



## ORIGINAL ARTICLE

# Unmanned Aerial Systems in Sarawak: Suitability of Work System Theory for Unmanned Traffic Management Frameworks

\*<sup>1,2</sup>Daniel Yong Wen Tan, <sup>1,2</sup>Huong Yong Ting, <sup>1,2</sup>Abdulwahab Funsho Atanda, <sup>1,2</sup>Siew Ping Yiiiong, and <sup>1,2</sup>Cherry Yieng Siang Ling

<sup>1</sup>Design and Technology Centre (DeTec), University of Technology Sarawak, 96000 Sibul, Sarawak, Malaysia

<sup>2</sup>School of Computing & Creative Media, University of Technology Sarawak, 96000 Sibul, Sarawak, Malaysia

**ABSTRACT** - The sporadic adoption rate of Unmanned Aerial Systems (UAS) in various sectors such as agriculture, logistics, search and rescue, and environmental monitoring, among others, calls for robust Unmanned Traffic Management (UTM) frameworks to ensure a secure and seamless UAS operation. The development and integration of UTM into the existing air traffic management (ATM) framework present unique challenges that require well-researched solutions. Sarawak's diverse geography and topological terrain, characterized by hilly and inaccessible roads and dangerous waterways, necessitate the adoption of UAS for emergencies, logistics, and disaster management. This paper determines the suitability of Work System Theory (WST), which promotes a holistic understanding and practical design of systems for developing UTM frameworks for Sarawak. The capability of WST to allow dynamic interactions between technology, processes, participants, and the environment in the work system sets it apart from other traditional information systems theories, such as General System Theory, Sociotechnical System Theory, and the Actor-Network Theory. This paper argues that WST provides a more comprehensive and adaptable foundation for UTM frameworks in Sarawak through the review of related information system theories, highlighting their strengths and limitations. The findings suggest that WST provides a valuable theoretical foundation for creating safe, efficient, and sustainable UTM systems that can support the growth of the UAS industry in Sarawak while addressing the unique socio-cultural and environmental contexts of the region. This work contributes to both theoretical discourse and practical advancements in UTM, advocating for WST as a foundational framework for emerging technologies in complex environments.

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**INTRODUCTION**

Technological advancement and enabling regulation have spurred the adoption of Unmanned Aerial Systems (UAS) that are revolutionizing industries across the globe, from agriculture and logistics to disaster management and environmental monitoring [1]. Driven by the potential uses, benefits, and risks of UAS, there has been a heightened global race to enable the safe integration of UAS into society [2], including Malaysia [3]. Sarawak is the largest state in Malaysia with a land mass of 124,450 square kilometres [4], characterised by craggy topography consisting of mountainous terrain and a vast river network, constituting substantial logistical problems [5]. Commuting to many rural communities scattered across the state by road is a herculean task; worse still, the waterways are infested with crocodiles posing a high risk to transportation by boat [6]. A mid-air collision of two commercial flights over the Grand Canyon, US, in 1956, resulting in the death of all 128 passengers onboard, necessitated the development of an Air Traffic Management (ATM) system [7]. The increasing number of UAVs, coupled with security and safety concerns, not only poses a security risk to buildings and property, but also to the general public and air travel [8],

necessitating an appropriate level of organization. The rising rate of UAV adoption causing congested air traffic has forced all international civil aviation regulators to address the issue of integrating unmanned aircraft into the ATM system [9] amplifying the call for the development of a robust Unmanned Traffic Management (UTM) framework to ensure the safe, secure, efficient, equity, and regulated integration of UAS into the airspace [7]. The growing adoption of UAS requires a strong and easily dependable system for safe and effective control of both conventional and autonomous aircraft in our airspace. Achieving such a system is laced with a lot of challenges to ensure an appropriate level of organisation and clarity built upon a sound regulatory framework [8]. The major barrier hampering the adoption of UAS in Sarawak is the lack of an operational framework that encompasses airspace operations requirements, procedures, and support functions. Likewise, the successful development, implementation, and integration of UTM into ATM requires cooperation among regulators, industry stakeholders, and the general public [3], each having different roles and responsibilities [7].

UTM is a framework specifically designed to facilitate the safe, efficient, and scalable operation of UAVs, especially in low-altitude airspace [10]. As the use of drones has expanded rapidly for a variety of applications, from commercial deliveries to aerial surveillance, there is a need to integrate these systems into the global airspace safely. UTM aims to manage drone traffic, ensuring safety, security, and efficiency in the airspace. It involves a set of technologies, rules, and procedures that are collectively used to manage and monitor drone flights. The goal is to enable a shared environment where both manned and unmanned aircraft can safely coexist. Key aspects of UTM include communication, navigation, and surveillance systems that provide traffic management for drones, akin to traditional air traffic management systems for manned aircraft but adapted to the unique characteristics of UAVs [11], taking into consideration their geographical and use cases [7].

