ABSTRACT:

Facility managers usually work in complex and dynamic environments where they have to make important decisions. This decision-making process and its consequent performance can be improved by enhancing ambient awareness of the facility manager. Enhancing the ambient awareness of system-users who work in complex and dynamic environments can be achieved through the concept of Situation Awareness (SA). The purpose of this study is to provide a conceptual model of an SA approach that can be applied to the facility management domain. Developing facility management methods and support systems centered on SA requirements is a part of this conceptual model. This study applies the Goal Directed Cognitive Task Analysis (GDTA) technique in order to obtain the key goals and SA requirements of a facility manager. These SA requirements lay the foundation for future role-based decision support systems that can assist facility managers in their decision making process within dynamic and information-rich environments of the operational phase of a facility.

Keywords: Decision-making, Facility Management (FM), human factors, Situation Awareness (SA)

INTRODUCTION

The International Facility Management Association (IFMA) has a broad definition for facility management (FM) which is “the practice or coordinating the physical workplace with the people and work of the organization; integrates the principles of business administration, architecture, and the behavioral and engineering sciences.” As it is clear in this definition, facility managers work in a complex domain with a large amount of information to keep up with. Therefore, they should be capable of building an accurate mental picture of their practices in their working environment and make sure those mental pictures are correctly implemented. For clarifying this mental picture, facility managers should have a clear understanding of what their goals, decisions, and information requirements are. This need can lead facility managers to use Situation Awareness (SA), which has the potential to be applied in the FM domain and to provide them with the said mental picture. For designing a system that supports SA, interviews were conducted with professionals in the field of facility management. These professionals are referred to as Subject Matter Experts (SMEs) due to their professional background, experience and expertise in the area of facility management. By following the methodology of the Goal Directed Cognitive Task Analysis (GDTA), a hierarchy of goals, decisions and related information requirements was developed. The findings presented through this hierarchical SA structure have the potential to be the basis for the development framework of a human-computer interface that can be used on desktop computers, Personal Digital Assistants (PDAs), and Smart Phones to help facility managers to access appropriate information anytime anywhere and improve decision-making performance in their respective domains.
BACKGROUND

Concept of Situation Awareness (SA)

A widely accepted definition of Situation Awareness (SA) is, “knowing what is going on so you can figure out what to do” (Adam, 1993). Basically, SA is having awareness about what is happening around, in order to make decisions based on that information, now and in the future. In more detail, SA clarifies what is needed for reaching the goals of a specific job by understanding what important information is to be used in the decision-making process. Actually this means “only those pieces of information that are relevant to the task at hand are important for SA” (Endsley et al., 2003). Formally, SA has been defined by Endsley (1988, 1995, and 2000) as “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future”. In other words, the formal definition of SA is categorized into three hierarchical phases: Perception of elements in current situation; Comprehension of current situation; and Projection of future status. The relationships between these phases and task/system and individual factors are illustrated in Figure 1. Endsley et al (1998) have expanded these hierarchical phases as follows:

![Figure 1: Endsley's model of situation awareness (adapted from Endsley, 1995)](image)

Level 1 SA, Perception of the elements in the environment: “The first step in achieving SA involves perceiving the status, attributes, and dynamics of relevant elements in the environment. For example, a pilot needs to accurately perceive information about his/her aircraft and its systems (airspeed, position, altitude, route, direction of flight, etc.), as well as weather, air traffic control clearances, emergency information, and other pertinent elements” (Endsley et al., 1998). For example, within the construction safety management domain, safety managers should perceive information such as the activities on the jobsite, safety practices on the jobsite, historical hazard data, educational practices, and safety procedures (Gheisari et al., 2010). In this research, facility managers should perceive information such as service contracts, collaborative groups’ information needs, priorities in terms of facility needs, and budget constraints among others.
Level 2 SA, Comprehension of the current situation: “Comprehension of the situation is based on a synthesis of disjointed Level 1 elements. Level 2 SA goes beyond simply being aware of the elements that are present to include an understanding of the significance of those elements in light of the pilot’s goals. Based upon knowledge of Level 1 elements, particularly when put together to form patterns with other elements, a holistic picture of the environment will be formed, including a comprehension of the significance of information and events” (Endsley et al., 1998). For example, within the construction safety management domain for “determining different aspects of accidents and performing needful procedures” (one of the safety manager’s goals), safety managers should understand issues such as (1) determining type and severity of accidents, and treatment/recovery from them; (2) insurance issues; (3) root cause analysis for determining correction measures; and (4) different forms for collecting data (Gheisari et al., 2010). This understanding would provide safety managers with a mental picture of what they should do to achieve their goal of “determining different aspects of accidents and performing needful procedures”.

