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DIAGNOSING FACILITY MANAGEMENT WORK SYSTEMS FOR FACTORS IMPACTING SITUATION AWARENESS

Uttam Jodawat[1], Prajwal Prabhu[1], Vishal Singh[1] and Siva Kumar T[2]
[1]Indian Institute of Science, Bangalore, India
[2]Bosch Limited, India

Abstract

This paper introduces a method for diagnosing facility management (FM) work systems to improve situation awareness (SA). Identifying SA as a critical factor of success in FM, we propose a method to diagnose FM work systems, integrating multiple methods and offering a comprehensive sociotechnical systems perspective. The findings show the internal validity of the method, its application, and the identification of SA-impacting factors in FM work systems. Implications include continuous improvement and a proactive approach to addressing SA challenges in the FM work systems.

Introduction

The Facilities Management (FM) industry faces mounting pressure to align with sustainable development goals, exacerbated by the escalating complexity of digital transformation in the built environment (Nielsen et al., 2016; Okoro, 2023). This complexity necessitates a shift from traditional social systems to sociotechnical systems within FM work systems, wherein technical and social components are integral to decision-making processes (Yalcinkaya and Singh, 2014). However, this transformation has introduced challenges, particularly in maintaining up-to-date and comprehensive situation awareness (SA), which is crucial for informed decision-making.

SA, a critical factor in various domains such as nuclear power plants, healthcare, and aviation, remains relatively underexplored in the FM domain despite its evident importance (Gheisari and Irizarry, 2011; Gheisari, 2013; Akinci, 2014). Existing literature suggests two dominant and distinctive views on situation awareness; one defines SA as a cognitive product of individuals, and the other views it as an emergent property from interactions in a system. Acknowledging the multifaceted nature of SA, there is a need to adopt a sociotechnical systems perspective, where both views are accounted for, considering FM actors, FM technologies, and their interdependencies in achieving and maintaining SA. Evidence suggests that many individual and system-level factors interdependently influence SA in sociotechnical systems (Lau and Boring, 2016; Kurapati, 2017).

Improving FM work systems necessitates diagnosing the work systems and addressing the problems to support situation awareness. In this direction, the research community has put significant efforts into assessing the situation awareness of individuals and groups, taking a descriptive approach where only the social aspect of the work system is considered (Gawron, 2019; Alhaider, 2022). We argue that a normative approach with a sociotechnical systems perspective is required to effectively guide the interventions to address the SA-related issues in complex work systems. Moreover, existing methods expect a certain level of expertise in the SA domain (Salmon et al., 2006), presenting a barrier for the practitioners in the FM industry to utilize these methods and take an interest in them.

This research aims to bridge these gaps by establishing a problem-solving approach to address situation awareness-related issues in the FM sociotechnical (work) systems. In this regard, we propose a method to diagnose FM work systems to identify underlying patterns of SA-impacting factors.

By integrating insights from individual and system-level SA processes, this approach seeks to enhance SA within FM work systems, ultimately improving facility performance and supporting informed decision-making.

This work presents empirical findings from applying our proposed method and discusses implications for research and practice in the FM industry.

Literature review

This literature review delves into the evolution of contemporary Facilities Management (FM) work systems, understanding the shift from social systems to complex sociotechnical systems. Then, we inspect the challenges this transformation poses for achieving and maintaining high situation awareness (SA) levels among FM actors. Additionally, we explore strategies for diagnosing FM work systems to effectively address SA challenges, thereby augmenting informed decision-making and overall system performance.

