Running Head: IMPACT OF AUTOMATIC VEHICLE LOCATORS ON INCIDENT RESPONSE

Leading Community Risk Reduction

Impact of Automatic Vehicle Locators on Incident Response Times in the Honolulu Fire Department

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Certification Statement

I hereby certify that this paper constitutes my own product, that where the language of other is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

Signed:______________________________________

Abstract

The problem was upon dispatch to emergency incidents, Honolulu Fire Department (HFD) fire companies were not meeting response times goals stated in the HFD's *Standards of Response Coverage* (SORC). The research purpose was to determine the impact of automatic vehicle locators (AVLs) on incident response times in the HFD after AVL implementation in 2006. Causal-comparative research was used to study the problem. The null hypothesis was AVLs had no impact on incident response times in the HFD. The alternative hypothesis was AVLs had an impact on incident response times in the HFD.

Fire departments and other first response agencies across the U.S. have spent millions to implement and integrate AVLs, computer-aided dispatch systems (CADS), enhanced and wireless 9-1-1 systems, and geographic information systems (GIS). Is there an established model to evaluate and document the effectiveness of such systems? What return on investment can other fire departments and public safety agencies expect for the financial resources they allocate to implement similar systems? This study's results provide insight into these issues.

Incident response time data was obtained from the HFD's Records Management System (RMS) database. Incident response times from the years 2001 and 2007 were compared to determine the impact of AVL implementation. Statistical analysis was performed on the data. Analysis generated statistically significant results, which supported rejection of the null hypothesis. The research results indicated AVLs have an impact on incident response times in the HFD. The results also indicated AVLs facilitate compliance with the HFD's established total response time goals.

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Impact of Automatic Vehicle Locators on Incident Response Times in the Honolulu Fire Department

Introduction

Measurement of incident response times has long been the primary metric fire departments use to evaluate the quality of service delivered to the public. Research indicates there is a relationship between incident response times and incident outcomes (Waters, 1999). Incidents with the shortest response times result in the best outcomes, whether the incident involves fire or an emergency medical situation (Dean, 2008; Fitch, 2005; United States Fire Administration [USFA], 2006). Thus, as a best practice, fire departments and EMS agencies dispatch resources with the shortest response time to an incident (Williams, 2005). The combination of automatic vehicle locators (AVLs), the Global Positioning System (GPS), computer-aided dispatch systems (CADS), and geographical information systems (GIS) is the enabler to seamlessly dispatch the closest fire department or EMS resource, unit, or apparatus, to an emergency incident. The use of these systems to allocate fire department resources to emergency incidents represents a substantial paradigm shift from dispatching methods used in the past. Can the new method of dispatching fire units be quantitatively supported as an improvement over previous methods? Successful implementation of AVLs and integration with CADS requires substantial commitment of fire department financial and human resources. It has been assumed fire department AVL implementation results in reduced incident times, but this assumption has not been empirically validated in published literature. The applied research project (ARP) that follows will statistically analyze Honolulu Fire Department (HFD) incident response times before and after AVL implementation to determine the impact of AVLs.

Problem Statement

The problem is HFD fire companies are not meeting response time goals established in the HFD *Standards of Response Coverage* ([SORC], 2005) document, potentially affecting public safety and incident operations at emergencies. Implementation of AVLs and CADS were intended to resolve this problem. Since these systems were implemented, however, there has been no effort to evaluate the effectiveness of AVLs on incident response times.

Purpose of the Research

The research purpose is to examine the impact of AVLs upon incident response times in the HFD. The results and analysis of the study will support documentation of lessons learned from AVL implementation. The study results could be used to document the return on investment (ROI) on the AVLs. Lessons learned from the AVL project will be used to improve implementation and enhance or maximize ROI of future IT projects by the HFD. Statistical analysis in the study may be used as a model to evaluate other IT related projects in the HFD. Finally, study results on the impact of AVL effectiveness may facilitate documentation to satisfy Homeland Security grant reporting requirements.

The research document will also satisfy the National Fire Academy's (NFA), Executive Fire Officer Program (EFOP), Leading Community Risk Reduction (LCRR) course requirements for the applied research project (ARP) (Department of Homeland Security [DHS], 2008).

Research Methodology

The research method to study the problem will be causal-comparative. Incident response times will be obtained from the HFD's records management system (RMS) database. Statistical analyses will be applied to the data. Incident response times from the year 2001 will be compared to incident response times from the year 2008 to test the hypothesis.

Research Hypothesis

The null hypothesis is AVLs have no impact on incident response times in the HFD. The alternative hypothesis is AVLs have an impact on incident response times in the HFD.

ARP required elements and sections

This ARP will contain 7 required elements, which are: (a) the Title page, (b) the Certification Statement, which assures originality of the ARP content by the researcher, (c) the Abstract, (d) the Table of Contents, (e) the Main body, (f) the Reference list, and (g) appendices. Within the ARP main body, there will be 7 sections: (a) the Introduction, which is this section, (b) Background and Significance, (c) Literature review, (d) Procedures, (e) Results, (f) Discussion, and (g) Recommendations (DHS).

Background and Significance

Purpose of this Section

In this section, the background of the problem introduced in the previous section will be explained in detail. The past, present, and future impact of the problem on the HFD will be discussed in this section. The method in which this ARP is related to the NFA, EFOP, LCRR course will also be discussed. Finally, linkage between this ARP and one of five USFA operational objectives will be revealed (DHS).

Background of the HFD

The HFD protects the entire island of Oahu, 604 square miles that comprise the City and County (C&C) of Honolulu. King Kamehameha III established the HFD in 1850. The HFD is considered the 12th largest metro fire department in the U.S. For the fiscal year 2006, the HFD operating budget was approximately $70 million. The HFD received initial accreditation from the Commission on Fire Accreditation International in 2000, and reaccredidation in 2005. The Fire Operations section of the HFD provides multi-mission emergency incident response with a workforce of approximately 1,100 career fire fighters from 44 stations in 5 battalions. Fire Operations provides fire suppression, emergency medical service (EMS), technical rescue, and hazardous materials incident response to over 900,000 residents and over 5,000,000 visitors annually. The resource numbers and types within Fire Operations are (a) 42 engine companies, (b) 13 ladder or quint companies, (c) 2 rescue companies, (d) 2 hazardous materials companies, (e) 2 tower companies, (f) 1 fireboat company, (g) 5 battalion commanders, (h) 1 assistant fire chief, (i) 5 tankers, (j) 1 mobile command center (MCC), (k) 2 helicopters, and (l) 1 helicopter tender. In 2006, HFD Fire Operations responded to approximately 36,000 emergency incidents. The HFD's Administrative Services Bureau, Support Services Division, and Planning and Development support Fire Operations (*Annual Report*, 2005).