Level 3 SA, Projection of future status: “It is the ability to project the future actions of the elements in the environment, at least in the near term, that forms the third and highest level of Situation Awareness. This is achieved through knowledge of the status and dynamics of the elements and a comprehension of the situation (both Level 1 and Level 2 SA)” (Endsley et al., 1998).

![Figure 2: Situation awareness feedback loop (Adapted from Endsley and Garland, 2000)](image)

Improved SA can lead to better decision-making and performance (Endsley & Garland, 2000). As highlighted in Figure 2, there is a relationship between environment, situation awareness, decision-making, and performance. Within the SA process, at the first level, the operator should perceive relevant information (Level 1 SA), then integrate this data with task goals (Level 2 SA), and at the end, predict future events based on his own understanding (Level 3 SA).

Although it is stated that improved SA can result in better decision-making, this may not be true in all situations. There are other factors such as strategy, experience, training, personality, and organizational and technical constraints that can also affect the decision-making process (Endsley & Garland, 2000). There are cases where situation awareness is lost and individuals are usually slower in finding problems within the system resulting in the need for additional time to diagnose the problem and perform corrective actions (Endsley & Kiris, 1995). As even small lapses in situation awareness may cause serious problems, different manner of application domains have started to embed this concept in their potential areas (Endsley, 1995).

Various domains, such as fighter aircrafts, electronic systems and automation technology, driving and ground transportation, energy production and distribution, space operations, nuclear power plant management, and medicine, are applying the SA methodology (Endsley, 2000). One example is Son et al. (2008) application of SA in a disaster response system. They found that SA is very relevant to (1) ensuring the effectiveness of a current disaster response system cognitively and physically, and (2) in understanding the system’s supportiveness of the responders at both strategic and operational levels. In addition, they found that for effective situation aware decision making support, IT-based systems should be designed to support individual responder as well as group decision making, considering complex socio-behavioral-technical interaction at individual, team and inter/intra-organizational. They concluded that SA would support users’ ability to get the required information on an as-needed basis under dynamic and complex
conditions, which would result in improvements in decision-making and response efforts. Gheisari et al. (2010) applied the very same concept to construction safety management. They found that the main goal of a safety manager is “providing a safe workplace for parties in construction to reduce accidents, injuries, and hazards on jobsite.” For achieving this main goal, safety managers should accomplish three major sub goals; (1) performing inspections for hazards on jobsite, (2) providing training for parties working on jobsite, and (3) managing accidents. They concluded that this SA-based technique has great potential of improving safety management practices on jobsites by identifying critical information and requirements for decision-making. The facility management area has not applied this methodology in spite the clear parallels to many goal driven domains. This study takes the initial steps in the application of Situation Awareness to the facility management area.

**SA Applied in the Facility Management Domain**

Due to the complex environment of the facility management domain, facility managers cannot easily filter and organize information in an accurate manner. This results in less than optimal decisions being made.

Figure 1 illustrates a proposed conceptual model based on the SA concept, which can help facility managers to overcome the complexity of provided information on their working environment. SA can filter the large amount of information and provide the facility manager with organized and required information. The organized information requirements not only can shape the mental picture of the facility manager but also have the potential to be used as a basis for developing human-computer interfaces and applications. The improved mental picture together with human-computer interfaces can prosper the decision making process of facility managers and can lead to the achievement of their goals in the facility management domain. Goals such as reducing errors and improving task performance can lead to the improvement of facility manager’s practices on their working environment. Application of an SA-centric method is not intended to provide a one-size-fits-all solution to facility management related issues. Its purpose is to increase SA and assist facility managers by enhancing access to relevant information that may lead to improved performance. It is each specific facility manager who is ultimately responsible for the final analysis of the available information and the corresponding course of action. Although this method may measure the measurable, management personnel should be vigilant of other factors that can influence decision-making.
RESEARCH METHODOLOGY

The Goal Directed Cognitive Task Analysis (GDTA) Technique

For designing a system, which supports SA, the operator must identify and illuminate the individuals’ needs/tasks in the team, their interaction with one another to meet the common goals, and their information needs to perform the tasks. In this research a form of cognitive task analysis, the goal directed cognitive task analysis (GDTA), has been used for this purpose (Bostald, Riley, Jones, and Endsley, 2002). The GDTA has been employed broadly for analyzing SA requirements of individuals (Endsley, 1993; Endsley and Rodgers, 1994). Reasons for selection of the GDTA include (1) it is not tied to the technology being used to carry out the task (i.e., it is independent of how tasks are done within a given system but it depends on what information is needed); (2) it does not just focus on people’s data needs, but on how the said data can be used within decision making and the goal attainment process; and (3) it focuses on obtaining an accurate depiction of the SA requirements and key goals for each individual (Strater, Endsley, Pleban, and Mathews, 2001; Bostald et al., 2002).

