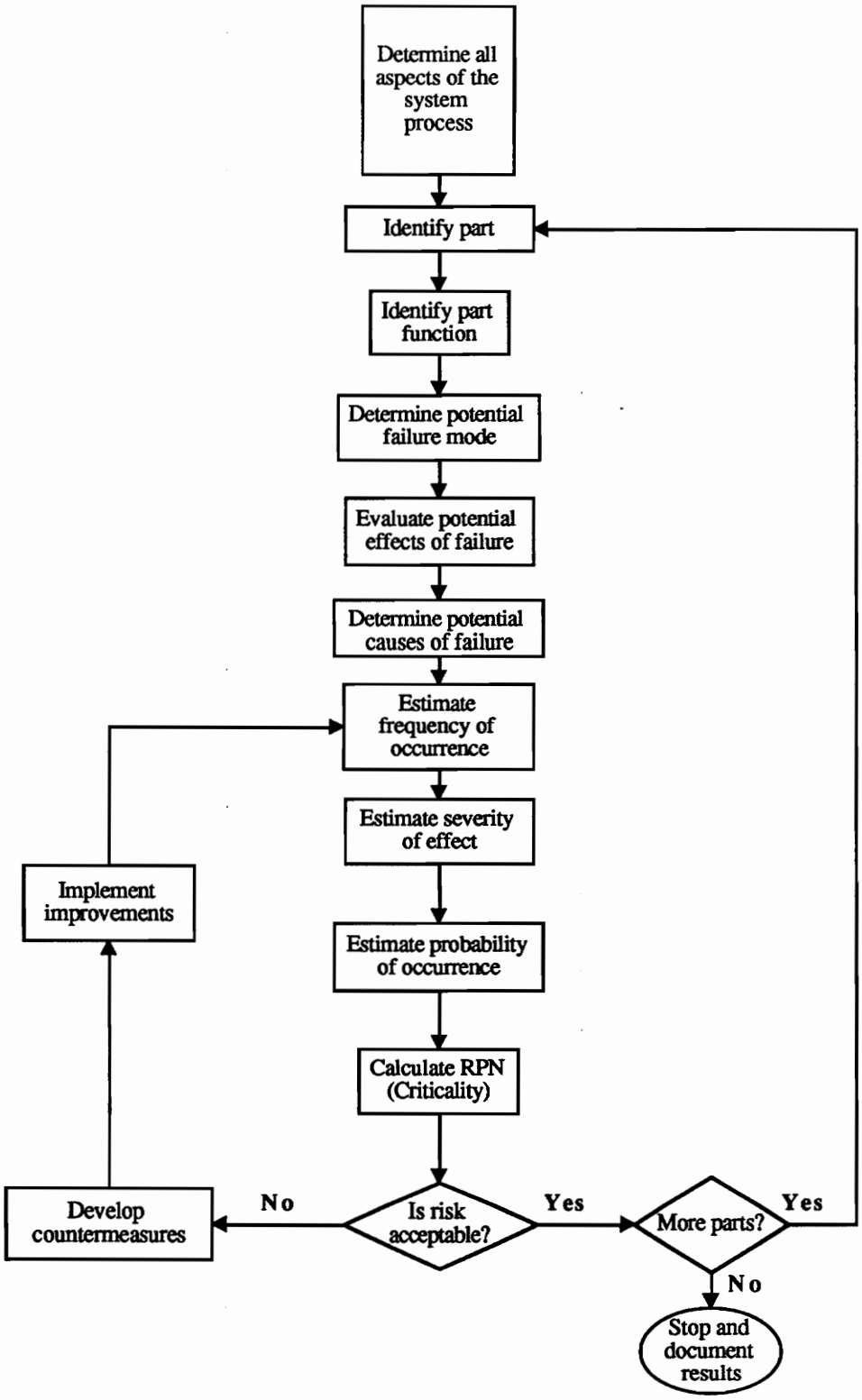


Figure 6.1 - FMECA Steps

outlines the steps in undertaking the FMECA process as described previously. Figure 6.2 shows the basic steps that were used as a guideline during the course of this project.

The process of routing a 9-1-1 call is illustrated in Figure 6.3. The initial step is receiving the call at the central office. As long as the dedicated trunk is not busy, the call is routed to one of three Rockwell SCX tandem switches via dedicated trunks. If the dedicated trunk is blocked, the call is routed to one of three Rockwell SCX tandem switches via the public shared network. Then, selective routing classifies the call.

Calls are conventional or integrated. With IPSAP equipment, the SCX transmits ANI and ALI information at 4.8 kb/s over the same analog circuit as the call within the first half second before the call is connected. Since calls can be held at the SCX rather than the PSAP, IPSAP terminals can handle multiple calls from a single terminal. Therefore, the number of voice trunks required to each PSAP is reduced.

For conventional calls, the call and the ANI are routed to the assigned PSAP. The local PSAP switch accesses an ALI database subsystem. When the local PSAP switch receives the ALI, it routes the call to the appropriate PSAP telecommunicator who then takes over the call. However, for integrated calls, the Rockwell SCX accesses an ALI database subsystem and then routes the call, the ANI, and the ALI to the appropriate PSAP position. ANI and ALI data is transmitted and an audible tone signals the operator that he/she is connected with the caller. Once again, the PSAP telecommunicator then takes over the call.

The process for transferring a call is demonstrated in Figure 6.4. Once the operator receives a call he/she must determine if the call is an emergency. If not, the caller is referred to the telephone directory or given the correct seven-digit number. This is called call referral. If the call is an emergency, it must then be decided if the answering center has the authority to dispatch and if the public safety agency is remotely located

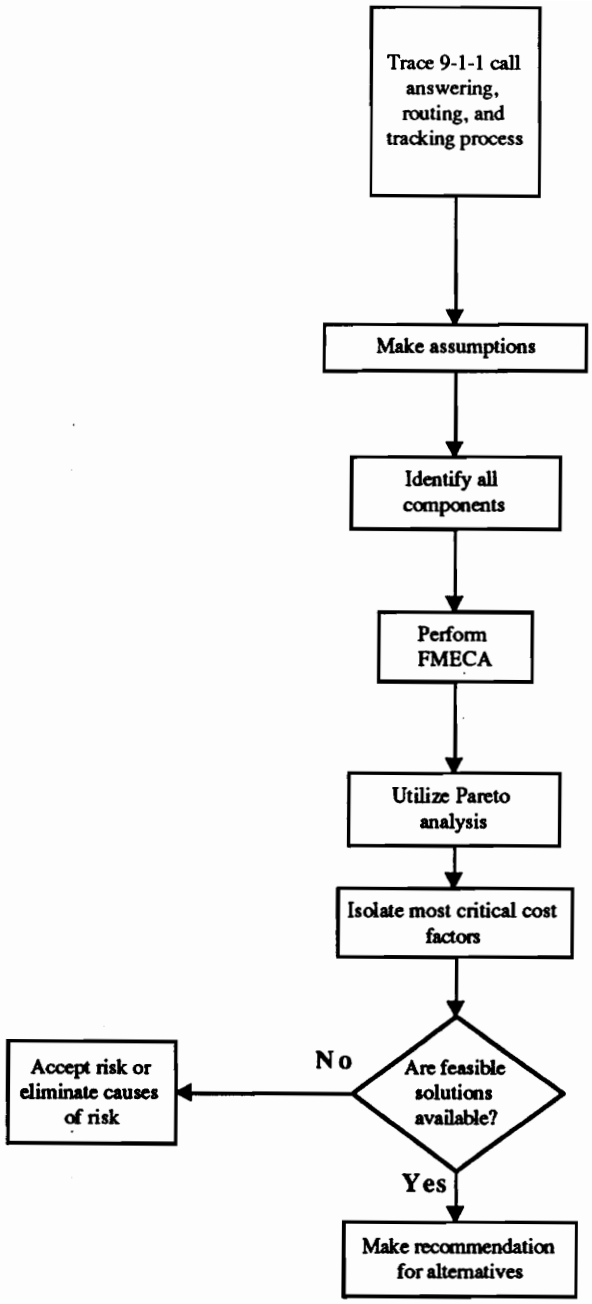


Figure 6.2 - Project steps

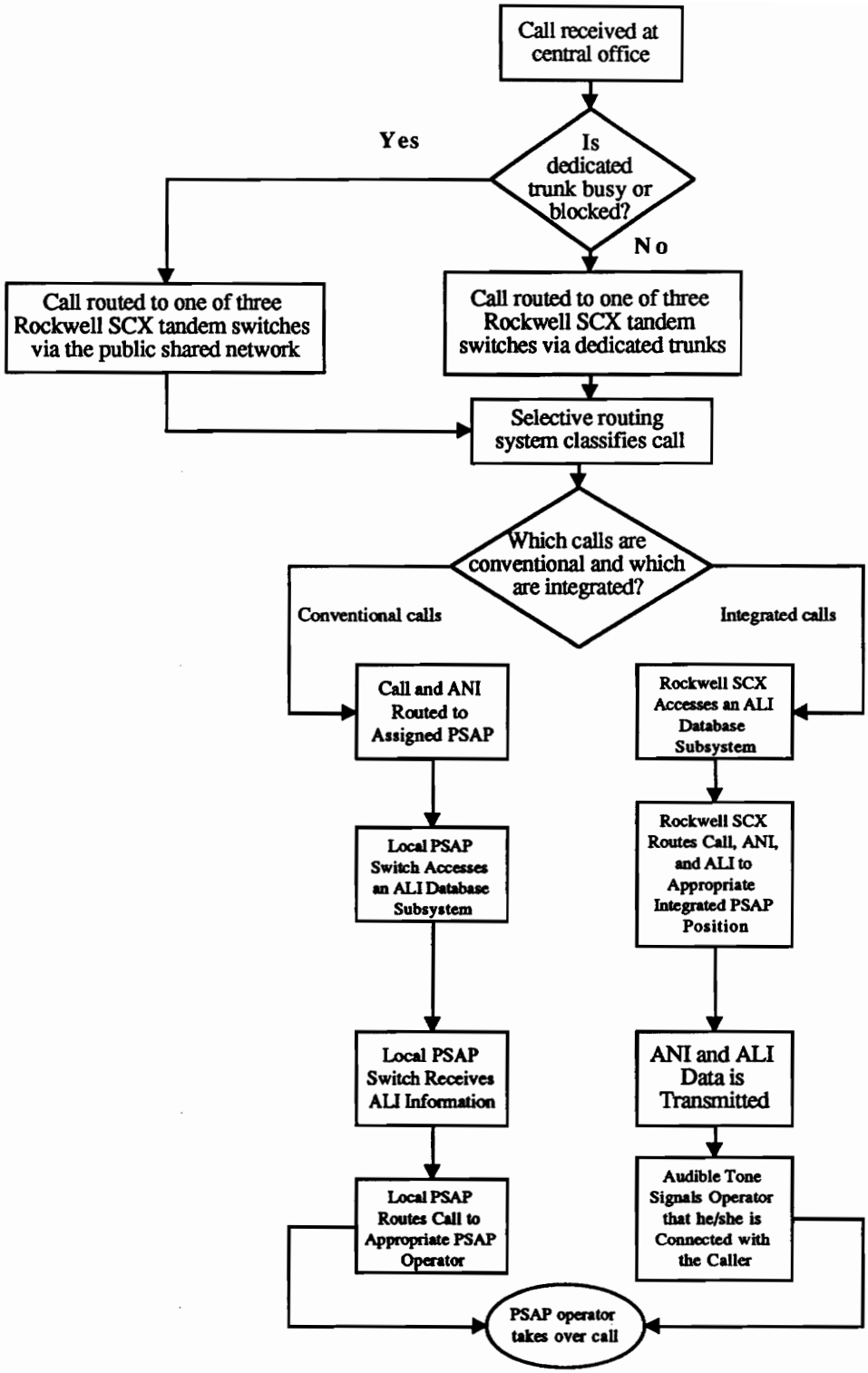


Figure 6.3 - 9-1-1 routing steps

from the answering center. If the answering center has the authority to dispatch, the operator determines emergency status and acts as the complaint writer. He/she obtains all information and conveys it to the dispatcher. The correct emergency service is then dispatched. This is known as a direct dispatch.

If the agency does not have the authority to dispatch or if the public safety agency is remotely located from the answering center, the operator must determine the proper agency that is needed. As long as the caller is not emotionally distressed, call transfer is used; that is, the call is transferred to the agency's complaint writer or dispatcher, and the proper emergency services are dispatched. When the caller is emotionally distressed, call relay is utilized, whereby the caller is not transferred, but the needed information is transferred to the agency's complaint writer or dispatcher and the proper emergency services are then dispatched. [2]

6.5 NEW JERSEY 9-1-1 RESOURCE ALLOCATION

Resource allocation is the assignment of requirements to the operations of the overall process. This aids the designer in developing a product or process that will be compatible with the system requirements. All standards are listed below and Figure 6.5 will help to outline the allocation to the various system components. [28]

- All components must meet or exceed a P.01 grade of service. That means that there cannot be more than one busy signal in 100 call attempts in the average busiest hour.
- All PSAPs must be operated on a full time basis (24 hours a day, 7 days a week).
- All calls must be answered within 10 seconds, except during the average busiest hour where 10% of the calls may be answered in 20 seconds.
- No more than 2% of incoming calls should overflow to an alternate PSAP. Alternate routing trunk tables and directions for their use are contained in Appendix C.