AVL Project Background

In 2005 and 2006, the HFD installed AVLs along with mobile data terminals (MDTs) to all first-line apparatuses within the fire operations section. Integration of AVLs with the CADS was intended to optimize HFD resource allocation across the jurisdiction, whether companies were traveling within or out of their first-due areas. The primary function of the AVL was to provide the real-time GPS location of all apparatuses to the CADS. The system would enable fire dispatchers to assign the closest available HFD resource(s) to an emergency incident. The CADS dispatch *solution* would be based on the actual position of available resources, and not based upon the dispatchers' best estimate. The process, known as *dynamic dispatching*, would theoretically reduce incident response times for all AVL-equipped apparatuses (*2006-2010 Master Strategic Plan*, 2006).

In 2005, the HFD first deployed AVLs and MDTs as a pilot project to first-line apparatuses in a single battalion within fire operations. Once a major hardware-software problem with the MDT was resolved from the pilot project, the MDT project manager was satisfied with system reliability. In 2006 the HFD deployed of AVL-MDTs to all first-line apparatuses in the remaining four fire operations battalions. Upon completion of deployment, AVLs were installed in 42 engines, 15 aerials, 2 hazmat vehicles, 5 battalion chief vehicles, and 1 mobile command center. AVL-MDT installation into 2 heavy rescue vehicles has not been completed at the time this document was written.

Past, present, and future impact of the problem on the HFD

Dispatch process before CADS implementation

In the years prior to CAD implementation, the HFD dispatch process was based partially on IT, but relied more heavily on the diligence and cognitive skills of fire dispatchers. Upon receipt of a 9-1-1 call, the call-taker within Fire Dispatch would obtain and write the incident location and incident type on a punch card. The punch card was handed to the dispatcher, who then entered the location into a computer program titled the Master Street Address Guide (MSAG). The MSAG provided a list of recommended fire apparatuses to assign to the incident location, based on proximity of closest fire stations. An apparatus status board constructed of a metal backing and magnetized toy trucks labeled with apparatus type and number were used to track companies assigned to incidents, out-of-service, or relocated to other areas. Maintaining the status board properly required diligence from the dispatcher to move the magnetic trucks representing fire companies into areas on the board that designated them as assigned, out-of-service, or relocated. Occasionally, the availability of one or more fire companies was misrepresented, based solely on the location of the magnetic trucks on the status board.

Before dispatching the MSAG recommended companies, however, the dispatcher would need to check the status board to ensure companies on the MSAG list were available. The dispatcher then assigned the companies from the MSAG list that appeared available after cross-checking the status board. Due to reasons such as the example in the last sentence of the preceding paragraph, unavailable companies were occasionally dispatched by radio to emergencies. Efforts to correct such errors resulted in delays to resend appropriate resources to these incidents. Such delays in providing emergency services had the potential to adversely affect public safety and incident operations. These consequences, in turn, could increase liability exposure for the HFD and put public citizens and HFD personnel at risk.

Incident times were manually stamped on the punch card by a time clock and companies assigned to incidents were written on the punch card by pencil. Upon incident termination and return to station, companies assigned to the incident would phone Fire Dispatch to obtain their times, incident address, and incident number so they could journalize the information and use it to complete their NFIRS report.

The dispatch system described in the preceding paragraphs was labor intensive, time-consuming, and had a high potential for errors anywhere along the workflow. If two or more multi-company incidents evolved simultaneously, the workload for fire dispatchers increased dramatically. In addition, the high volume of radio traffic during these situations intensified stimuli and workload for fire dispatchers.

HFD CADS Implementation

In the year 2000, the HFD implemented its CADS, the primary tool fire dispatchers now use to allocate resources to emergency incidents. The CADS provides a recommended dispatch *solution* based on (a) incident location, (b) a pre-defined response plan according to incident type, (c) the location of available resources (apparatuses) within their respective first-due areas, and (d) the most direct route to the incident location. The dispatcher can choose to accept the CAD recommendation, or reject it. Early in the CADS learning curve, experienced fire dispatchers found they could mentally generate a dispatch solution much quicker than the CADS. Dispatchers would frequently eschew CADS recommendations, and based on the dispatchers' past experience, assign companies to emergencies.

The main advantage of the CADS was it could track unavailable fire companies that were assigned to incidents, out-of-service for various reasons, or relocated into first-due areas other than their own. Therefore, the CADS could quickly generate an accurate dispatch recommendation when 5, 10, or more companies were either assigned to incidents, out-of-service, or relocated. The concept of span of control (Omodei, McLennan, & Reynolds, 2005) states an individual can maintain situational awareness of only 3-7 discrete objects at a time, while 5 objects is optimal. The CADS still requires diligence from dispatchers to maintain the appropriate status of HFD companies. However, the CADS accounts for unavailable resources in its recommendation and eliminates the need to check an additional information source prior to dispatch. Thus, dispatch errors are reduced and fire companies are assigned to emergencies more rapidly when compared to the manual dispatch process. Finally, call processing time and dispatch time are reduced when using CADS.

The CADS generates an incident number for each emergency which occurs in the HFD's jurisdiction. Information from enhanced 9-1-1 calls such callers' name, address, and phone number are passed directly into the CADS Incident Call Taker's screen by the local telephone utility's Automatic Number Identifier-Automatic Location Identifier (ANI-ALI [pronounced *annie-alley*]) system. Once the call-taker enters selects the incident type and the incident radio channel, the emergency workflow enters the CADS Incident Queue. The fire dispatcher can now review the CADS resource recommendation and assign the recommended resources to the incident, or choose to assign other resources to the incident.