Contemporary FM Work Systems and Rising Complexity

As the FM domain approaches contributing to sustainability, it is expected to play a strategic role beyond achieving efficiencies in operations and maintenance of the buildings and infrastructure (Collins and Junghans, 2015). In this broader context, FM can be considered "an integrated approach to operating, maintaining, improving and adapting the buildings and infrastructure of an

organization to create an environment that strongly supports the primary objectives of that organization" (Barrett and Baldry, 2003). Towards addressing the sustainability challenges, i.e., achieving operational efficiencies, gaining competitive advantages, maintaining stakeholders' satisfaction, adhering to regulatory compliances and standards, and achieving resilience and sustainability of the built environment, the FM domain is going through a technological transition where advanced technologies like BIM, IoT, AI-ML, AR-VR, Building Automated Systems, ICT-based tools, Digital Twin-CPS, Blockchain/ DLT and emerging technologies, are becoming integral parts of FM work systems (Araszkiewicz, 2017; Yalcinkaya and Singh, 2019; Lee et al., 2021; Elyasi et al., 2023). Figure 1 explains FM as a sociotechnical (work) system adopting the framework proposed by (Brandt and Cernetic, 1998) where complex networks of social and technical systems (i.e. large teams of technicians, managers at different organizational levels, third-party companies and various technical systems associated with FM process and smart infrastructure) need to work collaboratively for effective management of the built environment. The attempts to bring sophistication to the built infrastructure and the intricacy of the FM work systems have posed challenges to FM actors in achieving and maintaining situation awareness, leading to poor decision-making and negative outcomes for facilities while increasing complexity.

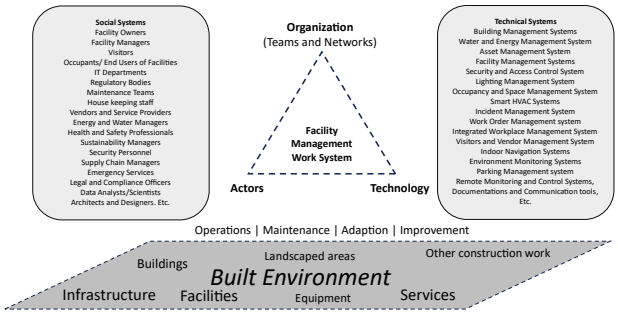

Figure 1:Facility Management as a sociotechnical system.

To further emphasize our claim, we analyze the dimensions of complexity suggested by (Vicente, 1999) in Table 1 to characterize FM work systems as a complex sociotechnical system.

Table 1: Characterizing FM work systems as a complex sociotechnical system with dimensions of complexity by (Vicente, 1999)

Dimensions of complexity	Definitions	Application to FM
Large problem space	Many different elements and forces	Many multidisciplinary functions shall be met by integrating people, processes, technology and places by effectively understanding the needs of the organizations and their peoples.
Social System	Composed of many actors who must work together	Inhouse social system + Outsourced social system + Customers + Owners
Heterogeneous perspectives	Actors with different backgrounds and disciplines	Operational and strategic perspectives, different disciplines, and conflicts of interests
Distributed system	Sub-systems located in different places	Different building systems at different locations, remote operations, teams at different locations, Cloud Computing
Dynamic system	Effects of actions, changes with times	Complex and dynamic built environment
Hazards	The high degree of potential hazards	Failures of critical infrastructures
Coupling	Highly coupled interactive subsystems	Tight coupling with organization and loose coupling between technical systems
Automation	Highly automated systems	Building Automated Systems, AI in FM
Uncertainty	Uncertainty in data available to actors	Rely on first responders, manual collection of data, and fragmented subsystems.
Mediated interactions	Systems not observable directly by actors	CAFM, Observable by Digital Interfaces
Disturbances	Actors dealing with unanticipated events	Unpredictable behaviours and activities of occupants, facility failures

Situation Awareness in FM Work Systems

The primary function of FM work system is to ensure the functionality, safety, comfort, efficiency and sustainability of the built environment (IFMA, 2024). To achieve this, the FM work system, i.e. the actors and FM technologies, continuously interacts with the facilities, its occupants and the core organization to get required situation awareness, which supports decision-making and performance of actions to deliver the agreed services successfully (see Figure 2). SA enables teams and individuals to keep an accurate mental picture of their environment and helps them anticipate changes and make well-informed decisions in complex and dynamic settings (Sorensen and Stanton, 2016). In other words, an adequate level of SA for FM actors will mean that they are aware of what has happened (Perception), what is happening (Comprehension), and what could happen (Projection) at any point, which is fundamental to making well-informed decisions. For instance, in a large office building with a

centralized HVAC system, FM actors continuously monitor temperature, airflow, and energy usage to be aware of what has happened and what is happening. If they detect a sudden temperature increase in a zone, they anticipate a potential malfunction or high occupancy. This awareness of the current situation enables them to make informed decisions and take proactive actions to maintain comfort and optimize resource usage.