As a concept, the UTM is described as a system of technical systems and stakeholders working together in specific interactions and in compliance with regulations specific to different countries to guarantee air traffic control. Conversely, the UTM system is a tangible technical implementation that consists of the drones themselves, the software, and the infrastructure required to execute the program [12]. In actuality, UTM is a complex system made up of several components and entities working harmoniously to ensure safe, secure, and efficient operations of UAS. Developing such a framework requires a theoretical foundation that captures the complexities of UAS operations and guides practical implementation. Amongst the numerous information systems (IS) theories, Work System Theory (WST) stands out for its holistic approach. The objective of this paper is to evaluate the suitability of WST for developing a UTM framework in Sarawak, comparing it to other prominent theories to justify its adoption.

## **UAS AND UTM CHALLENGES IN SARAWAK**

The UTM system, a collection of services providing automated airspace management, makes UAV flights in regulated and uncontrolled airspace safe and secure [12]. The rising realisation of an operational UTM system integrated into ATM for effective and secure UAS operation has motivated several studies [8; 12], [13; 14]. UAS is gradually finding its way into Malaysia to tackle issues related to urbanisation, such as pollution, traffic jams, urban sprawl, and a lack of social amenities. Effective adoption in Malaysia, however, requires solving identified obstacles such as regulations, flying time and range limitations, knowledge gaps, a shortage of trained staff, privacy and security concerns, among others [3].

Sarawak, Malaysia's largest state, presents a unique set of logistical challenges due to its expansive and diverse topography [4]. The advent of UAV technology offers a promising solution to these challenges. The rural and often isolated communities in Sarawak stand to benefit significantly from UAV adoption. These systems promise to bridge the gap between urban centres and remote villages, ensuring equitable access to essential goods and services. This not only addresses the logistical challenges of physical terrain but also promotes socio-economic development in rural areas. The introduction of UAVs in Sarawak can revolutionize the supply chain dynamics, enhancing the accessibility of agricultural inputs, educational materials, and other critical resources as asserted in [14]. However, Sarawak's geographical and socio-economic diversity poses challenges such as limited infrastructure, variable weather conditions, and regulatory complexities to the successful adoption of UAVs. These factors make a case for a UTM framework that is not only robust but also adaptable to local contexts.

## INFORMATION SYSTEM THEORIES

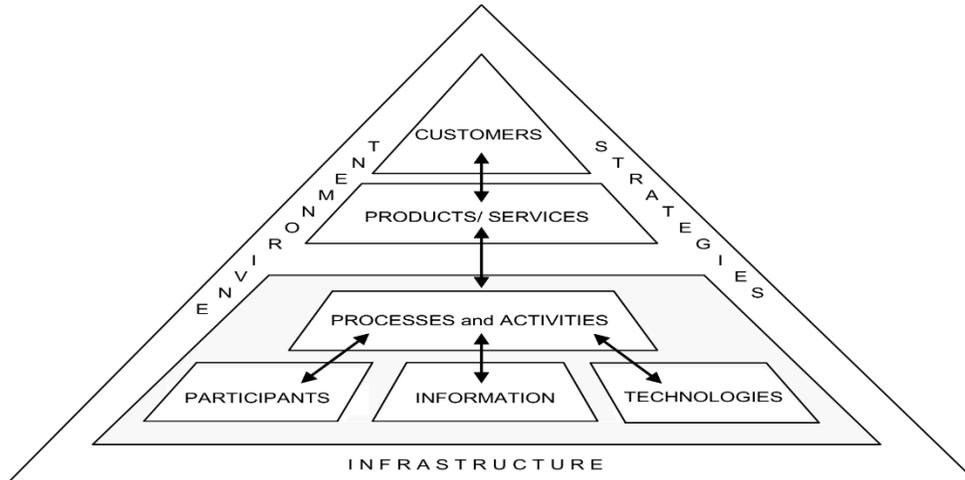
Information systems (IS) are systems for providing information services to the user by receiving, storing, accessing, transforming, transferring, and processing information to generate desired information services. The value of IS lies in its ability to be involved in a set of system activities resulting in improved activities [15]. Theories are enablers that allow researchers to make general working assumptions about elements being investigated and to specify which components of a framework are relevant for answering certain types of questions [16]. A conceptual framework for evaluating and creating information systems that assist business operations is known as information systems theory (IST) [17].

Over time, as information technology has evolved and been widely adopted, several theories have been developed to guide and inform IS practices. These theoretical frameworks help researchers and practitioners understand and predict interactions between technology, users, and organizations. Among IS theories include the Technology Acceptance Model (TAM) [18], Innovation Diffusion Theory (DOI) [19], Structuration Theory [20], Information Systems Success Model (ISSM) [21], Critical Social Theory (CST) [22], General System Theory [23], Actor-Network Theory (ANT) [24], Sociotechnical Systems Theory (STS) [25], and Work System Theory (WST) [26]. The former set of IS theories, such as TAM, Structuration, DOI, and CST, are better at providing deep insights into specific aspects of IS, such as user behaviour, adoption processes, and power dynamics. On the contrary, the strength of the latter set of IS theories, such as GST, STS, ANT, and WST, lies in their holistic and systems-oriented perspective, making them well-suited for understanding and designing complex, interconnected systems [27; 28]. Hence, based on the fact that the choice of theory depends on the research goals and the scope of analysis, and given the complexities of designing a framework for UTM, the latter set of theories is reviewed to determine the most suitable one for the task of developing a UAS framework work for UTM in Sarawak.

