Extending Situation Awareness Theory to Non-Critical Domains with the Work System Perspective

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Abstract

The construct of situation awareness (SA) has been rigorously theorised and measured for over three decades. However, its development has remained largely confined to safety-critical domains such as aviation, military operations, power plants, and healthcare. This work attempts to challenge this confinement. Drawing on Steven Alter's Work System Theory and the 18 generic Facets of Work, we systematically map three levels of SA onto every facet of work and demonstrate that SA is not a specialist cognitive requirement solely for high-stake work, but a universal cognitive foundation underpinning all adaptive, goal-directed work. We argue that the ongoing digital transformation of ordinary work, characterised by information overload, faster decision cycles, and distributed interdependencies, renders a critical-systems-only perspective theoretically untenable and practically limiting. Failures in SA within business and organisational contexts, while they may not be disastrous, can impose considerable economic and operational costs that remain largely unexplored in current literature. This work contributes to a facet-level theoretical synthesis, a model integrating SA in work systems, and a research agenda spanning measurement, antecedents, human-AI teaming, and design science. Bridging human factors, information systems, and management research, we position SA as a core, designable property of all work systems and advocate for its comprehensive investigation across organisational domains.

Keywords

Situation Awareness, Work Systems, Facets of Work

1. Introduction

Situation awareness (SA) has been a key construct within cognitive engineering and human factors research. Widely accepted, Endsley's model of SA defines it as "the perception of environmental elements within a volume of space and time, the comprehension of their meaning, and the projection of their status in the near future" [13]. This model comprises three hierarchical levels: perception (Level 1), comprehension (Level 2), and projection (Level 3), and stands as a basis for analysing and supporting operators' performance in complex, dynamic systems [12]. Empirical studies of SA have predominantly focused on safety-critical domains such as aviation, military command and control, nuclear power operations, and healthcare [15, 24]. In these settings, SA is considered a critical cognitive precursor to effective performance, with its degradation being directly associated with catastrophic outcomes. Consequently, SA is

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conceptualised as a construct inherently linked to environments characterised by high stakes, acute time pressure, and fatal risk [24]. The SA measurement and design approaches have therefore been developed and validated almost within this narrowly defined scope.

Parallel to this established tradition, the nature of routine organisational work has transformed significantly today. Contemporary work systems, such as project management, information technology operations, supply chain coordination, and professional services, are primarily shaped by enterprise information systems, real-time data streams, and distributed, digitally mediated collaboration. Within these contexts, workers routinely face information overload, compressed decision cycles, and highly interdependent processes that demand continuous monitoring and adaptive responses [21]. This expansion of cognitive demands also aligns with Alter's characterisation of contemporary workspaces as highly competitive, agile, and data-driven ecosystems [2]. Whether a product manager analysing evolving user analytics or an IT analyst diagnosing failures across cloud infrastructures, these actors are invariably engaged in cognitive activities that essentially require perceiving salient cues, interpreting their relevance within operational goals, and projecting potential future states. Despite these clear parallels, SA theory has not been systematically extended to such non-safety-critical work environments. The shift towards fluid, data-saturated workflows highlights a historical tension. As noted by Mumford [18], the evolution of information and communication technologies has often led organisations to prioritise lean production and cost-cutting, often at the expense of human-centric work design. Extending SA to ordinary work systems addresses Mumford's [18] advocacy for reintegrating socio-technical principles that humanise technology within contemporary, fast-paced organisational settings.

In information systems and management literature, SA is often referenced in a relatively informal way, such as "being attentive" or "mindfulness", without the theoretical precision or operational clarity associated with the perception-comprehension-projection model [10]. This points to an important gap in existing literature. The common assumption that situation awareness (SA) is a specialised cognitive concept limited to high-risk environments has remained largely unquestioned. As a result, many research initiatives and design efforts in work systems proceed without a clear conceptual foundation for SA, even though the application domains involve cognitive demands analogous to SA constructs.

This gap can also be understood as a failure of mutual enrichment between domains. As Human Factors Engineering (HFE) has developed a cognitive mechanism with SA, it has largely confined SA to safety-critical domains, leaving it without a general organisational architecture. Information Systems (IS) research, especially Work System Theory (WST), offers a domain-independent architecture of work but lacks a granular cognitive mechanism to explain how Participants perceive, comprehend, and project in real time. Management research studies coordination, decision-making, and performance, but often lacks a shared cognitive foundation. Integrating SA with WST can address this mutual deficit.