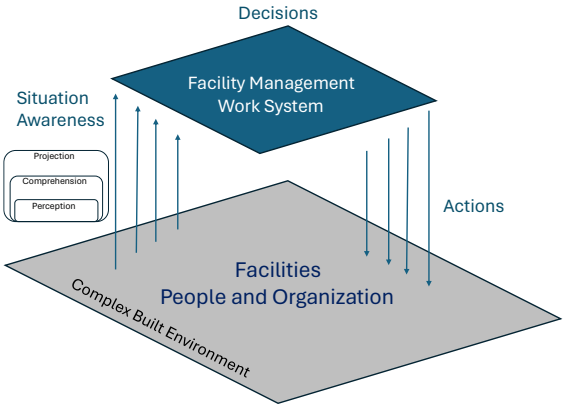

Figure 2 : Situation Awareness in Facility Management Work Systems

However, contemporary FM work systems can be characterized as complex sociotechnical systems where achieving and maintaining SA is challenged by an intricate interplay of many SA-impacting factors (Salmon, 2008; Boy, 2013; Lau and Boring, 2016). This necessitates a case for a sociotechnical systems approach to study SA in FM work systems.

The most influential work of situation awareness defines it as the perception and understanding of elements within an environment, coupled with the comprehension of their meaning and the projection of their status in the near future (Endsley, 1995). Apart from this, (Sarter and Woods, 1991) describe situation awareness as built on working memory and mental models: "Situation awareness is based on the integration of knowledge resulting from recurrent situation assessments". Additionally, (Tenney et al., 1992; Smith and Hancock, 1995)'s models are some of the most cited situation awareness models. Most of these theoretical constructs of situation awareness take an individualist view where situation awareness is considered a product of the active situation assessment process. This view highlights task-related, individual, and environmental factors impacting SA. Stanton presents another dominant view for situation awareness with a systems perspective, i.e. Distributed Situation Awareness (DSA). DSA expands on the idea of SA to include human and technological agents that work collaboratively, and SA emerges from SA transactions amongst them (Stanton et al., 2006; Salmon, 2008). This viewpoint strongly emphasizes team members' shared mental models, communication, and coordination to preserve a thorough grasp of the operating environment. Apart from the Stanton model on situation awareness, Endsley's and Jones's model on situation awareness and Artman and Garbis's distributed cognition model are some of the models that account for situation awareness from a team perspective (Artman and Garbis, 1998; Endsley and Jones, 2001). The reviewed literature suggests five dimensions for factors impacting SA in a sociotechnical system, i.e. individual, team, task/domain, technological, and environmental. Table 2 presents factors identified in literature impacting situation awareness in the sociotechnical system.

Table 2: List of factors impacting SA from the literature.

Categories	Factors Impacting SA
Individuals	Attention Tunneling, Errant mental models, Requisite Memory Trap, Out-of-the-loop syndrome, Goals and Expectations, Experience and training, Stress and fatigue, Training, Cognitive Load
Technology	Complexity Creep, Misplaced salience, Interface Design, System Capability, System Design, Procedures, Reliability and Robustness, Data Integrity
Team	Communication, Coordination, Roles and responsibilities, Team Cohesion, Attitude, shared mental models, Trust and Collaboration.
Tasks/ Domain	Information Overload, Lack of required information, Quality of information, Fragmented Information, Complexity, Automation, Workload, Workflow
Environment	Environmental stressors (Loud Noises, Lighting Conditions, Thermal Discomfort, Air Quality, Large Crowds, etc.), Complexity of the environment

