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Assessment of the Building Situation Tool Adoption Among Firefighters

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Assessment of the Building Situation Tool Adoption Among Firefighters (Filip Sever)
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Technology and technical tools have become standard resources that first responders use in their work. Throughout an incident, technology serves to improve communications, planning, safety, situational awareness, and decision-making. Certain incidents require specialized tools to resolve the crisis, whether it is for the law enforcement, medical, or firefighter unit to manage. One under-utilized technology is building sensors, recording information on temperature, CO2, smoke, airflow, and movement in the building. While modern buildings include sensors to monitor for potential dangers, that information is not shared with the fire department beyond notification of a fire alert. Despite the considerable number of hardware and software solutions adopted, firefighters in Kainuu, Finland still rely on paper plans when examining indoor disasters. The Building Situation Tool (BUST) was developed to utilize the building sensors and visualize the building as a 3D model, to provide firefighters with a real-time overview of the site during emergencies.

The purpose of this study is to investigate the technological competencies of firefighters, determine the usability and ease of use of BUST, and examine the factors that influence the adoption of BUST. The constructs of the Technology Acceptance Model (TAM), self-efficacy, and workplace learning are used. These three constructs provide insight into how the intention to use technology is modeled, how users perceive their knowledge and use of technology, and how the workplace influences learning and performance.

A mixed-method approach was used in this study. The firefighter’s technology self-efficacy, perceived usefulness, and ease of were recorded through quantitative questionnaires. The firefighter’s experiences in using the technology and factors that influence adoption were recorded through a questionnaire and interview. The findings show a sufficient level of competency, that first-time users prefer guided instructions, clarity in the user interface, controls, and options to customize the user interface. The findings have practical implications for the future development of BUST and its adoption in the workflow of firefighters.

Keywords: *technology self-efficacy, workplace learning, user experience, disaster management, indoor disaster management, perceived usefulness, perceived ease of use*

Contents

Introduction

Modern buildings in Finland are equipped with various sensors which monitor and manage the building, such as temperature, air quality, smoke, and movement. The systems allow the building to maintain certain temperatures, circulate the air and automatically lock and unlock doors. The system monitors for fire outbreaks and sends out an alarm to the authorities in case a fire is detected. While the building is equipped with a wide array of sensors, firefighters still rely on paper versions of the building plans, which are located within the building premises. Having access to sensor data and being able to start preparations during the approach would allow the firefighters more time to plan their actions, enhance awareness of the field of operations, and provide data on the incident. Sensor installation standards require buildings to have one temperature sensor for every $30m^2$ and one smoke sensor for every $60m^2$ of the building. Standardization of temperature and smoke values (Ahola et al., 2018) allows for precise sensor calibration, where sensors can be calibrated to detect abnormal and concerning values, allowing for a pre-emptive response to a potential threat.

The Building Situation Tool (BUST) is a computer program, that shows a 3D model of the disaster site, highlighting sensors reporting abnormal data, and allowing the first responder to see available resources (extinguishing pipes, fire compartments, ventilation sections, fire extinguishing equipment, hazardous areas) and form their plan of attack and retreat through the path-planning function. Developed in the FASTER project, BUST serves as a proof of concept to close the information gap firefighters have. The software is installed on a laptop in the leading car and operated by the team leader. BUST is used at the beginning of an emergency to provide a situational overview of the incident scene inside a building, to help firefighters plan their operations, and as a monitoring tool to track potential threats and victims still in the building. During the development of the software, regular meetings were held with firefighters to gather test BUST and gather feedback for further development.

To efficiently use new tools, first responders, in this research firefighters, need to be accepting of the technologies, confident in their skills, have support from the workplace, have time to learn how to use them, and the technologies must be suitable for their adoption. For this purpose, this study uses the Technology Acceptance Model (Davis, 1989). Research with TAM focuses on measuring the user’s intention to use technology through constructs such as perceived usefulness and perceived ease of use and includes factors measuring external variables influencing the intention to use (Venkatesh & Davis, 2000; Venkatesh et al., 2003). Most research focuses on the quantitative approach of the assessment for technology acceptance. In the case of this study, we look to both assess the technology and examine the experiences leading to the approval of the technology by the participants of the study. TAM has been extensively used in the assessment of learning technologies (Granić & Marangunić, 2019) and emergency service technologies (Steward, 2019; Weidinger et al., 2021).

For firefighters to become accepting of BUST, the technology must be available for testing and the workplace must support learning through formal or informal methods. Significant constructs influencing the workplace learning process are the user's self-efficacy beliefs, the learning environment in which the learning takes place, and the context of learning (Lunenburg, 2011a; Tynjälä, 2008). To positively facilitate learning, self-efficacy beliefs, and adoption, a fire officer is consulted throughout the development process of BUST. The consultation aims to develop software with elements familiar from other technologies firefighters use, provide a supportive environment for learning and training, and facilitate the engagement of further participants to address the questions posed in this research. Subsequently, during the introduction of BUST to the study participants, individual introductions of BUST are given in one-on-one sessions to each firefighter. To enable learning in the workplace, factors of workplace learning need to be met for both the learner and the learning context. The learner requires a challenge, value, feedback, support, confidence, and commitment. The context of the learning requires structure, measures of performance and progress, and support from the working environment (Eraut, 2004). Using the constructs of self-efficacy and user experience, we examine the firefighters' beliefs in using technology in their work, and how technology can be shaped to address their needs.

While procedures may be similar, specific tasks within an emergency may differ. Not all work and working environments are the same, and learning and performance differ between workplaces, tasks, and employees. As Tynjälä (2008) writes, employees may work on repetitive tasks with narrow task descriptions, providing few opportunities to experience new challenges or opportunities to learn. On the other end of the spectrum, work may constantly provide new challenges, and require workers to continuously learn, collaborate, cooperate and perform autonomously. Such is the case in emergencies, where procedures are in place for emergencies, but elements within the incident vary and require learning, adaptation, and decision-making at various levels, depending on the scenario at hand.

Both learners and the organizations around them are affected by variables influencing self-efficacy. In environments where the persons' work requires collaboration, such as team sports, the teams' self-efficacy is significantly more influenced by wins and losses, as opposed to personal self-efficacy (Feltz & Lirgg, 1998). Participants in collaborative environments, therefore, rely on the team, and their perception of the team when considering the outcomes of their performances.

This study examines the use of BUST through qualitative and quantitative research approaches. Technology self-efficacy, perceived usefulness, and ease of use are measured using existing quantitative questionnaires. Use experience and learning are measured using qualitative approaches, an open-ended questionnaire, and interviews. Finally, we assess the experiences of firefighters when using this new technology and how future development can enhance adoption.

Theoretical Framework

The theoretical framework of this study consists of constructs of technology acceptance, self-efficacy, and learning in the workplace. We examine how users come to adopt new technologies in the context of their work, how a person's self-efficacy is influenced, how it guides a person's choices, and finally, workplace learning and performance. This chapter describes the constructs and their relation to the study.

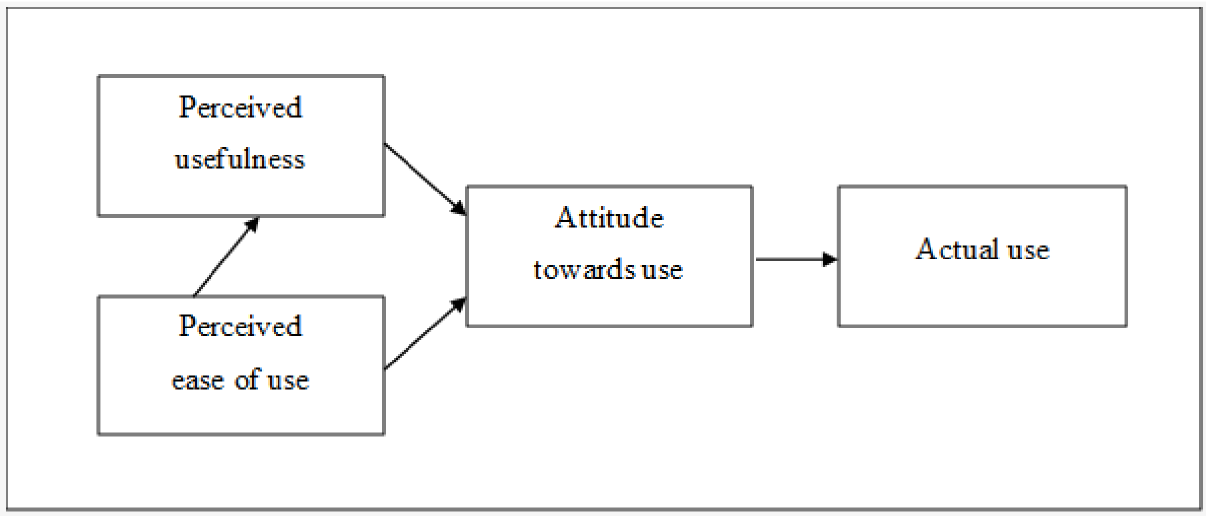
2.1 Technology acceptance

Proposed by Fred Davis (1989), the technology acceptance model (TAM) (Figure 1) provides insight into how individuals come to accept and use technologies. The model includes factors to examine the perceived usefulness (PU) and the perceived ease of use (PEOU) of a technology. Perceived usefulness examines the degree to which a technology is useful to the applied context. As part of this study, perceived usefulness is applied to the relationship between firefighters' tasks during emergencies and the ability of the tool to meet the requirements of the actions taken. Perceived ease of use describes the degree of effort required to use the tool. Elements such as interactivity, interface design, and navigation influence the user's attitude towards the perceived ease of use of the tool. Based on the findings from perceived usefulness and perceived ease of use, the attitude towards using the tool is modeled.