This paper addresses the identified gaps by examining SA within a generic, domain-independent framework of work activity. To do so, it draws on Steven Alter's Work System Framework, which describes 18 Facets of Work, including decision-making, communication, information processing, planning, coordination, improvisation, service delivery, value creation, and security management [3]. The primary research question guiding this study is*: Why is it both necessary and valuable to study situation awareness in non-critical, everyday work systems?*

To address this question, we first conduct a theoretical synthesis in which the three levels of SA are mapped onto the 18 facets of work, thereby demonstrating that every generic work activity is fundamentally dependent on an actor's ability to perceive, comprehend, and project. Second, we argue that the ongoing digital transformation of ordinary work renders the traditional confinement of SA to safety-critical domains theoretically untenable and, in practice, limiting, particularly because SA failures in organisational or business settings can incur substantial economic and organisational consequences. Third, we articulate a research agenda and discuss the implications of treating SA as a core, designable property applicable to all work systems.

The main contribution of this paper lies in its systematic demonstration that SA can be understood as a universal cognitive foundation for any work system, rather than a construct limited to high-risk domains. The paper thereby connects perspectives from HFE, IS, and management research, providing a foundational justification for the study and design of situation-awareness-sensitive work systems across the full spectrum of organisational domains.

2. Theoretical Foundations

In this section, we present the conceptual foundation supporting our argument. We begin with a review of the core tenets of SA theory, focusing on hierarchical three-level structure and its established role within complex and dynamic systems. Subsequently, we introduce the work system perspective and Alter's 18 facets of work, presented as a domain-independent characterisation of work activity. Finally, we identify the conceptual gap that arises from aligning these two bodies of knowledge and articulate the opportunity for synthesis.

2.1. Situation Awareness

Situation awareness (SA) is defined as a cognitive state comprising three hierarchical levels: the perception of relevant elements in the environment within a volume of space and time (Level 1), the comprehension of their meaning in relation to operative goals (Level 2), and the projection of their future status (Level 3) [13]. Critically, SA is distinguished from decision-making and action performance as an underlying foundation. The quality of an actor's SA is shaped cognitively by the interaction among attentional resources, working memory, long-term memory, and the richness of domain-specific mental models [11]. Additionally, it can be affected by individual factors such as goals, objectives, expectations, abilities, expertise, and training, as well as task, environment and system factors such as system capabilities, stress and workload, interface design, complexity, and automation [13].

Subsequent theoretical developments have extended the construct to contain collaborative and systemic dimensions. Team SA emphasises the shared understanding of task interdependencies and role-specific responsibilities required for coordinated action [20]. The concept of distributed SA shifts the unit of analysis from the individual mind to the socio-technical system, viewing awareness as an emergent property of interactions among human and technological agents rather than a phenomenon residing solely within an operator's mind [23]. These extensions are valuable for studying modern work environments, where collaborative technologies and automated agents are becoming prominent.

Central to SA is the concept of mental models — learned internal representations that guide experts in rapidly interpreting cues and projecting future states [11]. In safety-critical domains, these models are largely shaped by physical laws and operational procedures of the specific work domain: a pilot's mental model of aerodynamics, for instance, is invariant across contexts, and the procedures for take-off or landing are almost the same. In business/organisational work systems, by contrast, mental models are bound by institutional rules, business logic, and software architectures that are often opaque, inconsistent, or subject to frequent changes, and the operational context is shifting from stable routine work to dynamic, fluid knowledge work. This can make it more challenging for actors to achieve and maintain accurate SA, making studying SA in this context more urgent.

Empirical research on SA has largely focused on domains characterised by high consequences, time pressure, and operational complexity, especially aviation, air traffic control, military operations, and healthcare [15, 24]. Within these contexts, SA has been operationalised using objective freeze-probe techniques, subjective rating scales, and performance-based metrics, and has been causally linked to safety outcomes [14]. This body of work has produced a mature, empirically grounded theory of how operators maintain an actionable internal model of a dynamic situation. However, the very success of this tradition has reinforced a scholarly boundary, implicitly positioning SA as a construct relevant primarily to environments in which physical harm or loss of critical infrastructure is an immediate and salient risk.

2.2. Work System Theory and the 18 Facets of Work

Work System Theory (WST) provides a generic, domain-independent lens for understanding how work is accomplished within organised human activity. Alter defines a Work System (WS) as “a system in which human participants and/or machines perform processes and activities using information, technology, and other resources to produce products or services for internal or external customers” [5]. The WST promotes a systems lens rather than an isolated focus on individuals, software artefacts, or individual tasks; the work setting, including WS elements - Participants, Processes, Technologies and Information, and their interactions, becomes the primary unit of analysis. It has been applied across a wide range of organisational contexts, from healthcare and manufacturing to financial services and software development [4].

In much of the existing literature, the 'Information' element of WST is often treated as a structural resource—databases, records, documents, or static data—to be stored, processed, retrieved, and transmitted, overlooking the cognitive transformation required for data to become actionable awareness for human participants. As Checkland and Holwell [9] argue that information is not a static resource; it is created when human actors select data, convert it to capta, and attribute meaning within a context of purposeful action. This highlights a missing dynamic and cognitive transformation aspect within the WST that is responsible for adaptive performance in dynamic settings.