### Work System Theory (WST)

WST [29] is an integrated framework for understanding systems within organizations, particularly those relying on IT. At its core, WST includes two primary components: a Type 1 analytical theory called the work system framework and a Type 2 explanatory theory called the work system life cycle model [30]. Together, these form the basis for a design theory known as the Work System Method (WSM). The theory's domain of greatest relevance is IT-reliant work systems, which are central to the field of IS. WST is not a theory of everything for the IS discipline. Still, it provides a comprehensive perspective for understanding a wide array of systems in organizations, excluding certain areas like the nuances of human-computer interaction and competitive uses of IT.

At the heart of WST is the concept of a "work system" as the natural unit of analysis for considering systems in organizations. As defined by [31], "A work system (WS) is a system in which human participants and/or machines perform work (processes and activities) using information, technology, and other resources to produce specific products/services for internal and/or external customers or themselves". This concept encompasses both sociotechnical systems, where people perform processes and activities, and totally automated systems in which all activities are performed by machines. Key implications include the necessity of alignment within the system's components and interactions, the purpose of work systems to produce products/services for customers, and their evaluation based on both internal process efficiency and customer evaluations. The WS framework is a foundational tool for describing and analysing IT-reliant WS within organizations. It outlines a WS's form, function, and environment, focusing more on business concerns rather than IT specifics. The framework consists of nine elements, categorizing processes, activities, participants, information, and technologies as internal to the WS, and viewing customers, products/services, environment, infrastructure, and strategies as having both internal and external influences. **Error! Reference source not found.** shows the WS framework.



**Figure 1.** Work System Framework [29]

The Work System Life Cycle Model (WSLC) offers a dynamic view of how work systems evolve over time through planned and emergent changes. This model reflects the iterative nature of WS development and change, capturing the ongoing adaptations, innovations, and improvements within work systems. Its comprehensive focus on interactions among participants, processes, and technology aligns well with the multifaceted demands of UTM in Sarawak. Key strengths of WST include:

- **Contextual Adaptability:** WST's emphasis on system-environment interactions enables it to accommodate Sarawak's diverse operational contexts.
- **Practical Design Guidance:** By focusing on actionable system design, WST bridges the gap between theoretical analysis and implementation.
- **Stakeholder Inclusivity:** WST facilitates the coordination of diverse stakeholders, from regulatory bodies and UAS operators to local communities.

### General System Theory (GST)

GST formulated by [32] and [33], is an interdisciplinary theory that provides a framework for understanding the structure and behaviour of complex systems in various fields, including biology, ecology, engineering, and social sciences. The central tenet of GST is that complex systems exhibit common patterns and behaviours that can be understood and modelled in a unified way, despite the diversity of their components and interactions. This theory seeks to transcend the boundaries of traditional scientific disciplines by emphasizing the commonalities that systems share, promoting a more integrated and holistic approach to scientific inquiry [34]. The focus of GST is on the identification and modelling of the general principles that govern the behaviour and evolution of systems. It looks at systems as wholes, considering not just the individual components but also their interactions and the emergent properties arising from them. This approach leads to a better understanding of how complex behaviours and patterns emerge from simple rules and interactions, which is a fundamental aspect of many natural and man-made systems [35].

In practice, GST has a wide range of applications across various disciplines. In biology and ecology, it helps in understanding the complex interactions within ecosystems and the interdependence of organisms [36]. GST also has significant philosophical implications. It challenges the traditional reductionist approach in science, which tries to understand complex phenomena by breaking them down into simpler components. Instead, GST promotes a holistic view, suggesting that the whole is more than the sum of its parts and that understanding the system's overall behaviour is crucial. This perspective acknowledges the limitations of reductionism, especially in dealing with complex and interconnected systems where emergent properties play a significant role [37]. In summary, General Systems Theory is a broad and influential framework that has significantly impacted many fields of study. By promoting a holistic and integrated approach to understanding complex systems, GST has helped bridge the gap between various disciplines,

leading to new insights and innovations. Its focus on common patterns and principles across different systems, combined with its practical applications and philosophical depth, makes it a fundamental theory in the study of complex phenomena.

### **Sociotechnical System Theory (STS)**

STS is an integrative approach to understanding organizations by emphasizing the social and technical factors' interrelatedness and mutual influence in work environments. Originating from the seminal work of Trist and Bamforth in the early 1950s, STS challenges the traditional view of organizations by advocating for the simultaneous optimization of both the social system (including people, culture, and organizational structure) and the technical system (comprising technology, processes, and tasks). The theory posits that neither aspect can be effectively optimized in isolation without considering its impact on the other, advocating for a holistic approach to organizational design and performance improvement [38].