The CADS semi-automatically maintains a database of incident time benchmarks, such as (a) 9-1-1 call receipt time, (b) first key stoke in the CADS, (c) time dispatch information entered CADS Incident Queue, (d) time of apparatus dispatch, (e) enroute to scene time, (f) arrival at scene, and (g) time apparatus was available from the incident. Fire dispatchers record items *d-g* listed above by mouse clicks in the CADS. The incident number, times, location and resources assigned to the incident are passed to the HFD RMS once the incident is terminated. The information passed from CADS to RMS forms the basis for the NFIRS-compliant incident record database maintained by the HFD. Each incident record must be completed by the officer of the first-due company assigned to the emergency. Utilization of the NFIRS-compliant RMS is required of the HFD because it has accepted Assistance to Firefighters Grants (AFG) from DHS.

CADS after AVL Integration

Geographic information systems (GIS) and the global positioning system (GPS) integration extend applications associated with vehicle tracking and routing. The AVL receives a GPS signal and updates the apparatus location every 5 seconds back to the CADS. The CADS tracks the location of all AVL-equipped apparatuses in a georeferenced database which contains all streets in the HFD's jurisdiction. Once an emergency incident location is entered into the CADS, the location is verified by the CADS streets database. The CADS then recommends the dispatch based on (a) incident location, (b) a pre-defined response plan according to incident type, and (c) the real-time location of the HFD apparatus with most direct route to the incident location. This process is known as dynamic dispatching, which is based on the updated GPS location of each HFD resource. Dynamic dispatching represents a paradigm shift from the traditional method of fire dispatching based on first-due areas. Effective use of dynamic dispatching should theoretically reduce overall incident response times for the HFD. Furthermore, dynamic dispatching enables fire operations to meet fire suppression and emergency response goals described in the HFD's *Standards of Response Coverage* (2005).

Insufficient Leverage of AVLs

Although the AVL system is deployed throughout all first-line apparatuses in the HFD, there are situations where the full capability of the AVL isn't leveraged. For example, fire companies will occasionally self-dispatch to emergency incidents when they hear other companies being assigned to an incident. The reason is officers of the self-dispatched companies believe they can reach the scene faster than the original company that was assigned to the incident. The HFD has an unwritten policy that both companies will respond to the scene in such situations, and after the first company arrives at scene, the second company is cancelled if they're not needed. This policy puts two companies at risk of motor-vehicle collision or other hazard(s) during emergency response, rather than just one company. Consequently, the potential risk is doubled for public citizens who are traveling along the response routes the two fire companies are using to get to the same incident.

There are personnel within the HFD that may be wary of IT solutions regardless of the solutions' proven reliability. Their reluctance to rely on IT is published in research by Davis (1985) on the Technology Acceptance Model (TAM), which will be discussed within the Literature Review. Thus, such personnel may not accept nor rely on the AVL to the system's full capability.

The two preceding examples illustrate the reasons there may be an adverse impact on incident response times because the AVL is not allowed to function as designed.

ARP Justification

Over the past several years, the HFD has invested substantial human and financial resources in various IT projects. This ARP may help the HFD to identify appropriate methodologies or strategies to evaluate the impact and effectiveness of such projects. This study may also establish a framework to assess the ROI of other IT projects in the HFD.

Research Problem Linkage to LCRR Course content

The research problem is linked to the content of the LCRR course which declares risk reduction involves the balancing risk and fire department resources in a comprehensive strategy. The HFD has established incident response time goals published in its SORC as a component of its strategy. Chapter 3 of the HFD SORC (2005), states:

> In order to save lives and limit property damage, fire companies must arrive as quickly as possible with adequate resources to do the job. One of the greatest challenges facing fire department managers is to ensure the timely arrival of resources so fire can be effectively controlled without increasing the risks to fire fighters.
>
> Time is a critical factor since the growth of a fire is exponential. Fires continue to grow until they run out of fuel or the fire department intervenes. Response time critically affects the level of service provided to those requesting assistance, including medical and rescue assistance.

The research problem is also linked to LCRR course content related to the application of data analysis while developing a strategy for community risk reduction.

Research Problem Linkage to USFA Operational Objectives

The research problem in this ARP is linked to the USFA operational objective "to respond appropriately in a timely manner to emerging issues" (DHS, 2008, p. II-2). Insight into the research problem may help the HFD to identify factors that have an impact on incident response times. The research problem is also linked to the USFA operational objective to reduce loss of life of firefighters (DHS).

Definition of Terms

Georeferenced: "To assign coordinates from a known reference system, such as latitude/longitude, universal transverse Mercator, or State Plane, to the coordinates of an image or planar map" (Kennedy, 2003, p. 57).

Literature Review

Purpose of this section

The purpose of this section was to achieve an exhaustive review of related literature associated with the research problem. The literature review was intended to support the researcher during investigation of the problem. This section concentrated on the discovery of other similar cases where organizations leveraged IT and used AVLs or similar solutions to improve incident response times. This section also focused on the application of GPS technology in industries with similar operational environments to public safety response agencies. Through review of prior similar studies, a benchmark or starting point was established for this ARP.

Literature Review Methodology

The Literature Review began with examination of various reference materials at the NFA's Learning Resource Center. Research continued at various Honolulu public libraries, Hawaii Pacific University's library, and the University of Hawaii's libraries. Research for this ARP was also conducted using EBSCO's (http://web.ebscohost.com/) online research database and Google's Scholar search engine (http://scholar.google.com/). The search for reference material first started with materials that were related to AVLs and public safety agencies. Subsequent searches included peer-reviewed journals related to management of information systems and military strategies. Finally, the HFD's own internal documents, memos, meeting minutes, manuals, and publications were examined for the Literature Review.

Incident Response Times as Benchmarks

Analysis of incident response times has long been the traditional method to evaluate performance throughout the fire service industry. In addition, EMS agencies use response time analysis as one measure to evaluate performance (Dean, 2008). However, the use of fractile analysis, rather than averages of response times is quickly gaining traction within both fire service and EMS agencies. According the fourth edition of the Commission on Fire Accreditation International's (CFAI) *Creating and Evaluating Standards of Response Coverage for Fire* (2003), fractile response time analysis is far more effective to evaluate response performance than average response time analysis.

Assigning the resource with the most direct route to an emergency is the core dispatch strategy for the HFD (*Standards of Response Coverage*, 2005). This strategy is consistent with other fire and EMS providers listed in this section.