The original TAM model could account for 40 to 50 percent of user acceptance. Over time the model has been improved, and factors in additional variables, which account for additional constructs influencing technology acceptance. The technology acceptance model is a three-stage process. External factors (design features of a technology) trigger cognitive responses in the users (perceived ease of use and perceived usefulness) which lead to the formation of affective responses (attitude towards using the technology), which influences behavior (Davis, 1993; Davis, 1989; Marikyan & Papagiannidis, 2021).

The expanded model TAM2 includes additional factors to capture social influence, cognitive instrumental processes, and experience (Venkatesh & Davis, 2000). Through TAM2, up to 60 percent of user acceptance can be explained. Given the specific use case of the tool, TAM2 provides further insight into the individuals' perception of usefulness influenced by external variables: *subjective norm* (including *experience* and *voluntariness), image, job relevance, output quality*, and *result demonstrability*.

Figure1 Technology Acceptance Model (Davis, 1989)



The first external variable, *Subjective norm* is defined as a ''person's perception that most people who are important to him think he should or should not perform the behavior in question'' (Fishbein & Ajzen, 1975). To mitigate social influence and pressure from the users' surroundings, implementation of the system and the possibility to trial is required. Having the possibility to *experience* the tool, gain knowledge about it, and understand its' strengths and weaknesses diminished the pressure over time (Agarwal & Jayesh, 1997; Hartwick & Barki, 1994). However, Hartwick and Barki (1994) found that when users are separated into mandatory usage and voluntary usage, subjective norms have a significant effect on intention only in mandatory settings. In the context of technology adoption for firefighters, although technology may be mandated, users may choose to not comply, and usage intention may vary. Therefore, experience and perceived usefulness have a crucial role in the learning process to facilitate the adoption. *Image* is defined as ''the degree to which use of an innovation is perceived to enhance one's…status in one's social system'' (Moore & Benbasat, 1991). As such, an individual performing a behavior believes it will increase his standing in the group, and that the performance carries a high degree of interdependence, improving the users' power and influence in the group (Blau, 2017; Pfeffer, 1981; Pfeffer, 1982). *Job relevance* refers to the person's perception of outcomes by using technology. The variable has shown a considerable influence of the perceived usefulness of information technologies (Alambeigi & Ahangari, 2016). *Output quality* is the consideration of how well a system performs the tasks, and a user is inclined to the system providing the highest output quality. A positive perception of technology influences the technology’s relevance to the job (Marikyan & Papagiannidis, 2021). *Result demonstrability measures* the discernability between the technology use and positive results, to aid in the perception of job-relevant results (Venkatesh & Davis, 2000). Usage intention and result demonstrability have been shown to have a significant correlation (Agarwal & Jayesh, 1997).

In 2003, Venkatesh et al. formulated the Unified Theory of Acceptance and Use of Technology (UTAUT). The study aimed to gather the fragmented research and theory on acceptance of information technology using the eight established models. The UTAUT model confirmed strong support for three determinants of intention to use (performance expectancy, effort expectancy, and social influence) and two direct determinants of usage behavior (intention and facilitating conditions). The study highlighted that effort expectancy on intention to use is influenced by gender and age, in particular for women and older workers, however, these influences decrease with experience. In addition, social influence is a significant factor in older workers and particularly women, however, only in the early stages of the adoption (Venkatesh et al., 2003). Although UTAUT is extensively used in technology acceptance and use, researchers tend to extend the model with suitable constructs for their studies. Chao’s (2019) study extended the UTAUT model with the constructs of mobile self-efficacy, perceived enjoyment, satisfaction, trust, and perceived risk for assessing mobile learning in university students. The study confirmed the significant positive effects of performance expectancy and effort expectancy on behavioral intentions. Given the many TAM models and constructs for predicting the intention to use technology, researchers adapt the suitable model depending on their needs.

2.1.1 Technology acceptance in the context of civil security

As technologies advance, and become widely available and affordable, stakeholders consider their potential in the use for prevention and safety. The demand for security technologies has expanded from economic sectors, such as the automotive industry and banking, into the public sector and government institutions. Civil security policy, research, development, and adoption of methodologies and technology are part of the European Union agenda (Bierwisch et al., 2015).

Technology acceptance research is used to examine both software (Haskins et al., 2020) and hardware (Allen, 2019; Weidinger et al., 2021) solutions for civil security. Technologies are evaluated to provide training for specific scenarios or support various aspects of the emergency services work. Training solutions must be a realistic replication of fieldwork, to replicate potential scenarios and situations that can arise. To facilitate adoption, tools must be dependable, easy to use, meet communication needs, and have user-centered design principles (Haskins et al., 2020). Haskins et al., (2020) propose a list of concepts that virtual reality training should adopt: *General concepts*, where virtual reality should serve as a supplement to training, rather than as a complete replacement, provide context to the simulation and why the skills/knowledge are required, and ensuring that the simulation matches real-world scenarios. *Learning*, where participants can gain practical and theoretical knowledge through active learning, are allowed to make mistakes in the learning process, receive immediate feedback, and have variability in the scenarios they learn, while having the option for repetition. *Training tasks*, where the system supports the accomplishment of the mission, allows for the testing or training with equipment, and supports the practice of communication skills. *Trainer capabilities*, allow the trainer to plan and configure scenarios for their teaching needs, observe the learners, adjust the difficulty by altering the incident variables, and provide after-action reviews for learners without interrupting the immersed experience. *Research*, for collection of participants’ data for assessment, diagnostics, and task performance, and experimental control for altering and assessing a range of factors in the experiential and learning process.

Although limited, prior research on the use of TAM with firefighters has examined relevant variables of technology acceptance. A study by Weidinger et al. (2021) on German firefighters examined their acceptance of the emergency response information system (ERIS). The purpose of ERIS is to provide a situational overview of responding units in real-time. The information includes a situation map of the scene, highlighting units, danger zones, or staging areas; sensor data gathering information on units in the field, levels of water tanks, and weather conditions; and incoming data from other tools such as drones, ground robots, and intelligent clothing. The study focused on adapting TAM for the needs to assess the acceptance of ERIS. For the study, Weidinger et al., (2021) developed their model based on

TAM and its extensions. The final 7-point Likert scale survey was distributed to 228 German firefighters.

A second study by Steward (2019) evaluated self-efficacy, facilitating conditions, and social influence variables of TAM to improve the likelihood of technology acceptance in the fire service. For this study, technology self-efficacy represents the first responder's confidence in using technology. The choice to use technology self-efficacy stems from Holden and Rada's (2011) findings that technology self-efficacy focuses on the user's ability to perform tasks on a specific technology, in this study on the use of BUST.

A study by Lluch and Gros (2018) examined the relationship between the age, grades, and TAM scores when testing with firefighters in Catalonia, Spain. The findings showed no relationship between the variables of age, grades, and TAM scores, but did find a relationship between intention to use, perceived usefulness, voluntariness, and the obtained grades. Lluch and Gros (2018) suggest that there are such variables that are determinant in measuring certain relationships within technology acceptance research. We postulate that the same concepts proposed by Haskins et al. (2020), *teaching general concepts, learning, planned training tasks, suitable trainer capabilities, and the research element* are significant elements in enabling learning through other technologies as well. The learning environment for firefighters requires immersiveness and learning goals aimed at acquiring knowledge and skills applicable to the scenario being practiced. Therefore, the chosen assessment for technology acceptance requires the context of civil security and the assessment of technologies in that area of work. Most notably, Allen's (2019) use of TAM for the iCOP mobile phone application, provides police officers with a database to search the local county databases for persons, addresses, or vehicles.