A distinctive contribution of WST is the identification of 18 generic Facets of Work (FoW), which collectively describe the elemental activities that constitute work in any domain [3]. These are socio-technical activities enacted by Participants using Information and Technology within Processes to produce Products/Services for Customers [5]. These facets encompass cognitive activities such as making decisions, thinking, planning, processing information, and applying knowledge; interactive and social activities such as communicating, coordinating,

interacting socially, and co-creating value; physical and execution-oriented activities such as performing physical work, performing support work, and controlling execution; and integrative activities such as providing service, creating value, improvising, representing reality, and maintaining security [3]. The facets are not mutually exclusive. A single work activity may draw upon several simultaneously, but each is conceptually distinct and collectively exhaustive for the work activity. The framework thus offers a stable, comprehensive vocabulary for describing what work is, regardless of domain or risk profile.

2.3. Conceptual Gap and Synthesis

When SA theory and WST are juxtaposed, an evident gap emerges. SA research has focused primarily on where work outcomes can be dangerous; WST has focused comprehensively on *what* work consists of. The former provides a rich account of the cognitive processes that enable adaptive performance in dynamic environments but has confined its empirical reach to a narrow set of operational domains. The latter offers a universal descriptive architecture of work but lacks a cognitive mechanism to explain how work is performed adaptively in real time. Neither body of knowledge, in its current form, directly addresses the SA requirements of ordinary, non-critical work.

This gap theoretically supports the untested assumption that SA is a domain-specific construct rather than an omnipresent cognitive basis. Practically, it leaves the design of ordinary WS, such as enterprise dashboards, collaborative platforms, workflow engines, and decision-support tools, without a principled basis for supporting the perception, comprehension, and projection that actors require to perform effectively in a work system. The opportunity, therefore, is to integrate these two frameworks by systematically mapping the three levels of SA onto Alter's 18 facets of work and to claim SA's universal applicability across all kinds of work systems (WS). This integration addresses Alter's [6] call for an IS development paradigm that harmonises technical capabilities with human operational realities.

Although Alter [2] explicitly identifies 'data-driven' and 'smart' environments as core challenges for modern socio-technical design, the WS perspective [4] primarily focuses on the structural arrangement of the WS elements. Merging this with Endsley's theory introduces the explicit cognitive mechanisms required to understand how human participants actually navigate the information overload inherent in these modern value ecosystems. These provide the justification needed to introduce cognitive mechanisms like Endsley's [13] SA into the WS architecture, moving the framework beyond static process modelling and into real-time cognitive enablement.

The conceptual gap also highlights a broader challenge in systems design: technical models often treat operational data as abstract inputs, ignoring the human reality. As Bednar and Welch [8] point out, true socio-technical practice requires an explicit focus on the user's psychological and environmental context. Mapping Endsley's cognitive hierarchy onto Alter's structural facets can operationalise this requirement by providing a framework for analysing how system architecture influences situated human experience.

Furthermore, bridging HFE with IS requires navigating distinct disciplinary paradigms. As Wynn and Vallo Hult [26] demonstrate in their comprehensive review of critical research in IS and HCI, understanding how humans interact with technology within complex organisational settings demands methods that account for situated practices, power dynamics, and systemic

contexts rather than isolated laboratory metrics. Synthesising SA with WST can lead to exactly this type of integrative, socio-technical analytical approach.

3. Mapping SA to Facets of Work

The central thesis of this paper is that SA forms a universal cognitive requirement for all goal-directed work activities. Establishing this claim necessitates demonstrating that the three-level SA constructs (perception, comprehension, projection) are imperative to every generic facet of work identified by Alter [3]. Mapping SA to FoW serves a dual purpose. First, it provides a theoretical validation: if SA can be shown to underpin all 18 facets, then SA must be regarded as a foundational property of any work system irrespective of its criticality profile. Second, it generates a diagnostic vocabulary, allowing researchers and practitioners to identify performance deficits at specific levels of awareness and facets, thereby opening pathways for targeted intervention. Given space limitations, the analysis groups the 18 facets into five clusters, and only representative facets are discussed in detail to illustrate the argument. The complete mapping for 18 facets is provided in **Table 1**.

3.1. Analysis and Mapping

The 18 facets of work are clustered into cognitive, interactive and social; physical and execution; value and service; and security and representation facets. In the current study, the analysis is presented for representative facets of the clusters due to space limitations. However, we cover all facets by mapping the specific SA requirements across three levels to each facet, along with the potential consequences of SA failure, in **Table 1**.