Diagnosing FM work system for SA-related issues

To be innovative and efficient in the fast-changing demands and needs of client organizations, FM work systems must adopt strategies for continuous adaptation and improvement of the work systems (Duffy, 2000; Roberts, 2001; Nazali and Pitt, 2009). This necessitates adopting a problem-solving approach to identify poor performance outcomes/challenges within the work system, define problems, and design and implement solutions throughout the work system's life cycle. Poor performance outcomes in the work system can directly be attributed to poor SA, provided the actors can and are willing to decide and act with their SA (Endsley, 2020). This indicates that addressing SA-related issues in the work system can improve its performance. In order to achieve that, one should conduct a comprehensive diagnosis, which can guide interventions aimed at enhancing SA. The existing literature predominantly focuses on descriptive assessment of SA, which can describe whether a work system holds required and

accurate SA or not. There are also few supports available in terms of guidelines for system design to support situation awareness (Endsley et al., 2003; Alhaider, 2022). However, we do not find any evidence of support available for diagnosing the work system for SA-related issues. Diagnosis in complex work systems demands systems thinking (Senge, 1994; Testa and Sipe, 2006; Wilson, 2014). The literature review discovered the iceberg model of systems thinking and its potential and applicability in diagnosing various work systems (Al-Homery et al., 2019; Ttr and Sivakumar, 2019). The researchers modified and adapted the iceberg model to guide the diagnosis of SA-related issues in the FM work system. (Refer to Figure 3 for details). For the scope of this research, we limit the diagnosis to one layer down to the iceberg model, where it uncovers patterns of individual, environmental, team, task/domain, and technological factors impacting situation awareness in FM work systems. Future work should focus on identifying mental models and sociotechnical interactions responsible for the emergence of SA-impacting factors in the FM work systems.

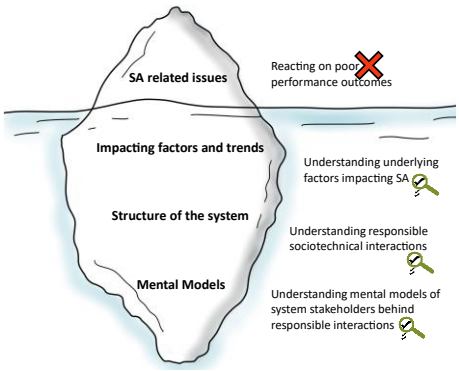

Figure 3:Iceberg model of systems thinking for diagnosing FM work system for SA-related issues.

Methodology

The ergonomic and human factors domain suggests integration of methods with a systems approach to address complex problems of sociotechnical systems (Stanton, 2018; Salmon and Read, 2019). With this inspiration, based on the literature review of situation awareness, sociotechnical systems, and facility management domains, we propose a qualitative method to support diagnosing FM work systems for situation awareness-related problematic situations. Figure 4 shows overall research methodology to be adopted for this research.

With a focus on improving situational awareness in FM work systems, the literature review on situational awareness comprehensively lists the factors that impact SA. The literature review on situation awareness touches on the different aspects of the sociotechnical systems, i.e., individuals, teams, technologies, tasks/domains, and the environment. Based on the different aspects of the sociotechnical systems, the corresponding factors that impact SA have been reviewed and listed in the Table 2. Based on the factors listed from the literature, the FM work system is investigated using the proposed method, which integrates multiple methods (see Table 3). Furthermore, while evaluating the FM work system with the proposed method, there could be a possibility of new factors that result from the diagnosis that are also included while diagnosing the work system. Overall, at meta level the method itself can be evaluated and improved for its effectiveness for FM work system but this is beyond the scope of this research work.