2.1.2 The technology acceptance model in learning

The TAM model is extensively used in the context of education to assess learning technologies. TAM is used to assess behavioral intentions to use e-learning (Prieto et al., 2016), classroom chat, classroom response systems, mobile virtual reality (Sprenger & Schwaninger, 2021), and learning management systems (Park, 2009). The strongest determinant for the adoption of technologies for learning is the perceived usefulness construct (Granić & Marangunić, 2019). A study by Young Hwang et al. (2009) found that the constructs of enjoyment, learning goal orientation, and application-specific self-efficacy had a positive influence on the decision, and subsequent actual use of the tested technology. In addition, the study found a significant relationship between the constructs of learning goal orientation and technology-specific self-efficacy. Learners who focus on mastering the content are more likely to increase their confidence in using the technology. Therefore, self-efficacy is a vital element in verifying technology acceptance and is examined in the context of the BUST tool.

Besides assessing learning technologies for the learners, studies (Holden & Rada, 2011; Milutinović, 2022; TEO, 2009) utilize TAM to examine the teacher's adoption of technologies in the classroom. For the technology to be adopted into the classroom, the teacher must have the competencies to use it, be able to integrate it with diverse types of knowledge content and see it as a beneficial tool in their teaching approaches (Koehler & Mishra, 2009). A meta-analysis by Scherer et al., (2019) of the TAM model and its external variables found a positive influence on subjective norms, computer self-efficacy, and facilitating conditions. BUST is therefore considered a learning technology, transitioning current practices from physical into digital, and a means to learn the technology through hands-on training and co-development between firefighters and the developers. Users familiarize themselves with the incident location and its resources in the same manner as with traditional paper-based maps.

2.2 Self-efficacy

Introduced by Bandura (1978), the term self-efficacy is an ''individuals' belief in their capacity to execute behaviors necessary to produce specific performance attainments''. The construct of self-efficacy and its beliefs have been found related to clinical problems: phobias, addiction, depression, social skills, assertiveness, stress, smoking, pain control, health, and athletic performance (Pajares, 1997). We can deduce that the areas of stress, health, and athletic performance are of relevance to firefighters. The construct has a wide-ranging application in assessing, and understanding, the domains of human behavior. People acquire self-efficacy from various *performances*, *vicarious experiences*, *social persuasion*, and *physiological indexes* (van der Bijl & Shortridge-Bagget, 2001): *Performance accomplishments*, personal experiences, such as practice, success, and the feeling of mastery are the most important source of self-efficacy. Regular failure may decrease self-efficacy, in particular early in the learning process. Once a person develops a strong self-efficacy, the failures have less influence. However, with high self-efficacy the person may generalize between experiences and meet failure, contributing to the outcomes too poor effort or strategy. Persons with lower self-efficacy will perceive that the failure is due to their capacities. *Vicarious experiences,* the observation of successful performance by others is a significant source of self-efficacy. To the observer, performances by others serve as an assessment of difficulty. The observation of others aids the observer in identifying characteristics relevant to the problem solving, and as a comparative assessment, depending on the perceived levels of skills between the object and the observer. While direct experiences are a stronger source of self-efficacy, observation can contribute to the assessment of the observers' self-efficacy. *Verbal persuasion,* the most used source of self-efficacy is verbal persuasion. By providing instructions, suggestions, or advice persons can try convincing others that they will succeed in a task. Credibility, expertise, trustworthiness, and prestige of the person persuading are important. However, persuading others has a weaker influence on self-efficacy than the prior two sources, as it is not based on personal experiences. The influence of persuasion is also dependent on the persons' prior convictions in their abilities, and their belief that the completion of the task is a realistic goal. *Physiological information: self-evaluation and emotional states,* a person's information on their body can influence their self-efficacy beliefs. Persons judge their capacity based on physiological and emotional situations, such as tension, anxiety, and depression, which are interpreted as deficiencies. Persons expect to be more successful when not under stress. Self-efficacy can be negatively influenced by stress. Of the four sources of self-efficacy, practice is the most powerful, and the experience of success or failure is immediate. The other three sources are based on indirect information and require more cognitive processing. *Other sources of self-efficacy,* in addition to the four described sources, other factors can have an influence on self-efficacy. Internal factors such as personality traits, mental states and processes, self-esteem, self-confidence, and an internal locus of control. Furthermore, experiences of mastery, modelling, persuasion, and physiological information influence self-efficacy (Gist & Mitchell, 1992). External or environmental factors such as expectations and support from others and the presence of support (van der Bijl & Shortridge-Bagget, 2001).

Self-efficacy, therefore, influences how a person may approach and act in various situations they encounter. Persons motivate themselves by forming beliefs about their capabilities, and the likelihood to be successful in the task. High self-efficacy individuals are more persistent when facing difficulties, while lower self-efficacy individuals are more likely to give up (Bandura & Cervone, 1983). Furthermore, self-efficacy beliefs affect the person’s motivation, learning, self-regulation, and achievement outcomes (Wentzel et al., 2016). In the professional environment, a person’s self-efficacy influences work-based performance. The influence of self-efficacy is greater than interventions through goal setting, feedback, or organizational behavior intervention (Stajkovic & Luthans, 1998).

The work of firefighters takes place under demanding conditions. Emergencies follow different procedures depending on the type of incident, and firefighters require practice and mastery in their work and the equipment they use. For any new technology, sufficient practice is required to develop self-efficacy and ensure users can both use and troubleshoot the technology if needed. Careful consideration is required of new equipment, and how it affects the workflow and emergency protocols.

2.2.1 Self-efficacy in learning

In the context of learning, self-efficacy describes the learner’s confidence in their ability to achieve an educational goal. We identify several types of self-efficacy: for performance, for learning, for self-regulated learning, collective, teacher, and collective teacher. As learners progress through their schooling, competence beliefs decline. Poor preparation, ability groupings, or social comparison can weaken self-efficacy beliefs (Wentzel et al., 2016). However, systematic interventions can boost learning performance (Jackson, 2002). Employees with higher self-efficacy beliefs work harder to learn how to perform new tasks, as they are more confident in their success (Lunenburg, 2011b). When introduced to new technologies, persons with lower self-efficacy may exert less effort to learn and succeed in the use of the technology. When a person is learning to use new technologies, perceived similarities and differences from prior experience influence the learning in the new context (Marton, 2009). As such, adopting common design elements and interactive methods is important in the acceptance and adoption of technologies.

Zimmerman (1995) highlights five unique properties of self-efficacy implicit in its assessment methodology. First, self-efficacy requires the judgment of capabilities, rather than the personal qualities of the learner. Second, efficacy beliefs are multidimensional, and case dependant, not a general descriptor of the perception. Third, self-efficacy is context-dependent, as the learner may feel different levels of efficacy in competitive compared to cooperative classrooms. Fourth, self-efficacy depends on a mastery criterion of performance, not a normative criterion. Fifth, self-efficacy is measured before the student's performance, therefore informing the temporal ordering for the evaluation of the role of self-efficacy beliefs.

Self-efficacy influences academic motivation and impacts the learner's choice of activities, level of effort, persistence, and emotional reactions (Zimmerman, 2000). Students with higher self-efficacy beliefs choose to tackle challenging tasks more willingly. Similarly, learners with higher self-efficacy beliefs show a positive correlation in the solving rates of arithmetic problems, and the level of self-related mental effort and achievement from learning which was perceived as difficult. Learners with higher self-efficacy and motivation are more persistent in task achievement and skill acquisition. Lastly, learners' beliefs about their efficacy influence their emotional state while regulating their stress, anxiety, and depression (Zimmerman, 2000).

To facilitate self-efficacy improvement in learners with learning and motivational deficiencies, special techniques can be used where learners model self-regulatory techniques, describe their form, and enactive feedback is provided on the impact. Setting proximal goals enhances self-efficacy and skill development more effectively than setting distal goals, due to the immediate feedback through the progress achieved (Zimmerman, 2000). Having a planned learning experience can improve the learner's self-efficacy and motivational deficiencies. Proximal goals allow complex or long procedures to be divided into subtasks to ease the learning and provide continuous feedback to the users.