The focus of STS is on how organizations can achieve higher levels of productivity, innovation, and employee satisfaction by recognizing and harmoniously integrating the social and technical dimensions of work. The social aspects pertain to human interactions, cultural norms, and organizational structures, whereas the technical aspects relate to the tools, technologies, and processes used in the production of goods and services. By considering these aspects jointly, STS aims to create work environments that are more humane, satisfying, and effective, leading to both improved organizational outcomes and a better quality of work life for employees [39]. The theoretical framework of STS includes several key principles and concepts. At its core is the notion of 'joint optimization', which means designing work systems that enhance the social and technical elements together, rather than optimizing one at the expense of the other [40]. This involves recognizing the complex, often nonlinear interactions between people and technology and designing systems that accommodate these dynamics. Another critical concept is that of open systems, which view organizations as entities that constantly interact with their environment. This perspective acknowledges that changes inside the organization can affect and be affected by external factors, requiring a flexible and adaptive approach to organizational design and management. STS also emphasizes the importance of minimal critical specifications, variance control at the source, the need for multi-skilled workers, and the design of work to support both individual autonomy and group collaboration. In conclusion, STS offers a comprehensive, nuanced view of organizational design and development. It underscores the importance of considering the complex interplay between social and technical factors in work systems and provides a guiding framework for creating more integrated, adaptive, and human-centered organizations. As businesses and technologies continue to evolve, the principles of STS remain relevant, guiding efforts to enhance organizational effectiveness, adaptability, and the quality of work life in an increasingly complex and fast-paced world.

### **Actor-Network Theory (ANT)**

ANT is a conceptual approach that views social, technological, and natural entities not as distinct and separate but as collectively forming a network of relations. ANT posits that actors, or actants, encompass both human and non-human entities, such as technological artefacts, which are equally capable of influencing and shaping socio-technical networks. The theory's key concept revolves around understanding how these diverse entities collaborate, interact, and form alliances to create a network or a socio-technical system. ANT is fundamentally about exploring the interconnectivity and relationality of things, emphasizing that the nature of an entity is defined by its relationships within a network [41; 42].

The theory is particularly notable for its focus on how networks are maintained, the role of power within them, and how change occurs as actors negotiate and translate their interests. It challenges conventional distinctions between humans and non-humans, subject and object, society and technology, instead proposing that the socio-technical system is a result of the associations between various entities. This perspective allows for a deeper exploration of the intricacies of technological and social change, as it acknowledges the influential role of non-human entities in shaping human society and vice versa. In practice, ANT has been utilized to analyse a wide range of phenomena, particularly in the field of science and technology studies, organizational studies, and sociology [43]. It has been applied to study the development and implementation of technologies, organizational changes, and more broadly, the understanding of complex socio-technical arrangements. Researchers use ANT to trace the network of

relations and understand how technological systems, policies, and organizational structures evolve and are stabilized or changed over time. Its application often involves case studies where the network of relations is meticulously traced and analysed to understand the formation and transformation of socio-technical systems. WST, GST, STS, and ANT are influential theories in the field of systems and organizational studies that have found wider applications in IS. Each offers a unique lens through which to understand complex systems, their components, and their interactions. Below is a comparative table that outlines their features.

**Table 1.** Comparison of Four Major IS Theories

Theory	Focus	Holism	Dynamic Interaction	Sociotechnical Integration	Complexity	Design Orientation
WST	Work systems in organizations	✓	✓	✓	✓	✓
GST	Interconnected parts of a system	✓	✓	Partial	✓	Partial
STS	Social and technical subsystems	✓	✓	✓	✓	✓
ANT	Networks of human and non-human actors	✓	✓	✓	✓	Partial

Based on Table 1 above, it is evident that of the four system-based IS theories, WST and STS are tied given the comparison metrics. However, while STS provides valuable insights into balancing social and technical components, WST enables a more comprehensive and practical framework for developing a UTM framework for UAS operations in Sarawak. The holistic approach of WST for integrating technical innovation with human and environmental factors, adapting to unique environments, and highlighting practical outcomes such as efficiency, safety, and sustainability makes WST more suitable than STS. Its broader scope and design focus make WST mostly well-suited for addressing Sarawak's complex operational and environmental requirements. Hence, the choice of WST in developing the UTM framework for the operation of UAS in Sarawak.

## MATERIALS AND METHODOLOGY

To evaluate the suitability of WST for developing UTM frameworks in Sarawak, this study adopts a multi-method approach (mixed method). Using quantitative and qualitative methods to generate new knowledge is known as mixed methods (or multimethod) research. These methods can be used sequentially or concurrently to pursue a path of inquiry. Their shortcomings can be overcome, while their complementary strengths can be activated through combination [44]. The integrated mixed methods enable researchers to pursue emergent topics instead of restricting their work to questions that lend themselves to a specific method [45]. The methodology of this research comprises the following steps:

**Literature Review:** A comprehensive review of existing UAS operations, UTM frameworks, and information system theories was conducted. Sources included academic journals, industry reports, and regulatory documents to have a clear understanding of the practical challenges and requirements of UTM for UAS operations in Sarawak, including geographic, economic, and regulatory factors. The literature review also aimed to identify the strengths and limitations of different IS theories, such as ANT, STS, GST, and WST.

**Comparative Framework Analysis:** Related UTM UAS frameworks were methodically compared using criteria that include contextual adaptability, design guidance, and stakeholder inclusivity. Then WST's principles were mapped against Sarawak's UTM needs to determine WST's relevance and applicability.

**Conceptual Model Development:** A conceptual UTM model grounded in WST is developed based on the mapping of UTM's requirements to the WST framework. The model integrates key components, including operational processes, stakeholder interactions, and regulatory compliance mechanisms. Feedback from local stakeholders and domain experts was incorporated to refine the model.