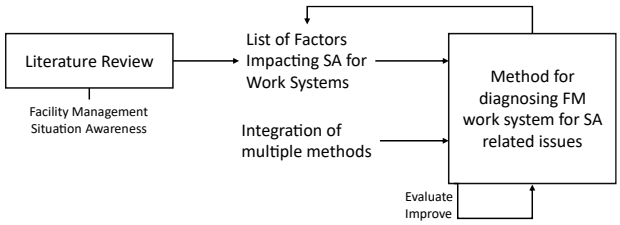

Figure 4:Adopted Research Methodology

Table 3: Proposed research method for diagnosis of the FM work system for SA related issues

Phases	Objectives	Activity	Outputs	Involvement of Participants
Data Collection	To understand the work system thoroughly	In-depth interviews, direct observations, system and operators' logs	Recordings, Notes and documents	Provide relevant information
Data Processing	To prepare data for analysis	Transcription and documentations	Documents	Not Required
	To identify and define potential problematic situations in the work system	Qualitative Analysis Who? What? When?	List of Problems	Verification of Problems for their occurrence
Data Analysis	To identify problems relevant to Situation Awareness and related possible causal factors	Reasoning How? Why?	Problems relevant to SA and related causal factors	Active Involvement in Reasoning
Interpretation of results	To interpret the results of the analysis	Visualization	Frequency Distribution of Responsible SA impacting factors	Not required

Case Study

The applicability of the proposed method was tested in an industrial FM setting. The industrial setting had multiple work systems like water management, helpdesk, energy, access control, security, etc. Out of the different work systems, the helpdesk work system is central to the efficient functioning of the different work systems together. Recent trends in FM emphasize the adoption of a helpdesk for the large and complex built environment with many occupants to process work orders, complaints, and service requests of the clients effectively. The principle of helpdesk systems is similar to the IT helpdesk – "to respond to a customer's inquiry as quickly as possible and follow it through until it has been satisfactorily resolved". However, the functioning of the helpdesk work system in the FM domain can be complex and challenging, as it deals with a large problem space with multiple interrelated support team networks and a complex-built environment. In this regard, the helpdesk work system was chosen as the place of interest for the study. The unit of analysis for this study was the whole helpdesk work system with two helpdesk executives and a facility manager responsible for its functioning, as shown in the Figure 5

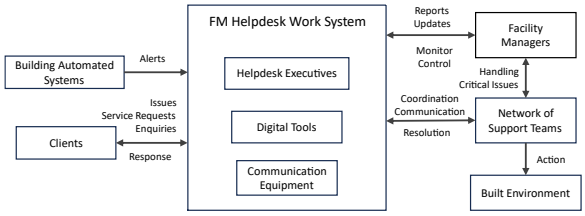

Figure 5:Basic structure of the FM helpdesk work system.

The study began with an informal discussion among the researchers and the help desk executives with two major objectives: for the researchers to familiarize themselves with the operations of the help desk work system and for executives to familiarize themselves with the study plan. After the informal discussion, the researchers conducted observational studies at different times to understand and record the basic functioning of the work system. Two separate questionnaires (See Table 4 and Table 5) were prepared to conduct semi-structured interviews with helpdesk executives and the facility manager to thoroughly understand the work system and its problems. The three and half-hour overall interviews were recorded and transcribed. The transcripts of the interview and the notes of the observational study were used together to do a qualitative analysis to understand the detailed functioning of the help desk work system and identify potential problematic situations. A more precise description of the problems was prepared with an understanding of who is involved, what the problem is, and when it occurs in the work system. Precise description helps to improve understanding of the problems, which supports the relevant stakeholders' diagnosis of the work system. These problems were revisited to check their uniqueness, relevance to SA and duplications were removed. The helpdesk executives further verified the problems identified for their occurrence. Diagnosing each problem was performed with reasoning to identify all possible causal factors that can impact SA in the work system by the researcher. This was done carefully with the factors identified in the literature and newly realized factors from the reasoning activity.

Questionnaires:

These questionnaires were prepared for semi-structured interviews to understand the helpdesk work system thoroughly as shown in Table 4 and Table 5.