2.2.2 Technology self-efficacy

The technology self-efficacy construct describes a person's belief in their ability to successfully perform a technologically sophisticated new task. As such, the construct describes a person's confidence in successfully using a particular technology, rather than general competencies. The study by (Holden & Rada, 2011) suggested that, while the constructs of technology self-efficacy and computer self-efficacy may be similar, only technology self-efficacy influences perceived ease of use. Outcomes and findings from variables may vary depending on the population sample and technology used in the research.

Research has verified a significant positive influence of technology self-efficacy on technology acceptance and utilization (Pan, 2020), and regards technology self-efficacy as a determinant of the persons' beliefs on technology use (Venkatesh & Davis, 1996). The technology self-efficacy construct is used to capture the competencies of the participants to examine the relationships between potential adoption and factors that may influence it. The attitude towards technology has a significant positive influence on technology self-efficacy and explains it at a ratio of 41% (Celik & Yesilyurt, 2013).

Technology is increasingly used in the work of firefighters, to improve safety, enhance situational awareness, communicate, and plan operations. Many students enter college or the workforce without basic computer knowledge or skills, directly affecting their technology self-efficacy, and causing higher levels of anxiety when using technology (Huffman et al., 2013). Technology self-efficacy of users increases through the use of technology. Therefore, time, training, vicarious experience, positive attitude, and organizational support are required to facilitate the learning and growth of the self-efficacy beliefs of the users (Kent & Giles, 2017). The participants perceived self-efficacy variable is required, to establish a reference point against the studies' TAM findings, and the qualitative outcomes of the testing.

2.3 Learning in the workplace

Firefighters have established procedures and computer software they use in their work. Periodic exercises are held to practice various emergency scenarios, and the training includes all levels of the command chain. When evaluating new tools and technologies for their procedures, the personnel require training in the tool to familiarize themselves with its capabilities, and how it can be used within the framework of the procedure. Such training requires time and interaction between novices and experts. Experts offer guidance and teach processes and concepts which contribute to the performance and completion of the task (Billett, 2004).

Studies in workplace learning highlight how people learn at work: 1) independently, 2) through cooperation and interaction with colleagues, 3) through client interactions, 4) through formal education, and 6) in extra-work contexts (Tynjälä, 2008). Unlike learning at school which follows planned activities for the learners, workplace learning is primarily informal (Eraut, 2004). While school education focuses on general knowledge and widely applicable skills, workplace learning is specific to the workplace. Resnick (1987) was the first to analyze these differences: First, school tasks and grading are individual, while workplace activities require cooperation or collaboration. Second, in school, learning and assessment are primarily based on theories and memory, without the use of notebooks or calculators, while workplace activities use various tools. Third, school learning is characterized by various symbols to represent objects or events, whereas everyday activities may utilize objects. Fourth, workplace learning aims to teach situation-specific competencies, while in the school the aim is to teach more general skills and principles. Regarding what workers learn, (Eraut, 2004) presents his typology with eight categories:

Task Performance includes speed and fluency, the complexity of tasks and problems, the range of skills required, communication with a wide range of people, and collaborative work. *Awareness and understanding* of colleagues, customers, and superiors, contexts and situations, one's organization, problems and risks, priorities and, strategic issues, and value issues. *Personal development* includes self-evaluation, self-management, managing emotions, building and sustaining relationships, disposition to address other perspectives, disposition to consult and work with others, disposition to learn and improve one's practice, accessing relevant knowledge and expertise, and the ability to learn from experts. *Teamwork* through collaborative working, facilitation of social relationships, joint planning and problem solving, and the ability to engage in and promote mutual learning. *Role performance* includes prioritization, responsibility, supporting the learning of others, leadership, accountability, supervisory role, delegation, managing ethical issues, coping with unexpected problems, crisis management, and keeping up to date. *Academic knowledge and skills* include the ability to use evidence and arguments, accessing formal knowledge, research-based practice, theoretical thinking, knowing what one may need to know, use of knowledge resources, and learning how to use relevant theory. *Decision-making and problem-solving* include the ability to know when to seek expert help, dealing with complexities, group decision making, problem analysis, generating, formulating, and evaluating options, time management, and decision making under pressure. *Judgment* includes quality of performance, output and outcomes, priorities, values issues, and levels of risk.

Eraut’s typology offers insight into the many facets of what people learn at work. We consider the typology an important aspect of the learning as it highlights the significance of the co-creation process in the development work of BUST. While software developers may understand the functional capabilities and logic within the software, a lack of insight from practitioners may lead to a product that does not facilitate learning.

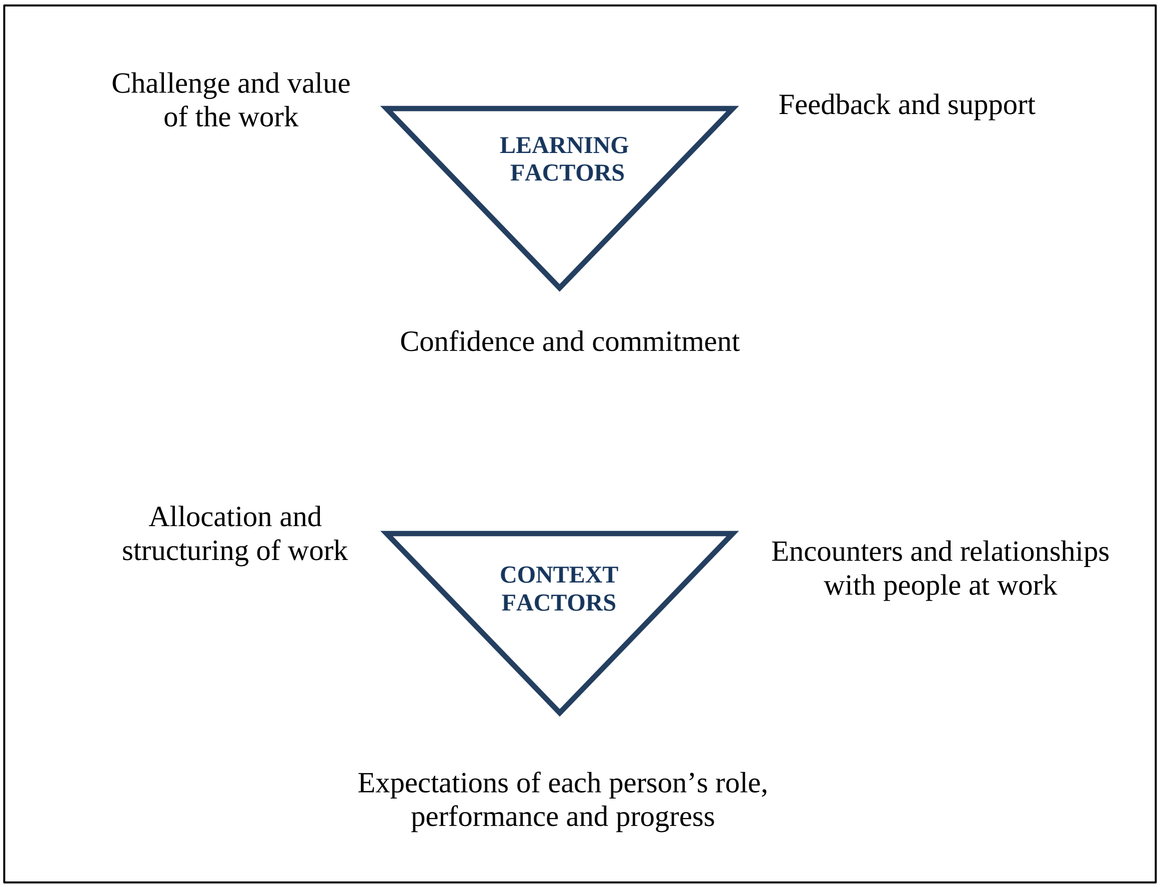
Recent research highlights the significance of networking and social interaction for learning and organizational development (Tynjälä, 2008). Knowledge is developed through social interactions in communities within the organization and with external stakeholders. These communities serve as means to exchange, transform, and create knowledge. Participation in such networks enables the exchange of knowledge across organizations and expertise areas. Such communities can exist at the scale of cities or provinces, forming ‘’learning regions’’. Such learning communities across organizations are beneficial in our study approach as well, where emergency services experts and researchers from the university engage in collaboration. Expertise in emergency operations with insight into the needs and practical knowledge provides researchers with the insight required in the development process. Such collaboration provides new knowledge to participants that are not strictly in their domain, widening their perspectives, while enabling collaboration and participation.