Research by Dean (2008) found efficient deployment of EMS resources presented a substantial challenge for emergency managers in Baltimore, Maryland. The research results recommended the best improvement to effectively deploy EMS resources was to dispatch the closest ambulance to an emergency. The study indicated the use of dynamic dispatching could likely achieve the recommended improvement. Although the study did not specifically mention AVL as a technology, it did recommend a solution to track the real-time GPS location of EMS resources.

The dispatch policy for Puckett EMS in Cobb County, Georgia is to send the EMS unit that is closest to the emergency incident. For Puckett EMS, the policy is driven by their belief that "the faster EMS can respond to calls, the better the overall patient care" (Garrison, 2008).

Implementation of CADS in combination with AVL/GPS technology has enabled Puckett EMS to comply with this dispatch policy.

The Colorado Springs Fire Department found AVL and CADS technology improved its dispatch process because the system provided live routing information. Live routing is a computer algorithm that calculates the shortest route to an incident from a resource location. The algorithm accounts for street routes, speed limits, and a time penalty based on apparatus size and weight to determine which resource has the shortest response time to an incident (Blankinship, Harris, Kolarik, & Wrobel, 2006).

In the article *Incident Management: Process Analysis and Improvement*, Hall (2001) declared response units should be spatially located to minimize response times. In addition, the article stated information regarding the accurate location of resources would be extremely valuable to public safety agency dispatchers. The article concluded that real-time, GPS-based resource location data is imperative for dispatchers to ensure the closed units are deployed to an emergency.

GPS use in the military

During the Gulf War of 1991, Operation Enduring Freedom in Afghanistan, and Operation Iraqi Freedom, U.S. Armed Forces deployed a system known as Network-Centric Warfare (NCW). NCW integrates a combination of different information gathering devices and GPS technology to obtain an accurate assessment of the battlespace, available resources, and enemy positions. Many analysts believe the capability to leverage NCW allowed U.S. forces to inflict maximum destruction upon enemy targets while practicing economy of force. In these theaters NCW facilitated target destruction while minimizing the impact of collateral damage, civilian deaths or injuries; and exposing U.S. forces to a comparatively minimal amount of casualties (Alberts, Garstka, & Stein, 2001).

NCW integrates GPS with a variety of sensors from different platforms to accurately depict the battlespace. For example, data obtained from orbiting satellites, airborne warning and control system (AWACS) aircraft, remotely-piloted unmanned airborne vehicles (UAVs), joint surveillance and target attack radar system (J-STARS), and ground-based intelligence gathering units all combine to provide improved situational awareness for U.S. battlefield commanders. Improved situational awareness permitted the flexibility of redirecting in-flight cruise missiles in real time to new targets even after they were launched (Wall & Fulghum, 2003).

By using NCW and GPS the U.S. military reduces s*ensor-to-shooter* time, or the elapsed time from target detection to threat engagement. Sensor-to-shooter time was typically many hours or even days in past conflicts (Pustam, 2003). This lag would be highly ineffective in the current battles in Afghanistan and Iraq where mobile, flexible targets emerge within a few minutes, strike, then quickly return to hiding. The U.S. military's goal is a sensor-to-shooter time of ten minutes or less. Military planners believe the goal is achievable through the use of IT to automate many of the processes that now require human intervention (Murdock, 2002).

Conceptually, the mission of fire service organizations has the same objectives as the military. The fire service also battles an enemy in accomplishing its mission. The enemy may be an uncontrolled fire, hazardous chemical release, building collapse, or people trapped in cars from an automobile accident. Fire departments continually seek to reduce their own sensor-to-shooter time, or the elapsed time between incident notification and the initial arrival of resources at the incident. Therefore, fire departments must deploy the closest available resources to an emergency. Furthermore, fire departments must also preserve the lives and property of civilians and protect fire department personnel from injury. Finally, fire departments must prevent collateral damage to property when extinguishing a fire or mitigating a chemical release.

While it is unlikely that domestic fire service organizations will deploy a network of satellites and AWACS aircraft, GPS technology used in NCW has trickled down to the fire service. GPS technology is integrated with CADS to accurately locate fire department assets-trucks or apparatuses. The combined systems are used to dispatch the closest available and appropriate resource(s) to the emergency incident. Dispatching the closest resources to an incident helps improve patient survivability in the case of a medical response, or improve property conservation during a fire-related incident (Garrison, 2008).

Lifting the Fog of War

Warfare on the battlefield is likely the most difficult decision-making environment imaginable. The major influence is the fog of war, first described by Carl von Clausewitz in 1812. Von Clausewitz characterized the concept as “the realm of uncertainty; three quarters of the factors on which action is wrapped in a fog of greater or lesser uncertainty” (Owens, 2000, p. 12). According to Admiral Bill Owens (2000), NCW lifted the fog of war during Operation Desert Storm, providing the U.S. coalition forces with enhanced situational awareness, a common operational picture, and economy of force. The fire ground is potentially the second most difficult decision-making environment, especially during the first few moments of operation. AVL implementation may generate an additional benefit during incident operations. AVL-enabled MDTs allow incident commanders (ICs) to see GPS locations of responding units, which may help the IC formulate incident strategy and tactics.

The Technology Acceptance Model

The TAM by Davis (1989) is widely accepted throughout information systems research as a robust and legitimate model that describes ease of IT use, IT usefulness, and intention to use IT. Indeed, a search of the EBSCO online research database using *technology acceptance model* as a keyword and *peer-reviewed journals* as a parameter returned more than 300 individual citations. Davis established the TAM in 1986 based upon the TRA (Adams & Nelson, 1992). The TRA demonstrated individuals rationalize practical and social impacts of their actions when deciding what to do. Individuals then devise a plan of action based on *value-bearing* ideas concerning impact of the behavior and beliefs about others' opinion of the behavior. TRA also claims an individual's execution of a specific behavior and intent is mutually determined by that individual's attitude and *subjective norm* concerning the specific behavior (Koufaris, 2002).

The TAM has been the basis for many studies in information systems (IS) since it was first introduced. The TAM was developed to forecast and explain the voluntary usage of IT in the workplace. The primary purpose of TAM was to establish a foundation for detecting the impact of external factors on internal beliefs, attitudes, and intentions. External factors might consist of system design, training, documentation, and user support. Such external factors are expected to impact intentions and usage through perceived ease of use and perceived usefulness (Davis, 1989). The TAM recommends perceived usefulness and perceived ease of use as drivers for an individual's use of a new technology (see Figure 1). TAM variables have been verified to be reliable and legitimate in many applications and replications that included diverse technologies and user populations (Wexler, 2001). The TAM has also received extensive support through numerous studies as described in a meta-analysis by Ma and Liu (2004). In these studies the TAM has been found to be a robust model regardless of time, environment, populations, and technologies.