Cognitive Facets: This cluster includes making decisions, thinking, processing information, planning, and applying knowledge and is representative of the interplay between the Information and Participant elements of WST. Each of these activities requires the actor to operate on a mental representation of the situation. For *making decisions*: Level 1 SA provides perceptual cues such as options, constraints, and trigger events that define the decision space. Level 2 integrates these cues into a comprehension of their meaning relative to the goals and priorities. Level 3 enables projection of the likely consequences of alternative courses of action, supporting proactive rather than reactive choice. With absent or degraded SA, decision-making can fall into stimulus-bound or rule-bound behaviour that may be misaligned with the actual state of the world. Similarly, *planning* is an exercise in projection anchored in current reality. With SA, Level 1 provides awareness of available resources and active constraints; Level 2 synthesises this awareness into an understanding of dependencies and risks; and Level 3 generates the very sequence of projected future states that constitute the plan. Planning with degraded SA is likely to fail in the real dynamic conditions.

Interactive and Social Facets: This cluster includes communicating, coordinating, interacting socially, providing information, and co-creating value, all of which depend on awareness of other actors' states, intentions, and contexts. It foregrounds the Participant element in social interaction with other Participants, where such interactions are crucial for maintaining compatible distributed situation awareness (synchronised SA) [23, 25] and can be supported by Technologies and Processes. *Coordinating* across interdependent actors requires what Salas et al. [20] term team SA: each actor must perceive the actions and intentions of

others (Level 1), comprehend how their own tasks interlink with the collective activity (Level 2), and project the timing and resource implications of others' future actions to achieve synchronisation (Level 3). *Co-creating value*, as in consultant-client engagements, demands mutual SA, i.e., each party must perceive the other's contributions and feedback, comprehend the partner's constraints and expertise, and project how the collaboration will evolve to produce a collaborative outcome. When either party lacks SA, co-creation can slip into burden or passive compliance.

Physical and Execution Facets: This cluster includes performing physical work, performing support work, and controlling execution, and may appear less cognitively demanding than the preceding clusters, yet it is no less dependent on continuous perception–action coupling [17]. It largely relates to the Participants, Technology, and Processes elements, in which participants must maintain continuous perception-action coupling with physical or digital systems to perform effectively. *Controlling execution*: the act of monitoring a process and applying corrections requires Level 1 perception of real-time process variables, Level 2 comprehension of the significance of deviations (i.e., distinguishing random variation from meaningful trends or faults), and Level 3 projection of the deviation trajectory to apply proportional correction. Control performed without SA is either open-loop drift or delayed overreaction. *Performing support work*, such as IT maintenance, demands SA of the operational context: perception of system status and user activities, comprehension of dependency chains, and projection of the disruption a support action might cause. Without such SA, support activities can create a risk for unplanned outages.

Value and Service Facets: This cluster includes providing service, creating value, and improvising, and largely relates to the Participants, Customer and Product/Service elements, requiring participants to perceive and comprehend the beneficiary's context and to project value outcomes and emergent possibilities. *Providing service* that is personalised and satisfying depends on Level 1 perception of clients' cues, Level 2 comprehension of unexpressed needs and emotional states, and Level 3 projection of which service actions will meet or exceed clients' expectations. Indifferent, scripted service is a direct manifestation of SA failure, leading to client dissatisfaction because their requirements cannot be adequately met. *Improvising*: the creative, real-time response to an unexpected event is frequently mischaracterised as a purely intuitive act. In fact, effective improvisation relies on deep SA. Level 1 perception of the novel problem and the available means at hand, Level 2 comprehension of the affordances and risks associated with repurposing those means, and Level 3 projection of the likely outcome of the improvised action before committing to it. Improvisation with deficient SA can introduce new hazards, whereas SA-informed improvisation may likely be the most resilient and resourceful.

Security and Representation Facets: This cluster includes maintaining security and representing reality, and is largely related to the Participants, Information and Technology elements. *Maintaining security*, whether in the physical or informational domains, requires Level 1 perception of weak signals and anomalies, Level 2 comprehension of these signals as threat patterns, and Level 3 projection of threat trajectories to enable pre-emptive responses. Security without adequate SA can become static and reactive, advantageous to the threat. This vulnerability is empirically demonstrated by Sadok, Alter, and Bednar [19], who used a WS lens to expose severe disconnects between formal corporate security policies and the actual, situated security practices of workers. When security protocols are introduced merely as compliance mandates rather than integrated into the dynamic awareness of daily work practices, human

participants experience a breakdown in Level 2 comprehension and Level 3 projection, often disregarding vital security risks due to a perceived lack of localised relevance. *Representing reality* with building models, dashboards, or digital twins demands Level 1 perception of the actual system state, Level 2 comprehension of which variables are salient and how they interrelate, and Level 3 projection of the model's intended use to determine its reliability. A representation constructed with deficient SA is a distorted mirror that can institutionalise false assumptions among all participants who rely on it by hindering system transparency.

The mapping presented below in **Table 1** is obtained through systematic conceptual analysis by the authors' subjective interpretations. The definition of each facet from [1, 3] were examined against the three levels of SA, asking whether the facet's effective enactment would require perception, comprehension, and projection. If yes, what are the SA requirements for these three levels, and what can go wrong if they are not met?