2.3.1 The process of learning and performance in the workplace

While workplace environments and the work may differ between jobs, the factors that influence learning, however, are similar. Both informal and formal learning occurs. Eraut (2004) distinguishes between three types of informal learning: implicit learning, reactive learning, and deliberate learning. Implicit learning refers to unconscious learning without the learner’s awareness of the new knowledge or skills acquired. Reactive learning requires consciousness and effort but provides little time to think. Deliberate learning are situations with the clear goal to acquire new knowledge through learning. Formal learning, on the other hand, is organized training and learning activities meant to generate explicit, formal knowledge and skills (Tynjälä, 2008). To summarize his findings that influence learning, Eraut (2004) summarizes them into two triangles (Figure 2).

The first triangle depicts the work context for learning. The factor of *confidence* had overwhelming importance for both novices and experienced workers. Learning occurs through work and proactivity in seeking learning opportunities. *Challenges* is the second factor, and by competing challenges the worker's confidence rises. To take on challenges, learners need to feel *supported*, and the extent of confidence relies on the degree of support they feel. The second triangle focuses on the context of the factors for learning. The allocation

Figure 2 Factors affecting learning in the workplace (Eraut, 2004)



and structuring of work is affected by the difficulty or challenge at work, whether the task is individual or collaborative, and the opportunities to meet, observe and work together with people with more, or different expertise. For novice workers, the majority of the tasks need to be new to challenge them but allow for space for reflection, instead of leaving them to resort to ineffective coping mechanisms. The second factor is expectations of performance and progress, as learning in the workplace is facilitated or constrained by the organization and allocation of work, and the relationships and social climate of the workplace. Expectations of each person’s role and the allocation and structuring of work are influenced by encounters and relationships with people at work.

For new technologies to be accepted, the factors affecting workplace learning need to be met. The learner needs to identify the technology as a solution to a problem, be motivated to learn and master the technology. We posit that a supportive environment fosters learning, through practice the self-efficacy of the user is heightened, leading to greater intentions to use.

When considering their performance, team members evaluate themselves within the context and environment of their work. This inevitably leads to quality assessments within teams, and perceptions of own and team capabilities (Feltz & Lirgg, 1998). In their study on self-efficacy perceptions, Feltz and Lirgg, (1998) found that the aggregated team efficacy beliefs are a stronger predictor of performance than player efficacy beliefs. In the context of workplace learning and measuring performance towards achieving goals, two schools of thought exist. Assessment of the task performance as an outcome of a particular behavior towards achieving the set goal (Motowidlo & Kell, 1993), or as the behavior itself (Campbell, 1990). Therefore, the performance of a user can be measured through the outcomes of the task, or the behaviors exhibited during the task. The elements measured to assess performance include the total expected value generated, performance results, productivity, success, quality, efficiency, effectiveness, and work attendance (Abun et al., 2021). As highlighted by Abun et al., (2021) the limitation of measuring work performance based on outcomes carries limitations, as it does not include the dimensions of work behaviors within work performance. We consider Campbell’s approach in this study, as the focus of the study is on the factors that influence adoption, usefulness, and ease of use, during the performance, rather than measurable outcomes of the completed tasks. As highlighted by Scherer et al., (2019), the TAM model and its external variables found a positive influence on subjective norms, computer self-efficacy, and facilitating conditions. The variables of subjective norms and facilitating conditions inform the user’s perception of their work environment, and the system in place, influencing their behavior. As such, the variables reflect workplace learning factors (Eraut, 2004) and are utilized in the qualitative examination of the users’ experiences.

Aim and research questions

This study aims to examine BUST as a new tool for the use of firefighters. The study will assess the competencies of firefighters with technology and how they perceive BUST in the context of their work. Furthermore, this study will examine what factors influenced the decision to accept or reject BUST as a potential new tool. Lastly, the study will assess how the participant's experiences vary when learning to use the tool.

RQ1 - What is the technology self-efficacy of firefighters, perceived ease of use of BUST, and perceived usefulness of BUST among the firefighters?

RQ2 - What factors contribute to the acceptance or rejection of BUST?

RQ3 - How do user experiences vary when learning to use BUST?

Methodology

4.1 Context and Participants

The BUST system is designed to replace paper versions of building plans and provide an enhanced situational overview of the disaster scene to firefighters. Being developed in collaboration with firefighters, ease of use and usability are reflected in the user interface (visually) and behavior of the software (functionality). In the context of learning, technology self-efficacy is a determinant of ease of use both before and after the direct experience with the technology (Venkatesh & Davis, 1996). During early development, firefighters set the requirement for the tool to be intuitive to use, quick to learn, and not require advanced computer skills. The difficulty to learn and use needs to be comparable to that of similar tools used by firefighters in mission management and field operations. Options to visualize points of interest in the building, recognize sensor types, read sensor information, examine timestamps, and plot routes must be shown clearly and concisely. The use of the touch functionality should be as intuitive as on smartphones: pinch to zoom, two-finger interaction to manipulate 3D models, hold and drag objects, double-tap to confirm.

The participants (n=20) for the study are firefighters and fire officers. All contacted respondents agreed to complete the study, and Table 1 shows the demographic data of the participants. Most of the participants were male (95%), between the age of 25 and 44 (70%) and had over 11 years of experience (60%). The number of participants without, or with an incomplete university degree was higher (65%) than the number of participants with a completed degree (35%).

Table 1 Demographic data of participants

Characteristic	n	%
Gender		
Male	19	95
Female	1	5
Age		
18-24	1	5
25-34	6	30
35-44	8	40
45-54	4	20
55-64	1	5
65+	0	0
Years of experience		
0 - 2	3	15
3 - 5	2	10
6 - 10	3	15
11 - 20	6	30
21+	6	30
Highest education		
Vocational school	10	50
University but not completed	3	15
Bachelors’ degree	4	20
Masters’ degree	3	15
PhD	0	0

BUST was designed to provide a situational overview of the disaster and allow the firefighters to evaluate and plan while driving to, or already at the disaster site. The application testing is therefore limited to officers and firefighters working in the field. The study was conducted in March 2022, over three weeks. The long collection period is due to rotating shifts and the small number of staff per shift. All contacted respondents agreed to complete the study.

The study was done with one participant at a time, to introduce BUST, ensure all questionnaire parts are answered, and support can be provided if needed with using BUST. The testing scenario framed in the context of testing is an emergency at a local school. Participants are asked to complete a set of tasks using BUST for which traditionally papers are used.

4.2 Research design

The mixed-method study approach is used to collect, analyze and report qualitative and quantitative findings of the study The constructs of self-efficacy, perceived ease of use, and perceived usefulness use 7-point Likert scales, and are part of the quantitative study design. The open-ended questionnaire and interview are part of the qualitative study design. Text data includes responses from open-ended questions, notes, or interview data. Audio and video data can include pictures, videos, or interview recordings from a site or setting (Creswell, 1999). A classification by Greene, Caracelli and Graham (Greene et al., 1989) distinguishes five purposes for using the mixed method approach: *Triangulation*, to find the convergence of the results through different methods. *Complementarity*, to elaborate, enhance, and clarify the results of one of the methods by using the other. *Development*, through the use of results from one research method to facilitate the development or inform the other research method, where the development includes sampling and implementation, as well as measurement. *Initiation*, to discover a paradox or contradiction, find new perspectives of frameworks, and reformulate questions with the opposing method. *Expansion*, to extend the range of inquiry through the use of different methods for different components.

The complementarity method approach offers further insight into the understanding of data. Additional insights can be collected through a quantitative and qualitative approach, rather than using only one approach.

Technology self-efficacy

Technology self-efficacy describes a person’s perceived capacity to use technology to complete tasks. Technology self-efficacy has a positive influence on the acceptance of new technologies (Pan, 2020). Therefore, it is a significant factor in the assessment for acceptance of new technologies. Holden and Rada’s (2011) adjusted the original TAM model for their study, to account for the usability of the users. The purpose of the adjustment was to account for the requirements of the users with the technology, rather than perceived ease of use in the standard form. Their study found that the adjusted perceived ease of use + usability construct was population independent and generalizable. Given the mixed-method approach that this study will utilize, it was decided to use Holden and Rada’s (2011) adaptation of the TAM questionnaire.

User experience

The term user experience is associated with multiple meanings. User experience is the perception and responses when using or anticipating the use of a system or service (Nakamura et al., 2019). Alternatively, Hassenzahl and Tractinsky (2006) suggest a focus on pragmatic (accomplishment of tasks) or hedonic (emotions) aspects of experiences. The pragmatic aspects contribute to the autonomy or competency perception, while hedonic aspects contribute to the perceptions of positive experiences (Nakamura et al., 2019). Nakamura et al., (2019) found that qualitative approaches should include space for participants to express their opinions in addition to quantitative scales. In this study, user experience was collected through an open-ended questionnaire (Annex 1) after the completion of the tasks. In addition, semi-structured interviews were held with four participants in the survey.