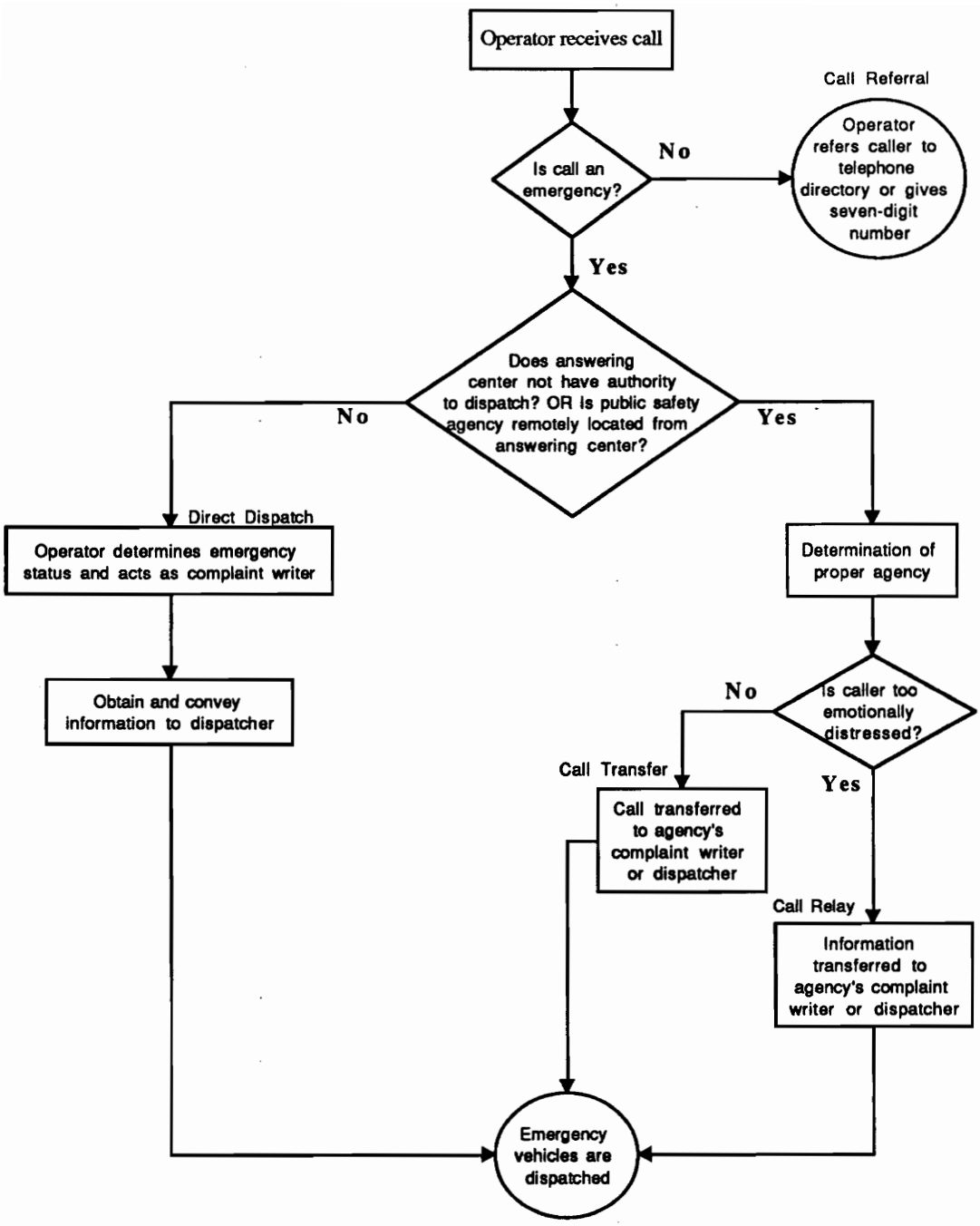


Figure 6.4 - 9-1-1 agency transfer steps

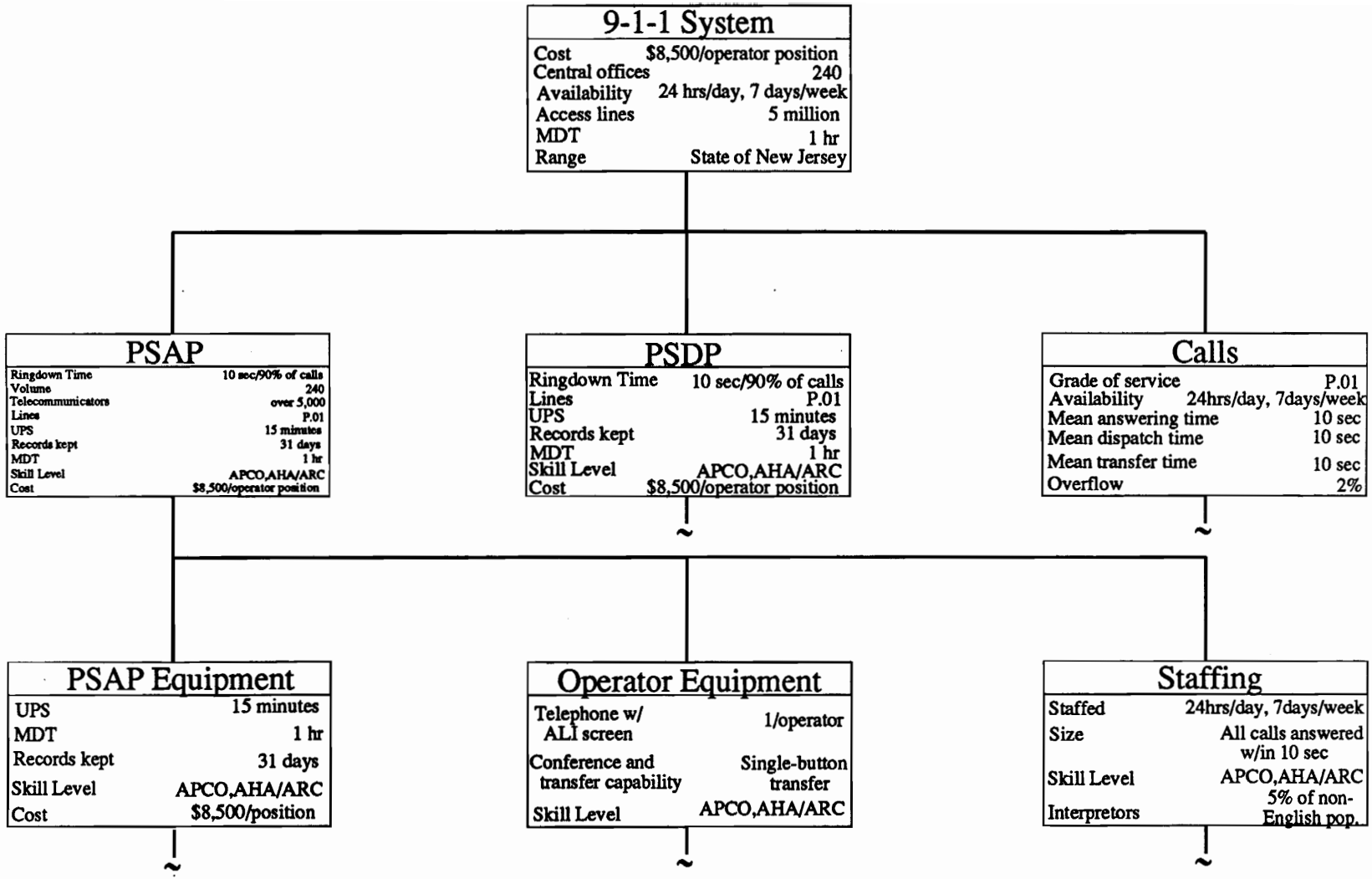


Figure 6.5 - Resource Allocation

• No call should be answered with a response that would identify the PSAP as a police department, fire department, or emergency medical service or that gives a geographical or political location of the PSAP. Suggested answering statements are "9-1-1 Emergency, what are you reporting?" or "9-1-1, may I help you?" or "9-1-1, what is the emergency?"

• No telecommunicator should transfer a call without first advising the caller that the call is being transferred and that the caller should remain on the line until the call is connected. No blind transfers are permitted, that is, under no circumstances should a telecommunicator transfer a caller to another agency without first advising the caller of the pending transfer.

• All PSAPs should maintain interagency communications capabilities in the case of emergency coordination.

• The numerals 9-1-1 may not be used by any company or organization, public or private, in their name, or display the numerals 9-1-1 on their property or in advertising unless authorized by the 9-1-1 Commission.

• Within 10 seconds from the receipt of a call, ninety percent of all transfers from PSAPs to the appropriate PSDP should be initiated.

• All PSAP transfers should be received on lines primarily identified as 9-1-1 emergency lines.

• Ninety percent of the PSAP transfers should be answered within 10 seconds during the average busiest hour and all others must be answered within 20 seconds.

• The primary published emergency number should be "9-1-1" and will be the only number on the "Emergency" page of the public telephone directory. A seven-digit backup number must be maintained for each PSAP and should be listed in the white pages as an alternate emergency number.

• If a non-emergency call is received (one that does not require emergency services) the

telecommunicator should clear the line as quickly as possible for the given circumstances. If appropriate and conditions permit, the telecommunicator may refer the caller to the appropriate public safety agency verbally or through a pre-recorded message.

- Three dedicated Rockwell SCX tandem switches are utilized as network controllers (located in Camden, New Brunswick, and Newark).
- Two dedicated IBM System 88 computers are used as data base managers (located in Madison and Freehold).
- A third IBM System 88 computer, normally used for other purposes, can be brought on-line as a backup if required.

The design is the only multi-switch seamless 9-1-1 system in the nation. The Rockwell SCX tandems were selected because they have internodal capability which allows for inter tandem transfers between SCXs via primary and secondary T-3 circuits. Through DACS, the system in New Jersey can perform without comprise in the event that one switch fails. This allows the system to function normally and pass calls to the appropriate PSAP. Also, they help to isolate the 9-1-1 system from failures that may otherwise occur if the shared public switched telephone network is also used as a 9-1-1 tandem. [22]

6.6 BUDGET

In 1991, New Jersey entered a lease purchase agreement through 2005 for Bell Atlantic 9-1-1 equipment and service. To cover the installation and maintenance of the network, certificates of participation were issued in the amount of $94,565,000. The State Treasury spends about $12,000,000 per year for this service. The State of New Jersey is responsible for payment of costs related to the network including the dedicated telephone lines, the network switching equipment, and the database. [22]

The local municipalities cover the expense of equipment and staff for the operation of the PSAP and PSDP. If joint PSAPs or PSDPs are formed, these costs may be shared on a regional basis. PSAP equipment is usually in the range of $7,000 to $10,000 per telecommunicator position. If the PSAP is not equipped as required by the new provisions, then additional equipment must be purchased between the range of $2,000 to $20,000. [28]

CHAPTER 7

RESULTS: FMECA APPLIED

After examination of the design and use of the 9-1-1 system, all failure modes are listed in a FMECA worksheet. Then, the effects of the failure are determined. These consist of the impact on the performance or effectiveness of related functions and on the overall system. The causes of failure are next considered. A failure cause is a process, defect, misapplication, or any other means which can "trigger" a system failure mode. Rankings of the frequency, probability of detection, and severity of the failure modes are determined. For use in this report, consistent definitions and scales were used and are further described.

7.1 STANDARD SCALE USED

Probability is an assessment on the likelihood of the failure mode being detected before failure actually occurs. The failure is assumed to have occurred and then detection capabilities are assessed. Low rankings were specifically not assigned just because the occurrence is low. A 1 - 10 scale was implemented, where 1 indicates a very high chance that the defect will be detected at the earliest possible point, before anything is effected by it, 3 indicates a high or good chance that the defect will be detected in a timely manner, 5 indicates a moderate probability that the defect may be detected in a timely manner, 7 indicates that there is a poor probability of detecting the defect, and 9 indicates that the defect will have a remote chance of being detected, if detected at all. Even numbers were used to represent indices between the numbered descriptions above.

Frequency represents how often the failure cause is projected to occur. Only occurrences resulting in the failure mode were considered. A 1 -10 scale was used, where

1 indicates that the failure is unlikely or has a remote chance of occurring, no failures are ever associated during operation, 3 indicates that only isolated failures occur, 5 indicates that there is a moderate rate of occurrence for this failure, this failure has generally occurred in the past, but not in major proportions, 7 indicates a high frequency of occurrence, this failure has generally occurred often in the past, and 9 indicates that failure is almost inevitable. Even numbers were used to represent indices between the numbered descriptions above.

Severity is an assessment of the seriousness of the effect of the potential failure mode if it occurs. It applies only to the effect. Once again a scale of 1 - 10 was utilized, where 1 indicates no noticeable effect, 3 indicates a low ranking associated with slight performance inconvenience and minor rework, 5 indicates a moderate ranking which causes some damage or unscheduled rework and repairs, 7 indicates a high ranking associated with inoperability and serious disruption of the system, and 9 indicates a very high ranking where people are in outright danger. Even numbers again were used to represent indices between the numbered descriptions above.

A questionnaire has been completed by a 9-1-1 coordinator and a 9-1-1 manager. From the two sets of rankings that were obtained, an average was estimated and used for computing the RPN. When this average was a fraction, a conservative approach was utilized and the number was rounded to the next highest. The RPN was determined by taking the product of the frequency, probability, and severity. Lastly, recommendations for appropriate corrective measures or improvement were devised. The FMECA worksheet, used as the questionnaire in its earliest from, is shown in its completed form in Table 7-1.