Table 1 illustrates the full mapping of SA dependencies across all 18 facets, indicating the core SA requirements at each level and the potential impact of SA failure.

Table 1. Situation Awareness Dependency Across the 18 Facets of Work

Facet of Work	**Core SA Requirement (L1, L2, L3)**	**Impact of SA Failure**
Making Decisions	L1 - perceive possibilities, constraints L2 - comprehend decision space L3 - project outcome of alternatives	Uninformed or stimulus-bound choices; misaligned actions
Communicating	L1 - perceive receiver's state, channel L2 - comprehend information needs L3 - project message impact	Misunderstanding, irrelevance, confusion, and communication breakdown
Processing Information	L1 - perceive data sources, quality L2 - comprehend meaning, relevance L3 - project downstream use	Errors, distorted analysis, decontextualised output
Thinking	L1 - perceive problem elements L2 - comprehend relationships L3 - simulate future states	Narrow or irrelevant ideation; impractical solutions
Representing Reality	L1 - perceive actual system state L2 - comprehend salient variables L3 - project model usage	Inaccurate models, institutionalised false assumptions
Providing Information	L1 - perceive the recipient's context L2 - comprehend decision needs L3 - project timing, format	Decontextualised data, critical signals lost in noise
Applying Knowledge	L1 - perceive triggering cues L2 - comprehend situational novelty L3 - project outcome of applied knowledge	Rigid misapplication, expertise as liability
Planning	L1 - perceive resources, constraints L2 - comprehend dependencies, risks L3 - project plan evolution	Rigid, over-optimistic plans; collapse under dynamic change

Facet of Work	Core SA Requirement (L1, L2, L3)	Impact of SA Failure
Controlling Execution	L1 - perceive process variables L2 - comprehend deviation significance L3 - project trajectory	Open-loop drift, over-correction, delayed response
Improvising	L1 - perceive problem or opportunities, means L2 - comprehend affordances L3 - project outcome of improvised action	Unsafe workarounds, secondary failures, systemic failures
Coordinating	L1 - perceive others' actions L2 - comprehend interdependencies L3 - project collective future states	Conflicting efforts, duplication, delays and deadlocks
Performing Physical Work	L1 - perceive environment, hazards L2 - comprehend physical affordances L3 - project movement consequences	Accidents, product damage, injuries, and inefficient motion
Performing Support Work	L1 - perceive system status L2 - comprehend disruption risk L3 - project impact of support action	Unplanned downtime, clash with live operations
Interacting Socially	L1 - perceive emotional/social cues L2 - comprehend norms, relationships L3 - project interpersonal impact	Tone-deaf behaviour, eroded trust, loss of psychological safety
Providing Service	L1 - perceive customer cues L2 - comprehend deeper needs L3 - project satisfying actions	Indifferent, scripted service, customer frustration, churn
Creating Value	L1 - perceive beneficiary's context L2 - comprehend the job to be done L3 - project use and adoption	Misaligned outputs, effort wasted on unsolved problems
Co-creating Value	L1 - perceive partner's input L2 - comprehend mutual constraints L3 - project joint outcome	Imposition, passive compliance, loss of ownership
Maintaining Security	L1 - perceive weak threat signals L2 - comprehend threat patterns L3 - project threat trajectory	Blind spots, undetected intrusions, mis-prioritised alerts

L1 = Perception; L2 = Comprehension; L3 = Projection

3.2. Theoretical Claim and Conceptual Model

The above analysis in **Table 1** supports a strong theoretical claim: that **situation awareness is a necessary cognitive basis for the effective performance of every facet of generic work.** From abstract cognitive tasks such as thinking and planning to embodied physical work, and from social interaction to maintaining security, the quality of an actor's SA directly governs the effectiveness of work activity. Thus, SA emerges beyond a specialist concern of high-risk professions to a universal cognitive mechanism that converts the structural resources of a work system, i.e. information, technology, processes, and participants, into situationally appropriate performance.