The TAM is also based upon the theory of planned behavior (TPB), which was used to interpret and forecast individuals' behavior in various settings (see Figure 2). The TPB was used to examine user reactions and technology usage performance of 118 workers introduced to a new software system over a five-month period. The TPB found technology usage decisions by younger workers were positively influenced by attitude toward using technology, while older workers were positively influenced by subjective norm and perceived behavioral control (Venkatesh & Morris, 2000).

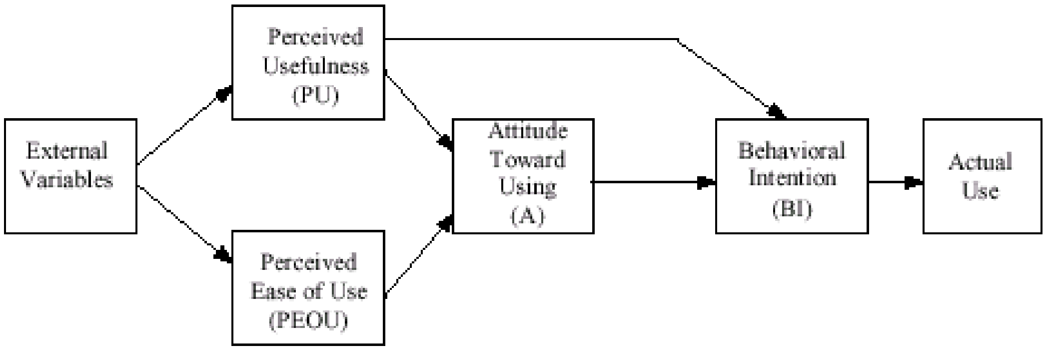

Figure 1.

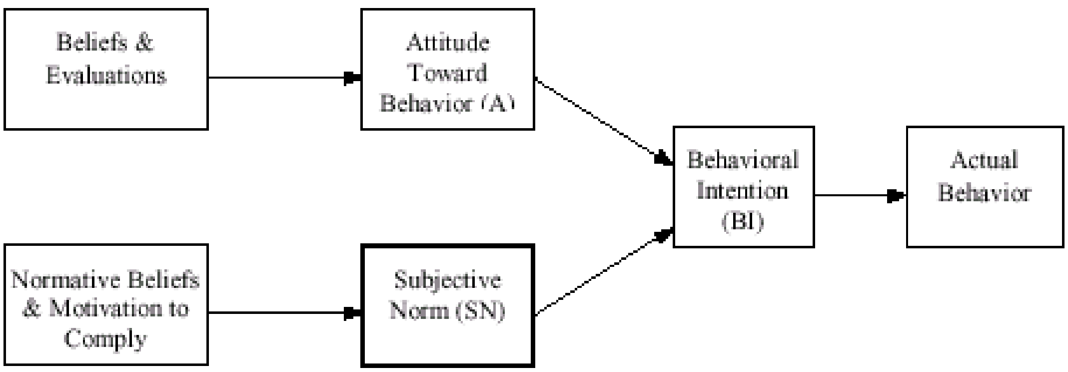

Figure 2.

Procedures

Purpose of this Section

This section will explain how the final results of the research were obtained. The procedures described in this section will provide sufficient information so others may replicate the ARP. This section will also describe methods the researcher implemented to achieve final results (DHS).

Data collection

The data collected in this study was obtained from the HFD RMS. Using Microsoft Excel, the data was downloaded from the RMS server to an Excel spreadsheet using a open database connection (ODBC). After connecting to the RMS database remotely, the table containing incident response times for the years 2001 and 2007 were located. Only columns containing data needed for the study were selected, and then opened in MS Excel.

The sample data set is a subset of the Apparatus tables in the contained in the HFD RMS relational database. The Apparatus table for each year used in the study has more than 40 columns and more than 37,000 rows. Each row is a record for each incident occurring within the HFD's jurisdiction. Therefore, only the table columns relevant to the study were downloaded.

Data from 2001 was downloaded because there no apparatuses in the HFD with an AVL at that time. Data from 2007 was used because all HFD apparatuses had an AVL installed, except for 2 heavy rescue vehicles.

A cross section of incident response times containing various apparatus types, months of the year, and different response areas were downloaded to adequately sample the HFD population. Although this methodology is not totally random, it is assumed to be adequate for this study. For example, different months of the year were sampled when road conditions contained various levels of traffic congestion. In addition, different hours of the day were sampled such as times during peak and off-peak traffic flow. These efforts were intended to normalize the sample distribution. Incident response times from three levels of concentration listed in the HFD SORC; (a) urban, (b) suburban, and (c) rural were obtained so these factors could be included in the analysis. Although fractile incident response time information is readily for HFD apparatuses, the fractile times were not used because they do not represent a sample of the entire population. Use of the 80% fractile times would have eliminated sampling 20% of the population. Finally, information whether the incident times contained relocating companies was factored into the data because this characteristic may have an impact on incident response times.

Analysis

The data contained in the Excel spreadsheets were opened using the Statistical Package for Social Sciences (SPSS) 13.0 for Windows software. Once data entry was completed, statistical procedures were performed on the data. Output from the statistical procedures summarized in the Results section. Outputs from the statistical procedures are displayed in the Appendix.

Variables

The incident response time dataset contained these variables: (a) apparatus, or company identification, (b) incident number, (c) shift (platoon), (d) NFIRS incident type, (e) Census Tract, (f) total response time (TRT), (g) turnout time, (h) dispatcher call-processing time, and (i) drive time (elapsed travel time). Drive time is automatically calculated in the RMS by subtracting the time the company reported enroute to scene, and their arrival at scene. The *arrival at scene* column from the RMS Apparatus table captures the arrival of the first HFD company, whether the emergency is a single or multi-company incident. Not all these variables were used directly for this study. However, the variables were obtained to facilitate further similar research. Variables added manually to the incident response time dataset were: (a) *TRT goal* met; (b) *relocating company*; (c) *AVL installed*; (d) *SORC concentration type*-urban, suburban, or rural; (e) *apparatus type*-engine, ladder, or quint; and (f) *special operations* company. A few of the variables in the sample dataset were recoded for statistical analysis by SPSS.