Table 7.1 - Completed FMECA Worksheet for 9-1-1 System

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS

ID	Failure Mode	Failure Cause	Failure Effect	Risk Assessment				Countermeasure
				Severity	Probability	Frequency	RPN	
1	Power outage/ complete failure	Lightning	System does not respond	5	2	1	10	Cad-welded grounds
		Natural disaster	System does not respond	5	2	1	10	Switched access system
		Breakdown of system	System does not respond	5	2	1	10	Alternate communications capabilities
2	Call is not answered w/in 10 sec	Insufficient operators	Help is not dispatched	6	2	4	48	More operators
3	Line is busy That is more than one call in 100 attempts are blocked during the average busiest hour.	Line overload	No response to some emergencies	5	1	1	5	More call answer units
		Non-emergency calls	True emergencies are not given proper attention	7	5	4	140	Public education program
		Prank calls	True emergencies are not given proper attention	7	3	3	63	
		Transfer rate is low	Total time given to call is increased	5	3	3	45	One button transfer Selective transfer Speed call number
		Cellular lines are blocked	Emergency relief personnel cannot communicate	5	5	3	75	Cellular priority access system/Priority access and channel assignment
4	Power surge	Electrical storms	System does not respond/ equipment may be damaged	5	3	2	30	Surge protection
5	Operator does not dispatch appropriately or is rude and not helpful to caller	Insufficient basic training	Help does not arrive in time	5	4	4	80	NRC Telecommunicators
		Insufficient annual training	Help does not arrive in time	5	4	4	80	Training Standards
6	Operator cannot communicate	Interpretor not available	Neccessary information is not retrieved	6	1	2	12	Interpretors on call
		Caller is hearing or speech impaired	Neccessary information is not retrieved	6	4	2	48	TDD/TTY

Table 7.1 - Completed FMECA Worksheet for 9-1-1 System (continued)

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS

ID	Failure Mode	Failure Cause	Failure Effect	Risk Assessment				Countermeasure
				Severity	Probability	Frequency	RPN	
7	Operator receives no answer	Calling party has hung up	Neccessary information is not retrieved	6	1	1	6	Calling party hold/Ringback/ voice response feature
		Call has been abandoned	True emergencies are not given proper attention	7	1	3	21	Idle-circuit-tone application
8	Necesary information not readily available	ANI display not installed/ working properly	Dispatch time is lengthened	6	2	3	36	Computer-Aided Dispatch Transfer call and use call conferencing option
		ALI screen not installed/ working properly	Dispatch time is lengthened	6	1	2	12	
		Line printer not installed/ working properly	Dispatch time is lengthened	6	1	2	12	
9	Sufficient information not made available to operator from caller	Caller is emotionally distressed	Dispatch time is lengthened	6	3	4	72	
		Caller is a child	Dispatch time is lengthened	6	3	4	72	
10	Call cannot be made	Pay phone not programmed for 9-1-1	Call is not received/"0" is dialed	8	1	1	8	Dial tone first
11	Dispatcher uses remote emergency services	Community range is not known	Help arrival time is increased	6	3	4	72	Master Street Address Guide
12	Circuit fails	Circiut manipulated or contacted accidentally	Circuit disabled	5	3	3	45	Protected circuits Diverse routing
13	Selective routing is not possible	ANI failure	Call not transferred to the proper agency	6	1	1	6	Default routing
		Garbled digits	Call not transferred to the proper agency	6	1	3	18	Alternate routing Repeat ALI button/repeat key
		Dedicated trunk is busy	Increased call time	6	4	1	24	More trunk monitor/dial units

Table 7.1 - Completed FMECA Worksheet for 9-1-1 System (continued)

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS

ID	Failure Mode	Failure Cause	Failure Effect	Risk Assessment				Countermeasure
				Severity	Probability	Frequency	RPN	
14	Tracking is not complete	Call from cellular or other wireless phone	Increased call time/number of trunks/operators/costs	7	2	1	14	Cellular interface unit
		Remote call forwarding	Dispatch to wrong address	6	3	1	18	
		Private branch exchange	Dispatch to wrong address	6	3	1	18	Station Translation System
		Dual address listing	Dispatch to wrong address	6	3	1	18	
		Information is out of date	Dispatch to wrong address	6	4	1	24	Wider bandwidth on network
15	Call is not transferred w/in 10 sec	Switch failure	Dispatch time is lengthened	6	3	2	36	DACS, Switch protection Instantaneous network backup More call transfer units
16	Call is not received	Wrong number dialed	Call not answered by 9-1-1 telecommunicators/ redial neccessary	7	3	2	42	Emergency 9-1-1 Feelers
17	More than 2% of calls overflow to alternate PSAP	Insufficient operators	Overflow at alternate PSAP	5	3	1	15	More operators
18	Operator cannot obtain help, test the system, or log in	CMND key malfunction	Operator cannot use console	4	1	1	4	

7.2 RESULTING RPNS

All RPNs have been computed from the estimated rankings. A total RPN was calculated for each failure mode by adding up all of the RPNs for each cause and effect. These numbers are presented in Table 7-2. It can be determined from this data that the greatest problem encountered by the 9-1-1 system is that the line is busy.

The second is that the telecommunicator does not act properly or is just plainly unhelpful. This was recently seen this year (1996) in Philadelphia, where a panic-stricken person called 9-1-1 screaming frantically that the boy on the street in front of her eyes was badly beaten and was dying. The operator yelled back, threatened to hang up, did not gather information quickly enough, and emergency services were not dispatched in time. The young victim died. There is now a law suit pending.

The failure mode of least concern is the operator not being able to test the system, log in, etc. Other negligible modes of failure include the call not being able to be made (almost all pay phones have been converted), more than two percent of the calls overflowing to an alternate PSAP, the operator receiving no answer, and a power failure or surge.

7.3 COUNTERMEASURES AND COSTS

The countermeasures and costs herein are based on a study of New Jersey's Camden County 9-1-1 system. The costs contained throughout are founded on a department that serves approximately 220,000 residents and receives around 1,100 emergency calls a day. [3]

Table 7.2 - Risk Priority Numbers (RPNs) at the Failure Mode Level

ID	Failure Mode	RPN
3	Line is busy	328
5	Operator does not dispatch appropriately or is not helpful	160
9	Sufficient information not made available to operator	144
14	Tracking is not completed	92
11	Dispatcher uses remote emergency services	72
8	Necesary information not readily available	60
6	Operator cannot communicate	60
13	Selective routing is not possible	48
2	Call is not answered w/in 10 sec	48
12	Circuit fails	45
16	Call is not received	42
15	Call is not transferred w/in 10 sec	36
1	Power outage/complete failure	30
4	Power surge	30
7	Operator receives no answer	27
17	More than 2% of calls overflow to alternate PSAP	15
10	Call cannot be made	8
18	Operator cannot obtain help, test the system, or log in	4

7.3.1 Non-emergency Calls

Non-emergency calls account for a large percentage of total calls each day. Requests for directions, weather reports, and traffic conditions are most common among most cellular 9-1-1 calls. This problem has carried over from inappropriate use of emergency seven-digit numbers. About 60 percent of incoming calls are law enforcement related. However, the ratio of non-emergency calls to emergency calls to law enforcement immensely exceed the ratio for fire or medical. Fire and medical emergency service attention prove to be much more obvious to the public. If there is a fire, one would call for the fire department. If there is serious injury, one calls the for medical services. An occupied, disabled vehicle may not be an emergency. However, if the vehicle is in a high crime ridden area, it is way below normal temperatures and is snowing, and the driver is elderly and has a heart problem, this may be an appropriate emergency call.

The problem is what constitutes a law enforcement emergency? This probably depends on the philosophy of the chief executive, the size of the force, the population, its demands, and its general activity. The level of service gives the public its expectations and determines the public's view of what a law enforcement agency is. Also, many regions used the same number to report both emergency and non-emergency calls prior to the implementation of 9-1-1. Many times the public was encouraged to call 9-1-1 for the same reasons that they always had called the other numbers and sometimes a high call volume was desired. So, service techniques and the public's misguided view generally make up the problem.

A comprehensive public education program must be initiated after an "emergency 9-1-1 call" is defined. According to Colonel Earnest E. Ricci, PSAP administrators must enforce a zero tolerance policy for non-emergency calls [34]. Now, the problem is being

dealt with by adding staff members and equipment and enlarging the facilities. This is not a cost-effective approach to the problem and does not provide for an effective service to emergency 9-1-1 callers. Once the public education program is carried through, Ricci identifies the following benefits that the PSAP will encounter:

- A decrease in overall call processing activity
- More time to improve call processing procedures and training
- Lower probability of blocked lines
- Faster answering time
- A decrease in total response time to emergencies
- The stabilization of staffing levels
- An easier managed and maintained PSAP
- Improved working conditions
- Positive work attitudes
- Improved quality of service
- A more supportive public that identifies itself with the organization's mission

Calls which are borderline emergency calls should not be processed as non-emergency calls, but should be prioritized according to policies established at the PSAP. Those asking for weather reports or administrative calls which may be appropriate to a division of the agency are non-emergency calls. Administrative numbers must be published. If they are published and these calls continue to come in on 9-1-1 lines, more activity than expected is probably being conducted on these administrative lines. If they are always busy, callers will then try 9-1-1 as an alternative. Administrative calls and other non-emergency calls should be referred or transferred to other telephone numbers and the telecommunicator should be courteous in instructing the caller how to properly use the system. This will have a direct influence on the non-emergency callers although

it probably will not have as great an effect more widely.

Ricci also recommends messages sent along with telephone bills a few times a year entitled "when to use 9-1-1" and an explanation of how its abuse will not only raise costs which will in turn increase their taxes, but could also cost someone their life. Public service messages may be used on radio or television and messages can be included in AAA and ALA member newsletters. "How to use 9-1-1 properly" may be the theme for essay contest in schools since early education is a most effective form. Crime or fire prevention officers can offer explanation on its use when they give lectures at schools, PTA meetings, and senior citizen centers. Messages can even be posted on buses, bumper stickers, flyers, and even coloring books. A public education program for a county costs about $10,000 per year which is negligible comparable to the total cost spent per year.

7.3.2 Insufficient Training

Training is another important aspect that is dealt with in failure mode number 5. One of four challenges proposed by William E. Stanton at the 1995 NENA (National Emergency Number Association) National Conference in Nashville, Tennessee, is a call for national training standards for all telecommunicators.

NENA represents all areas of the public services, law enforcement, fire and medical, and is recognized as one of the leaders in the public safety communications industry. NENA would be unlikely to compromise the excellence of standards since it has no connection to the manufacture, production, or distribution of training programs or materials.

NENA's main concern is in assisting and supporting states that wish to establish training standards. A committee was created, the National Resource Center (NRC) for

Telecommunicator Training Standards. These were tailored for New Jersey and were discussed in detail previously. NENA simply advocates the adoption of a minimum standard for training telecommunicators and realizes differences in each state's level of required sophistication. APCO has now joined teams with NENA to encourage the adoption of one national standard. The cost per county is approximately $120,000 per year to implement these standards set forth by the NRC. [16]

7.3.3 Cellular Congestion

Cellular phones are used widely in emergency situations. For instance, on April 19, 1995, cellular phone lines were overloaded in Oklahoma City during the tragic explosion. Cellular congestion also was the result during other disasters such as the World Trade Center bombing, the Loma Prieta earthquake, and Hurricanes Hugo and Andrew.

The cellular interface unit provided by Teltone Corporation provides access to the cellular network when wireline access is not available. When a remote office becomes isolated from its host, uninterrupted 9-1-1 service is assured. Costs of these units are $1,980 for the cellular interface unit for CO installation, $1,880 for the cellular interface unit for PSAP installation, and $2,250 for the cellular interface unit for Remote Office installation.

Teltone's 9-1-1 Switched Access System (SAS) allows the survival of the network through natural disasters, service interruptions, or traffic overload. It continuously performs self-testing, network integrity checks, and has alarm reporting. Call steering, call prioritization, and a voice response feature that keeps callers on the line while routing their call are features of the 9-1-1 SAS.

As a standalone system, ANI delivery and call routing are performed. 9-1-1 SAS

can also be used as a backup since it is easily integrated into existing architectures for alternate routing and call overflow. The assumption has been made that a system providing all of these features is similar to Camden County's 9-1-1 and the regular phone system, which are estimated together to cost $500,000. PSAP equipment ranges from $7,000 to $10,000 per telecommunicator position. [29]

7.3.4 Miscellaneous

Another solution for some failure modes is to obtain more telecommunicators or possibly have more of them stay to work during busy hours. A sufficient staff for a county accounts for about $1,500,000 per year. This includes salary and benefits for 24 telecommunicators, 4 lieutenants, and 2 administrative officers. Overtime costs account for about $250,000 per year. Maintenance contracts with other phone systems account for about $40,000 [3]. Each call answer unit is $975 and each call transfer unit is $750. For the addition of trunks, a trunk dial unit is $1,850 and a trunk monitor unit is $1,800 [29]. A list of all costs are shown in Table 7-3.

7.4 PARETO ANALYSIS

In the 1800's, Vilfredo Pareto, an Italian sociologist and economist, stated that 80 percent of the wealth is controlled by 20 percent of the people. In 1950, Joseph Juran was guided by the similar principle that 80 percent of the costs occur from 20 percent of the defects. Pareto analysis is much like a histogram, except for the fact that, as in this case, the failure mode with the highest RPN is on the left and the rest follow in descending order. [31]

Table 7.3 - 9-1-1 Costs

Costs	Amount
Personnel salaries plus benefits per year*	$1,500,000
Telephone system*	$500,000
Overtime per year*	$250,000
Training per year*	$120,000
Maintenance contracts per year*	$40,000
Public education per year*	$10,000
PSAP equipment per position*	$8,500
Cellular interface unit for Remote Office installation†	$2,250
Cellular interface unit for CO installation†	$1,980
Cellular interface unit for PSAP installation†	$1,880
Trunk dial unit†	$1,850
Trunk monitor unit†	$1,800
Call answer unit†	$975
Call transfer unit†	$750

* designates costs obtained from reference [3]

† designates costs obtained from reference [29]

7.4.1 RPN and Costs

From the completed FMECA worksheet, a Pareto analysis of RPNs was performed and is shown in Figure 7.1. Also, Pareto analysis of costs for some of the countermeasures has been performed and is illustrated in Figure 7.2.

The most critical form of failure by far is that of the lines being busy. It has a RPN more than two times that of the second place failure. From previous discussion, it has been determined that non-emergency calls largely contribute to that column. By, looking at Figure 7.2, it is seen that an economical solution for that problem would be to implement a public education program or add somewhat to an already existing one. The wrong move to make would be to add more personnel as that takes up the majority of the money spent already. Public education, at the cost of $10,000 would educate the community and help the problem in the long run, whereas adding more operators is a short term fix that will deplete more money and do nothing for the long term. If repeated, the system is no longer feasibly implemented.

