IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Received 2 November 2022, accepted 17 November 2022, date of publication 24 November 2022, date of current version 30 November 2022.

Digital Object Identifier 10.1109/ACCESS.2022.3224456

METHODS

UAF Strategic Planning for Enterprises

MOHAMMADREZA TORKJAZI, (Member, IEEE), ARTURO J. DAVILA-ANDINO, (Member, IEEE), AHMAD ALGHAMDI, (Member, IEEE), AND ABBAS K. ZAIDI, (Senior Member, IEEE)
Department of Systems Engineering and Operations Research, George Mason University, Fairfax, VA 22030, USA

Corresponding author: Mohammadreza Torkjazi (mtorkjaz@gmu.edu)

This work was supported in part by the Department of Systems Engineering and Operations Research, George Mason University.

ABSTRACT In this paper, we propose an extension to the Unified Architecture Framework (UAF) Profile to leverage the potential of the widely used SWOT analysis in modeling the UAF strategic viewpoint of an enterprise or System of Systems (SoS). This novel methodology assists with capturing the capabilities an enterprise needs to achieve its goals through the SWOT analysis. Capabilities are key elements in the UAF Strategic viewpoint. Previous works for identifying capabilities only showcase the resulting strategic views without interpreting their ties to the UAF strategic elements. The absence of a common methodology for incorporating strategic planning into the UAF is a potential deterrent for enterprises to accept the UAF. To address this gap, we propose using the SWOT analysis as an established method of strategic planning that has been used for many years in various enterprises. The four SWOT elements, i.e., Strength, Weakness, Opportunity, and Threat, are comparable to the UAF strategic elements Challenge and Opportunity which are the basis for capturing the enterprise capabilities. We extend the UAF profile to enable SWOT elements in the UAF and provide dependency relationships to illustrate traceability between SWOT elements and capabilities. This paper provides two key contributions. First, this work extends the UAF Profile to identify capabilities from SWOT analysis which takes both internal and external conditions of the enterprise into account. Second, we develop the methodology to create the necessary views which trace the SWOT elements to the stakeholders and capabilities. The proposed method is one that enterprises and SoS managers can employ to adopt UAF with minimal to no disruption to their current business processes. We also demonstrate a seamless integration of the SWOT analysis into the UAF. Finally, we use an illustrative example of a hypothetical enterprise to demonstrate the new SWOT diagrams enabled through the proposed extension.

INDEX TERMS Unified architecture framework (UAF), UAF strategic viewpoint, UAF profile, SWOT analysis, strategic planning.

I. INTRODUCTION

Architecture frameworks define a normative way to design systems and guarantee consistent modeling [1], [2]. Architecture frameworks also assist systems engineers in creating various views, each representing the system's model from a particular viewpoint to different stakeholders [3]. Having multiple views and viewpoints enables an architecture framework to better describe the complexities in the architecture of enterprises and Systems of Systems (SoSs) [1], [4], [5], [6] and to provide architects with cross-cutting traceability for verification and validation purposes [2].

The associate editor coordinating the review of this manuscript and approving it for publication was Hongli Dong.

Department of Defense Architecture Framework (DoDAF), Ministry of Defense Architecture Framework (MODAF), and NATO Architecture Framework (NAF) serve as standardized architecture frameworks [7] with the common goal to facilitate the planning and management practices of complex systems [8]. DoDAF, MODAF, and NAF were primarily created for the defense industry, making it difficult to apply them to other industries due to the lack of security and human-machine integration views [7], [9], [10]. Moreover, cross-country projects throughout NATO nations highlighted the need for a unified architecture to yield the greatest benefits [9] since interoperability between architectures created by various entities is crucial [11]. Therefore, the Object Management Group (OMG) developed the Unified

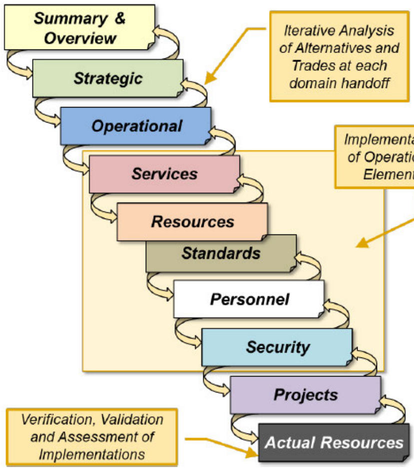


FIGURE 1. UAF viewpoints [15].

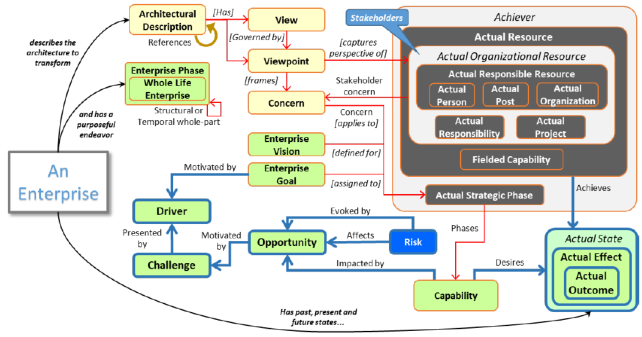


FIGURE 2. The UAF conceptual schema for architecture management [15].

Architecture Framework (UAF) as a unified architecture for DoDAF, MODAF, and NAF to be applicable to both military and commercial enterprises [9], [11]. Tirone et al. [11] depict the evolution of architecture frameworks since 1987 and how they unified and resulted in the UAF in 2016.

The UAF can be used to model complex interrelationships between all involved individual systems that form the enterprise or SoS [9]. Examples of applications of UAF architectures in both defense and commercial domains include modeling electrical grids [1], autonomous transportation SoS for a quarry [8], an insurance enterprise [12], Industrial Internet of Things (IIoT) for microwave production in a home appliance enterprise [9], naval combat systems [11], multi-UAV (Unmanned Aerial Vehicle) SoS for forest firefighting [3], air traffic management SoS [4], [5], parcel delivery SoS [13], and a command system for a space situational awareness system [10]. A UAF-developed model provides stakeholders with a high level of control of the enterprise since such a model consists of detailed systems development [8]. This advantage is reinforced by the various viewpoints offered by the UAF, shown in Fig. 1, where each viewpoint consists of various views, each contributing to the entire architecture [14], [15]. The UAF offers viewpoints that are not addressed by other architecture frameworks, i.e., *Security* and *Personnel*, making it even more powerful in modeling architectures from various viewpoints to address the stakeholders' concerns [14], [15].