The methodology used to code the variables used for the study will be explained here. The variable for *travel time* was coded as an interval data type. The variables: (a) *TRT goal met*, (b) *relocating company*, and (c) *AVL installed* were all nominal data types, but were coded as *0* for *no* and *1* for *yes* for statistical analysis. The variable for *SORC concentration type* was coded *1* for urban, 2 for suburban, and *3* for rural. The *apparatus type* variable was coded *1* for engine, *2* for ladder, and *3* for quint. Criteria for variables *TRT goal met* and *SORC* *concentration type* can be found in the HFD SORC (2005). The determination of *apparatus type* was self-explanatory based on the fire company identification. Criteria for determining a company as *relocating* was obtained verbally through conversations with HFD fire dispatchers.

The dependent variable for the study is *drive time*. The covariate is *TRT goal met*, because this variable is related to drive time. The primary independent variable is *AVL installed*. The remaining variables are also independent variables. Statistical analyses will be applied to the primary and other independent variables to study their impact on the dependent variables. If there are statistically significant results, these will be used to support rejection or failure to reject the null hypothesis.

Limitations

The first limitation of this study is the sample dataset may not be a reflection of the standard normal distribution. However, the dataset was obtained using a methodology with this limitation in mind. The data gathering methodology is explained in the *data collection* section.

The second limitation of this ARP is time. The ARP was allowed a six-month timeframe for completion (DHS). The ARP is required to be sent by August 15, 2008 to the NFA, EFOP office.

The third limitation is the financial limitation applied to this study. This ARP had no formally established budget; therefore, no financial resources were allocated to this study. Finally, the researcher is currently on a restricted budget, which will further limit the study.

Delimitations

The scope of this study was limited to incident response times of fire apparatus within the Operations section in the HFD. The data set containing HFD incident response times from the years 2001 and 2007 was downloaded. The reason is in the year 2001; no HFD fire apparatus had an AVL, although the CADS was fully implemented. In 2007 all HFD fire apparatuses had AVLs, except for the 2 heavy rescue companies. Therefore, incident response times from 2001 and 2007 will be examined for any statistically significant difference(s).

As much as possible, the sample data obtained was a relatively normal distribution of incident response times. The dataset contained a sample of HFD incident response times across various factors, which are listed in the *data collection* section, above.

Strengths and Weaknesses

Strengths

The researcher complied with established research methodologies for the ARP. The data was obtained by download to limit the potential for typographical error during data entry. SPSS 13.0 for Windows will be used for statistical analysis on the data. SPSS is a powerful and robust tool that has been widely used for statistical analyses throughout many businesses and research organizations.

Weaknesses

The possibility exist that the data gathered for the study has been altered. Although the time stamps that reflect response times are passed automatically from CADS to RMS, personnel responsible for completing incident reports in the RMS had the capability to edit these times. The personnel may have edited the times in cases they believed the times were inaccurate. Furthermore, capture of response times in the CADS requires human input, and there may have been occasions when human interaction with the CADS occurred at the wrong moment. For example, in 2001, capture of incident times in the CADS required a mouse click by dispatchers when officers announced by radio their companies were “responding to scene” or “at scene”. There may have been occasions where such radio announcements were not heard by dispatchers, or the workload within the dispatch environment prevented them from clicking the mouse at the correct moment to capture the time in the CADS.

Assumptions of the ARP

The ARP was conducted under the following assumptions. First, the data obtained from the RMS database is generally accurate. Second, the data has not been modified, manipulated, or tampered with by any means or motive. Third, the purpose of the study is to evaluate the impact and effectiveness of AVLs and to gain insight into factors affecting its effectiveness. It is not the study's purpose to place blame or criticize the personnel, policies, procedures, strategies, or tactics of the HFD. It is assumed anyone reviewing this ARP will maintain a similar position.

Alternatives to this ARP

The HFD may choose to hire an individual consultant or firm to determine the impact of AVLs on incident response times. The second alternative is the HFD may use analysts employed within the Honolulu C&C to conduct a similar study. The third alternative is the HFD may use other officers seeking to satisfy NFA EFOP requirements to conduct research similar to this ARP.

Results

Purpose of the section

This section will describe the study results. This section will explain if data from the survey results support rejection of the null hypothesis. Descriptive results for each variable will be described in narrative form. Statistical procedures will be applied to the data in order to test the hypothesis. Other factors related to the research problem will be analyzed, because EFOP ARP Guidelines permit publishing unexpected results that have potential impact on the problem (DHS). Results at the .05 or .01 significance level will be summarized in this section, as these confidence levels are commonly accepted within the research community as statistically significant (APA, 2001).

Descriptive Results

The sample size of incident response times is 978. The mean of the incident response times (drive time) is 3.71, the standard deviation is 3.233, and the variance is 10.450. Skewness is 3.560, which is reflected in the shape of the Histogram. The variable drive time does not appear to have a normal distribution according to the Histogram, which is found in the Appendix. This was confirmed by the *One-Sample Kolmogorov-Smirnov* (K-S) test. The result of the K-S test was statistically significant at $p < .05$, therefore, drive time does not have an approximately normal distribution. The distribution for the variable drive time appears to be log normal. Because the sample does not have a normal distribution, non-parametric statistical procedures will be used.

The percentage of urban fire companies used in the study is 70%, suburban companies is 23%, and the percentage of rural fire companies in the study is approximately 7%. The percentage of engine companies used in the study is 65.2%, percentage of ladder companies is 30.6%, and the percentage of quints in the study is 4.2%. The percentage of companies meeting their TRT goals in the sample is 54.6% and the percentage of companies that did not meet their TRT goals is 45.4%. The percentage of fire companies in the sample not designated as relocating is 76.6%, and the companies designated as relocating is 23.4%.

Non-parametric Correlational Results

Statistically significant results were found between pairs of variables when performing non-parametric correlational tests on the sample data. A relationship was discovered between the primary independent variable, *AVL installed*, and the dependent variable, *drive time*. Correlations were also discovered between variables for *SORC concentration type* and the variable representing *TRT goals*. The dependent variable *TRT goals* was found to be related to the independent variable for *relocating company*. The results of the correlational tests can be found in the Appendix.