The second largest RPN is for operators who are not knowledgeable or helpful. Training is $120,000 per year and is the fourth largest cost, but is only about 5 percent of the total that is spent. Therefore, it is worth making sure that full and effective training is completed by all telecommunicators.

Third on the RPN list is the case when sufficient information is not made available to the telecommunicator from the caller. If the area has many cellular phones causing a tracking problem, then cellular interface units can be purchased for a negligible amount compared to the telephone system itself. Also, it may be that the PSAP equipment is out-of-date. New equipment is about $8,500 per position. With this manageable cost and all of the features that have been previously discussed concerning Enhanced 9-1-1, the equipment is beneficial to any community when viewing all of the

failure modes that it may prevent.

There are many other devices that are of negligible cost such as 9-1-1 Feelers which are commercially priced for at-home use. They help people feel which buttons to dial if it is dark or if they are blind.

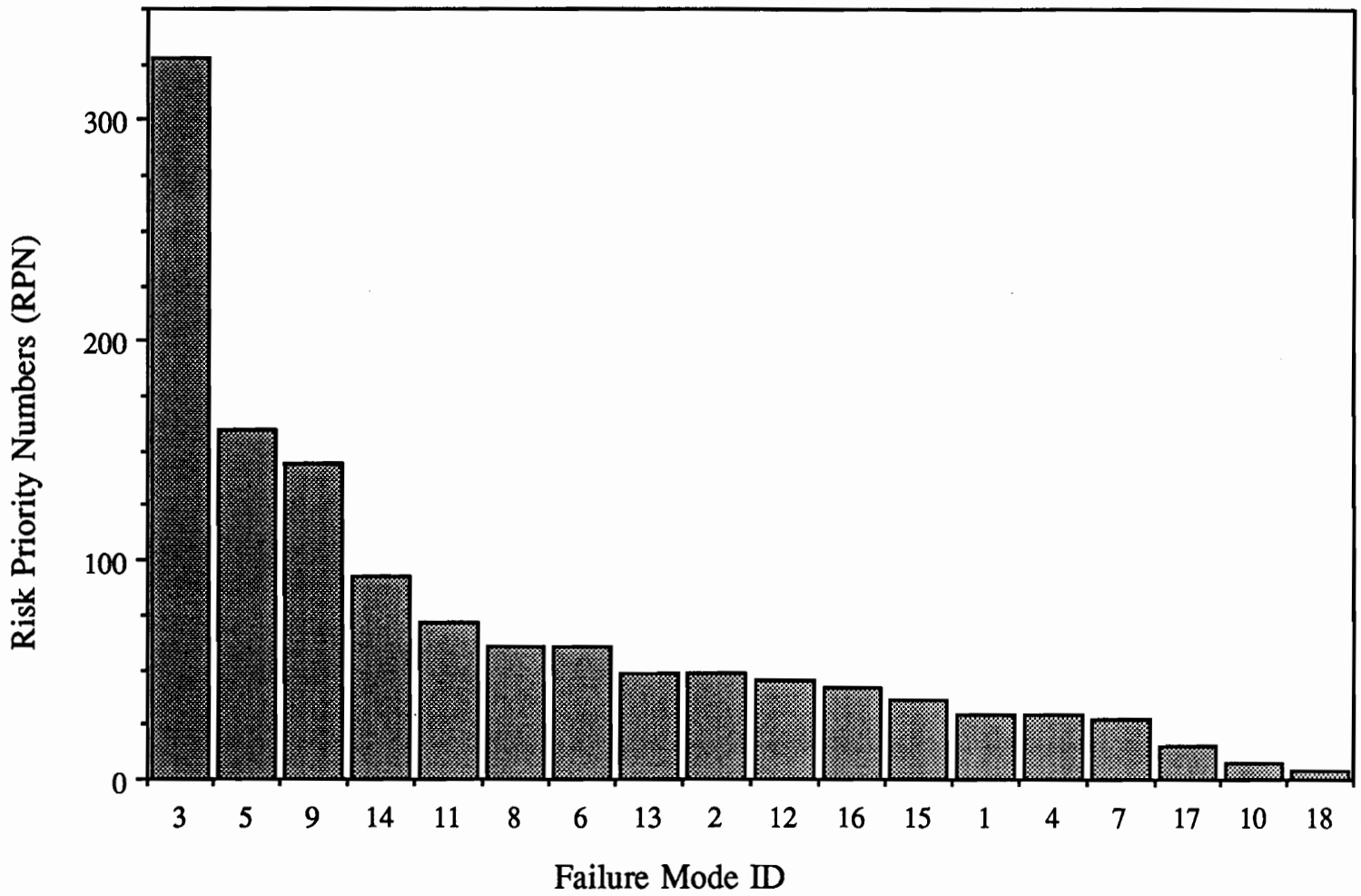


Figure 7.1 - Pareto Analysis with RPNs

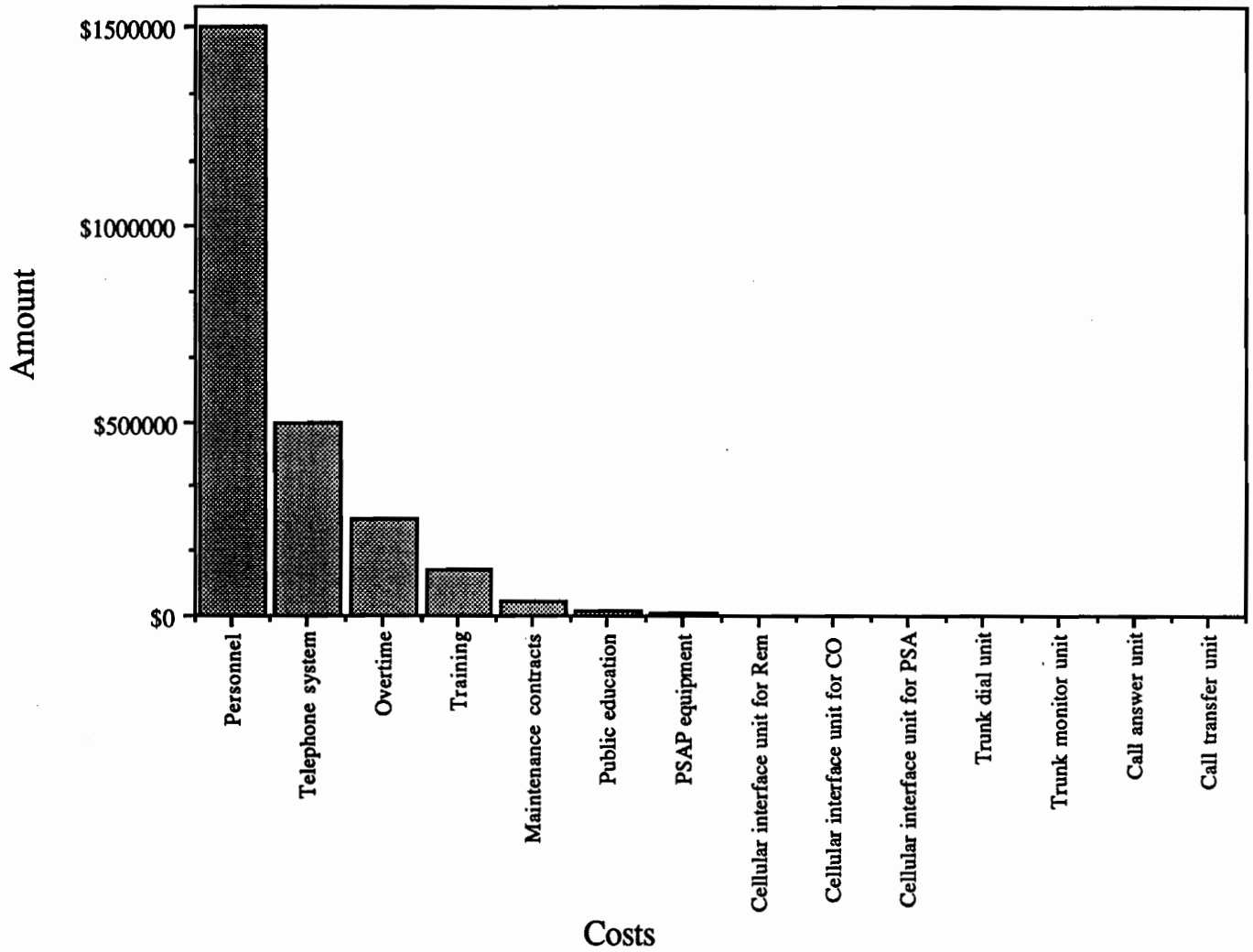


Figure 7.2 - Pareto Analysis of Costs

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

Presented in this chapter are final conclusions with regard to the 9-1-1 system, its effectiveness, and the decision of whether or not FMECA was the proper tool that should have been applied. Furthermore, recommendations and suggestions for topics that may be of future interest are briefly introduced.

8.1 FINAL CONCLUSIONS

8.1.1 PROJECT OVERVIEW

This report demonstrated the use of FMECA as applied to New Jersey's 9-1-1 system through the Systems Engineering Process. The failure mode that any 9-1-1 facility should be most concerned with is that of the lines being blocked. This failure mode exceeded the risk presented by any other mode of failure by more than twice the amount. Public education programs are not expensive to implement and are the only hope to diminish non-emergency calls in the long-term future.

Adding more personnel contributes to the highest area of spending and is only a short-term solution to line overload. Even having personnel spend overtime hours to handle all of the incoming calls, contributes to the same dilemma. Also, a high amount is spent for overtime. In Camden County, $250,000 a year is allotted to overtime. That's half of what the 9-1-1 and regular telephone system costs. Overtime is not a solution.

Another area of high risk is when the operator does not prove to be helpful. This seems to be occurring more and more frequently. Proper training and screening of

telecommunicators is a necessity.

Cellular interface units are inexpensive to install and help to prevent cellular line overload allowing emergency personnel to communicate. More trunk lines, answer units, and transfer units can be installed if needed for small amounts.

FMECA was a useful tool in evaluating this system. It helped to isolate failure modes. The Pareto analyses allowed the most critical failure modes and the highest costs to be found at a glance. Also, each failure mode's risk can be compared against others through Figure 7.1. The same can be done with costs through Figure 7.2.

8.1.2 9-1-1 OVERVIEW

The 9-1-1 system is an effective tool for handling emergency calls. Its implementation provides for rapid, reliable, and convenient access to emergency services. The 9-1-1 system has many benefits over the original seven-digit, site specific numbers that were listed in telephone directories. The most significant benefit derived from the system by the public is the reduction in response time for obtaining assistance from emergency service agencies.

The 9-1-1 system is advantageous since it gives the public only one number to remember instead of presenting many numbers for the different types of aid to an individual under severe stress or to a small child that is panicked and is not sure in which jurisdiction he/she is located at the time.

9-1-1 is easily memorized and retained. Faster access to emergency services is permitted by this easy-to-dial number. The number is easily dialed in the dark, by children, by elder people, and by blind people. Unfamiliar visitors and new residents to any area benefit by already knowing these three simple digits. Instead of calls being handled by untrained "0" operators, they are taken by individuals who are able to screen

out non-emergency calls and are capable of obtaining the necessary information from highly emotional people.

For threatening calls, such as those with bomb threats, or calls made by those who cannot speak, the call can be traced and services dispatched to that address. It enables people to use pay phones for an emergency without the use of coins. Overall, the 9-1-1 system promotes and facilitates cooperation between various public safety providers and promotes involvement among citizens. Greater public awareness and acceptance of these agencies are created along with a heightened sense of responsibility.

8.2 RECOMMENDATIONS FOR FUTURE INVESTIGATIONS

8.2.1 Address Updating

There seems to be a very long time from when old/new addresses have been delivered to the Address Management Systems (AMS) team of the Postal Service until they are approved. (When AMS receives an old/new address, the local Postmaster verifies that the information is correct to the best of his/her knowledge. Then, the AMS assigns the Zip Plus Four zip code to each address that has been converted.) These delays make the work done by 9-1-1 Boards and addressing contractors inaccurate due to the mobility of our society, even in rural communities.

New computer systems are being worked upon in order to speed up data entry and the Zip Plus Four assignment. NENA has suggested that AMS work toward being able to accept electronic formats of edit sheets and maps. Through these, typographical errors may decrease and turnaround time may improve. This may prove to be helpful in the future to 9-1-1 Boards and of course the callers. Communication between the Postal Service and 9-1-1 professionals must be improved. [11]

8.2.2 Number Portability (Remote Call Forwarding)

Number portability proposes a new threat to call tracking. This takes on two basic meanings: 1.) one number can be used to reach a person anywhere, 2.) being able to use the same telephone number wherever one travels. Being able to provide it means being a competitor against the Local Exchange Carrier and possibly having customers retain their telephone numbers without regard to the provider of the dial tone. In most instances, this is completed through remote call forwarding (RCF).

RCF works in the following manner. A customer dials a company's main number. The call is routed in a normal fashion through the public switched telephone network (PSTN). When it reaches the end office at the company's extension, the call must be routed to another phantom number that belongs to the competitive local exchange carrier (CLEC). The call is routed to the forwarded number through the PSTN to the CLEC switch. The company's phone system is made aware of this incoming call.

When RCF is used and 9-1-1 is dialed, the 10 digit phantom number is displayed. The ANI/ALI screen will display the correct address if the CLEC's numbers are in the 9-1-1 database. At the operator's request to confirm caller's number, the caller will render the company's number, but the phantom number will be displayed.