The *Summary & Overview* viewpoint illustrated in Fig. 1 is concerned with identifying stakeholders, needs, strategic drivers, challenges, and opportunities. The *Strategic* viewpoint focuses on representing capabilities, their interdependencies, and their dependency relationship to the enterprise goals they will meet [12], [14]. Enterprises typically implement strategic planning to facilitate the accomplishment of their overall vision and goals [16]. It is important for an enterprise to understand its internal position, external opportunities, and threats to create strategies. Strategic planning aims to determine what capabilities the enterprise is expected to provide to achieve its goals by taking opportunities and challenges into account. The motive of this paper is to build the traceability between the *Summary & Overview* and *Strategic* viewpoints and to assist systems architects in identifying capabilities from presented challenges and opportunities.

Capability is the key element in the *Strategic* viewpoint [11]. A capability is the ability to achieve the desired effects and meet the enterprise's goals through employing various resources [1], [2], [3], [7], [11]. The defined capabilities will later be used for verification and validation of the developed UAF model [7], [17]. Fig. 2 is a part of the UAF conceptual schema, illustrating the relationships between goals, drivers, challenges, opportunities, and capabilities. According to the Enterprise Architecture Guide (EAG) [15] published by the OMG, challenges and opportunities are the bases for capabilities. Thus, a traceability diagram can be beneficial in understanding the interdependencies between these elements since it highlights any potential to improve or modify the specified capabilities.

OMG has released publications to assist with understanding and creating the UAF views, such as the UAF Domain Metamodel (DMM) [18], EAG [14], [15], and the search and rescue sample problem [19]. The OMG publications and the aforementioned studies for UAF applications do not address a normative and well-defined approach for identifying architectural drivers, challenges, and opportunities that establishes the foundation for specifying the enterprise's required capabilities.

As previously stated and shown in Fig. 2, challenges and opportunities need to be taken into account when deciding on capabilities. However, most studies published to showcase UAF implementation do not consider these strategic elements and directly determine capabilities either by the operational concept [1], [20], goals [3], [9], [11], or requirements [5], [8], [10], [21]. This is due to the lack of an established process for identifying capabilities from these elements. Additionally, software tools do not incorporate all of the elements shown in Fig. 2 of the UAF conceptual schema, which are necessary to address the gap. As an example of a widely used tool, Magic Systems of Systems Architect 2021x does not contain modeling elements representing architecture drivers, challenges, and opportunities which are the bases to start the UAF strategic viewpoint. Such a process is necessary since properly identifying an enterprise's capabilities aids in the design of other viewpoints of an enterprise's UAF architecture.

In this paper, we address the need for such a process and facilitate the precursor to the UAF strategic viewpoint for enterprises. The majority of enterprises perform strategic planning to evaluate their "Strengths," "Weaknesses," "Opportunities," and "Threats," i.e., the SWOT analysis. The SWOT analysis is a well-known approach that aids planners in understanding all internal and external factors impacting the enterprise's goals [22]. The final outcome of a SWOT analysis is a list of strategies the enterprise needs to take to achieve its goals and, consequently, the capabilities it must provide. The SWOT elements conform to the UAF strategic elements of challenges and opportunities. To enable the SWOT process in a UAF model, we will propose an extension to the UAF profile that integrates the existing enterprise's SWOT analysis, into the UAF views. The proposed extension is the very first attempt to provide a process for capabilities identification, and it allows for UAF adoption to be considerably more straightforward for systems architects.

The remainder of this paper is organized as follows: Section 2 examines the UAF user guide steps, existing UAF methodologies, and the conformity of UAF strategic planning to SWOT analysis, Section 3 describes our proposed UAF extension and its implementation and provides new diagrams for addressing SWOT analysis for a case study, Section 4 discusses the importance of our methodology and compares it to previously published approaches, and finally, Section 5 presents the conclusions and next steps for this research.

II. LITERATURE REVIEW

A. THE STEPS OF THE ENTERPRISE ARCHITECTURE GUIDE FOR UAF

The OMG published the EAG [15] as a workflow based on the UAF viewpoints, demonstrated in Fig. 1, for creating different UAF views for the enterprise architecture. The arrows in Fig. 1 demonstrate how integrated the UAF design process is. Moving downwards from the top of the diagram indicates a detailed design process, and returning upwards allows an enterprise to make necessary modifications before proceeding. Using the presented workflow along with the published sample problem of a search and rescue SoS [19] aids systems engineers in understanding and creating the UAF views.

As shown by arrows in Fig. 1, each step provides inputs for the following step. The first step is identifying stakeholders, needs, strategic drivers, challenges, and opportunities in the *Summary & Overview* viewpoint. The *Strategic* viewpoint defines the enterprise's visions, goals, the capabilities needed to achieve them, and their dependencies. The *Operational* viewpoint models the logical architecture of the enterprise and describes the operational structure and behaviors required to realize the capabilities [4], [23]. The *Resources* viewpoint describes a solution architecture composed of various resources to realize the operational elements and behaviors. The *Services* viewpoint defines the required services implemented by elements in the *Resources* viewpoint to support operational elements and capabilities [20]. The *Services* viewpoint is helpful for service-oriented architecture solutions [4]. The *Personnel* viewpoint describes the role of human factors in architecture and defines human resources who implement the operational activities [5], [10]. The *Security* viewpoint is concerned with defining risks, threats, security assets, security behaviors, and protection and mitigation plans for the enterprise or SoS [5], [23], [24]. The *Projects* viewpoint describes the projects and their milestones as well as how they deliver the modeled resources in the *Resources* viewpoint to realize the identified capabilities in the *Strategic* viewpoint. Finally, the *Actual Resources* viewpoint illustrates the instantiation of the solution architecture in the real world and is used for verification and validation purposes.