Table 4:Questionnaire for Semi-structured Interview of Helpdesk Executives

Questions
What is your association with the Facility Management Work System?
Can you briefly explain the helpdesk work system?
Can you describe your role and responsibilities related to the helpdesk work system?
What is your work experience related to your current role? How do you gain experience?
What are your day-to-day operations at work? Are there any specific tools or software you use?
Do you work as a team? What is your specific role in this team?
Have you or your team identified any training or skill gaps required to improve your performance?
What reporting and documentation processes do you follow to keep track of system performance, issues, and resolutions?
How do you communicate with other stakeholders to address issues or to seek support?
How do digital tools and equipment impact your daily operations?
What issues do you face in the daily operations related to digital tools and equipment?
What are the anticipated risks if the issues are not resolved?
What improvements or changes could be made to enhance the efficiency and effectiveness of your role as an operator of this solution/system?

Table 5:Questionnaire for Semi-structured Interview of Helpdesk Work System Manager

Questions
Can you provide an overview of the facility management helpdesk work system's structure and its role within the organization?
What are the primary objectives and goals of the facility management helpdesk work system in ensuring smooth facility operations?
Could you describe the key processes and workflows the helpdesk team follows to manage facility requests and issues?
What are the key performance indicators (KPIs) or metrics used to measure the success and efficiency of the facility management helpdesk?

What are the most common challenges or bottlenecks the helpdesk team encounters in addressing facility-related issues?
How are facility requests and issues assigned and tracked within the helpdesk system, and what tools or software are used for this purpose?
How does the helpdesk team coordinate and communicate with facility management staff and other relevant departments to resolve issues promptly?
How is the helpdesk equipped to handle unexpected facility-related emergencies or disruptions effectively?
What technologies or tools support the facility management helpdesk's work processes and decision-making?
How do you ensure your helpdesk team has the resources and training to manage facility requests and issues effectively?
What strategies and practices are in place to continuously improve the facility management helpdesk's operations and service delivery?
How are conflicts or issues typically managed and resolved within the helpdesk team or with other facility-related stakeholders?
Can you share recent examples of successful facility management initiatives or improvements facilitated by the helpdesk team?
What future developments or changes do you foresee for the facility management helpdesk, and how are you preparing for them?
How does the helpdesk gather and utilize feedback from facility users and staff to enhance its service quality and efficiency?
What leadership and management style do you employ to ensure the success and satisfaction of the helpdesk team?
Are there any specific training or development needs you believe would benefit the helpdesk team's performance in managing facility requests and issues?
How does the facility management helpdesk contribute to fostering a positive facility management culture and ensuring high levels of user satisfaction?
Can you share experiences where the helpdesk effectively responded to critical facility-related situations or challenges?
What are the most important lessons you have learned as a leader of the facility management helpdesk, and how have they influenced your approach?

Results:

A total of seventy-one potential problematic situations related to poor performance outcomes were identified, and diagnosis was performed to identify related SA-impacting factors obtained from the literature and through analysis. Figure 6 shows the frequency distribution of the SA impacting factor relevant to the identified problematic situations in the FM helpdesk work system in decreasing order where ineffective communication and lack of knowledge and experience are the highest occurring factors, this could be the case as the industrial setting is in under digital transformation and very frequently new facilities and related teams are being introduced. Ineffective feedback mechanisms, the complex network of actors, lack of accountability, lack of multidisciplinary knowledge, work constraints, lack of standardization, and poor data handling are the new factors realized with reasoning activity in the data analysis phase which can impact SA.

The environmental stressor, team attitude, goal and expectations and out-of-the-loop syndrome did not show up in the analysis. The environmental conditions were well maintained in terms of lighting and air quality. Also, a dedicated space is allocated to the helpdesk team which lacks large crowd and loud noises. Team attitude and goal and expectations has complex relationships with SA which is difficult to put into the reasoning. The helpdesk executives were proactively engaging with the other relevant actors to get and provide updates which avoids out-of-the-loop syndrome.