In order to solve this dilemma, bigger problems may be created. An Advanced Intelligent Network (AIN) is being approached with its prominent concept being a break between the customer network address (CNA) and the network node address (NNA). These two numbers are presently identical. A person's home number is assigned to them and the number stands for a terminal address of the telephone line to the house. This physical relationship is broken by AIN. The relationship is substituted by one in a database. Therefore, all network routing is based on NNAs. So, the customer dials the company's CNA. AIN is activated in the originating office and the database supplies the

NNA. The call is routed through the PSTN to the CLEC through the NNA.

Since the NNA is displayed, an address can be found. However, the NNA would not be able to be dialed by the PSAP operator and they could not be called back. It is most likely that in the attempt to dial the NNA, it would be taken as a CNA and routed to an unwanted location. Problems for 9-1-1 are hence encountered. [7]

8.2.3 Cellular Priority Access Service (CPAS)

Emergency responders generally use cellular telephones for communication among one another. Therefore, the cellular congestion, discussed before, that occurs in the event of a disaster also prevents communication efforts of response teams. After the identified need for CPAS by the National Security Telecommunications Advisory Committee (NSTAC), President Clinton, on January 11, 1995, directed the National Communications System (NCS) to help implement it.

CPAS would be available at all times on authorized instruments in equipped markets, without any activation methods. To use, an authorized person would dial a universal feature code, which has not yet been determined. The user would then be placed at the top of the queue and await the next available channel. The user does not, however, overpower connected calls.

Priority levels differ in CPAS according to the users critical contribution to the emergency effort, especially within the first 24 to 72 hours. The highest level, priority 1, is dedicated to high executive policy personnel within federal, state, and local jurisdictions. Priorities 2 and 3 are assigned to "first responders." Priority 4 is reserved for personnel who perform stabilization functions, and Priority 5 is for disaster recovery personnel.

No standards have been developed so there is no provider able to render CPAS.

A recent version of the developing standards contains Priority Access and Channel Assignment (PACA). PACA's impact on the air interface portion of the network is being studied. The joint effort for CPAS's development by Time Division Multiple Access subcommittee and Analog and Code Division Multiple Access subcommittees should make CPAS a reality sometime in 1997. [1]

8.3 FINAL STATEMENT

The objectives of this report have been achieved. FMECA was applied appropriately to the analysis of the 9-1-1 system. Failure modes were identified, and some economical solutions (Table 7.3) offered were public education programs, cellular interface units, and proper training programs. The New Jersey 9-1-1 system can view potential hazards and take the proper precautions. Also, any state, county, jurisdiction, etc., that does not yet have a 9-1-1 system implemented will have the opportunity to "design out" failure modes.

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APPENDIX A

NUMBER OF TRUNKS REQUIRED

To estimate the number of trunks needed, the CCS (hundred call-seconds) must be determined. CCS is the unit used to measure the degree of loading on the 9-1-1 system. The following equation is implemented:

$$CCS = \frac{P \times aHT \times aBH \times CPT}{100 \times 1{,}000} \qquad (A.1)$$

where P = the population served by the PSAP,

aHT = average hold-time including ringdown time (seconds),

aBH = average busy hour call volume / average daily call volume,

CPT = call per thousand people per day.

Real time call volume and hold-time is used. aBH is typically 10 to 15 percent of the daily call volume. Once the CCS is calculated, Table A-1 is used to find the proper number of trunks for the specified grade of service. [33]

Table A-1 - PSAP Trunk Capacity

Trunks	CCS per hour									
	P.01	P.02	P.03	P.04	P.05	P.06	P.07	P.08	P.09	P.10
1	0.4	0.7	1.1	1.5	1.9	2.2	2.6	3	3.4	3.8
2	5.4	7.9	9.7	11.3	12.9	14.2	15.5	16.8	18	19.1
3	15.7	20.4	24	26.9	29.4	31.7	33.9	35.9	37.8	39.6
4	29.6	36.7	41.6	45.7	49.1	52	55	58	60	63
5	46.1	55.8	61.6	66.6	70.9	75	78	81	85	88
6	64.4	76	82.8	89.3	94.1	99	103	107	110	113
7	83.9	96.8	105	112	118	123	128	132	136	140
8	105	119	129	137	143	149	154	159	163	168
9	126	142	153	162	169	175	181	186	191	195
10	149	166	178	188	195	202	208	214	219	224
11	172	191	204	214	222	230	236	242	248	253
12	195	216	230	240	249	258	264	270	277	282
13	220	241	256	267	277	286	292	299	306	311
14	244	267	283	295	305	314	321	328	335	341
15	269	293	310	322	333	342	350	357	364	370
16	294	320	337	350	362	371	379	387	394	401
17	320	347	365	378	390	400	409	416	434	431
18	346	374	392	407	419	429	438	446	455	462
19	373	401	420	436	448	458	468	476	485	492
20	399	429	449	465	477	488	498	506	516	523
21	426	458	478	494	507	517	528	537	546	554
22	453	486	507	523	536	547	558	567	577	535
23	480	514	536	552	566	577	589	598	607	616
24	507	542	564	582	596	608	619	629	638	647
25	535	571	593	611	626	638	650	660	669	678

Table A-1 - PSAP Trunk Capacity (continued)

Trunks	CCS per hour									
	P.01	P.02	P.03	P.04	P.05	P.06	P.07	P.08	P.09	P.10
26	562	599	623	641	656	669	680	691	700	710
27	590	627	652	671	686	699	711	722	731	741
28	618	656	682	701	717	730	742	753	763	773
29	647	685	711	731	747	761	773	784	794	805
30	675	715	741	762	778	792	804	815	826	836
31	703	744	771	792	809	823	835	846	858	868
32	732	773	801	822	840	854	867	878	890	900
33	760	803	831	852	871	885	898	909	922	932
34	789	832	861	883	902	917	930	941	954	964
35	818	862	891	913	933	948	961	973	986	996
36	847	892	922	944	964	979	993	1005	1018	1028
37	878	922	952	975	995	1011	1024	1037	1050	1060
38	905	952	982	1006	1026	1042	1056	1069	1082	1092
39	935	982	1013	1037	1057	1074	1087	1101	1114	1125
40	964	1012	1043	1069	1088	1105	1119	1133	1146	1157
41	993	1042	1074	1099	1120	1137	1151	1165	1178	1190
42	1023	1072	1104	1130	1151	1168	1183	1197	1210	1222
43	1052	1103	1135	1161	1183	1200	1215	1229	1243	1255
44	1082	1133	1166	1192	1214	1232	1247	1262	1275	1287
45	1112	1164	1197	1223	1246	1263	1279	1294	1308	1320
46	1142	1194	1228	1255	1277	1295	1311	1326	1340	1352
47	1171	1225	1259	1286	1309	1327	1343	1358	1373	1385
48	1201	1255	1291	1317	1340	1359	1375	1391	1405	1417
49	1231	1286	1322	1349	1372	1390	1407	1423	1438	1450
50	1251	1317	1363	1381	1403	1422	1439	1455	1470	1482

APPENDIX B

NUMBER OF OPERATORS REQUIRED

The Poisson queuing theory equation is used in calculating the number of 9-1-1 operators required to handle an estimated busy-hour call volume. This equation is derived in the Stanford Research Institute Final Report 7543-80-FR-58 prepared for the U.S. Department of Justice. The results are included in Table B-1. The times at the top of the table represent the average effective operator occupied time per call.

Post-call-work of the operator between answering 9-1-1 calls is not taken into account by this equation and must be measured and included in the average call length. Post-call-work is the amount of time a PSAP operator and/or PSDP dispatcher is not available to accept additional incoming 9-1-1 calls due to the requirements necessary to handle the call previously received. Also, other imposed job duties and responsibilities which may impede operators from answering 9-1-1 calls within the standards are not designed into the equation.

Busy-hour call volume, average call length, and post-call-work is required in order to utilize this table. When call volume and call length, including post-call-work, exceed the requirement for "n" operators, the next highest operator number should be used to account for some unknown amount of unavailable time. Selecting the smaller number raises the probability of the caller having to wait more than 10 seconds to over 10 percent. [33]

Table B-1 - Busy Hour Operators
(90% of calls answered within 10 seconds)

Number of busy hour operators	Busy Hour Call Volume											
	10 sec	15 sec	20 sec	25 sec	30 sec	35 sec	40 sec	45 sec	50 sec	55 sec	60 sec	65 sec
1	78	41	27	20	16	13	11	9	8	7	6	6
2	333	189	129	97	77	64	54	47	42	37	34	31
3	637	375	260	197	157	131	112	98	86	78	70	64
4	960	577	404	308	247	206	177	154	137	123	111	102
5	1293	788	556	426	343	287	246	215	191	171	156	142
6	1632	1006	713	548	443	371	318	278	247	222	202	185
7	1975	1227	874	673	545	457	393	344	306	275	250	229
8	2321	1451	1038	801	650	545	469	411	365	329	299	274
9	2670	1677	1203	931	756	635	546	479	426	384	349	319
10	3019	1905	1371	1062	864	726	625	548	488	439	399	366
11	3370	2134	1539	1195	973	818	705	618	550	496	451	413
12	3722	2364	1709	1329	1082	911	785	689	614	553	503	461
13	4075	2595	1879	1463	1193	1005	866	761	678	611	555	509
14	4428	2827	2051	1598	1304	1099	948	833	742	669	608	558
15	4782	3060	2223	1734	1416	1194	1030	905	807	727	662	607
16	5137	3293	2396	1870	1528	1289	1113	978	872	786	715	656
17	5492	3527	2569	2007	1641	1385	1196	1051	937	845	769	706
18	5847	3761	2742	2145	1754	1481	1279	1125	1003	905	824	756
19	6203	3996	2916	2282	1868	1578	1363	1199	1069	965	878	806
20	6559	4231	3091	2420	1982	1674	1447	1273	1136	1025	933	856
21	6915	4466	3265	2559	2096	1772	1532	1348	1202	1085	988	906
22	7272	4702	3440	2697	2211	1869	1616	1423	1269	1145	1043	957
23	7628	4938	3616	2836	2326	1967	1701	1497	1336	1206	1098	1008
24	7985	5174	3791	2976	2441	2065	1786	1573	1404	1267	1154	1059
25	8342	5410	3967	3115	2556	2163	1872	1648	1471	1328	1210	1110
26	8700	5646	4143	3255	2672	2261	1957	1723	1539	1389	1265	1162
27	9057	5883	4319	3394	2787	2359	2043	1799	1606	1450	1321	1213
28	9414	6119	4495	3534	2903	2458	2128	1875	1674	1512	1377	1265
29	9772	6356	4671	3675	3019	2557	2214	1951	1742	1573	1434	1316
30	10130	6593	4848	3815	3135	2656	2300	2027	1811	1635	1490	1368

Table B-1 - Busy Hour Operators
(continued)

Number of busy hour operators	Busy Hour Call Volume										
	70 sec	75 sec	80 sec	85 sec	90 sec	95 sec	100 sec	105 sec	110 sec	115 sec	120 sec
1	5	5	5	4	4	4	4	3	3	3	3
2	28	26	24	23	21	20	19	18	17	16	16
3	59	55	51	48	45	42	40	38	36	34	33
4	94	87	81	76	71	67	64	60	57	55	52
5	131	122	113	106	100	94	89	85	80	77	73
6	170	158	147	138	130	122	116	110	105	100	95
7	211	196	182	171	161	152	143	136	130	124	118
8	252	234	218	205	192	182	172	163	155	148	142
9	295	273	255	239	225	212	201	191	181	173	165
10	338	313	292	274	258	243	230	219	208	199	190
11	381	354	330	309	291	275	260	247	235	224	214
12	425	395	368	345	325	307	290	276	262	250	239
13	470	436	407	382	359	339	321	305	290	277	265
14	515	478	446	418	393	371	352	334	318	303	290
15	560	520	485	455	428	404	383	364	346	330	316
16	606	563	525	492	463	437	414	393	374	357	342
17	652	605	565	530	498	471	446	423	403	385	368
18	698	648	605	567	534	504	477	453	432	412	394
19	744	691	645	605	569	538	509	484	460	439	420
20	791	734	686	643	605	571	541	514	489	467	447
21	837	778	726	681	641	605	573	545	518	495	473
22	884	822	767	719	677	639	606	575	548	523	500
23	931	865	808	758	713	673	638	606	577	551	527
24	979	909	849	796	749	708	670	637	606	579	554
25	1026	953	890	835	786	742	703	668	636	607	581
26	1073	997	931	873	822	777	736	699	666	635	608
27	1121	1042	973	912	859	811	769	730	695	664	635
28	1169	1086	1014	951	896	846	801	761	725	692	662
29	1217	1131	1056	990	932	881	834	793	755	721	689
30	1264	1175	1098	1029	969	915	867	824	785	749	716

APPENDIX C

ALTERNATE ROUTING ARRANGEMENTS

When alternate routing arrangements are needed, Table C-1 is used to determine group capacity. The numbers in this table are based on the Erlang "B" lost call cleared formula. The load carried by each trunk, the cumulative load carried by all trunks, and the load overflowed by a group of trunks is shown for a given offered load per hour in CCS. The basic assumptions behind the Erlang "B" theorem are that there are random offered calls from unlimited sources, holding time is either constant or varies exponentially with respect to an average value, and a call failing to find an idle trunk disappears from the system and does not reappear within the hour (lost call cleared).

The data is organized as if all trunks were arranged in a straight multiple. That is, a given load is first offered to trunk number 1, then number 2, and so on. However, this precise loading of individual trunks is not possible because of various devices such as multiple turnovers and preferential hunting at opposite ends of a group designated to equalize physical usage of trunks, but the addition of a trunk will always aggregate additional capacity to a group.