The provided workflow was designed to be informative, so each enterprise may choose to apply the steps in the EAG's sequence or in a different order that is more compatible with the enterprise. The EAG leaves the decision to systems architects and does not offer any methodology regarding the order in which these steps need to be taken for a successful architecture modeling [15]. Given that the UAF is a framework rather than a methodology, it is unclear how this framework can be leveraged to its greatest potential [7].

B. EXISTING METHODOLOGIES FOR UAF

The UAF offers many views to model the details in an architecture, making it difficult for designers to select appropriate views to suit their enterprise or SoS [3]. There is no approved methodology for implementing UAF modeling, resulting in various approaches being taken by designers [3]. Multiple studies have addressed this need by proposing methodologies to facilitate the UAF implementation. For example, Tirone et al. [11] simplify the UAF modeling to better fit their needs for designing a naval combat system by limiting to only three UAF viewpoints. However, tailoring still does not offer step-by-step guidance to create the entire architecture for the enterprise or SoS. To address this gap, Abhaya [3] proposes a methodology composed of five sequential main activities, each with several steps. She believes that this methodology can be applied to any system since it employs the most-used elements from the UAF meta-model. Zhang et al. [4] propose a method for the architecture of an air traffic management SoS by only considering five viewpoints, skipping over *Strategic* and directly moving to *Operational* after establishing the objectives. Comparably, Li and Deng [5] propose a six-step methodology to implement the UAF for architecting an air transportation information management SoS. To ensure verification at each step of the model development, Eichmann et al. [25] develop a UAF model by leveraging the popular V-model which starts by analyzing requirements and then capturing capabilities directly from the requirements.

All of these methodologies aim to ensure consistency and traceability between the necessary viewpoints for modeling an architecture. For example, they select the *Strategic*, *Operational*, and *Resources* viewpoints to ensure that the chosen operational performers exhibit the capabilities needed to meet the enterprise's goals, and that the chosen resources can implement the identified operational performers. However, none of these methodologies offer a process for identifying capabilities, as they instead derive capabilities from either operational concepts, goals, or requirements. The UAF conceptual schema shown in Fig. 2 emphasizes that challenges and opportunities must be considered when determining what capabilities the enterprise needs to achieve its goals. Enterprises respond to challenges according to their current state [15], which escalates the need for effective strategic planning.

C. ENTERPRISE STRATEGIC PLANNING AND THE NEED FOR UAF EXTENSION

Strategic planning is the managerial practice of understanding the enterprise's current position and establishing a set of strategies to achieve its goals in order to strengthen the enterprise's position [26]. Continuous strategic planning gives businesses the ability to introduce fresh ideas to stay competitive [27]. An enterprise's strategic planning can be visualized using ArchiMate modeling language as shown by Kitsios et al. [28]. Additionally, the MODAF offers the visualization of an enterprise's capabilities and business strategies [8], and similarly, the UAF provides the *Strategic* viewpoint to visualize the enterprise's capabilities toward achieving its defined vision and goals according to the stakeholders' needs.

The SWOT analysis is the most common and widely used technique for strategic planning, as it provides a realistic, data-driven assessment of an enterprise [22]. For example, Niday [29] employs the SWOT analysis in his proposed framework to evaluate an enterprise's existing architecture and identify areas for improvement. A recent review conducted by Benzaghta et al. [30] shows that the SWOT method has been applied to developing strategies in a number of different industries, including management, education, marketing, social media, healthcare, and agriculture. The SWOT method aids in defining a set of strategies by taking into account a variety of factors that represent both an enterprise's internal condition and its external environment [31]. Internal factors are the ones that the enterprise has control over, i.e., Strengths and Weaknesses. Conversely, external factors are the ones the enterprise has little to no control over, i.e., Opportunities and Threats [32], [33]. Understanding such factors facilitates necessary and constructive strategic planning.

The SWOT analysis becomes more meaningful when Opportunities and Threats are listed first, followed by an examination of internal factors that assist the company to take advantage of Opportunities and overcome Threats [32]. Upon Completion of the SWOT table, the analyst is responsible to interpret it and create a list of strategies that improve

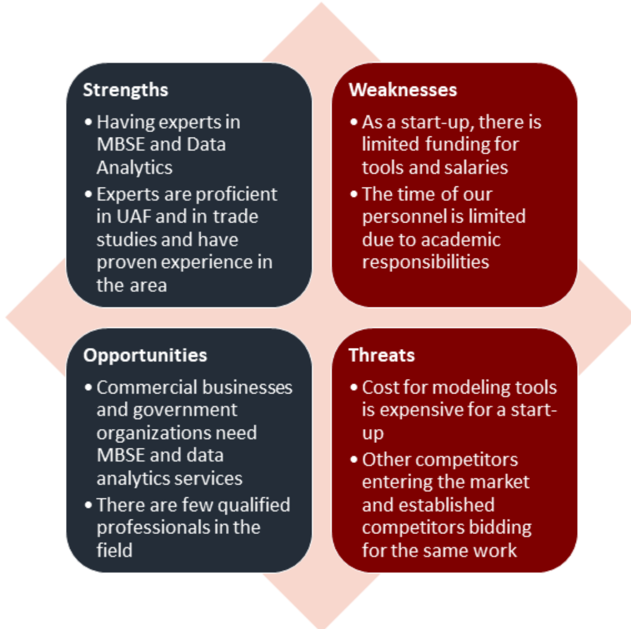


FIGURE 3. A sample SWOT analysis for the hypothetical digital engineering enterprise.

the enterprise's condition [34]. According to Gholami and Ramsin [35] and Benzaghta et al. [30], four types of strategies can be derived from a SWOT table, i.e., SO, ST, WO, and WT. While SO and ST leverage the enterprise's Strengths to seize Opportunities and avoid Threats, WO and WT concentrate on reducing Weaknesses to identify new Opportunities and mitigate external Threats. Fig. 3 illustrates the SWOT analysis of a hypothetical digital engineering enterprise. This enterprise is going to provide Model-Based Systems Engineering (MBSE) and data analytic services for both governmental and commercial enterprises. The existing SWOT analysis depicts the internal and external status of this enterprise.