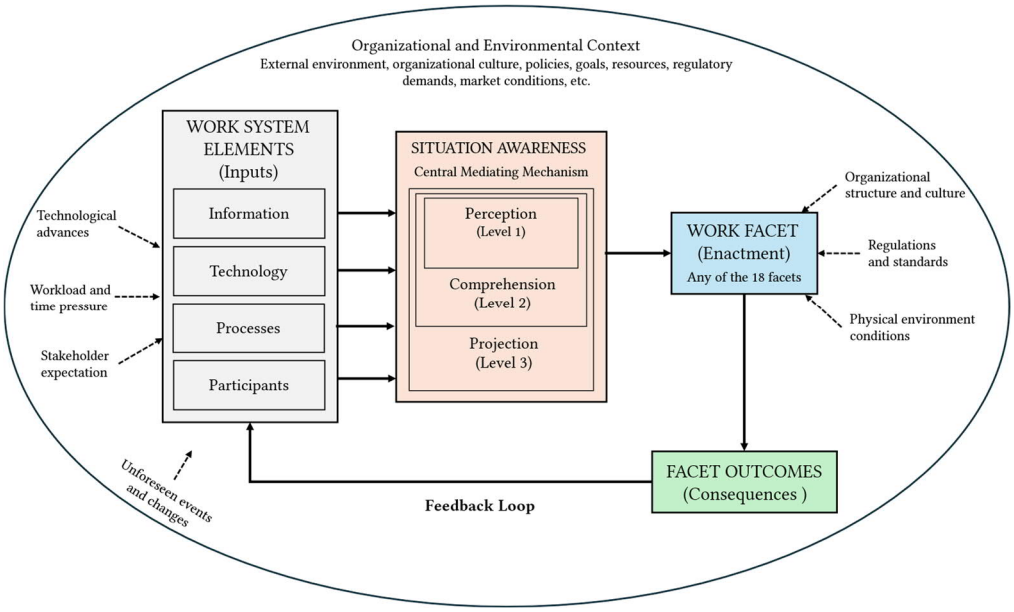


Figure 1. Model representing the integration of Situation Awareness Theory[13] into the Work System Theory [3, 4]

Figure 1 illustrates a model of SA-infused work facets in a WS. The model positions the hierarchical SA construct as the central mediating mechanism between WS elements and facet enactment. Information, Technology, Processes, and Participants serve as inputs to the SA mechanism, and the output is a dynamic mental picture that drives the execution of any relevant facet of work. Feedback from facet outcomes continuously updates SA and WS, creating a continuous adaptive loop. This adaptive loop operationalises the mechanisms of organisational learning defined by Argyris and Schön [7]. Immediate feedback loops enable single-loop learning, enabling real-time error correction and improvisation in work facet enactment by continuously updating participants' local SA. Global SA can facilitate double-loop learning. By projecting future states, human participants can actively challenge the underlying assumptions of the work system, enabling the WS to adapt structurally before systemic failures manifest. While SA is a necessary enabler, the enactment of work facets is also shaped by organisational structures, culture, regulations, standards, and physical conditions. As a result, a positive facet outcome cannot be guaranteed by sufficient SA alone. Moreover, the Work System's structure responsible for SA can change in planned or unplanned ways due to technological advances, workload, time pressure, and stakeholders' expectations. The proposed model (**Figure 1**) also responds directly to Alter's [6] call for an IS development paradigm that harmonises technical capabilities with human operational realities. By embedding Endsley's [13] three levels of SA as the central mediator, we operationalise how 'Participants' cognitively absorb 'Information' and utilise 'Technology' to achieve socio-technical balance during work execution. This model can provide a foundation for both diagnosis and design. It can be used to identify breakdowns by locating the deficient SA level within a particular work facet, and to guide interventions by indicating which SA-supporting mechanisms, such as visualisations to aid comprehension or predictive analytics to support projection, can be introduced into the WS.

4. Beyond the Critical-Systems Lens

4.1. Transformation in Contemporary Work

The traditional confinement of SA research to high-consequence domains assumes that only such environments generate the cognitive demands, i.e. dynamic complexity, time pressure, and severe failure costs, that necessitate continuous perception, comprehension, and projection. This premise, while historically grounded, has been eroded by digital transformation and the realities of everyday work, as the modern knowledge work is defined by constant organisational and economic change [18]. Contemporary work can be characterised by information overload from enterprise dashboards and real-time data streams, faster decision cycles driven by algorithmic processes, and distributed interdependencies spanning functions, time zones, and organisational boundaries. This expansion of cognitive demands also aligns with Alter's characterisation of contemporary workspaces as highly competitive, agile, and data-driven ecosystems [2]. A supply chain coordinator or cybersecurity analyst often operates in a cognitive environment that shares many characteristics with the traditional SA settings. Relevant signals must be distinguished from large volumes of information; emerging patterns must be interpreted with respect to changing goals; and future developments must be anticipated to support timely decisions. In this sense, the cognitive demands described by SA theory are not confined to safety-critical settings; they are becoming ever more common across everyday work systems. Moreover, technologies now tightly couple distributed business tasks, and workers face abstract, digital complexities that mirror those of high-risk domains, rendering a strict 'critical-systems-only' boundary for cognitive support obsolete.