**Validation through Expert Consultation:** Semi-structured interviews were conducted with selected experts in UAS, traffic management, and information systems. Their valuable feedbacks are used to validate the theoretical and practical alignment of the WST-based model with Sarawak's requirements.

## RESULTS AND DISCUSSION

Based on the identified components of the UAS UTM framework and the facts (known, partial, and unknown) in the components determined through a literature review, the elements are mapped into the WST framework as shown in Table 2. The mapping to the WST framework is tailored to suit the needs of medical delivery in Sarawak while adhering to the laws and regulations regulating UAS operations in Sarawak, Malaysia.

**Table 2.** Mapping of UAS UTM Framework for Medical Delivery to Work System Framework

Components	Status	Facts identification	Source	Method
Processes and Activities	Known	<ul style="list-style-type: none"> <li>Permit application.</li> <li>Operational Assessment.</li> <li>Safety Management System.</li> </ul>	CAAM Civil Aviation Directive – 6011 Part (V)	Literature review
	Unknown	<ul style="list-style-type: none"> <li>Loading and unloading medical parcels</li> <li>Delivery and handover</li> </ul>	Sibu General Hospital Clinical Research Centre and Pharmacy Department	Semi-structured Interview.
Participants	Partial	<ul style="list-style-type: none"> <li>Number of crew and roles.</li> </ul>	Apex flight	Semi-structured Interview.
	Unknown	<ul style="list-style-type: none"> <li>Healthcare providers' involvement</li> </ul>	Clinical Research Centre & Pharmacy Sibu Hospital	Focus Group Interview
Information	Known	<ul style="list-style-type: none"> <li>Operational requirements.</li> <li>Technical Requirements.</li> <li>Personnel Requirements.</li> </ul>	CAAM Civil Aviation Directive – 6011 Part (V)	Literature review
	Unknown	<ul style="list-style-type: none"> <li>Data from UAV.</li> </ul>	Aerlift	Semi-structured Interview.
	Unknown	<ul style="list-style-type: none"> <li>Data from UTM.</li> </ul>	Apex Flight	Semi-structured Interview.
	Unknown	<ul style="list-style-type: none"> <li>Flight route information such as topography</li> </ul>	Satellite map and actual aerial survey	Survey Operation
Technologies	Unknown	<ul style="list-style-type: none"> <li>Parcel type and special requirements</li> </ul>	Sibu General Hospital Clinical Research Centre and Pharmacy Department	Literature review. Semi-structured Interview.
	Known	<ul style="list-style-type: none"> <li>Delivery UAS model.</li> </ul>	Aerlift	Literature review
	Partial	<ul style="list-style-type: none"> <li>Unmanned Traffic Management.</li> </ul>	Apex Flight	Literature review. Semi-structured Interview.

Customers	Unknown	<ul style="list-style-type: none"> <li>Actual recipient based on scenario.</li> </ul>	Sibu General Hospital Clinical Research Centre and Pharmacy Department	Semi-structured Interview.
Products/ Services	Unknown	<ul style="list-style-type: none"> <li>Actual payload based on scenario.</li> <li>Type of delivery (EVLOS / BVLOS).</li> </ul>	Sibu General Hospital Clinical Research Centre and Pharmacy Department	Semi-structured Interview.
Environment	Known	<ul style="list-style-type: none"> <li>UAS operation regulations.</li> </ul>	CAAM Civil Aviation Directive – 6011 Part (V)	Literature review
	Unknown	<ul style="list-style-type: none"> <li>Healthcare provider opinion on UAS medical parcel delivery.</li> </ul>	Jabatan Kesihatan Negeri Sarawak (JKNS) / Sarawak State Health Department	Structured Interview
	Unknown	<ul style="list-style-type: none"> <li>Hospital policy on UAS medical parcel delivery.</li> <li>Medical parcels procedures</li> <li>Ethical considerations</li> </ul>	Sibu General Hospital Clinical Research Centre and Pharmacy Department	Semi-structured Interview.
Infrastructure	Unknown	<ul style="list-style-type: none"> <li>Technical infrastructure</li> <li>Human infrastructure &amp; Information infrastructure needed to support the UAS operation.</li> </ul>	<ul style="list-style-type: none"> <li>Sibu General Hospital Clinical Research Centre and Pharmacy Department</li> <li>Apex Flight</li> <li>Aerlift</li> </ul>	Semi-structured Interview.
Strategies	Unknown	<ul style="list-style-type: none"> <li>Strategy to integrate into existing Healthcare logistics management.</li> </ul>	Sibu General Hospital Clinical Research Centre and Pharmacy Department	Semi-structured Interview.
	Unknown	<ul style="list-style-type: none"> <li>Strategy to conduct UAS medical parcel delivery under traffic management</li> </ul>	To be formulated as a Framework	Analysis of interviews

A UTM framework based on WST enables the following:

1. **Operational Coordination:** Ensuring seamless interaction among drones, manned aircraft, and air traffic control systems.
2. **Regulatory Compliance:** Integrating local and international aviation regulations while considering Sarawak’s unique needs.
3. **Safety and Efficiency:** Designing processes to mitigate risks and optimize airspace utilization.
4. **Stakeholder Engagement:** Involving local communities and stakeholders in framework design to enhance acceptance and effectiveness.