When incident response times from the year 2001 to incident response times from 2007 were compared, a statistically significant difference was found using the Wilcoxon Signed Ranks Test.

The non-parametric test results listed in the preceding paragraphs support rejection of the null hypothesis. The results indicate AVLs have a statistically significant impact on HFD incident response times.

Discussion

Purpose of the Section

The researcher's interpretation of the results will be provided in this section. This section is the only one in the ARP where the researcher will express his opinion. Links between the results other research and the results of this ARP will be established. The impact of the research results to the HFD will also be presented in this section.

Correlations

The result that correlation was statistically significant at the $p < .01$ level between the variables of *AVL installed* and *TRT goals met* indicates AVL implementation is helping HFD resources to meet established benchmarks. The positive correlation supports the conclusion that the HFD resources with an AVL will meet their total response time goals. The negative correlation between the variables *relocating* company and *TRT goals* indicate that relocating companies may have difficulty meeting total response time goals. The cause could be such companies are unfamiliar with the areas they relocate into, and the routes they use during incident response may not be optimal. Furthermore, the relocating companies may travel at slower speeds than first-due companies in the same area, possibly due to the precautions relocated companies take to ensure they don't bypass an incident location. A third possibility is relocated companies respond to incidents from locations more distant than first-due companies, therefore prolonging incident response times.

A significant negative correlation was generated between the variables *AVL installation* and *drive time*. Upon consideration, this appears consistent with this study's alternative hypothesis. The variable *AVL installed* is coded as *0* for no and *1* for yes; while *drive time* data was downloaded directly from the RMS, with the shorter response times preferred. Therefore, an HFD resource with an AVL, coded as *1*, will experience decreasing incident response times as indicated by the negative relationship between the variables. Hence, the study's results support rejection of the null hypothesis. From the research results, AVL implementation has an impact on incident response times in the HFD.

The non-parametric test for *2 related samples* revealed a statistically significant difference in incident response times between 2001 and 2007. The *Wilcoxon Signed Ranks Test* result was significant at $p < .05$, which also supports rejection of the null hypothesis. From this test, there appears to be a significant difference in HFD incident response times after AVLs were installed in fire apparatuses.

Recommendations

Purpose of the Section

This section will provide recommendations to resolve the research problem. The recommendations will be based on the research results. In addition, the need for additional research will be examined.

Response Times and Safety

The results from the statistical procedures in this ARP supported rejecting of the null hypothesis, that AVLs had no impact on incident response times in the HFD. AVLs only impact a small component of total response time, which is travel time. However, there are many other factors and components that have an impact on incident response times. The primary factor is safety. Fire response units must travel to an incident promptly, but with a degree of safety. It is recommended that any decision-maker in the HFD use a risk analysis process prior to making decisions. It could be accomplished informally and quickly, depending on the situation and risk, or it could be accomplished formally with modeling and documentation. The risk analysis may occur on a daily basis, for instance, an apparatus operator deciding to drive through an intersection against a red light during incident response. The operator must consider the benefit of his actions against the risks. The result is the calculated value (benefit divided by risk) of any incident action, tactic, or strategy. If the value of any planned action is less than one (benefit less than risk) an alternative plan of action is recommended. If the calculated value is equal to one (benefit equals risk); then the plan under consideration should be implemented with caution. If the value is greater than one (benefit greater than risk), the plan should be implemented.

Additional Research Needed

One of the most obvious solutions to the problem of resource allocation and incident response times is to deploy additional resources. On the surface, this solution seems straightforward. However, simply building more fire stations, purchasing more apparatuses, and hiring additional personnel is virtually impractical, if not impossible. Deploying a single fire apparatus in a new fire station and filing the newly created positions would require millions of dollars in implementation and maintenance costs. Furthermore, vacant land in Honolulu to implement such a solution is scarce, and Honolulu real estate is among the most expensive in the nation. Therefore, it is recommended the HFD conduct additional research using GIS analytics or similar tools to evaluate redeployment of existing resources across Honolulu.

The HFD may also desire to conduct a regression analysis to examine impact of AVLs or other factors on incident response times. The HFD may desire to analyze a larger dataset, in order to obtain a larger sample of the population and increase research accuracy. The HFD may choose to conduct additional research to examine the effect factors other than AVLs have on incident response times. A workflow analysis may be required to study each factor's impact on total response time and to recommend improvements to reduce response time components.

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Appendix

Table 1
Descriptive statistics for drive time

Elapsed travel time

N	Valid	978
	Missing	0
Mean		3.71
Median		2.89
Std. Deviation		3.233
Skewness		3.560
Std. Error of Skewness		.078