Perceived usefulness and perceived ease of use

The technology acceptance model is the leading method for assessing potential acceptance or rejection, as well as the leading method used in measuring learning technology acceptance by students, teachers, and other stakeholders (Granić & Marangunić, 2019). The constructs of perceived usefulness and perceived ease of use measure the users' responses to evaluating a technology. Through the use of a scale the extent of the affective response is measured, and the higher the response, the higher the likelihood of the intent to use (Marikyan & Papagiannidis, 2021). An adapted version of Allen's (2019) survey is used for perceived usefulness and perceived ease of use. Both constructs use 7-point Likert scales.

4.3 Data collection

A mixed-method approach (Table 2) was used to gather data on 1) participant demographics, 2) technological self-efficacy, 3) user experience, 4) ease of use, and 5) usefulness. The questionnaires on self-efficacy, ease of use, and usefulness use a 7-point Likert scale, ranging from strongly disagree to strongly agree. Participants complete the demographics section, and technological self-efficacy questionnaire first. Following the first two questionnaire sections, participants are introduced to BUST and its features. The purpose of the tool is explained, and its objectives are explained. The participants are introduced to the BUST software, elements of the user interface are explained, the functionality of each button is demonstrated, and the pilot site building is shown. Participants are asked to complete a set of tasks using the BUST tool. Once complete, the participants reply to a set of open-ended questions assessing their experiences. Finally, ease of use and usefulness questionnaires are answered.

Table 2 Research outline

Phase	Construct
Before tool testing	Demographic data Perceived technological self-efficacy
Tool testing	
After tool testing	Qualitative UX questionnaire Perceived ease of use Perceived usefulness Interviews

4.4 Data analysis

4.4.1 Quantitative data analysis

The quantitative data analysis utilizes existing TAM and self-efficacy instruments used in testing first responder technology acceptance (Allen, 2019) and technology self-efficacy (Holden & Rada, 2011). The three survey sections were built using Microsoft Forms, and survey responses are stored in an excel file. Following the completion of the questionnaires, the data was exported to SPSS for analysis. The three constructs are individually analysed with descriptive statistics. Table 4 shows the results summary of the descriptive statistics, mean, standard deviation, and reliability test. Due to the limited number of responses, the constructs are used as independent variables informing self-efficacy, ease of use, and usefulness.

4.4.2 Qualitative data analysis

With qualitative content analysis, we examine how users experience the BUST tool and which themes emerge from the collected questionnaires (Annex 1) and interviews conducted. While research using TAM in the emergency domain is limited, studies have used mixed methods to assess the practical potential of tools and identify the factors which contribute to the acceptance or decline of adoption (Weidinger et al., 2021).

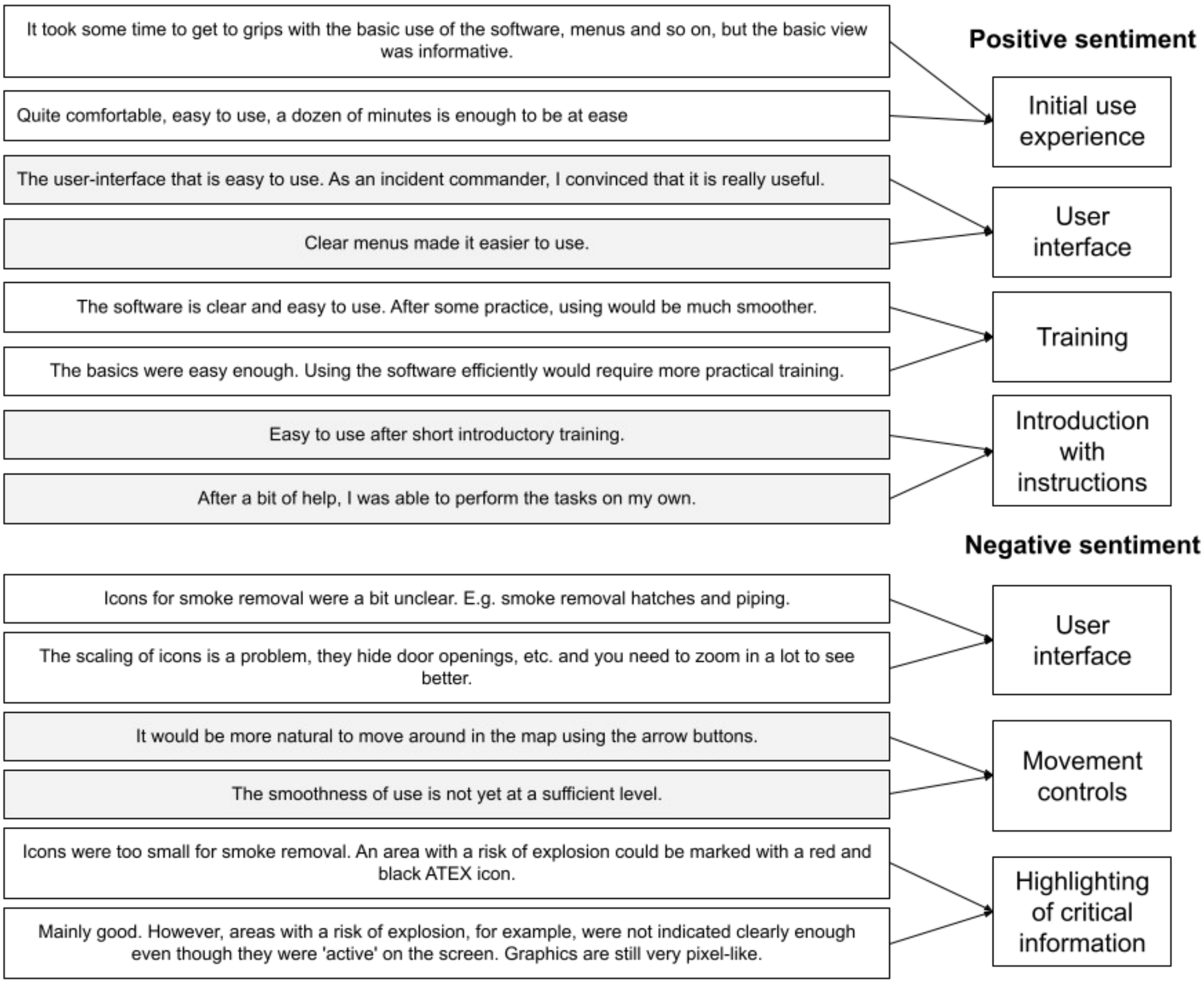
The interview recordings were transcribed for reading and imported into NVivo for automatic coding. The interview data was read multiple times to examine meaningful sentiments and categories. Table 3 shows the coding scheme used in the analysis. Using NVivo, the texts were analyzed with automatic coding, sentiment coding, and word frequency analysis. With NVivo and through reading, primary categories were formed: *use, menu, icons, interface layout, visibility, intuitiveness, introduction, instructions, training, learning, and interaction*. Figure 3 shows sample texts and their distribution to higher categories.

Higher categories were chosen depending on the element of BUST they concern, and the type of sentiment: positive or negative. The positive sentiment category is merged into *user experience, user interface, training,* and *introduction with instructions*. The negative sentiment category is merged into the *user interface, movement controls,* and *highlighting of critical information*. The chosen categories represent factors contributing to positive or negative sentiments in experiencing BUST. No secondary coding was done in this study.

Table 3 Coding scheme

Code	**Coding rule**	**Example**
Use experience	Mentioning the use of BUST, interaction with functionalities, and intuitiveness. Mentions of feelings towards the experience.	‘’It took some time to get to grips with the basic use of the software, menus, and so on, but the basic view was informative.’’
Training	Mention of training as a requirement to improve skills with the technology.	‘’ Using the software efficiently would require more practical training.’’
User interface	Mentioning various visual elements on the screen, including icons, buttons, colors, and animations.	‘’Well-functioning user interface. I would hope for clearer icons and menus ‘’
Introduction	Mention of the initial introduction of the tool by the researcher, including an explanation of the components and functionalities.	‘' I'm sure it would have been challenging to get started without the preliminary instructions.’’

Figure 3 Response samples and their sorting into higher level categories, including sentiment



Results

The following chapter describes the research findings of the mixed-method approach. Data from the quantitative approach is used to determine the perceived self-efficacy of participants, perceived usefulness of BUST, and perceived ease of use of BUST. The qualitative approach examines the user's experience with BUST. Both research designs are used to examine the user's potential adoption of the technology for their work.