The GDTA has three main components: goals, decisions, and SA requirements (Endsley et al., 2003). It focuses on (1) the basic goals of the operators (2) the major decisions for accomplishing these goals, and (3) the SA requirements for each decision. The knowledge obtained through the GDTA can help designers to design systems, which enhance situation awareness leading to better decision-making and process performance. The steps involved in the GDTA interview are as follows (Endsley et al., 2003):

1. Identification of key decision makers: the key decision makers who are playing the significant role should be chosen for applying the GDTA methodology.
2. Identification of major goals and associated sub-goals for each decision maker: each decision maker should be asked about his/her main goal.
3. Identification of the primary decision needed for each sub-goal: each decision maker should be enquired about the sub goals, which are necessary to accomplish the main goal.
4. Identification of the SA information requirements for making those decisions and performing each sub-goal: The sub goals would serve to set the direction for clarifying the primary decision needed for each sub-goal and the information needs to accomplish those sub goals.

The information obtained from the GDTA is organized into figures depicting a hierarchy of the three main components of the GDTA (i.e., goals/subgoals, decisions relevant to each subgoal, and the associated SA requirements for each decision).

Brief Overview of the Facility Management (FM) Profession

The old-fashioned perspective of facility management consisted of caretaking, cleaning, repairs and maintenance. But nowadays, it has increased beyond early concepts and covers a large scope of real estate management; financial management; change management; human resources management; health and safety; contract management; building and engineering services maintenance; and domestic services (Atkin & Brooks, 2009). Various definitions have been used for facility management. The British Institute of Facilities Management (BIFM) defines facility management as “the integration of multi-disciplinary activities within the built environment and the management of their impact upon people and the workplace. Effective facilities management is vital to the success of an organization by contributing to the achievement of its strategic and operational objectives (Chanter & Swallow, 2007). The United States Library of Congress defines facilities management as “The infrastructure that supports the people in the organization in their endeavours to achieve business goals. The practice of co-ordinating the physical workplace with the people and work of the organization; integrates the principles of business information, architecture and the behavioural and engineering sciences” (Chanter & Swallow, 2007). The most recent definition of facility management is “a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process, and technology” which was presented by the IFMA (The
International Facility Management Association (IFMA). Another broader definition by IFMA is “The practice or coordinating the physical workplace with the people and work of the organization; integrates the principles of business administration, architecture, and the behavioural and engineering sciences.” Facility managers should work in a complex environment in which they have to keep up with a large amount of information. This information is the basis for developing the facility manager’s mental picture of their working environment and SA can help facility managers in the development of this mental picture.

**Application of the GDTA to the Facility Management Domain**

Application of the GDTA involved structured interviews in which the interviewer asked each subject about his/her main goal as a facility manager. The interviewer continued to enquire about the sub goals, which are necessary to accomplish the main goal. These sub goals would serve to set the direction of the remainder of the interview and clarifying the information needs to accomplish the sub goals of a facility manager. At the end of the interview, subjects were asked to indicate if there were any type of technology that would help them to accomplish those goals, what would this technology be. Six facility managers in the Atlanta, Georgia (USA) area participated in the GDTA. Creating a comprehensive GDTA for a particular job will take anywhere from 3 to 10 interviews, depending on the complexity of the position (Endsley et al. 2003). One-on-one interviews were conducted with those managers following the GDTA methodology. The interviews lasted approximately one hour and were video recorded for the purpose of reviewing responses. Subjects provided their consent before the interviews and the study protocol was reviewed and approved by the Georgia Tech Institutional Review Board for compliance with Human Research Subjects regulations.

**RESULTS & DISCUSSION**

The GDTA-based interviews conducted with facility management SMEs provided the necessary information for developing the goal hierarchies and related SA requirements. By combining these hierarchies, a unique hierarchy of goals for the facility managers was achieved. This section explains the hierarchy of goals and SA requirements.

The main goal of a facility manager was identified as “Proper care of existing facilities and manage the facility safety and productivity.” The following figure illustrates the hierarchy of main goal and sub goals of a facility manager.

As illustrated in Figure 4, for achieving this main goal, facility managers should accomplish three major subgoals. These three subgoals are (1) monitoring the activities within the facility, (2) determining facility needs, and (3) managing facility resources.

![Figure 4: Goal hierarchy of facility managers](image-url)
“Monitoring the activities within the facility” is the first subgoal, which was declared by SMEs for accomplishing the main goal of a facility manager. Based on Figure 5, for achieving this subgoal, facility managers should answer two questions:

1. Do facility managers understand the contracts to get the best values of the services, which they are contracting for?
2. What groups are using facility managers’ data? Why are they using the data?