4.2. SA Deficits as Manifestation of Socio-Technical Vulnerabilities

The costs of SA failures in business and organisational contexts are less immediate and less visible than those in aviation; nonetheless, they can be substantial and inadvertently underestimated. When an executive team fails to perceive and comprehend a market shift, the consequences can include strategic misjudgement, an eroded competitive position, or even revenue loss. When an IT support technician performs maintenance unaware of a cascading dependency, it can result in an unplanned service outage affecting thousands of users, inviting reputational and financial penalties. These performance deficits reflect the underlying socio-technical tensions that Alter [2] highlights in modern ecosystems, where a hyper-focus on lean efficiency or algorithmic speed can actively undermine workers' holistic understanding of the system. Digital transformation often increases the distance between the worker and the actual work, making perception harder and introducing cognitive friction: the effort required to extract meaningful signals from opaque interfaces [22]. When tools are engineered strictly for technical throughput, they can degrade Level 2 comprehension and Level 3 projection, resulting in costly operational errors that are misattributed to process failures rather than design flaws. Thus, SA deficits in a business system can be understood as a latent design flaw in the WS itself, where the Technology and Information elements have failed to support the Participant's cognitive needs. Misattributing such failures to 'human error' obscures the problem's structural origin and prevents systemic remediation. Hence, these failures should be considered not merely operational inefficiencies but manifestations of deeper socio-technical vulnerabilities.

In practice, these failures can easily be misattributed to process inadequacy, communication breakdown, or individual error, but a facet-level analysis can reveal a deficit at one or more levels of SA, a missed cue, a misinterpreted pattern, or a failed projection. The economic and organisational costs of such SA deficits are real but largely unexplored in modern WS, as the research on SA has remained confined to its traditional domains.

4.3. A Design Opportunity

The recognition that SA is foundational to all facets of work opens up a significant, unexplored design opportunity. The digital tools that constitute the contemporary workplace, such as business intelligence dashboards, collaborative platforms, workflow automation, and AI-driven decision aids, are overwhelmingly engineered to deliver data rather than cultivate SA. They prioritise information access, often without regard for how a particular interface facilitates or hinders Level 1 perception, Level 2 comprehension or Level 3 projection. As a result, digitalisation can also undermine SA in unintended ways. Fragmented dashboards may divide attention across multiple information sources, excessive notifications can interrupt sense-making, and algorithmic recommendations may encourage overreliance on automation at the expense of independent judgment and anticipation. This reflects the disconnect identified by Alter [6] between rigid technical conceptualisations and actual business realities. Designing for SA can ensure that technology actively supports human perception, comprehension, and projection, fulfilling the socio-technical mandate to create systems that respect and empower the human participant. Studying SA within general work systems can help researchers and designers identify these challenges and develop Work Systems that better support perception, comprehension, and projection. Prominent examples include organising signals/alerts more effectively, using visualisations to reveal patterns, and providing forecasting or simulation tools to explore potential future states. This approach can shift enterprise systems beyond their traditional role as information repositories and toward supporting the cognitive work required for effective adaptation and human performance.

5. Implications and Future Research

5.1. Theoretical Contributions

The argument advanced in this paper carries three principal theoretical implications. First, it extends the boundary of situation awareness theory beyond its historical confinement to safety-critical domains. By demonstrating, at the facet level, that perception, comprehension, and projection are constitutive of all generic work activities, we reposition SA as a general cognitive foundation for adaptive performance across all work systems. This broadens SA theory's explanatory reach, establishing a continuum from everyday work to high-stakes operations.

Second, the mapping contributes to WST by adding the missing cognitive mechanism. Alter's framework [5] describes what work is, but says little about how it is adaptively steered in real time. Our synthesis frames SA as the dynamic mediator between the structural components of a work system and the quality of outcomes of facet enactment. The addition transforms the WST from a static descriptive framework into a dynamic cognitive architecture capable of explaining variation in performance, resilience, and degradation.

Third, the paper helps connect three research communities that have largely addressed related problems from different perspectives. Human Factors Engineering (HFE) has developed a substantial body of knowledge on situation awareness, but its application has remained concentrated in safety-critical domains. At the same time, Information Systems (IS) research focuses on designing and evaluating digital technologies that support work, often without incorporating cognitive engineering principles. Management research similarly examines decision-making, coordination, and performance, but lacks a common framework for understanding the cognitive processes underpinning these activities.

This paper also advances the broader socio-technical agenda by considering Mumford's [18] directive for new analytical frameworks capable of navigating constant technological displacement. By formalising Endsley's cognitive levels within Alter's structural facets, we provide a modern mechanism to ensure information architectures protect human cognitive capacity rather than overwhelming it.

Finally, by positioning SA as an engineered property of work systems, this paper attempts to address the historical separation between cognitive engineering and organisational design. This alignment responds directly to the broader interdisciplinary trajectory outlined by Wynn and Vallo Hult [26], who advocate for a closer alignment between HCI's focus on human experience and IS's focus on institutional infrastructure to capture the realities of digitalised work. Thereby the paper provides a basis for greater integration across these fields and for the development of cumulative, cross-disciplinary theories.

5.2. Practical Implications

Treating SA as a core property of Work Systems has several practical implications. For managers, the framework provides a way to diagnose performance issues by locating the SA failure within a specific work facet and identifying which WST element—Information, Technology, Processes, or Participants — or system configuration is failing to support it. It shifts attention outside skills, processes, and motivation to examine whether the underlying problem lies in perception (Level 1), comprehension (Level 2), or projection (Level 3). Each can point to different interventions, such as improving information displays, supporting sense-making, or strengthening anticipatory planning.