According to the EAG [15], drivers may emerge from factors such as laws and regulations, market forecasts, and stakeholders, and significantly impact the goals of the enterprise. As illustrated in Fig. 2, enterprises seek opportunities to overcome the challenges that are presented by drivers. These opportunities impact the capabilities of an enterprise. Similar to the UAF, drivers necessitate enterprises to engage in SWOT analysis and evaluate all challenges and opportunities while accounting for their risks to the enterprise.

The first step in the EAG, shown in Fig. 1, conforms to the existing SWOT analysis used by enterprises. SWOT analysis can be an alternative to the UAF *"Driver," "Challenge," "Opportunity,"* and *"Risk"* elements as depicted in Fig. 4. SWOT elements of "Weakness" and "Threat" are conceptually associated with internal and external challenges respectively. Similarly, the UAF *"Opportunity"* element can be represented by elements of "Strength" and "Opportunity" in SWOT analysis. The implementation of SWOT analysis in the UAF is reasonable since the SWOT concept allows

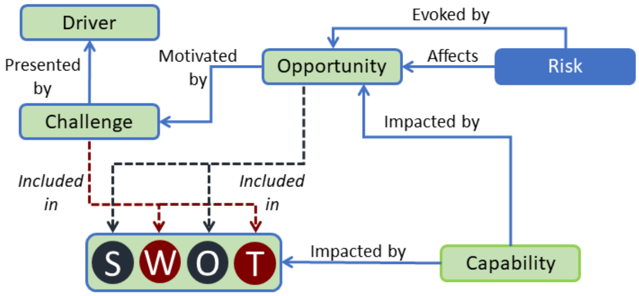


FIGURE 4. UAF elements included in SWOT analysis.

enterprises to adopt the UAF by mapping their SWOT elements to the UAF conceptual schema, as shown in Fig. 4, and identifying current and future capabilities. Implementing a standard methodology for identifying and connecting these elements can strengthen the overall UAF workflow.

Although modeling tools, e.g., Magic Systems of Systems Architect 2021x, document the *Driver*, *Opportunity*, and *Challenge* elements [36], no such elements are defined in the UAF profile in the widely used tool. Due to the lack of a documented standard approach, the literature either suggests implementing custom extensions or completely ignores the *Strategic* viewpoint [4], [24]. For example, Hause and Kihlstrom [37] implement an extension to the UAF profile by adding the stereotypes of *Driver*, *Challenge*, and *Opportunity* to design a UAF model for the Texas electricity grid. Similarly, Morkevicius [38] adds the same stereotypes to the UAF profile and uses a UAF view named *Strategic Motivation* to depict interdependencies. However, neither of these studies suggests a methodology for identifying capabilities.

In this paper, we provide a methodology for the first step of the EAG by proposing an extension to enable SWOT elements in the UAF profile. The proposed extension allows for leveraging the products of the existing enterprise's SWOT analysis and integrating it into the UAF to identify current and future capabilities the enterprise provides. The presented methodology will make UAF adoption more straightforward for enterprises that have already completed a SWOT analysis. It also assists systems architects in representing the traceability between SWOT strategic elements, the stakeholders expressing them, and capabilities.

III. METHODOLOGY

A. THE PROPOSED EXTENSION

We propose an extension to the UAF profile through the following methodology to enable SWOT elements in the UAF. These elements can then be used as alternatives to the challenges and opportunities portion of the conceptual schema as presented in Fig. 4. The purpose of this extension is to provide traceability between the elements of SWOT analysis and their associated capabilities that will be modeled in the architecture.

The SWOT profile was developed with an approach consistent with commercial practices [39] and the UAF profile [36].

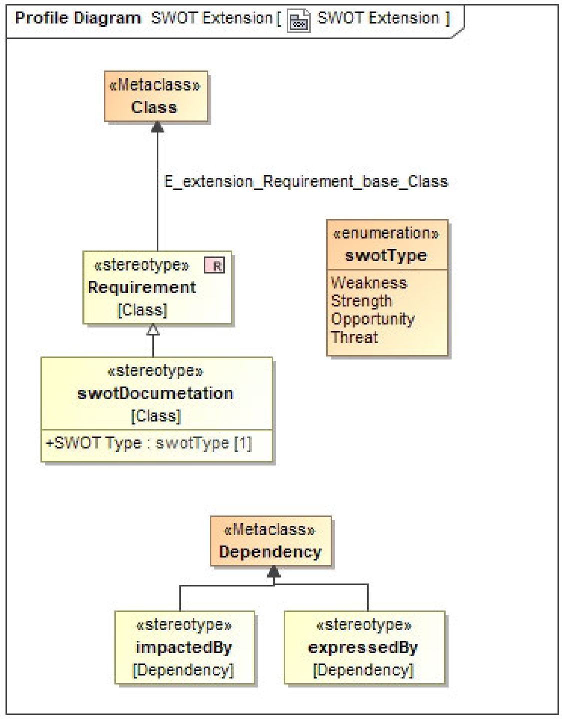


FIGURE 5. Profile diagram for the proposed SWOT extension.

The process involves creating an abstract syntax that would be compatible with the UAF conceptual schema in Fig. 4 and then implementing a profile to satisfy the concrete syntax. Therefore, the profile is scoped by the abstract syntax in the UAF DMM [18] and the conceptual schema for architecture management in Fig. 2. However, the abstract syntax documented in the UAF DMM is developed separately from the profile implementation in the UAF Modeling Language (UAFML). This complicates delegating the syntactic rules of the abstract syntax to the profile [40]. Thus, most constraints for the profile are expressed as Object Constraint Language (OCL) elements, and customization is made possible by the modeling tool.

The proposed extension is illustrated in Fig. 5. The *"swotDocumentation"* stereotype is a specialization of a "Requirement" class, thereby inheriting the concrete syntax of the "Requirement" profile and OCL constraints. For example, the proposed stereotype inherits an ID and text field. A *"swotType"* property was also included in the stereotype to capture all four types of SWOT elements. Moreover, there are two associated dependencies defined in this profile. One dependency allocates the *"swotDocumentation"* to the stakeholder by the *"expressedBy"* dependency, thereby providing traceability of *"swotDocumentation"* to the appropriate stakeholder. The other dependency defined as *"impactedBy"* traces *"swotDocumentation"* to the identified capability.