These questions show the decisions that facility managers should make to accomplish “monitoring the activities within the facility” (first subgoal). The bullet points in the figure 5 are the information and SA requirements that a facility manager needs in order to make these decisions. For knowing whether the facility managers have understood the contracts to get the best values of the services which they are contracting for, facility managers should for example consider previous contracts, the total scope of the contract or clarify the price range for each contract. For understanding what groups are using facility managers’ data and why they are using this data, SMEs recommended that facility managers should for example determine who the various groups/stakeholders in the company are or should find out the target/audience of the project. A project here means a facility management project.
SMEs declared “determining facility needs” as the second subgoal for accomplishing the main goal of a facility manager. Figure 6 shows that for achieving this subgoal, a facility manager should answer two different questions:

1. What are the priorities for facility needs?
2. Have the workers been chosen based on the facility needs?

These questions show the decisions that facility managers should make to accomplish the second subgoal (determining facility needs). The bullet points in Figure 6 are the information and SA requirements that a facility manager needs in order to make these decisions. For knowing what the priorities for facility needs are, facility managers should for example consider document and communication with contractors or assess the current situation of the project and where it is going. For understanding whether the workers have been chosen based on the facility needs, SMEs recommended that facility managers should for example measure the current business needs in the company/project, and determine the previous hired workers’ skills and abilities.
SMEs declared “clarifying the concerns/constraints of the business the work is done for” as the third subgoal, for accomplishing the main goal of a facility manager. Figure 7 shows that for achieving this subgoal, facility managers should answer following questions:

1. Have the economic issues of the project (budgeting concerns) been determined?
2. Have the safety issues of the project been determined?
3. Have the timing concerns of the project been determined?
4. Have the IT concerns of the project been determined?

These questions show the decisions that facility managers should make to accomplish the third subgoal (clarifying the concerns/constraints of the business the work is done for). The bullet points in Figure 7 are the information and SA requirements, which a facility manager needs in order to make these decisions. This means that for making decisions related to determining the economic issues of the project (budgeting concerns), the facility managers should get requirements and information such as preparing a good purchasing policy or performing an economic analysis and life cycle costing. For determining the safety issues of the project, the facility managers should be provided with proper training and having fresh perspective toward safety issues. The timing constraints should be clarified in order to be determined where to fit in the plan. Furthermore, for understanding the IT resources to support the facility, all the allowable and feasible IT issues and the people in charge of them should be determined.

**Challenges in the Application of GDTA**

One of the main challenges in this study was applying the GDTA methodology in the facility management domain. The main sign of this challenge was the discrepancy of SA goals or requirements between various facility management SMEs. Each interviewee had his/her own SA goals and requirements that were sometimes totally different from the other facility manager’s goals and requirements. This can be due to two main reasons. Firstly, the facility managers interviewed were in charge of different types of buildings such as governmental offices, schools and private office buildings, which may demand different goals and requirements. Secondly, the interviewed facility managers had different backgrounds. Facility management is an area in which employ individuals from varied disciplines. This also may influence their priorities, goals, and requirements as facility managers. To decrease this incompatibility between goals and requirements, the interviews should be conducted in a way that involves various experts or more
experienced interviewees. Furthermore, as another general challenge of applying GD TA, Ensley et al. (2003) indicates that, “not all interviews will go smoothly and result in optimal data collection.” It is believed that this challenge is mostly related to interviewee’s personality factors that sometimes negatively influence the interview. In addition, issues such as controlling for the experience of interviewees and pre-briefing them about the output of previous GD TA-based interviews can be useful strategies to overcoming this challenge.

CONCLUSION

Main decision makers in the complex facility management environment should be capable of building an accurate mental picture of their working environment and make sure those mental pictures are correctly implemented. Situation Awareness (SA) has the potential to be applied in the area of facility management and provide this mental picture. After conducting interviews with professionals in the field of facility management following the GD TA methodology, a hierarchy of goals, decisions and related information requirements was developed. The identified hierarchies have the potential to enhance ambient awareness of facility managers in their complex, dynamic working environments. Facility managers would make more accurate decisions by having previous knowledge of what could be their key goals and SA requirements. This technique has great potential of improving facility management practices by identifying critical information and requirements for decision-making. Through the application of the GD TA methodology, initial steps in systematic identification and mapping of the information needs of facility managers have begun. In addition, the SA hierarchy can be used as basis for the development of a human-computer interfaces, which can be installed on computers and mobile devices to be used as a decision making tools in facility management practices. This SA hierarchy can be improved in a way to embed more detailed goals and information and even be applied in other areas of built environment design, construction, and management. Applying this methodology to other areas of the AEC domain and understanding their various goals and information requirements can lead to developing a comprehensive SA framework for the AEC domain.

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