## CONCLUSION

Given the growing adoption of UAS globally in several sectors such as healthcare, agriculture, logistics, search and rescue, among others, it became imperative for UAS activities to be regulated to ensure safety and secure operations comparable to conventional aviation industries. Driven by this need, several Governments (US, UK, EU, Korea), regulatory bodies (ICAO, FAA, NASA), and stakeholders (the Single European Sky ATM Research (SESAR), European Union Aviation Safety Agency (EASA), the Global UTM Association (GUTMA)) are actively engaged in drafting, promulgating, enforcing regulations and active research and funding for the development and implementation of UTM for ensuring safe and efficient airspace management. As a result of differences in topology and regulations, each nation formulated regulations to regulate UAS operations in its territory. The location of Sarawak at the heart of Borneo, characterized by mountainous terrain and enclosing rivers, making commuting an arduous task. Hence, the adoption of UAS is seen as a viable alternative for logistics purposes such as medical delivery and rescue operations in Sarawak. Based on the definition of “UTM as a system of stakeholders and technical systems collaborating in certain interactions, and according to certain regulations to ensure air traffic management”, selecting a suitable IS theory becomes crucial for effective framework development. Hence, this work compared WST with other related theories and perspectives within the IS field, including GST, STS, and

ANT. Each of these theories offers different lenses for understanding the complexity and dynamics of systems within organizations, with WST providing a unique focus on IT-reliant work systems and their life cycle within the organizational context.

In the context of developing UAS's UTM framework for Sarawak, WST emerges as a superior IS theory due to its holistic perspective and practical design focus to address the limitations of other theories, providing a robust foundation for navigating the complexities of UAS integration. Future research should focus on pilot implementations of WST-based UTM frameworks in domains such as medical delivery of essential medical supplies to rural hospitals and clinics, and in search and rescue missions to further validate their applicability and refine their methodologies for broader adoption in other sectors across Sarawak.

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## CONFLICTS OF INTEREST

The authors declare no conflict of interest.

## REFERENCES

- [1] M. K. Banafaa, Ö. Pepeoğlu, I. Shaya, A. Alhammadi, Z. A. Shamsan, M. A. Razaz, M. Alsagabi, S. Al-Sowayan, "A comprehensive survey on 5G-and-beyond networks with UAVs: Applications, emerging technologies, regulatory aspects, research trends and challenges," *IEEE Access*, 2024. doi: [10.1109/ACCESS.2023.3349208](https://doi.org/10.1109/ACCESS.2023.3349208)
- [2] C. Stöcker, R. Bennett, F. Nex, M. Gerke, and J. Zevenbergen, "Review of the current state of UAV regulations," *Remote Sens (Basel)*, vol. 9, no. 5, p. 459, 2017. Doi: [10.3390/rs9050459](https://doi.org/10.3390/rs9050459)
- [3] A. M. Muhmad Kamarulzaman, W. S. Wan Mohd Jaafar, M. N. Mohd Said, S. N. M. Saad, and M. Mohan, "UAV Implementations in Urban Planning and Related Sectors of Rapidly Developing Nations: A Review and Future Perspectives for Malaysia," *Remote Sens (Basel)*, vol. 15, no. 11, p. 2845, 2023. doi: [10.3390/rs15112845](https://doi.org/10.3390/rs15112845)
- [4] T. Suntharalingam, "Malaysia: Peninsular Malaysia," in *Encyclopedia of European and Asian Regional Geology*, E. M. Moores, Ed., Dordrecht: Springer Netherlands, 1997, pp. 525–530. doi: [10.1007/1-4020-4495-X\\_64](https://doi.org/10.1007/1-4020-4495-X_64).
- [5] C. L. F. Fung and M. I. R. Suhrab, "Navigational safety of inland waterway transport system (IWTS) in Sarawak: Rajang River," *J Sustain Sci Manag*, vol. 18, no. 4, pp. 102–118, 2023. doi: [10.46754/jssm.2023.04.008](https://doi.org/10.46754/jssm.2023.04.008)
- [6] N. Mohd Reda, "Pharmaniaga ensures timely delivery of medicines to remote areas.," *The New Sarawak Tribune*, Kuching, Sarawak, Jun. 14, 2023. doi: <https://www.sarawaktribune.com/pharmaniaga-ensures-timely-delivery-of-medicines-to-remote-areas-2/>
- [7] P. Kopardekar, J. Rios, T. Prevot, M. Johnson, J. Jung, and J. E. Robinson, "Unmanned aircraft system traffic management (UTM) concept of operations," in *AIAA AVIATION Forum and Exposition*, 2016. doi: <https://ntrs.nasa.gov/api/citations/20190000370/downloads/20190000370.pdf>
- [8] L. Davies, Y. Vagapov, V. Grout, S. Cunningham, and A. Anuchin, "Review of air traffic management systems for UAV integration into urban airspace," in *2021 28th International Workshop on Electric Drives: Improving Reliability of Electric Drives (IWED)*, IEEE, 2021, pp. 1–6. doi: [10.1109/IWED52055.2021.9376343](https://doi.org/10.1109/IWED52055.2021.9376343)
- [9] P. Aposporis, "A review of global and regional frameworks for the integration of an unmanned aircraft system in air traffic management," *Transp Res Interdiscip Perspect*, vol. 24, p. 101064, 2024. doi: [10.1109/IWED52055.2021.9376343](https://doi.org/10.1109/IWED52055.2021.9376343)