B. DETERMINING CAPABILITIES FROM SWOT ANALYSIS

We use the sample SWOT analysis given in Fig. 3 to illustrate how the proposed UAF extension facilitates the identification

#	Id	Name	SWOT Type	Text
1	SWOT-1	MBSE Expertise	Strength	Employees having expertise in MBSE.
2	SWOT-2	Data Analysis Expertise	Strength	Employees having expertise in Data Analysis.
3	SWOT-3	Expertise in UAF	Strength	The experts are proficient in UAF.
4	SWOT-4	Expertise in System Trade Studies	Strength	The experts are proficient in executing trade studies and have proven experience in the area.
5	SWOT-5	Expert Availability Constraints	Weakness	The time of our personnel interested is limited due to academic responsibilities.
6	SWOT-6	Budgeting Constraints	Weakness	As a start-up, there is limited funding for tools and salaries.
7	SWOT-7	Government Needs	Opportunity	Government organizations need MBSE and Data Analysis services.
8	SWOT-8	Commercial Needs	Opportunity	Commercial businesses need MBSE and Data Analysis services.
9	SWOT-9	Scarcity of Experts	Opportunity	There are few qualified professionals in the field of Digital Engineering.
10	SWOT-10	Competitors	Threat	Other competitors entering the market and established competitors bidding for the same work.
11	SWOT-11	Expensive Tools	Threat	The cost for modeling tools are expensive for a start-up.

FIGURE 6. **A sample SWOT table.**

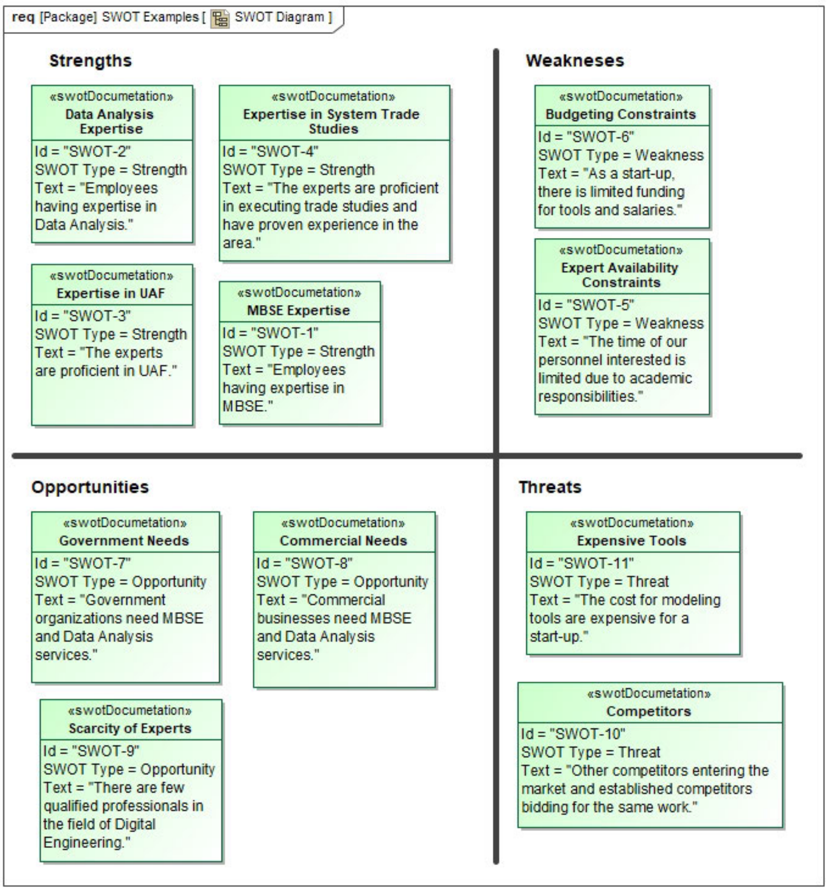


FIGURE 7. **A sample SWOT diagram.**

of capabilities. There are three main steps in the process of capturing capabilities from the enterprise's SWOT analysis:

1) Import the results of the SWOT analysis to the UAF model,

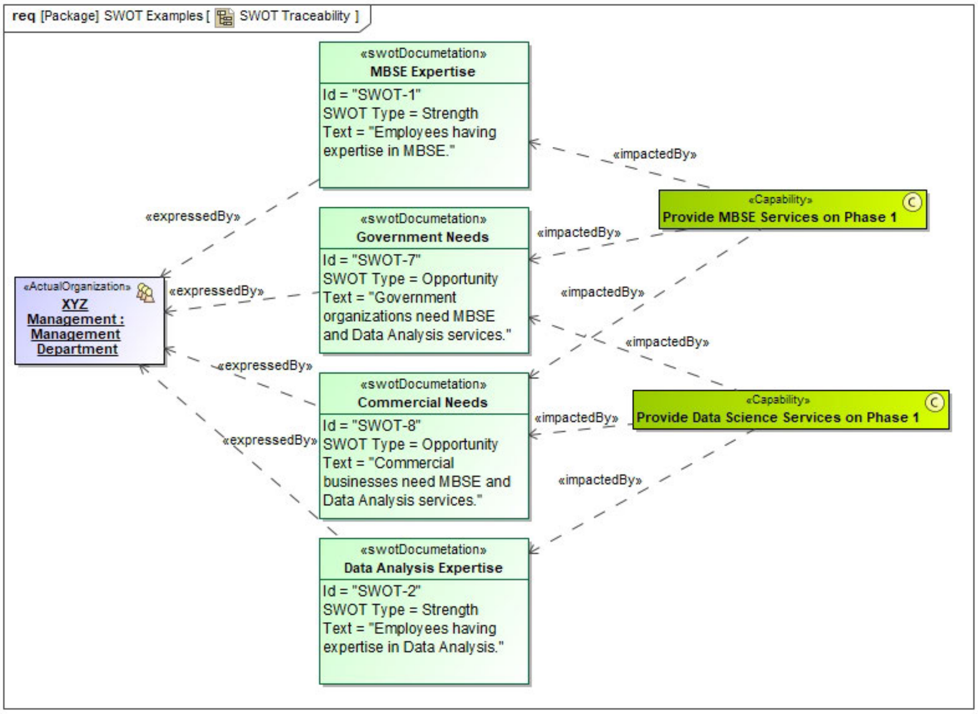


FIGURE 8. A sample SWOT traceability diagram.