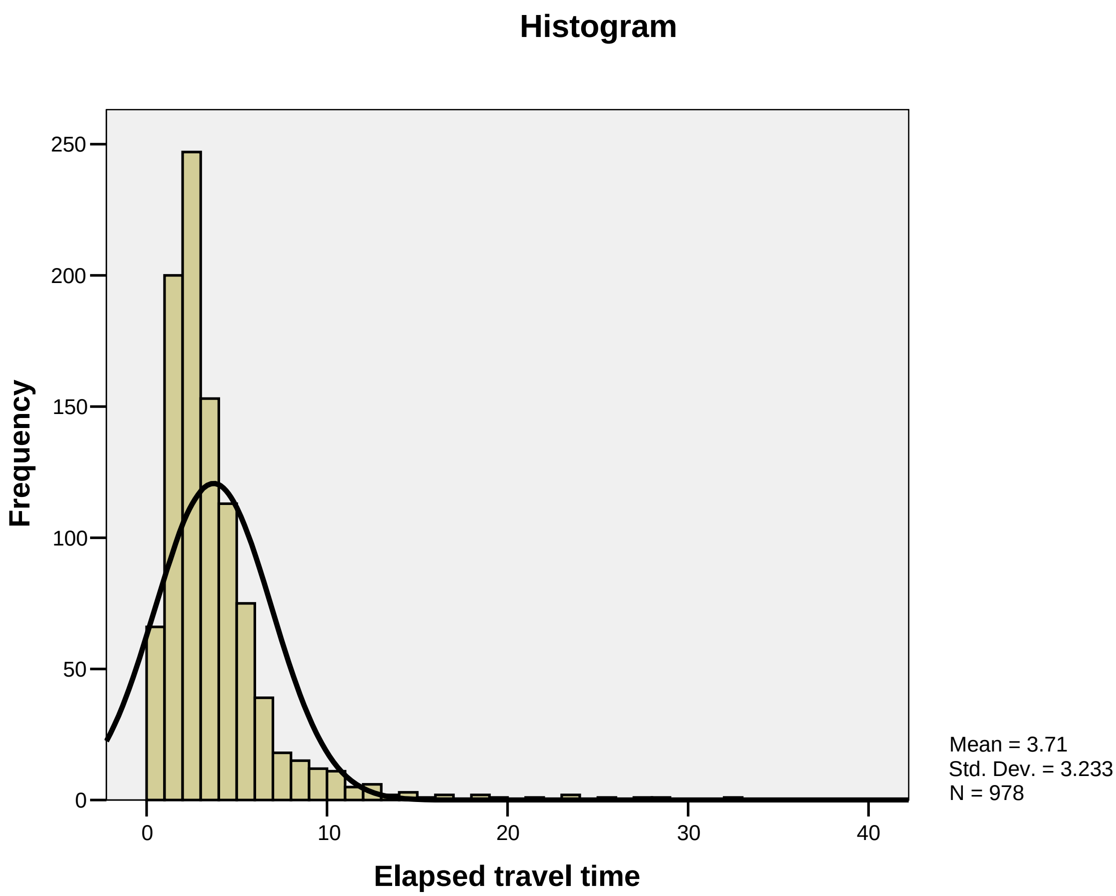

Figure 3.

Table 2
K-S Test for normal distribution

One-Sample Kolmogorov-Smirnov Test

		Elapsed travel time
N		978
Normal Parameters[a,b]	Mean	3.71
	Std. Deviation	3.233
Most Extreme Differences	Absolute	.158
	Positive	.158
	Negative	-.140
Kolmogorov-Smirnov Z		4.946
Asymp. Sig. (2-tailed)		.000

Table 3
Frequency table for apparatus type

AppType

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Engine	638	65.2	65.2	65.2
	Ladder	299	30.6	30.6	95.8
	Quint	41	4.2	4.2	100.0
	Total	978	100.0	100.0	

Table 4
Frequency table SORC concentration type

Type (U,S,R)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Rural	66	6.7	6.7	6.7
	Suburban	226	23.1	23.1	29.9
	Urban	686	70.1	70.1	100.0
	Total	978	100.0	100.0	

Table 5

Frequency table for compliance with TRT

TRT_Goal

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Doesn't meet TRT Goals	431	44.1	45.4	45.4
	Meets TRT Goals	518	53.0	54.6	100.0
	Total	949	97.0	100.0	
Missing	System	29	3.0		
Total		978	100.0		

Table 6

Frequency table for relocating companies

Reloc

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not a Relocating Company	749	76.6	76.6	76.6
	Relocating Company	229	23.4	23.4	100.0
	Total	978	100.0	100.0	

Table 7

Wilcoxon Signed Ranks Test

Test Statistics[b]

	Year2007 - Year2001
Z	-18.555[a]
Asymp. Sig. (2-tailed)	.000

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Table 8
Non-parametric correlations

Correlations

			AppType	Urban, Suburban, Rural	Reloc	AVL	TRT_Goal	DRIVETIME
Kendall's tau_b	AppType	Correlation Coefficient	1.000	-.098**	-.393**	-.071*	.108**	.033
		Sig. (2-tailed)	.	.001	.000	.025	.001	.198
		N	978	978	978	978	949	978
	Urban,Suburban,Rural	Correlation Coefficient	-.098**	1.000	-.054	-.020	.277**	.189**
		Sig. (2-tailed)	.001	.	.085	.512	.000	.000
		N	978	978	978	978	949	978
	Reloc	Correlation Coefficient	-.393**	-.054	1.000	.034	-.618**	.022
		Sig. (2-tailed)	.000	.085	.	.282	.000	.391
		N	978	978	978	978	949	978
	AVL	Correlation Coefficient	-.071*	-.020	.034	1.000	.121**	-.071**
		Sig. (2-tailed)	.025	.512	.282	.	.000	.007
		N	978	978	978	978	949	978
	TRT_Goal	Correlation Coefficient	.108**	.277**	-.618**	.121**	1.000	-.147**
		Sig. (2-tailed)	.001	.000	.000	.000	.	.000
		N	949	949	949	949	949	949
	DRIVETIME	Correlation Coefficient	.033	.189**	.022	-.071**	-.147**	1.000
		Sig. (2-tailed)	.198	.000	.391	.007	.000	.
		N	978	978	978	978	949	978
Spearman's rho	AppType	Correlation Coefficient	1.000	-.101**	-.400**	-.072*	.110**	.042
		Sig. (2-tailed)	.	.002	.000	.025	.001	.190
		N	978	978	978	978	949	978
	Urban,Suburban,Rural	Correlation Coefficient	-.101**	1.000	-.055	-.021	.281**	.236**
		Sig. (2-tailed)	.002	.	.085	.512	.000	.000
		N	978	978	978	978	949	978
	Reloc	Correlation Coefficient	-.400**	-.055	1.000	.034	-.618**	.027
		Sig. (2-tailed)	.000	.085	.	.283	.000	.391
		N	978	978	978	978	949	978
	AVL	Correlation Coefficient	-.072*	-.021	.034	1.000	.121**	-.086**
		Sig. (2-tailed)	.025	.512	.283	.	.000	.007
		N	978	978	978	978	949	978
	TRT_Goal	Correlation Coefficient	.110**	.281**	-.618**	.121**	1.000	-.180**
		Sig. (2-tailed)	.001	.000	.000	.000	.	.000
		N	949	949	949	949	949	949
	DRIVETIME	Correlation Coefficient	.042	.236**	.027	-.086**	-.180**	1.000
		Sig. (2-tailed)	.190	.000	.391	.007	.000	.
		N	978	978	978	978	949	978

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Figure Captions

Figure 1. The technology acceptance model by Davis (1989).

Figure 2. The theory of reasoned action by Ajzen and Fishbein (1977).

Figure 3. Histogram from SPSS incident response times.