- [10] International Civil Aviation Organization, "Unmanned Aircraft Systems Traffic Management (UTM)– A Common Framework with Core Principles for Global Harmonization Edition 3," Technical report," 2023. doi:<https://www.icao.int/safety/UA/Documents/UTM%20Framework%20Edition%203.pdf>
- [11] B. S. Ali, S. Saji, and M. T. Su, "An assessment of frameworks for heterogeneous aircraft operations in low-altitude airspace," *International Journal of Critical Infrastructure Protection*, vol. 37, p. 100528, 2022. doi:[10.1016/j.ijcip.2022.100528](https://doi.org/10.1016/j.ijcip.2022.100528)
- [12] A. Hamissi and A. Dhraief, "A Survey on the Unmanned Aircraft System Traffic Management," *ACM Comput Surv*, vol. 56, no. 3, pp. 1–37, 2023. doi:[10.1145/3617992](https://doi.org/10.1145/3617992)
- [13] T. McCarthy, L. Pforte, and R. Burke, "Fundamental Elements of an Urban UTM". *Aerospace* 2020, 7, 85. doi:[10.3390/aerospace7070085](https://doi.org/10.3390/aerospace7070085)
- [14] K. Jung, S. Kim, B. Jung, S. Kim, H. Kang, and C. Kang, "UTM Architecture and Flight Demonstration in Korea," *Aerospace*, vol. 9, no. 11, p. 650, 2022. doi:[10.3390/aerospace9110650](https://doi.org/10.3390/aerospace9110650)
- [15] B. Langefors, "Information systems theory," *Inf Syst*, vol. 2, no. 4, pp. 207–219, 1977. doi:[10.1016/0306-4379\(77\)90009-6](https://doi.org/10.1016/0306-4379(77)90009-6)
- [16] S. Alter, "A framework for describing theoretical perspectives: overview and application to the work system perspective," 2022. Doi: [hdl.handle.net/10125/80135\\_978-0-9981331-5-7](https://hdl.handle.net/10125/80135_978-0-9981331-5-7)
- [17] X. Huang, Y. Yuan, and J. Li, "A Review of Transformer Fault Diagnosis Based on Information System Theory and Machine Learning," 2023. doi:[10.20944/preprints202305.0036.v1](https://doi.org/10.20944/preprints202305.0036.v1)
- [18] F. D. Davis, "Technology acceptance model: TAM," Al-Suqri, MN, Al-Aufi, AS: *Information Seeking Behavior and Technology Adoption*, vol. 205, p. 219, 1989. doi:<https://quod.lib.umich.edu/b/busadwp/images/b/1/4/b1409190.0001.001.pdf>
- [19] R. L. Miller, "Rogers' innovation diffusion theory (1962, 1995)," in *Technology adoption and social issues: Concepts, methodologies, tools, and applications*, IGI Global, 2018, pp. 1558–1571. doi:[10.4018/978-1-5225-5201-7](https://doi.org/10.4018/978-1-5225-5201-7)
- [20] M. R. Jones and H. Karsten, "Giddens's structuration theory and information systems research," *MIS quarterly*, pp. 127–157, 2008. doi:[10.2307/25148831](https://doi.org/10.2307/25148831)
- [21] W. H. DeLone and E. R. McLean, "The DeLone and McLean model of information systems success: a ten-year update," *Journal of management information systems*, vol. 19, no. 4, pp. 9–30, 2003. doi:[10.1080/07421222.2003.11045748](https://doi.org/10.1080/07421222.2003.11045748)
- [22] O. K. Ngwenyama, "The critical social theory approach to information systems: problems and challenges," *Information systems research: Contemporary approaches and emergent traditions*, pp. 267–280, 1991. doi:[10.4135/9781849209687.n7](https://doi.org/10.4135/9781849209687.n7)
- [23] G. G. Whitchurch and L. L. Constantine, "Systems theory," in *Sourcebook of family theories and methods: A contextual approach*, Springer, 1993, pp. 325–355. doi:[10.1007/978-0-387-85764-0](https://doi.org/10.1007/978-0-387-85764-0)
- [24] M. Callon and O. Blackwell, "Actor network theory," *International encyclopedia of the social & behavioral sciences*, vol. 1, pp. 62–66, 2001. doi:[10.51952/9781447360124.ch001](https://doi.org/10.51952/9781447360124.ch001)
- [25] E. Trist and F. Emery, "Sociotechnical systems theory," in *Organizational Behavior 2*, Routledge, 2015, pp. 169–194. doi:[10.4324/9781315702001](https://doi.org/10.4324/9781315702001)
- [26] S. Alter, "Work system theory: A bridge between business and IT views of systems," *Lect. Notes Comput. Sci.(including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 9097, pp. 520–521, 2015. doi:[10.1007/978-3-319-19069-3](https://doi.org/10.1007/978-3-319-19069-3)
- [27] S. Alter, "Work system theory as a platform: response to a research perspective article by Niederman and March." *Journal of the Association for Information Systems*. 2015;16(6):1. doi:[10.17705/ijais.00398](https://doi.org/10.17705/ijais.00398)
- [28] M.-O. Olsson, "Schools of systems thinking-Development trends in systems methodology," *Systems approaches and their application: Examples from Sweden*, pp. 31–74, 2005. doi:[10.1007/1-4020-2370-7\\_1](https://doi.org/10.1007/1-4020-2370-7_1)
- [29] S. Alter, "Work system theory: Overview of core concepts, extensions, and challenges for the future," *J Assoc Inf Syst*, vol. 14, no. 2, pp. 72–121, 2013, doi: [10.17705/ijais.00323](https://doi.org/10.17705/ijais.00323).