For system designers, the framework highlights the need to support all three levels of SA. It demands the design of Technology and Information to support all three SA levels. Dashboards can help users identify patterns and anomalies rather than simply display data. Decision-support tools can include simulation and uncertainty visualisation to support anticipation. Likewise, AI-enabled systems should provide sufficient transparency to help users maintain their own understanding of the situation for all three levels. This way, the technology actively reduces cognitive friction rather than exacerbating information overload. Thereby transitioning software engineering away from purely data-centric layouts and toward what Sommerville [22] frames as context-aware, socio-technical system design.

For educators and trainers, the framework suggests that SA should be treated as a general workplace competency. The framework provides a pathway to bridge the policy-practice divide identified by Sadok et al. [19]. Rather than delivering abstract, generic training modules that fail to alter user behaviour, professional development must design scenario-based exercises that explicitly build facet-level SA, linking operational variables directly to the participant's localised situational context.

5.3. Future Research Directions

The theoretical and practical arguments developed in this paper point to several directions for future research in organisational and business contexts. Four areas seem especially important.

Measurement of SA in Contemporary Work Systems: How can the three levels of SA be measured in open-ended work settings where there is no clear ground truth? Evaluating SA within open-ended, dynamic organisational boundaries requires techniques that do not strip away real-world complexity. Many existing SA assessment techniques will fall short here because they were developed for domain-specific and procedural contexts. Future research should adopt the socio-technical practice of contextual inquiry, as articulated by Bednar and Welch [8]. By investigating human participants directly within their unique, localised contexts of use, researchers can qualitatively capture how workers actively perceive informational cues (Level 1 SA), construct meaning (Level 2 SA) and navigate structural uncertainties (Level 3 SA) during live operations, rather than relying on artificial simulations. Future research can leverage the qualitative and critical methodologies highlighted by Wynn and Vallo Hult [26], combining digital trace data with contextual inquiries and focused ethnographic studies to map how participants achieve and maintain SA within fluid organisational boundaries, and explore adaptations of existing SA assessment techniques.

Antecedents of SA in Work Systems: What individual, team, informational, technological and process-related factors contribute to effective SA? Questions may include how interface design, notification practices, and team coordination routines influence perception, comprehension, and projection. Using work system theory, research should examine how the configuration of Information, Technology, Processes and Participants either supports or hinders the Participant's SA.

SA in Human-AI teaming: As AI filters information and provides recommendations, how do they affect human SA? Research is needed to understand when automation supports SA and when it undermines it, particularly through overreliance on algorithmic outputs. As the role of AI evolves from a WS Technology to a WS Participant, research must advance to explore human-AI team SA.

Design of SA-Sensitive Work Systems: What design principles can help design work systems to support perception, comprehension, and projection better? We propose developing *Socio-Technical SA Design Principles* to guide the design of work systems from a sociotechnical perspective, adopting a balanced, holistic approach to support Participants' SA and the overall work system's functional success. Thereby, the term 'Socio-Technical SA Design Principles' describes a design orientation in which the Technology and Information elements of a work system are deliberately configured to support the Participant's SA. This will anchor a systemic design commitment to aligning technical infrastructure with human cognitive architecture.
It is also important to understand how such interventions can be evaluated in real-world settings. Consequently, developing design principles for SA-sensitive work systems will require iterative and context-sensitive methods that leverage qualitative, interpretive and critical research methodologies, such as design science research [8, 16, 26] and being fundamentally grounded in the sociotechnical practices.

Together, these directions provide a starting point for extending SA research into information systems, human–computer interaction, and management. Advancing this agenda will require interdisciplinary collaboration and a broader view of SA as a feature of everyday work rather than only of safety-critical environments.

6. Conclusion

This paper examined whether situation awareness (SA) should be studied in non-critical work systems. Mapping the three levels of SA onto Alter's 18 facets of work demonstrates that all generic work activities require perception, comprehension, and projection. These findings suggest that SA functions as a universal cognitive foundation, rather than being confined to safety-critical domains. It was argued that the digital intensification of ordinary work, characterised by information overload, compressed tempo, and distributed interdependencies, magnifies the practical consequences of SA failures. Consequently, a perspective limited solely to critical systems proves inadequate. Based on this synthesis, theoretical implications for extending SA and work system theory were outlined. Furthermore, practical directions for diagnosis, design, and training were proposed, along with an initial research agenda encompassing measurement, antecedents, human-AI teaming, and SA-sensitive design. These contributions establish a foundation for considering SA as a core property inherent to any work system and invite interdisciplinary research that moves SA inquiry beyond its traditional confines.

Declaration on Generative AI

During the preparation of this work, the authors used Grammarly in order to check grammar and spelling. After using these tool/service, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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