5.1 RQ1 What is the technology self-efficacy of firefighters, perceived ease of use of BUST, and perceived usefulness of BUST among the firefighters?

Research question 1 is designed to assess the technology self-efficacy of the participants, perceived ease of use, and perceived usefulness of BUST.

Table 4 Ranges, means and standard deviation, and reliability of the constructs

Construct	**Minimum**	**Maximum**	**M**	**SD**	**α**
Technology self-efficacy	1	7	4.66	1.79	.965
Ease of use	1	7	5.48	2.07	.851
Usefulness	1	7	4.70	1.77	.946

5.1.1 Technology self-efficacy of firefighters

For perceived technology-efficacy, most respondents stated (Table 5) that they *could not* complete any task without someone to tell them what to do (55%), with the relative majority (40%) unable to if they had not used the application before. The majority *could* complete the task with manuals for reference (65%), see someone else complete it before they use it (60%), were able to call someone if they get stuck (70%), if they had someone else to help them get started (70%), or they had a lot of time (65%), while a relative majority could complete the task with only the built-in help (45%). Most respondents could complete the task if someone showed them how to do it first (75%) or if they have used similar technologies in the past (75%). The findings show a positive level of self-efficacy reported by the participants. Although the lowest confidence was in the response ''…I had never used a technology like it before'' no participant failed to complete the given tasks. Furthermore, participants had not interacted with BUST before the testing, and were only being demonstrated how to use the technology.

Table 5 Responses for perceived technology self-efficacy

In general, I could complete any desired task using any computer/internet application if…	%Disagree	%Neutral	%Agree
…there was no one around to tell me what to do as I go.	55	5	40
…I had never used technology like it before.	40	25	35
…I had only the manuals for reference.	20	15	65
…I had seen someone else doing it before trying it myself.	20	20	60
…I could call someone for help if I got stuck.	15	15	70
…Someone else had helped me get started.	30	0	70
…I had a lot of time to complete the task for which the technology was provided.	35	0	65
…I had just the built-in help facility for assistance.	35	20	45
…Someone showed me how to do it first.	25	0	75
…I used similar technologies before this one to do the same task.	20	5	75

5.1.2 Perceived ease of use of BUST

The majority of (Table 6) respondents disagreed that BUST was cumbersome to use (70%), interaction is frustrating (80%), the application is rigid and inflexible to interact with (80%), and it takes a lot of effort to become skillful in the use of BUST (65%). Most of the respondents agreed that learning to operate BUST is easy (75%), find it easy to get BUST to do what they want (70%), find it easy to remember how to perform tasks in BUST (70%), agree that interaction with bust is clear and understandable (75%), and find BUST easy to use (75%). The responses were collected after the testing and completion of the assigned tasks. The findings reflect that the technology developed was sufficiently easy to use. There are no significant outliers from the responses collected. The lowest score observed is ‘’I find it takes a lot of effort to become skillful in BUST’’. Given the limited time for a demonstration, and use by participants, the assessment highlights the need for longer interactions, and focus on informal approaches to both assessment and learning. Given the highest standard deviation values, further emphasis is required on the ease of use and usability aspects of the technology. Similar findings are reflected in the qualitative sections of the findings. While interaction through keyboard and mouse is intuitive for most users, the particular functionalities of the various buttons, and accessing of sub-menus may require more hands-on training.

Table 6 Perceived ease of use of BUST

STATEMENT	%Disagree	%Neutral	%Agree
I find the BUST application cumbersome to use	70	0	30
Learning to operate BUST is easy for me	15	10	75
Interacting with BUST is often frustrating	80	0	20
I find it easy to get the BUST application to do what I want it to do	20	10	70
Bust application is rigid and inflexible to interact with	80	5	15
It is easy for me to remember how to perform tasks in BUST	15	15	70
Interacting with BUST requires a lot of mental effort	75	5	20
My interaction with BUST is clear and understandable	15	10	75
I find it takes a lot of effort to become skillful in BUST	65	10	25
Overall, I find the BUST application easy to use.	15	10	75

5.1.3 Perceived usefulness of BUST

Most of the respondents (Table 7) agree that BUST improves the quality of their work, while half (50%) agree that it gives them better control over their work, with the majority agreeing that it enables them to accomplish their tasks more quickly (75%), supports critical aspects of their job (70%), makes their job more efficient (70%), and improves their job performance (80%). However, the majority (50%) disagrees that BUST helps them to accomplish more work, while the relative majority (45%) agrees that it enhances their effectiveness on the job. The majority agree that BUST makes their job easier (55%), and that the BUST system is useful for their job (80%). The responses to the usefulness construct highlight key areas where further work is needed. The constructs of ‘’ Using bust application gives me greater control over my work’’ and ‘’ Bust application allows me to accomplish more work than would otherwise be possible’’ received the lowest scores. The findings indicate that further focus is required in the teaching of the tool use, clarity in functionality, and improvement in the user experience of the technology.

Table 7 Responses to perceived usefulness of BUST

Statement	%Disagree	%Neutral	%Agree
Using bust application improves the quality of the work	15	25	60
Using bust application gives me greater control over my work	35	15	50
Bust tool enables me to accomplish tasks more quickly	15	10	75
Bust application supports critical aspects of my job	25	5	70
Bust makes me more efficient in my job	15	15	70
Bust improves my job performance	15	5	80
Bust application allows me to accomplish more work than would otherwise be possible	50	15	35
Using bust application enhances my effectiveness on the job	20	35	45
Bust application makes it easier to do my job	25	20	55
Overall, I find BUST system useful for my job	10	10	80

5.2 RQ2 What factors contribute to the acceptance or rejection of BUST?

Research question two examines the learning experience of users, and how they perceive the experience of learning to use new technology. Context of the use is provided as the tool is introduced and participants complete tasks.

Participants mentioned the initial demonstration and introduction given during the testing process. An expert who is knowledgeable in BUST and its functionalities demonstrated the functionalities to the novice on the computer before initial use. The significance of having a person teach the user or having a person available to ask for help is mentioned in the responses to the technological self-efficacy questionnaire, as well as the user experience questionnaire.

Respondents highlighted the implications that such a tool has on the procedures and overall incident. As firefighters rely on paper plans located at the incident site, the control room at the fire station does not have information on the site, apart from descriptive reports. In such cases, if no executive fire officer is present on-site, the unit leader takes command as he is the person with the most knowledge. The firefighters consider BUST as a solution to fill this gap in information. The lack of information that firefighters face is addressed throughout the development process, where firefighters test BUST and interact with the developers regularly. During development, attention is given to the co-creation process. This model of project-based learning by solving work-related problems was first proposed by Poell et al. (1998). Later studies confirmed that project participants successfully develop their competencies and improve their work (Poell & van der Krogt, 2006).

Findings from the three constructs and qualitative findings show a positive level of self-efficacy, acceptance, and intention to use. Firefighters participating in the study associate these constructs with their workplace needs, resulting in close association in what their work tasks require, and what the technology should achieve. As learning occurs, similarities and differences become apparent to the learner (Hajian, 2019). When the purpose of the technology matches the use context of the tool, transfer of learning occurs in the learners. Learners can infer knowledge that needs to be adapted for the required context (Rivière et al., 2019). Furthermore, as participants complete tasks successfully, their self-efficacy is enhanced (Wentzel et al., 2016), leading to enhanced motivation, learning, self-regulation, and achievement (Schunk, 2012).

A sense of familiarity with the technology, from prior personal and professional experiences aided in the learning process with BUST. At the same time, the technology served a different purpose and as a replacement for current procedures which are done without the use of technology. The participants were introduced to a new challenge related to their work. The participants valued the introductory process and felt confident knowing that a knowledgeable person can provide aid when required. We, therefore, conclude that in the context of learning, the three factors proposed by Eraut (2004) were positively influenced, and met for the participants to enable learning and potential acceptance of the new technology.

5.3 RQ3 How do user experiences vary when learning to use BUST?

The respondents highlighted (Table 8) that with a prior introduction, the tool is easy to understand (n=14). Following the introduction, where responders are guided through the menus and the functionalities are shown, a set of tasks is given that they need to complete. All the steps to complete tasks, and how to navigate to the correct menu are demonstrated in the introduction.