For example, consider an offering of 300 CCS per hour to a group of 8 trunks. According to the table, trunk number 1 will carry 32 CCS and overflow 268 CCS which is offered to trunk number 2. Trunk number 2 will carry 31 and overflow 237 which is offered to trunk number 3. Trunk number 3 will carry 31 CCS and overflow 206 CCS to trunk number 4. Trunk number 4 will carry 29 CCS and overflow 177 CCS to trunk number 5. Trunk number 5 will carry 28 CCS and overflow 149 CCS to trunk number 6. Trunk number 6 will carry 27 CCS and overflow 122 CCS to trunk number 7. Trunk

number 7 will carry 24 CCS and overflow 98 CCS to trunk number 8. Trunk number 8 will carry 22 CCS and overflow 76 CCS. Each trunk in succession carries the same or less than the trunk immediately preceding it. This occurred until the last trunk carried 22 CCS and overflowed 76 CCS. The eight trunks, as a group, carry 224 CCS (300 CCS - 76 CCS). This is the amount shown in the carried total column.

Please note that it is possible to extend the limits that are provided herein. However, these ranges prove adequate for any practical problem and any other case would require special consultation. [41]

Table C-1 - Alternate Routing Tables

CCS Offered	Trunk Number 1 Carried Trunk	1 Carried Total	1 Overflow	2 Carried Trunk	2 Carried Total	2 Overflow	3 Carried Trunk	3 Carried Total	3 Overflow	4 Carried Trunk	4 Carried Total	4 Overflow	5 Carried Trunk	5 Carried Total	5 Overflow	CCS Offered
5	4	4	1													5
6	5	5	1													6
7	6	6	1													7
8	6	6	2													8
9	7	7	2													9
10	8	8	2													10
11	8	8	3													11
12	9	9	3													12
13	10	10	3													13
14	10	10	4													14
15	11	11	4	3	14	1										15
16	11	11	5	4	15	1										16
17	11	11	6	5	16	1										17
18	12	12	6	5	17	1										18
19	12	12	7	5	17	2										19
20	13	13	7	5	18	2										20
21	13	13	8	6	19	2										21
22	14	14	8	6	20	2										22
23	14	14	9	6	20	3										23
24	14	14	10	7	21	3										24
25	15	15	10	7	22	3										25
26	15	15	11	7	22	4										26
27	15	15	12	8	23	4										27
28	16	16	12	8	24	4										28
29	16	16	13	9	25	4										29
30	16	16	14	9	25	5	4	29	1							30
31	17	17	14	9	26	5	4	30	1							31
32	17	17	15	9	26	6	4	30	2							32
33	17	17	16	10	27	6	4	31	2							33
34	18	18	16	10	28	6	4	32	2							34
35	18	18	17	10	28	7	5	33	2							35

CCS Offered	Trunk Number 1 Carried Trunk	1 Carried Total	1 Overflow	2 Carried Trunk	2 Carried Total	2 Overflow	3 Carried Trunk	3 Carried Total	3 Overflow	4 Carried Trunk	4 Carried Total	4 Overflow	5 Carried Trunk	5 Carried Total	5 Overflow	CCS Offered
36	18	18	18	11	29	7	5	34	2							36
37	18	18	19	11	29	8	5	34	3							37
38	19	19	19	11	30	8	5	35	3							38
39	19	19	20	11	30	9	6	36	3							39
40	19	19	21	12	31	9	6	37	3							40
41	19	19	22	13	32	9	6	38	3							41
42	19	19	23	13	32	10	6	38	4							42
43	19	19	24	13	32	11	7	39	4							43
44	20	20	24	13	33	11	7	40	4							44
45	20	20	25	14	34	11	7	41	4							45
46	20	20	26	14	34	12	7	41	5							46
47	20	20	27	14	34	13	8	42	5	3	45	2				47
48	21	21	27	14	35	13	8	43	5	3	46	2				48
49	21	21	28	14	35	14	8	43	6	4	47	2				49
50	21	21	29	15	36	14	8	44	6	4	48	2				50
51	21	21	30	15	36	15	9	45	6	4	49	2				51
52	21	21	31	15	36	16	9	45	7	5	50	2				52
53	21	21	32	16	37	16	9	46	7	5	51	2				53
54	22	22	32	16	38	16	10	48	6	5	53	1				54
55	22	22	33	16	38	17	10	48	7	5	53	2				55
56	22	22	34	16	38	18	10	48	8	5	53	3				56
57	22	22	35	17	39	18	10	49	8	5	54	3				57
58	22	22	36	17	39	19	10	49	9	6	55	3				58
59	23	23	36	17	40	19	10	50	9	6	56	3				59
60	23	23	37	17	40	20	11	51	9	6	57	3				60
61	23	23	38	17	40	21	11	51	10	6	57	4				61
62	23	23	39	17	40	22	12	52	10	6	58	4				62
63	23	23	40	17	40	23	12	52	11	7	59	4				63
64	23	23	41	18	41	23	12	53	11	7	60	4				64
65	23	23	42	18	41	24	12	53	12	7	60	5				65
66	23	23	43	18	41	25	13	54	12	7	61	5				66
67	23	23	44	19	42	25	13	55	12	7	62	5	3	65	2	67
68	23	23	45	19	42	26	13	55	13	7	62	6	4	66	2	68
69	24	24	45	19	43	26	13	56	13	7	63	6	4	67	2	69
70	24	24	46	19	43	27	13	56	14	8	64	6	4	68	2	70

CCS Offered	Trunk Number 1 Carried Trunk	1 Carried Total	1 Overflow	2 Carried Trunk	2 Carried Total	2 Overflow	3 Carried Trunk	3 Carried Total	3 Overflow	4 Carried Trunk	4 Carried Total	4 Overflow	5 Carried Trunk	5 Carried Total	5 Overflow	CCS Offered
71	24	24	47	19	43	28	13	56	15	8	64	7	4	68	3	71
72	24	24	48	19	43	29	14	57	15	8	65	7	4	69	3	72
73	24	24	49	20	44	29	14	58	15	8	66	7	4	70	3	73
74	24	24	50	20	44	30	14	58	16	9	67	7	4	71	3	74
75	24	24	51	20	44	31	14	58	17	9	67	8	5	72	3	75
76	24	24	52	20	44	32	15	59	17	9	68	8	5	73	3	76
77	25	25	52	20	45	32	15	60	17	9	69	8	5	74	3	77
78	25	25	53	20	45	33	15	60	18	9	69	9	5	74	4	78
79	25	25	54	20	45	34	15	60	19	10	70	9	5	75	4	79
80	25	25	55	20	45	35	15	60	20	10	70	10	6	76	4	80
81	25	25	56	21	46	35	15	61	20	10	71	10	6	77	4	81
82	25	25	57	21	46	36	16	62	20	10	72	10	6	78	4	82
83	25	25	58	21	46	37	16	62	21	11	73	10	6	79	4	83
84	25	25	59	21	46	38	16	62	22	11	73	11	6	79	5	84
85	25	25	60	21	46	39	17	63	22	11	74	11	6	80	5	85
86	25	25	61	21	46	40	17	63	23	11	74	12	7	81	5	86
87	26	26	61	21	47	40	17	64	23	11	75	12	7	82	5	87
88	26	26	62	21	47	41	17	64	24	11	75	13	7	82	6	88
89	26	26	63	22	48	41	17	65	24	11	76	13	7	83	6	89
90	26	26	64	22	48	42	17	65	25	12	77	13	7	84	6	90
91	26	26	65	22	48	43	17	65	26	12	77	14	7	84	7	91
92	26	26	66	22	48	44	17	65	27	12	77	15	8	85	7	92
93	26	26	67	22	48	45	18	66	27	12	78	15	8	86	7	93
94	26	26	68	22	48	46	18	66	28	13	79	15	8	87	7	94
95	26	26	69	23	49	46	18	67	28	13	80	15	8	88	7	95
96	26	26	70	23	49	47	18	67	29	13	80	16	8	88	8	96
97	26	26	71	23	49	48	18	67	30	13	80	17	8	88	9	97
98	26	26	72	23	49	49	19	68	30	13	81	17	8	89	9	98
99	26	26	73	23	49	50	19	68	31	13	81	18	9	90	9	99
100	26	26	74	23	49	51	19	68	32	14	82	18	9	91	9	100
102	27	27	75	23	50	52	19	69	33	14	83	19	9	92	10	102
104	27	27	77	23	50	54	19	69	35	15	84	20	9	93	11	104
106	27	27	79	23	50	56	20	70	36	15	85	21	10	95	11	106
108	27	27	81	24	51	57	20	71	37	15	86	22	10	96	12	108
110	27	27	83	24	51	59	20	71	39	16	87	23	10	97	13	110

CCS Offered	Trunk Number 1 Carried Trunk	1 Carried Total	1 Overflow	2 Carried Trunk	2 Carried Total	2 Overflow	3 Carried Trunk	3 Carried Total	3 Overflow	4 Carried Trunk	4 Carried Total	4 Overflow	5 Carried Trunk	5 Carried Total	5 Overflow	CCS Offered
112	27	27	85	24	51	61	21	72	40	16	88	24	11	99	13	112
114	28	28	86	24	52	62	21	73	41	16	89	25	12	101	13	114
116	28	28	88	25	53	63	21	74	42	16	90	26	12	102	14	116
118	28	28	90	25	53	65	21	74	44	17	91	27	12	103	15	118
120	28	28	92	25	53	67	21	74	46	17	91	29	12	103	17	120
122	28	28	94	25	53	69	22	75	47	17	92	30	13	105	17	122
124	28	28	96	25	53	71	22	75	49	17	92	32	13	105	19	124
126	28	28	98	25	53	73	22	75	51	18	93	33	14	107	19	126
128	28	28	100	26	54	74	22	76	52	18	94	34	14	108	20	128
130	28	28	102	26	54	76	22	76	54	19	95	35	14	109	21	130
132	28	28	104	26	54	78	23	77	55	19	96	36	14	110	22	132
134	28	28	106	26	54	80	23	77	57	19	96	38	15	111	23	134
136	28	28	108	26	54	82	23	77	59	20	97	39	15	112	24	136
138	29	29	109	26	55	83	23	78	60	20	98	40	15	113	25	138
140	29	29	111	26	55	85	23	78	62	20	98	42	16	114	26	140
142	29	29	113	26	55	87	24	79	63	20	99	43	16	115	27	142
144	29	29	115	26	55	89	24	79	65	20	99	45	16	115	29	144
146	29	29	117	27	56	90	24	80	66	20	100	46	16	116	30	146
148	29	29	119	27	56	92	24	80	68	20	100	48	17	117	31	148
150	29	29	121	27	56	94	24	80	70	21	101	49	17	118	32	150
152	29	29	123	27	56	96	25	81	71	21	102	50	17	119	33	152
154	29	29	125	27	56	98	25	81	73	21	102	52	17	119	35	154
156	29	29	127	27	56	100	25	81	75	21	102	54	18	120	36	156
158	30	30	128	27	57	101	25	82	76	21	103	55	18	121	37	158
160	30	30	130	27	57	103	25	82	78	22	104	56	18	122	38	160
162	30	30	132	27	57	105	25	82	80	22	104	58	19	123	39	162
164	30	30	134	27	57	107	25	82	82	22	104	60	19	123	41	164
166	30	30	136	27	57	109	26	83	83	22	105	61	19	124	42	166
168	30	30	138	27	57	111	26	83	85	23	106	62	19	125	43	168
170	30	30	140	27	57	113	26	83	87	23	106	64	19	125	45	170
172	30	30	142	28	58	114	26	84	88	23	107	65	19	126	46	172
174	30	30	144	28	58	116	26	84	90	23	107	67	20	127	47	174
176	30	30	146	28	58	118	26	84	92	24	108	68	20	128	48	176
178	30	30	148	28	58	120	26	84	94	24	108	70	20	128	50	178
180	30	30	150	29	59	121	26	85	95	24	109	71	20	129	51	180

CCS Offered	Trunk Number 1 Carried Trunk	Total	Overflow	2 Carried Trunk	Total	Overflow	3 Carried Trunk	Total	Overflow	4 Carried Trunk	Total	Overflow	5 Carried Trunk	Total	Overflow	CCS Offered
182	30	30	152	29	59	123	26	85	97	24	109	73	20	129	53	182
184	30	30	154	29	59	125	26	85	99	24	109	75	21	130	54	184
186	30	30	156	29	59	127	26	85	101	24	109	77	21	130	56	186
188	30	30	158	29	59	129	27	86	102	24	110	78	21	131	57	188
190	30	30	160	29	59	131	27	86	104	24	110	80	22	132	58	190
192	30	30	162	29	59	133	27	86	106	24	110	82	22	132	60	192
194	30	30	164	29	59	135	27	86	108	25	111	83	22	133	61	194
196	30	30	166	29	59	137	27	86	110	25	111	85	22	133	63	196
198	31	31	167	29	60	138	27	87	111	25	112	86	22	134	64	198
200	31	31	169	29	60	140	27	87	113	25	112	88	22	134	66	200
202	31	31	171	29	60	142	27	87	115	25	112	90	23	135	67	202
204	31	31	173	29	60	144	28	88	116	25	113	91	23	136	68	204
206	31	31	175	29	60	146	28	88	118	25	113	93	23	136	70	206
208	31	31	177	29	60	148	28	88	120	25	113	95	23	136	72	208
210	31	31	179	29	60	150	28	88	122	26	114	96	23	137	73	210
212	31	31	181	29	60	152	28	88	124	26	114	98	23	137	75	212
214	31	31	183	29	60	154	28	88	126	26	114	100	24	138	76	214
216	31	31	185	29	60	156	28	88	128	26	114	102	24	138	78	216
218	31	31	187	30	61	157	28	89	129	26	115	103	24	139	79	218
220	31	31	189	30	61	159	28	89	131	26	115	105	24	139	81	220
222	31	31	191	30	61	161	28	89	133	26	115	107	24	139	83	222
224	31	31	193	30	61	163	28	89	135	27	116	108	24	140	84	224
226	31	31	195	30	61	165	28	89	137	27	116	110	24	140	86	226
228	31	31	197	30	61	167	29	90	138	27	117	111	24	141	87	228
230	31	31	199	30	61	169	29	90	140	27	117	113	24	141	89	230
232	31	31	201	30	61	171	29	90	142	27	117	115	24	141	91	232
234	31	31	203	30	61	173	29	90	144	27	117	117	25	142	92	234
236	31	31	205	30	61	175	29	90	146	27	117	119	25	142	94	236
238	31	31	207	30	61	177	29	90	148	28	118	120	25	143	95	238
240	31	31	209	30	61	179	29	90	150	28	118	122	25	143	97	240
242	31	31	211	30	61	181	29	90	152	28	118	124	25	143	99	242
244	31	31	213	31	62	182	29	91	153	28	119	125	25	144	100	244
246	31	31	215	31	62	184	29	91	155	28	119	127	25	144	102	246
248	31	31	217	31	62	186	29	91	157	28	119	129	25	144	104	248
250	31	31	219	31	62	188	29	91	159	28	119	131	25	144	106	250