2) Create any views planned for the imported SWOT model elements,
3) Define the traceability of the SWOT elements to the stakeholders who expressed the needs and from the corresponding identified capabilities.

In the first step, a list of the enterprise's existing SWOT elements can be manually entered or imported from a spreadsheet into the SWOT table. An illustration of the resulting table is shown in Fig. 6 for the hypothetical digital engineering enterprise. All fields are populated when manually entering the information from the SWOT analysis into the model. Each SWOT element in the model needs a unique identifier, *ID*, a *Name*, a *SWOT Type*, and a *Text* description. Conversely, all fields must be correctly formatted when importing from a spreadsheet source.

The SWOT table elements can then be used in the second step for creating SWOT views of the enterprise. These diagrams should serve a specific need or concern of the enterprise. An example of such a view is to recreate the SWOT matrix that was produced during the SWOT analysis. Therefore, we created a SWOT diagram, Fig. 7, to demonstrate how the results of a SWOT analysis like Fig. 3 can be represented in the architecture model of the enterprise. All SWOT elements are represented and distinguished by their types using the properties defined in the proposed extension.

Finally, SWOT traceability for stakeholders and capabilities is displayed in Fig. 8. This diagram showcases a subset of the hypothetical digital engineering enterprise's SWOT elements as an illustrative example. The inferred capabilities are traced to the relevant SWOT elements, which are then traced back to the stakeholders, explicitly linking all of these elements in the model.

C. CREATING ENTERPRISE's STRATEGIC VIEWS

After the SWOT analysis has uncovered the capabilities, they can be employed in creating the UAF strategic diagrams for the enterprise. As previously stated, the purpose of the *Strategic* viewpoint is to represent capabilities, their interdependencies, and how they relate to the enterprise's vision and goals. The *Strategic Structure* view, Fig. 9, illustrates the phases to be completed for founding and developing the hypothetical digital engineering enterprise. Distinct visions and goals can be defined for each phase as shown in this figure. Additionally, the *ActualEnterprisePhase* stereotype represents the planned phase of the enterprise and is assigned a time period within which a set of capabilities need to be deployed to achieve a set of desired conditions for the enterprise. Fig. 9 shows how the identified capabilities from the SWOT analysis are exhibited by the first phase. The *Strategic States* view, Fig. 10, also illustrates the traceability between, capabilities, desired conditions, and the enterprise's resources achieving those conditions.

As described in Section I, the *Operational* viewpoint employs the results of the *Strategic* viewpoint to identify the operational performers that are needed to carry

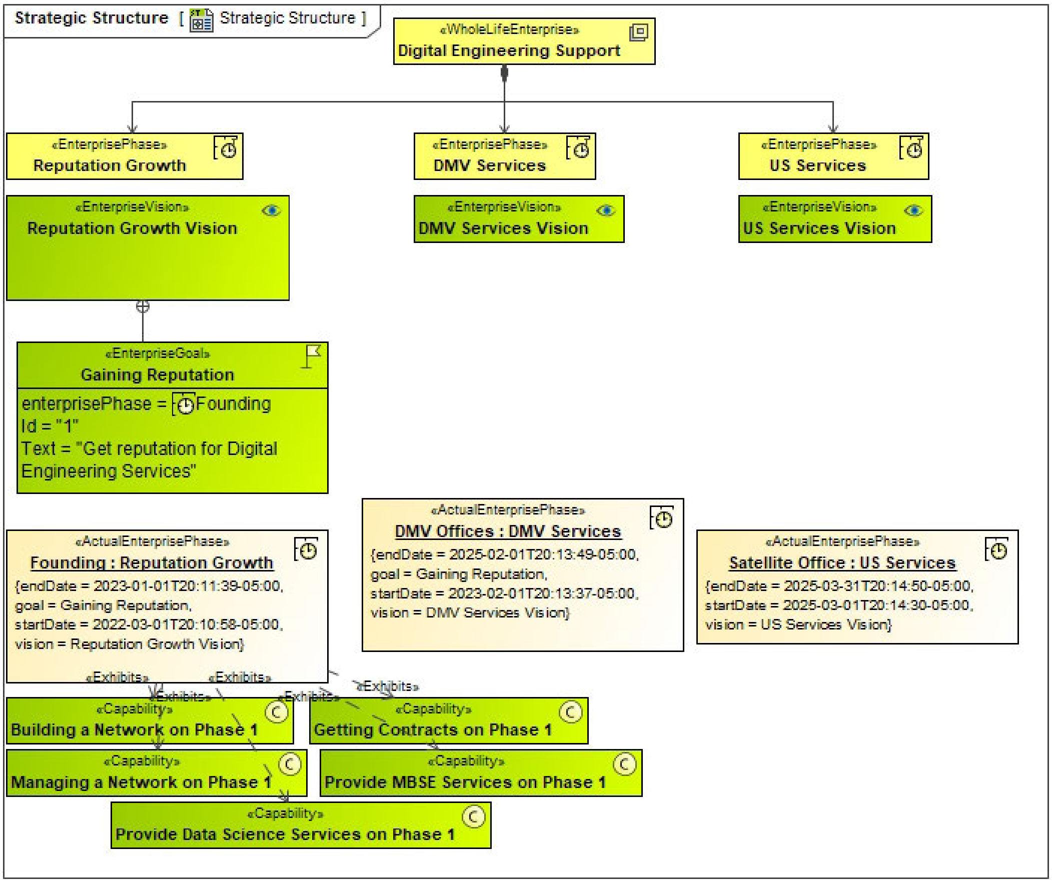


FIGURE 9. UAF Strategic Structure view.