During direct use, respondents highlight that the tool, features, and navigation through the menus are intuitive (n=43). Experience with similar programs, applications, or video games is mentioned as a contributing factor in quick familiarization and use. After the completion of the tasks, responders highlight that while the tools are easy to use, hands-on training is required to learn the tool completely, and make task completion quicker (n=18). The importance of thorough training with tools both in the lab, as well as in training exercises is mentioned. The user interface (n=28) is easy to navigate and logical, apart from icons, which need to be kept up to date, and larger. Users highlight the importance of keeping icons and symbols the same as in official documentation. Users mention that the tool does not require to be three-dimensional (3D).

Table 8 Qualitative responses

Category	n mentions
Positive	
Initial use experience	43
User interface	28
Training	18
Introduction with instructions	14
Negative	
User interface	5
Movement controls	3
Highlighting critical information	3

The negative sentiment of the participants mentioned the scale of the user interface, and clarity of the menus and icons (n=5). In the current version of BUST, the menus take significant space of the screen space available and having all menus open simultaneously results in poor visibility of the disaster site. Icons do not scale with zoom and maintain a constant size on the screen. Participants suggested including options to adjust the scale of menus and icons. Camera movement is set to the W, A, S, and D keyboard keys, which users (n=3) found confusing and expected to use the arrow keys for that function instead. The choice to use letters for the movement was made during development. The use of the letters allows simultaneous use of additional functions through other keys: space bar, shift, and ctrl. Users (n=3) mentioned that risk objects and areas are not highlighted. Users suggested lower color transparency and higher visibility colors. The highlighted shortcomings of usability and user experience match the qualitative findings from the usability construct, highlighting the need for further improvement.

The development project was a co-creation process, wherein regular meetings and end-user testing contributed to the design and functionality of BUST. Usefulness and ease of use are significant factors contributing to the last version of the program. Users highlighted the intuitive user interface and layouts, inspired by their experiences with other programs that firefighters have in use. These findings are in line with prior studies (Venkatesh & Davis, 2000) demonstrating the significance of the user’s perception of result demonstrability, which are determinants of ease of use.

Discussion

The findings reveal that the respondents are sufficiently competent in technology use, and have found BUST easy to use, and useful for their work. The results suggest that future research on technology adoption for civil security and crisis response can benefit from the direct contributions of firefighters. The requirements for BUST in the field are different from the requirements for the mission management room. In the field, a smartphone or tablet version would be sufficient, where points of interest and sensor data are displayed. For mission management, the current version is more suitable, allowing for an enhanced situational overview of the scene. Furthermore, while users are competent in technology use, the initial demonstration of the tool by a person is valued and contributes to the learning and consequent use experience. Personalization of the BUST user interface and on-screen elements should be improved through customizability, allowing users to manipulate the size, colors, and transparency of items. To fully grasp the users, experience with the technology, all three facets of the experience require consideration: the experiential, emotional and affectional, and beyond the instrumental (Hassenzahl & Tractinsky, 2006). Therefore, future research and development should look to create positive learning and usage experiences, rather than just prevent usability issues.

Having a new tool for testing poses a challenge to the participants, and with the inclusion of assignment tasks learning can be facilitated through procedural tasks. The firefighters can practice tool use through relevant scenarios while learning to use BUST. As further buildings are added to the software, a greater database is developed for technology learning, and operational use by firefighters, benefiting the organization as a whole. Therefore, both learning and contextual factors can be addressed to meet learning goals and facilitate workplace learning (Eraut, 2004).

The primary purpose of this study was the examination of BUST for firefighters, and factors that may influence adoption. We, therefore, reflect on BUST as a new product to learn and master. Workplace learning is both informal and formal. The study participants experienced bust through a series of questionnaires, a premade task, and open-ended questions. Beyond the researcher introducing the tool, and their completion of assigned tasks, there was no interaction with the technology. As Tynjälä (2008) suggests, the various positions of learners in terms of rank, experience on the job, and the tasks they have during interventions can influence outcomes. In future assessments, attention should be given to the learners' context, how learning is approached, and the experience of the technology perceived.

The TAM model has been extensively used to predict the user's behavior. Including marketing, advertising, e-commerce, mobile banking, virtual reality, and e-learning (Marikyan & Papagiannidis, 2021). The suitability of the model as an assessment tool is wide-reaching. Researchers in civil security have adopted TAM and its' iterations for technology acceptance as well, and it is extensively used in that context (Allen, 2019; Jones et al., 2010; Lluch & Gros, 2018; Oliveira & Santos, 2019; Steward, 2019; Weidinger et al., 2021). Due to the affordability and availability of technologies, as well as legislative and political developments, researchers have increasingly worked on solutions for civil security (Bierwisch et al., 2015). However, the use of TAM remains case-specific, as each study constructs and adapts TAM for the testing of their technology (Allen, 2019; Weidinger et al., 2021). This study used both qualitative and quantitative methods to examine the reasons beyond the potential adoption of BUST. Utilizing both methods allows the researcher to examine the problem in depth (Jaber, 2016). In the case of the BUST tool, the findings suggest the reasons highlight the competencies, perceptions of ease of use, usefulness, and factors influencing adoption.

One of the limitations of the study was that it focused on the adoption of technology by all firefighters, regardless of rank. As a method to gather information and gain situational awareness, it is useful for all operatives when departing to the disaster site. However, in the field, the unit leader primarily operates the tools. The second limitation is that the research was conducted primarily with firefighters from the Kainuu region in Finland. Future research should look to samples on a national level. Larger sample size will allow the inclusion of the TAM as a complete model and provide a representative sample on the national level. Future research should focus on fire officers exclusively. Once in the field, the fire officers are the primary users of the technology tools for enhanced situational awareness. Future research should consider differences in procedure across the regions, as a factor in assessing the adoption and use of tools. Furthermore, the ethnographic research approach should be considered when participants interact with the software. Observing how users interact with the tool and using the think-aloud method to gather data on decision making and process tracing.

Conclusion

The results of this study are in line with prior research (Allen, 2019; Young Hwang et al., 2009) emphasizing the particular needs of the participants of the study, and the acceptance of the technology for their needs. This study focused on examining the firefighters' views on the BUST tool. The findings of the qualitative analysis of the three constructs indicated that participants were competent in the use of technologies and had a positive response to the use of BUST. The following introduction and demonstration of BUST served as an overview of the functionalities of the tool, to help participants learn the capabilities and where to navigate completing their tasks. The assigned tasks followed the same steps as a standard procedure but BUST served as a replacement for the building plans that are used in paper format. All users were successful in completing the tasks. Following the tasks, users completed the TAM questionnaires on perceived usefulness and ease of use. The scores showed a positive result for BUST. Through the qualitative questionnaire and interviews, responders highlighted how usability and clarity of BUST can be improved through customization options.

We evaluated the use of BUST with the participants in laboratory environments. Therefore, the participants may experience BUST as a program with building knowledge, rather than a suitable tool in times of emergency. Further effort is required in understanding response procedures, and usability to make use more seamless and intuitive. Hassenzahl and Tractinsky (2006) describe the experiential perspective of user experience and emphasizes two aspects, situatedness and temporality. In this study, firefighters have field experience in crises, however, they have not experienced BUST in such a context.

Firefighters welcomed the opportunity to evaluate a new technology developed to aid them in their work. The purpose of the technology and the problem it aims to solve were well received, highlighting the knowledge of current shortcomings, and the benefit of closing the knowledge gap in current procedures. Although negative self-efficacy beliefs were reported by some of the participants, none of the participants of the study failed in completing the tasks through BUST.

This study confirmed the firefighter's competence in using new technologies, highlighted shortcomings of the learning process, and confirmed the usefulness of BUST. Although efficacy is a significant determinant in the intention to use technology, findings suggest that instructions and the availability of learning support are necessary. These findings are in line with prior research highlighting the significance of perceived support and its influence on learning motivation (Lai et al., 2016; Pan, 2020). Learning motivation is found to influence self-efficacy beliefs, technology acceptance, and therefore the learners' attitude toward using technology as a means of learning (Edmunds et al., 2012; Pan, 2020). The findings suggest that sufficient competence exists among the participants to evaluate technologies relevant to their work. The participants were supportive of the idea of BUST, and the potential of such a technology in their work.

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Appendix 1

User experience questionnaire

1. How do you feel after using the tool?
2. How was your experience?
3. What did you miss?
4. What was motivating?
5. What was demotivating?
6. How was it to use BUST without prior experience?
7. What would help users learn BUST better?
8. How was the user interface (buttons, symbols, menus, icons, text sizes…) ?
9. Was anything surprising?
10. Did something not perform as expected? Tell what
11. How difficult is it to learn to use BUST?