CCS Offered	Trunk Number 1 Carried Trunk	1 Carried Total	1 Overflow	2 Carried Trunk	2 Carried Total	2 Overflow	3 Carried Trunk	3 Carried Total	3 Overflow	4 Carried Trunk	4 Carried Total	4 Overflow	5 Carried Trunk	5 Carried Total	5 Overflow	CCS Offered
252	31	31	221	31	62	190	29	91	161	28	119	133	25	144	108	252
254	31	31	223	31	62	192	29	91	163	28	119	135	26	145	109	254
256	31	31	225	31	62	194	29	91	165	28	119	137	26	145	111	256
258	31	31	227	31	62	196	30	92	166	28	120	138	26	146	112	258
260	31	31	229	31	62	198	30	92	168	28	120	140	26	146	114	260
262	31	31	231	31	62	200	30	92	170	28	120	142	26	146	116	262
264	31	31	233	31	62	202	30	92	172	28	120	144	26	146	118	264
266	32	32	234	31	63	203	30	93	173	28	121	145	26	147	119	266
268	32	32	236	31	63	205	30	93	175	28	121	147	26	147	121	268
270	32	32	238	31	63	207	30	93	177	28	121	149	26	147	123	270
272	32	32	240	31	63	209	30	93	179	28	121	151	26	147	125	272
274	32	32	242	31	63	211	30	93	181	28	121	153	26	147	127	274
276	32	32	244	31	63	213	30	93	183	28	121	155	27	148	128	276
278	32	32	246	31	63	215	30	93	185	29	122	156	27	149	129	278
280	32	32	248	31	63	217	30	93	187	29	122	158	27	149	131	280
282	32	32	250	31	63	219	30	93	189	29	122	160	27	149	133	282
284	32	32	252	31	63	221	30	93	191	29	122	162	27	149	135	284
286	32	32	254	31	63	223	30	93	193	29	122	164	27	149	137	286
288	32	32	256	31	63	225	30	93	195	29	122	166	27	149	139	288
290	32	32	258	31	63	227	31	94	196	29	123	167	27	150	140	290
292	32	32	260	31	63	229	31	94	198	29	123	169	27	150	142	292
294	32	32	262	31	63	231	31	94	200	29	123	171	28	151	143	294
296	32	32	264	31	63	233	31	94	202	29	123	173	28	151	145	296
298	32	32	266	31	63	235	31	94	204	29	123	175	28	151	147	298
300	32	32	268	31	63	237	31	94	206	29	123	177	28	151	149	300
305				32	64	241	31	95	210	29	124	181	28	152	153	305
310				32	64	246	31	95	215	29	124	186	28	152	158	310
315				32	64	251	31	95	220	30	125	190	28	153	162	315
320				32	64	256	31	95	225	30	125	195	29	154	166	320
325				32	64	261	31	95	230	30	125	200	29	154	171	325
330				32	64	266	31	95	235	30	125	205	29	154	176	330
335				32	65	270	31	96	239	30	126	209	29	155	180	335
340				32	65	275	31	96	244	30	126	214	29	155	185	340
345				32	65	280	31	96	249	30	126	219	29	155	190	345
350				32	65	285	31	96	254	31	127	223	29	156	194	350

CCS Offered	Trunk Number 1 Carried Trunk	1 Carried Total	1 Overflow	2 Carried Trunk	2 Carried Total	2 Overflow	3 Carried Trunk	3 Carried Total	3 Overflow	4 Carried Trunk	4 Carried Total	4 Overflow	5 Carried Trunk	5 Carried Total	5 Overflow	CCS Offered
355				32	65	290	31	96	259	31	127	228	29	156	199	355
360				32	65	295	31	96	264	31	127	233	29	156	204	360
365				32	65	300	31	96	269	31	127	238	30	157	208	365
370				32	65	305	32	97	273	31	128	242	30	158	212	370
375				32	65	310	32	97	278	31	128	247	30	158	217	375
380				32	65	315	32	97	283	31	128	252	30	158	222	380
385				32	65	320	32	97	288	31	128	257	31	159	226	385
390				32	65	325	32	97	293	31	128	262	31	159	231	390
395							32	98	297	31	129	266	31	160	235	395
400							32	98	302	31	129	271	31	160	240	400
405							32	98	307	31	129	276	31	160	245	405
410							32	98	312	31	129	281	31	160	250	410
415							32	98	317	32	130	285	31	161	254	415
420							32	98	322	32	130	290	31	161	259	420
425							32	98	327	32	130	295	31	161	264	425
430							32	98	332	32	131	299	31	161	269	430
435							33	99	336	32	131	304	31	162	273	435
440							33	99	341	32	131	309	31	162	278	440
445							33	99	346	32	131	314	31	162	283	445
450										32	131	319	31	162	288	450
455										32	131	324	32	162	293	455
460										32	131	329	32	163	297	460
465										32	131	334	32	163	302	465
470										32	131	339	32	163	307	470
475										32	131	344	32	163	312	475
480													32	164	316	480
485													32	165	320	485
490													32	165	325	490
495													32	165	330	495
500													32	165	335	500
505													32	165	340	505
510													32	165	345	510
515													32	165	350	515
520													32	165	355	520
525													32	165	360	525

CCS Offered	Trunk Number 6 Carried Trunk	Total	Overflow	7 Carried Trunk	Total	Overflow	8 Carried Trunk	Total	Overflow	9 Carried Trunk	Total	Overflow	10 Carried Trunk	Total	Overflow	CCS Offered
71																71
72																72
73																73
74																74
75																75
76																76
77																77
78																78
79																79
80																80
81																81
82																82
83																83
84																84
85																85
86																86
87																87
88	4	86	2													88
89	4	87	2													89
90	4	88	2													90
91	4	88	3													91
92	4	89	3													92
93	4	90	3													93
94	4	91	3													94
95	4	92	3													95
96	5	93	3													96
97	5	93	4													97
98	5	94	4													98
99	5	95	4													99
100	5	96	4													100
102	6	98	4													102
104	6	99	5													104
106	6	101	5													106
108	6	102	6													108
110	7	104	6	3	107	3										110

CCS Offered	Trunk Number 6 Carried Trunk	6 Carried Total	6 Overflow	7 Carried Trunk	7 Carried Total	7 Overflow	8 Carried Trunk	8 Carried Total	8 Overflow	9 Carried Trunk	9 Carried Total	9 Overflow	10 Carried Trunk	10 Carried Total	10 Overflow	CCS Offered
112	7	106	6	3	109	3										112
114	7	108	6	4	112	2										114
116	7	109	7	4	113	3										116
118	8	111	7	4	115	3										118
120	8	111	9	5	116	4										120
122	8	113	9	5	118	4										122
124	9	114	10	5	119	5										124
126	9	116	10	5	121	5										126
128	9	117	11	6	123	5										128
130	9	118	12	6	124	6										130
132	10	120	12	6	126	6										132
134	10	121	13	6	127	7	4	131	3							134
136	10	122	14	7	129	7	4	133	3							136
138	11	124	14	7	131	7	4	135	3							138
140	11	125	15	7	132	8	4	136	4							140
142	11	126	16	8	134	8	4	138	4							142
144	12	127	17	8	135	9	5	140	4							144
146	12	128	18	8	136	10	5	141	5							146
148	12	129	19	9	138	10	5	143	5							148
150	13	131	19	9	140	10	5	145	5							150
152	13	132	20	9	141	11	5	146	6							152
154	14	133	21	9	142	12	6	148	6							154
156	14	134	22	9	143	13	6	149	7	4	153	3				156
158	14	135	23	10	145	13	6	151	7	4	155	3				158
160	14	136	24	10	146	14	7	153	7	4	157	3				160
162	14	137	25	10	147	15	7	154	8	4	158	4				162
164	15	138	26	11	149	15	7	156	8	4	160	4				164
166	15	139	27	11	150	16	7	157	9	4	161	5				166
168	15	140	28	11	151	17	8	159	9	4	163	5				168
170	16	141	29	11	152	18	8	160	10	5	165	5				170
172	16	142	30	12	154	18	8	162	10	5	167	5				172
174	16	143	31	12	155	19	8	163	11	5	168	6				174
176	16	144	32	12	156	20	9	165	11	5	170	6				176
178	17	145	33	12	157	21	9	166	12	6	172	6				178
180	17	146	34	12	158	22	9	167	13	6	173	7				180

CCS Offered	Trunk Number 6 Carried Trunk	6 Carried Total	6 Overflow	7 Carried Trunk	7 Carried Total	7 Overflow	8 Carried Trunk	8 Carried Total	8 Overflow	9 Carried Trunk	9 Carried Total	9 Overflow	10 Carried Trunk	10 Carried Total	10 Overflow	CCS Offered
182	17	146	36	13	159	23	10	169	13	6	175	7	4	179	3	182
184	17	147	37	13	160	24	10	170	14	6	176	8	4	180	4	184
186	18	148	38	14	162	24	10	172	14	6	178	8	4	182	4	186
188	18	149	39	14	163	25	10	173	15	7	180	8	4	184	4	188
190	18	150	40	14	164	26	10	174	16	7	181	9	4	185	5	190
192	18	150	42	15	165	27	10	175	17	7	182	10	5	187	5	192
194	18	151	43	15	166	28	11	177	17	7	184	10	5	189	5	194
196	19	152	44	15	167	29	11	178	18	8	186	10	5	191	5	196
198	19	153	45	15	168	30	11	179	19	8	187	11	5	192	6	198
200	19	153	47	16	169	31	12	181	19	8	189	11	5	194	6	200
202	19	154	48	16	170	32	12	182	20	8	190	12	5	195	7	202
204	19	155	49	16	171	33	12	183	21	9	192	12	5	197	7	204
206	19	155	51	16	171	35	13	184	22	9	193	13	6	199	7	206
208	20	156	52	16	172	36	13	185	23	9	194	14	6	200	8	208
210	20	157	53	16	173	37	13	186	24	10	196	14	6	202	8	210
212	20	157	55	17	174	38	13	187	25	10	197	15	6	203	9	212
214	20	158	56	17	175	39	13	188	26	10	198	16	7	205	9	214
216	21	159	57	17	176	40	14	190	26	10	200	16	7	207	9	216
218	21	160	58	17	177	41	14	191	27	10	201	17	7	208	10	218
220	21	160	60	18	178	42	14	192	28	10	202	18	7	209	11	220
222	21	160	62	18	178	44	15	193	29	11	204	18	7	211	11	222
224	21	161	63	18	179	45	15	194	30	11	205	19	8	213	11	224
226	22	162	64	18	180	46	15	195	31	11	206	20	8	214	12	226
228	22	163	65	18	181	47	15	196	32	12	208	20	8	216	12	228
230	22	163	67	19	182	48	15	197	33	12	209	21	8	217	13	230
232	22	163	69	19	182	50	16	198	34	12	210	22	9	219	13	232
234	22	164	70	19	183	51	16	199	35	12	211	23	9	220	14	234
236	22	164	72	20	184	52	16	200	36	12	212	24	9	221	15	236
238	22	165	73	20	185	53	16	201	37	13	214	24	9	223	15	238
240	22	165	75	20	185	55	16	201	39	13	214	26	10	224	16	240
242	23	166	76	20	186	56	17	203	39	13	216	26	10	226	16	242
244	23	167	77	20	187	57	17	204	40	13	217	27	10	227	17	244
246	23	167	79	20	187	59	17	204	42	14	218	28	10	228	18	246
248	24	168	80	20	188	60	17	205	43	14	219	29	11	230	18	248
250	24	168	82	21	189	61	17	206	44	14	220	30	11	231	19	250