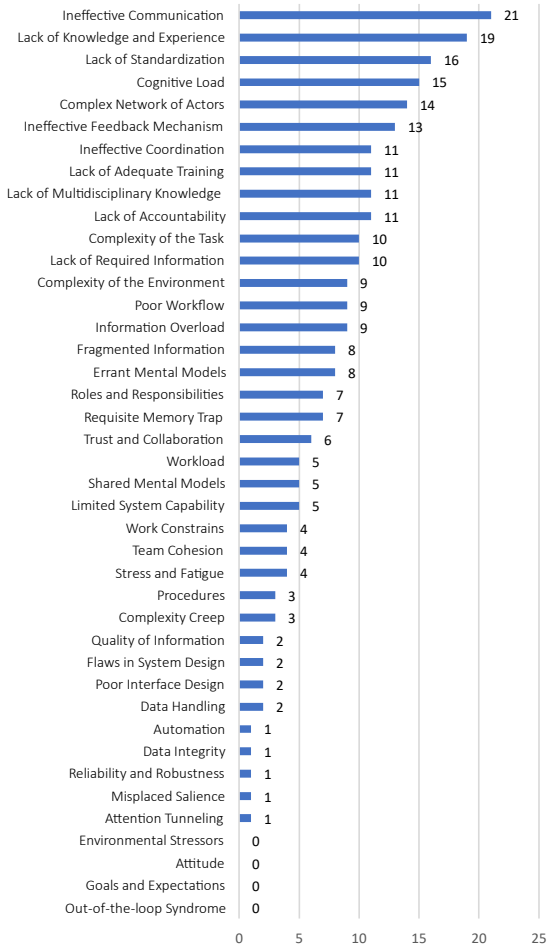

Figure 6: Frequency Distribution of the SA impacting factors from analysis.

Discussion and Conclusions

The method discussed in the study stemmed from the initial observations and discussion with relevant FM stakeholders of a help desk system in an industrial FM setting. These observations underscored the significant impact of poor situational awareness (SA) on the efficacy and functionality of the help desk system, prompting a comprehensive diagnosis of the underlying work system to enhance SA. The work system managers spend substantial time and effort in diagnosing the work system through routine meetings and discussions, but

they were not found to have a situation awareness-oriented approach. From Figure 3, they mostly react to the poor performance outcomes for surface-level solutions, but the literature suggests it requires systems thinking to understand the underlying cause and treat them. This highlighted the critical need for thorough analysis and diagnosis of FM work systems to address underlying challenges for SA effectively.

An adequate understanding of all the factors impacting situational awareness is essential for the stakeholders to diagnose the FM work system. Some of the factors that impact the FM work system may be difficult to reason out, requiring comprehensive reasoning ability of the stakeholders, for example, how goals and expectations and team attitude can affect SA. The result of the analysis represents how responsible each factor is in impacting SA; it should not be confused with how much impact a particular factor causes to SA in the work system. This analysis of the FM work system acts as a reference point to further investigate the underlying interaction through which the SA-impacting factors emerge in the system. While the involvement of stakeholders in the process is ideal, practical considerations such as time constraints may necessitate analysis by the researchers alone, where they are expected to have a detailed understanding of the work system. Furthermore, it is necessary to ensure that stakeholders are well-supported and informed about the different steps and factors in understanding the method in advance to facilitate their effective participation.

Although the suggested approach has shown itself to be useful in the setting of a help desk work system, more research should be done to see whether it can be scaled up to include a greater number of participants and other work systems. Expanding the methodology's scope to include a wider range of stakeholders and organizational contexts would offer important insights into its effectiveness for various FM work systems while it may also demand large efforts. We anticipate the potential for developing digital tools to support the effective use of the method by system stakeholders where the tool's knowledge base can be enhanced with each study, it can support reasoning, and the involvement of the researcher can be avoided. Furthermore, the analysis presented in the study is from the researcher's perspective owing to the constraints of time and availability of the systems stakeholders. As the study is a work in progress, a comprehensive analysis of the problematic situations of the help desk work systems from the active participation of stakeholders is something that needs to be looked at in future works.

Acknowledgments

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