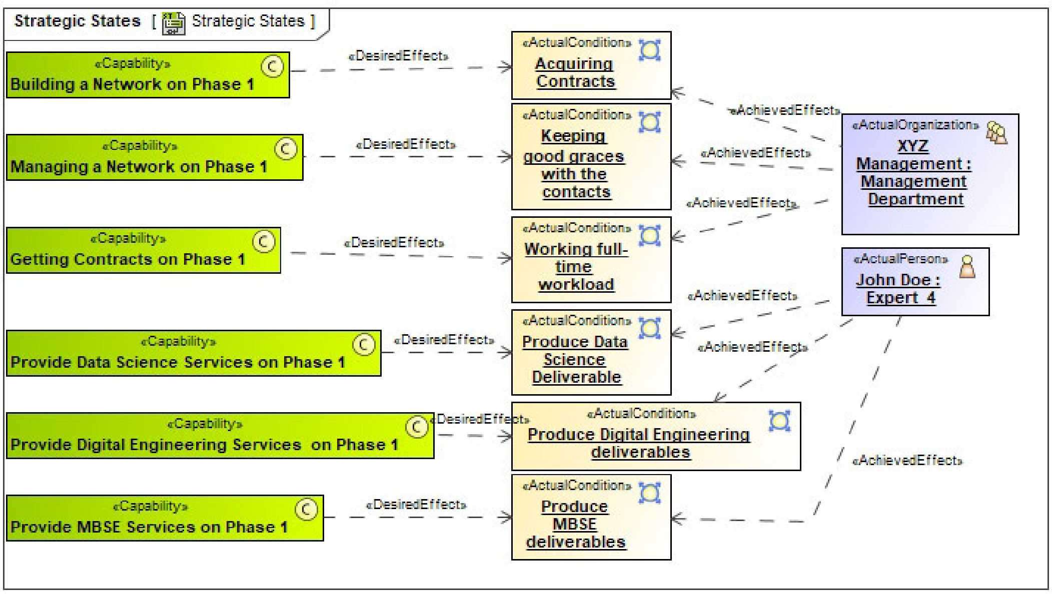


FIGURE 10. UAF Strategic States view.

out the designated capabilities for the enterprise. Subsequently, the *Resources* viewpoint determines what actual resources the enterprise needs to implement those operational performers. These traceability connections emphasize the significance of a UAF architecture's capabilities and the need for maintaining enterprise design consistency.

IV. DISCUSSION

Other publications in the literature focus on the technical implementation of extending the UAF or other frameworks without documenting the methodology. For example, Hause and Kihlstrom [37] and Morkevicius [38] focus on implementing the standard elements as defined by the conceptual schema and profile showcased in the UAF Profile documentation. However, as mentioned in Section I, the methodology for including the relevant information from the *Summary & Overview* viewpoint is still being developed. Thus, we use the information from the resulting SWOT analysis to populate similar elements and propose a clear methodology on how to implement the resulting views.

The profile also has several alternatives that can be included if the reader desires to improve upon the methodology. The three ways to tailor the solution that changes the resulting model include altering the conceptual schema, the syntax, and the tool customization. Altering the conceptual schema involves changing the ontology of the UAF to fit into a new paradigm. The modified conceptual schema can then be implemented in other languages and tools. Alternatively, changing the UAF syntax, whether abstract or concrete, will result in defining an extension necessary to build more element and dependency types. For example, in this paper, we generalized the stereotype of the SWOT element to the *Requirement* stereotype. While the impact of this decision is beyond the scope of this paper, we chose this course due to the prevalent practice of eliciting stakeholder needs and tracing them to stakeholder requirements. Finally, using customizations within the modeling tool allows one to constrain the use of the implemented extension. Specifically, we implemented customization to constrain the use of the defined dependencies in Fig. 5 to only be used by a SWOT element and in a specific direction.

Similar research focuses on extending other viewpoints in the UAF to tailor to the needs of systems architects. For example, Tirone et al. [11] extend the UAF profile by adding the stereotypes of *System of Interest*, *Actor*, and *Use Cases* to the *Operational* viewpoint, making it better suited for modeling a naval combat system. Lopez Garcia and Pereira [23] also tailor the UAF by extending the profile to include security-related elements, e.g., loss and hazard, required for identifying safety and security constraints in enterprises based on the STPA analysis tool. These extensions allow for the representation of other analyses, e.g., security analysis, along with the enterprise's architecture views for the stakeholders' reference.

In this paper, we improved the transparency of the methodology and extended the UAF profile to make it suitable for representing the existing SWOT analyses of enterprises as a UAF view. This research poses two key questions: firstly, can strategic planning processes be integrated within the UAF profile? Secondly, can we make the UAF *Strategic* viewpoint more accessible to current practitioners? Throughout our proposed methodology and results, we showcased a seamless integration of the SWOT analysis products into the UAF. The *Strategic Structure* and *Strategic States* views, Figs. 9 and 10, illustrate the strategic phases to be completed for the enterprise, its visions and goals, how the outputs of SWOT diagrams are exhibited by strategic phases, and how actual resources achieve the conditions that are desired by each capability obtained from the SWOT analysis. Moreover, this integration satisfies the main concern of incorporating SWOT into other strategic planning methods [22].

V. CONCLUSION AND FUTURE WORK

According to the UAF conceptual schema, drivers, challenges, and opportunities need to be identified to aid in capturing capabilities. However, previous research has not elucidated a clear approach that identifies and relates these elements for an enterprise. In this paper, we proposed an extension to the UAF profile to integrate the SWOT analysis as a well-known process for strategic planning. We presented this methodology as a means for enterprises and SoS managers to migrate toward the UAF with little to no impact on their processes.

The proposed methodology allows for a seamless adoption of UAF into most, if not all, enterprises and SoSs that have already completed SWOT analysis for their strategic planning. Our proposed extension can also be integrated easily into the EAG and other existing methodologies without disturbing other viewpoints. In addition to the software tool used for this project, our proposed extension can be used by other tool vendors to give systems architects access to SWOT analysis potential, further exemplifying the remarkable scalability of our proposed extension. The most prevalent limitation of this work is that we scope the methodology to the documentation of the results of the standard SWOT analysis. Therefore, we do not provide a comprehensive methodology for every extended strategic planning approach for enterprises. Equally, an enterprise should feel free to implement the products of its current processes by extending the UAF profile. An additional limitation is the lack of peer-reviewed research studies discussing a methodology for explicitly connecting the strategic elements.