- [30] S. Gregor, "The nature of theory in Information Systems," *MIS Q*, vol. 30, no. 3, pp. 611–642, 2006, doi: [10.2307/25148742](https://doi.org/10.2307/25148742).
- [31] S. Alter, "Steps Toward Articulating a Work System Perspective that Addresses a Grand Challenge for the IS Discipline," *Informing Possible Future Worlds*, p. 343. doi: [10.30819/5768](https://doi.org/10.30819/5768)
- [32] L. Von Bertalanffy, "The History and Status of General Systems Theory," *The Academy of Management Journal*, vol. 15, no. 4, pp. 407–426, Dec. 1972, doi: [10.2307/255139](https://doi.org/10.2307/255139).
- [33] K. E. Boulding, "General Systems Theory-The Skeleton of Science," *Manage Sci*, vol. 2, no. 3, pp. 197–208, Dec. 1956. doi: [10.1287/mnsc.2.3.197](https://doi.org/10.1287/mnsc.2.3.197)
- [34] W. Hofkirchner and M. Schafranek, "General System Theory," in *Handbook of the Philosophy of Science*, vol. 10, C. B. T.-P. of C. S. Hooker, Ed., Amsterdam: North-Holland, 2011, pp. 177–194. doi: [10.1016/B978-0-444-52076-0.50006-7](https://doi.org/10.1016/B978-0-444-52076-0.50006-7).
- [35] A. Rapoport, *General system theory: Essential concepts & applications*, vol. 10. CRC Press, 1986. doi: <https://archive.org/details/generalsystemthe000rapo/page/n287/mode/2up>
- [36] D. T. Campbell, "'Downward Causation' in Hierarchically Organised Biological Systems BT - Studies in the Philosophy of Biology: Reduction and Related Problems," F. J. Ayala and T. Dobzhansky, Eds., London: Macmillan Education UK, 1974, pp. 179–186. doi: [10.1007/978-1-349-01892-5\\_11](https://doi.org/10.1007/978-1-349-01892-5_11).
- [37] Skyttner L. *General systems theory: Problems, perspectives, practice*. World scientific; 2005. doi: [10.1142/5871](https://doi.org/10.1142/5871)
- [38] G. H. Walker, N. A. Stanton, P. M. Salmon, and D. P. Jenkins, "A review of sociotechnical systems theory: A classic concept for new command and control paradigms," *Theor Issues Ergon Sci*, vol. 9, no. 6, pp. 479–499, 2008, doi: [10.1080/14639220701635470](https://doi.org/10.1080/14639220701635470).
- [39] S. H. Appelbaum, "Socio-technical systems theory: an intervention strategy for organizational development," *Management Decision*, vol. 35, no. 6, pp. 452–463, 1997, doi: [10.1108/00251749710173823](https://doi.org/10.1108/00251749710173823).
- [40] A. Cherns, "Principles of Sociotechnical Design Revisted," *Human Relations*, vol. 40, no. 3, pp. 153–161, Mar. 1987, doi: [10.1177/001872678704000303](https://doi.org/10.1177/001872678704000303).
- [41] G. Walsham, "Actor-Network Theory and IS Research: Current Status and Future Prospects," *Information Systems and Qualitative Research*, pp. 466–480, 1997, doi: [10.1007/978-0-387-35309-8\\_23](https://doi.org/10.1007/978-0-387-35309-8_23).
- [42] B. Latour, "Social Theory and the Study of Computerized Work Sites," pp. 295–307, 1996, doi: [10.1007/978-0-387-34872-8\\_18](https://doi.org/10.1007/978-0-387-34872-8_18).
- [43] W. E. Bijker, "Do Not Despair: There Is Life after Constructivism," *Sci Technol Human Values*, vol. 18, no. 1, pp. 113–138, Jan. 1993, doi: [10.1177/016224399301800107](https://doi.org/10.1177/016224399301800107).
- [44] R. L. Harrison, T. M. Reilly, and J. W. Creswell, "Methodological rigor in mixed methods: An application in management studies," *J Mix Methods Res*, vol. 14, no. 4, pp. 473–495, 2020. doi: [10.1177/1558689819900585](https://doi.org/10.1177/1558689819900585)
- [45] K. C. Stange, B. F. Crabtree, and W. L. Miller, "Publishing multimethod research," 2006, *Annals Family Med*. doi: [10.1370/afm.615](https://doi.org/10.1370/afm.615)