CCS Offered	Trunk Number 6 Carried Trunk	6 Carried Total	6 Overflow	7 Carried Trunk	7 Carried Total	7 Overflow	8 Carried Trunk	8 Carried Total	8 Overflow	9 Carried Trunk	9 Carried Total	9 Overflow	10 Carried Trunk	10 Carried Total	10 Overflow	CCS Offered
252	24	168	84	21	189	63	18	207	45	14	221	31	11	232	20	252
254	24	169	85	21	190	64	18	208	46	14	222	32	11	233	21	254
256	24	169	87	21	190	66	18	208	48	15	223	33	12	235	21	256
258	24	170	88	21	191	67	18	209	49	15	224	34	12	236	22	258
260	24	170	90	22	192	68	18	210	50	15	225	35	12	237	23	260
262	25	171	91	22	193	69	18	211	51	15	226	36	12	238	24	262
264	25	171	93	22	193	71	19	212	52	15	227	37	12	239	25	264
266	25	172	94	22	194	72	19	213	53	16	229	37	12	241	25	266
268	25	172	96	22	194	74	19	213	55	16	229	39	13	242	26	268
270	25	172	98	22	194	76	20	214	56	16	230	40	13	243	27	270
272	25	172	100	22	194	78	20	214	58	16	230	42	13	243	29	272
274	25	172	102	23	195	79	20	215	59	16	231	43	14	245	29	274
276	25	173	103	23	196	80	20	216	60	17	233	43	14	247	29	276
278	25	174	104	23	197	81	20	217	61	17	234	44	14	248	30	278
280	25	174	106	23	197	83	21	218	62	17	235	45	14	249	31	280
282	25	174	108	23	197	85	21	218	64	17	235	47	14	249	33	282
284	25	174	110	23	197	87	21	218	66	17	235	49	15	250	34	284
286	26	175	111	23	198	88	21	219	67	18	237	49	15	252	34	286
288	26	175	113	24	199	89	21	220	68	18	238	50	15	253	35	288
290	26	176	114	24	200	90	21	221	69	18	239	51	15	254	36	290
292	26	176	116	24	200	92	21	221	71	19	240	52	15	255	37	292
294	26	177	117	24	201	93	21	222	72	19	241	53	15	256	38	294
296	26	177	119	24	201	95	21	222	74	19	241	55	16	257	39	296
298	26	177	121	24	201	97	21	222	76	19	241	57	16	257	41	298
300	27	178	122	24	202	98	22	224	76	19	243	57	16	259	41	300
305	27	179	126	24	203	102	22	225	80	20	245	60	16	261	44	305
310	27	179	131	25	204	106	23	227	83	20	247	63	17	264	46	310
315	27	180	135	25	205	110	23	228	87	20	248	67	18	266	49	315
320	27	181	139	25	206	114	23	229	91	21	250	70	18	268	52	320
325	27	181	144	26	207	118	23	230	95	21	251	74	19	270	55	325
330	27	181	149	26	207	123	24	231	99	21	252	78	19	271	59	330
335	27	182	153	26	208	127	24	232	103	22	254	81	19	273	62	335
340	28	183	157	27	210	130	24	234	106	22	256	84	19	275	65	340
345	28	183	162	27	210	135	25	235	110	23	258	87	20	278	67	345
350	28	184	166	27	211	139	25	236	114	23	259	91	20	279	71	350

CCS Offered	Trunk Number 6 Carried Trunk	Total	Overflow	7 Carried Trunk	Total	Overflow	8 Carried Trunk	Total	Overflow	9 Carried Trunk	Total	Overflow	10 Carried Trunk	Total	Overflow	CCS Offered
355	28	184	171	27	211	144	25	236	119	23	259	96	21	280	75	355
360	29	185	175	27	212	148	25	237	123	24	261	99	21	282	78	360
365	29	186	179	27	213	152	26	239	126	24	263	102	21	284	81	365
370	29	187	183	27	214	156	26	240	130	24	264	106	22	286	84	370
375	29	187	188	28	215	160	26	241	134	24	265	110	22	287	88	375
380	29	187	193	28	215	165	26	241	139	25	266	114	22	288	92	380
385	29	188	197	28	216	169	26	242	143	25	267	118	22	289	96	385
390	29	188	202	28	216	174	27	243	147	26	269	121	23	292	98	390
395	29	189	206	28	217	178	27	244	151	26	270	125	23	293	102	395
400	29	189	211	29	218	182	27	245	155	26	271	129	23	294	106	400
405	29	189	216	29	218	187	28	246	159	26	272	133	23	295	110	405
410	30	190	220	29	219	191	28	247	163	26	273	137	24	297	113	410
415	30	191	224	29	220	195	28	248	167	26	274	141	24	298	117	415
420	30	191	229	29	220	200	28	248	172	26	274	146	25	299	121	420
425	30	191	234	29	220	205	28	248	177	27	275	150	25	300	125	425
430	30	191	239	29	221	209	28	249	181	27	276	154	25	301	129	430
435	30	192	243	29	222	213	28	250	185	27	277	158	25	302	133	435
440	30	192	248	30	222	218	29	251	189	27	278	162	25	303	137	440
445	30	192	253	30	222	223	29	251	194	27	278	167	26	304	141	445
450	31	193	257	30	223	227	29	252	198	27	279	171	26	305	145	450
455	31	193	262	30	223	232	29	252	203	27	280	175	26	306	149	455
460	31	194	266	30	224	236	29	253	207	27	281	179	26	307	153	460
465	31	194	271	30	224	241	29	253	212	28	281	184	27	308	157	465
470	31	194	276	30	224	246	30	254	216	28	282	188	27	309	161	470
475	31	194	281	30	224	251	30	254	221	28	282	193	27	309	166	475
480	31	195	285	30	225	255	30	255	225	28	283	197	27	310	170	480
485	31	196	289	30	226	259	30	256	229	28	284	201	27	311	174	485
490	31	196	294	30	226	264	30	256	234	28	284	206	28	312	178	490
495	31	196	299	30	226	269	30	256	239	29	285	210	28	313	182	495
500	31	196	304	30	226	274	30	256	244	29	285	215	28	313	187	500
505	31	196	309	31	227	278	30	257	248	29	286	219	28	314	191	505
510	31	196	314	31	227	283	30	257	253	30	287	223	28	315	195	510
515	31	196	319	31	227	288	30	257	258	30	287	228	28	315	200	515
520	32	197	323	31	228	292	30	258	262	30	288	232	28	316	204	520
525	32	197	328	31	228	297	30	258	267	30	288	237	28	316	209	525

CCS Offered	Trunk Number 6 Carried Trunk	6 Carried Total	6 Overflow	7 Carried Trunk	7 Carried Total	7 Overflow	8 Carried Trunk	8 Carried Total	8 Overflow	9 Carried Trunk	9 Carried Total	9 Overflow	10 Carried Trunk	10 Carried Total	10 Overflow	CCS Offered
530				31	228	302	31	259	271	30	289	241	28	317	213	530
535				31	228	307	31	259	276	30	289	246	28	317	218	535
540				31	229	311	31	260	280	30	290	250	28	318	222	540
545				31	229	316	31	260	285	30	290	255	29	319	226	545
550				31	229	321	31	260	290	30	290	260	29	319	231	550
555							31	261	294	30	291	264	29	320	235	555
560							31	261	299	30	291	269	29	320	240	560
565							31	261	304	30	291	274	30	321	244	565
570							31	262	308	30	292	278	30	322	248	570
575							31	262	313	30	292	283	30	322	253	575
580							31	262	318	30	292	288	30	322	258	580
585										30	293	292	30	323	262	585
590										31	294	296	30	324	266	590
595										31	294	301	30	324	271	595
600										31	294	306	30	324	276	600
605										31	294	311	30	324	281	605
610										31	295	315	30	325	285	610
615										31	296	319	30	326	289	615
620										31	296	324	30	326	294	620
625										31	296	329	30	326	299	625
630										31	296	334	31	327	303	630
635										31	296	339	31	327	308	635
640										31	297	343	31	328	312	640
645										31	297	348	31	328	317	645
650										31	297	353	31	328	322	650
655										31	298	357	31	329	326	655
660										31	298	362	31	329	331	660
665													31	330	335	665
670													31	330	340	670
675													31	330	345	675
680													31	330	350	680
685													31	330	355	685
690																690
695																695
700																700

CCS Offered	Trunk Number 11 Carried Trunk	Total	Overflow	12 Carried Trunk	Total	Overflow
182						
184						
186						
188						
190						
192						
194						
196						
198						
200						
202						
204						
206	3	202	4			
208	4	204	4			
210	4	206	4			
212	4	207	5			
214	4	209	5			
216	4	211	5			
218	5	213	5			
220	5	214	6			
222	5	216	6			
224	5	218	6			
226	5	219	7			
228	5	221	7			
230	6	223	7			
232	6	225	7	3	228	4
234	6	226	8	4	230	4
236	6	227	9	4	231	5
238	6	229	9	4	233	5
240	7	231	9	4	235	5
242	7	233	9	4	237	5
244	7	234	10	4	238	6
246	7	235	11	5	240	6
248	7	237	11	5	242	6
250	7	238	12	5	243	7

CCS Offered	Trunk Number 11 Carried Trunk	Total	Overflow	12 Carried Trunk	Total	Overflow
252	8	240	12	5	245	7
254	8	241	13	6	247	7
256	8	243	13	6	249	7
258	8	244	14	6	250	8
260	9	246	14	6	252	8
262	9	247	15	6	253	9
264	9	248	16	7	255	9
266	9	250	16	7	257	9
268	9	251	17	7	258	10
270	10	253	17	7	260	10
272	10	253	19	7	260	12
274	10	255	19	7	262	12
276	10	257	19	7	264	12
278	10	258	20	8	266	12
280	10	259	21	8	267	13
282	11	260	22	8	268	14
284	11	261	23	8	269	15
286	11	263	23	8	271	15
288	11	264	24	9	273	15
290	12	266	24	9	275	15
292	12	267	25	9	276	16
294	12	268	26	10	278	16
296	12	269	27	10	279	17
298	12	269	29	10	279	19
300	13	272	28	10	282	18
305	14	275	30	10	285	20
310	14	278	32	10	288	22
315	14	280	35	11	291	24
320	15	283	37	11	294	26
325	16	286	39	12	298	27
330	16	287	43	13	300	30
335	16	289	46	13	302	33
340	17	292	48	14	306	34
345	17	295	50	14	309	36
350	18	297	53	14	311	39

CCS Offered	Trunk Number 11 Carried Trunk	11 Carried Total	11 Overflow	12 Carried Trunk	12 Carried Total	12 Overflow
355	18	298	57	15	313	42
360	18	265	95	16	281	79
365	19	268	97	16	284	81
370	19	269	101	17	286	84
375	20	272	103	17	289	86
380	20	273	107	17	290	90
385	20	275	110	18	293	92
390	20	277	113	18	295	95
395	21	279	116	19	298	97
400	22	282	118	19	301	99
405	22	282	123	20	302	103
410	22	284	126	20	304	106
415	22	286	129	20	306	109
420	23	322	98	20	342	78
425	23	323	102	21	344	81
430	23	325	105	21	346	84
435	23	326	109	21	347	88
440	24	327	113	22	349	91
445	24	328	117	22	350	95
450	24	329	121	23	352	98
455	24	330	125	23	352	103
460	25	332	128	23	355	105
465	25	333	132	23	356	109
470	25	334	136	23	357	113
475	26	335	140	23	358	117
480	26	336	144	24	360	120
485	26	337	148	24	361	124
490	26	338	152	24	362	128
495	26	339	156	24	363	132
500	27	340	160	25	365	135
505	27	341	164	25	366	139
510	27	342	168	25	367	143
515	27	342	173	26	368	147
520	27	343	177	26	369	151
525	28	344	181	26	370	155

CCS Offered	11 Carried Trunk	11 Carried Total	11 Overflow	12 Carried Trunk	12 Carried Total	12 Overflow
530	28	345	185	26	371	159
535	28	345	190	27	372	163
540	28	346	194	27	373	167
545	28	347	198	27	374	171
550	28	347	203	27	374	176
555	28	348	207	27	375	180
560	28	348	212	28	376	184
565	28	349	216	28	377	188
570	28	350	220	28	378	192
575	29	351	224	28	379	196
580	29	352	228	28	379	201
585	29	352	233	28	380	205
590	29	353	237	28	381	209
595	30	354	241	28	382	213
600	30	354	246	28	382	218
605	30	354	251	29	383	222
610	30	355	255	29	384	226
615	30	356	259	29	385	230
620	30	356	264	29	385	235
625	30	356	269	29	385	240
630	30	357	273	29	386	244
635	30	357	278	29	386	249
640	30	358	282	29	387	253
645	30	358	287	30	388	257
650	30	358	292	30	388	262
655	30	359	296	30	389	266
660	30	359	301	30	389	271
665	30	360	305	30	390	275
670	30	360	310	30	390	280
675	31	361	314	30	391	284
680	31	361	319	30	391	289
685	31	361	324	30	391	294
690	31	362	328	30	392	298
695	31	362	333	30	392	303
700	31	363	337	30	393	307
705	31	363	342	30	393	312

APPENDIX D

CALL LOG REPORT

A call log report is shown in Figure D.1. According to APCO, this example should be representative of the variations that may be encountered. The header would contain the date, time, name of the PSAP, and name of each field in the report. There is an option to also print every shift change, half-hour, hour, or 24 hours.

Each call seized is assigned an identification number, shown under the column labeled ID. ANSPT is the name of the PSAP that answered the call. ORTY is the origination type. There are four types: direct in, transferred in, overflowed in, or action made by a supervisor barged-in on a call. SOURCE is where the call came in from. ANI is the telephone number of the station initiating the call. If this information is not available, the CO number is printed instead. SZ TIME is the time the call was seized. ANS is the time the call was answered. PS/AGNT is the position number and telecommunicators initials that answered the call. ACTN is the action taken by the telecommunicator, or caller if call is not answered. These can be transfers, abandons, etc. DEST is the PSAP that the call was transferred to if the call was transferred. ACTN TIME is the time that the action took place.

ID	ANSPT	ORTY	SOURCE	ANI	SZTIME	ANSTIME	PS/AGT	ACTN	DEST	ACTN TIME
15	RCWL1	DRIN	DWN/GRCO	0/456-4567	10:03:44	10:04:10	O1/RJR	DISC		10:11:27
16	RCWL1	DRIN	DWN/GRCO	0/345-2345	10:13:12	10:13:36	O1/RJR	TSFR	IPSAP2	10:13:58
								DISC		10:15:32
16	IPSAP2	TSFR	RCWEL1	0/345-2345	10:13:12	10:14:00	O1/JAC	TSFR	PSAP3	10:14:19
								DISC		10:14:53
16	PSAP3	TSFR	IPSAP2	0/345-2345	10:13:12	10:14:26	O1/RDW	DISC		10:15:12

Figure D.1 - Sample Call Log Record

VITA

The author was born in Berlin, New Jersey on July nineteenth, nineteen hundred seventy-three. She was granted a Bachelor of Science degree from the Sibley School of Mechanical and Aerospace Engineering at Cornell University in May of 1995. This work is part of the requirements for a Master of Science degree in Systems Engineering at Virginia Polytechnic Institute and State University. This degree will be received in August of 1996. She will begin her career with RWD Technologies, Inc. as a member of the MRP II/SAP Implementation Support Division in Columbia, Maryland starting in September of 1996.

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