Through this research, we have uncovered many methodological opportunities for research topics. In the immediate future, we plan to investigate UAF cross-cutting trade studies across the *Strategic*, *Operational*, and *Resources* viewpoints to ensure that an enterprise's UAF design complies with the existing systems engineering standards, i.e., ISO/IEC/IEEE 15288:2015.

REFERENCES

[1] M. Hause, "Using MBSE to evaluate and protect the electrical grid as a system of systems," in *Proc. INCOSE Int. Symp.*, vol. 27, 2017, pp. 597–612.
[2] M. Hause, J. Buitelaar, M. van de Ven, and E. Burgers, "The use of MBSE in infrastructure projects—An MBSE challenge team paper," in *Proc. INCOSE Int. Symp.*, vol. 25, no. 1, pp. 371–387, 2015.

[3] L. Abhaya, "UAF (unified architecture framework) based MBSE (UBM) method to build a system of systems model," in *Proc. INCOSE Int. Symp.*, vol. 31, no. 1, 2021, pp. 227–241.
[4] Y. Zhang, C. Xing, Q. Wang, and J. Zhu, "A UAF based method for next generation air traffic management system development," in *Advances in Guidance, Navigation and Control*, L. Yan, H. Duan, and X. Yu, Eds. Singapore: Springer, 2022, pp. 4053–4063.
[5] S. Li and K. Deng, "UAF-based air transportation cooperative information SoS modeling under 'belt and road initiative,'" in *Proc. IEEE 6th Inf. Technol. Mechatronics Eng. Conf. (ITOEC)*, Mar. 2022, pp. 746–754.
[6] M. Torkjazi and A. K. Raz, "A taxonomy for system of autonomous systems," in *Proc. 17th Annu. Syst. Syst. Eng. Conf. (SOSE)*, Jun. 2022, pp. 198–203.
[7] J. Bankauskaite and A. Morkevicius, "Towards an automated UAF-based trade study process for system of systems architecture," in *Proc. INCOSE Int. Symp.*, Jul. 2020, vol. 30, no. 1, pp. 391–405.
[8] P. Sjöberg, L. Kihlström, and M. Hause, "An industrial example of using enterprise architecture to speed up systems development," in *Proc. INCOSE Int. Symp.*, vol. 27, Jul. 2017, pp. 401–417.
[9] A. Morkevicius, L. Bisikirskiene, and G. Bleakley, "Using a systems of systems modeling approach for developing industrial Internet of Things applications," in *Proc. 12th Syst. Syst. Eng. Conf. (SoSE)*, Jun. 2017, pp. 1–6.
[10] O. Carlson, S. Hohenstein, J. Bui, H. Tanquary, C. Fritz, and D. C. Gross, "Human factors in the unified architecture framework applied to space situational awareness," in *Proc. IEEE Int. Syst. Conf. (SysCon)*, Apr. 2019, pp. 1–7.
[11] L. Tirone, E. Guidolotti, and L. Fornaro, "A tailoring of the unified architecture framework's meta-model for the modeling of systems-of-systems," in *Proc. INCOSE Int. Symp.*, vol. 28, no. 1, 2018, pp. 1691–1705.
[12] E. Mileviciene. (2019). *Applying UAF: Strategic Domain for an Insurance Enterprise. | LinkedIn*. [Online]. Available: https://www.linkedin.com/pulse/applying-uaf-strategicdomain-insurance-enterprise-edita-mileviciene/
[13] F. Dandashi and M. C. Hause, "UAF for system of systems modeling," in *Proc. 10th Syst. Syst. Eng. Conf. (SoSE)*, May 2015, pp. 199–204.
[14] J. N. Martin and D. P. O'Neil, "Enterprise architecture guide for the unified architecture framework (UAF)," in *Proc. INCOSE Int. Symp.*, vol. 31, no. 1, 2021, pp. 242–263.
[15] (2021). *Enterprise Architecture Guide for UAF (Informative), Appendix C, Version 1.2*. [Online]. Available: https://www.omg.org/spec/UAF/1.2
[16] *What is Strategic Planning?* Accessed: May 13, 2022. [Online]. Available: https://corporatefinanceinstitute.com/resources/knowledge/strategy/strategicplanning/
[17] J. Bankauskaite, A. Morkevicius, and R. Butleris, "Early quality evaluation of system of systems architecture within trade study process," *IEEE Access*, vol. 8, pp. 220858–220868, 2020.
[18] (2021). *Unified Architecture Framework (UAF) Domain Metamodel, Version 1.2*. [Online]. Available: https://www.omg.org/spec/UAF
[19] (2021). *UAF 1.2—Appendix B: Sample Problem*. [Online]. Available: https://www.omg.org/cgi-bin/doc?dtc/21-12-12.pdf
[20] M. Hause and L.-O. Kihlström, "An elaboration of service views within the UAF," in *Proc. INCOSE Int. Symp.*, vol. 31, no. 1, 2021, pp. 728–742.
[21] J. Lee, A. Alghamdi, and A. K. Zaidi, "Creating a digital twin of an insider threat detection enterprise using model-based systems engineering," in *Proc. IEEE Int. Syst. Conf. (SysCon)*, Apr. 2022, pp. 1–7.
[22] M. M. Helms and J. Nixon, "Exploring SWOT analysis—Where are we now? A review of academic research from the last decade," *J. Strategy Manage.*, vol. 3, no. 3, pp. 215–251, Jan. 2010.
[23] J. J. López García and D. P. Pereira, "Analyzing system security architecture in concept phase using UAF domains," *INSIGHT*, vol. 25, no. 2, pp. 56–60, Jun. 2022.
[24] R. Anderson and M. Tolbert, "Model-based risk analysis & mitigation (MB-RAM) for cybersecurity using UAFP and RAAML," presented at the UAF Summit Hybrid Event Actionable Archit. 21st Century. Reston, VA, USA: Object Management Group, Mar. 23, 2022. [Online]. Available: https://virtual.boomset.com/session/117163/242893 and https://www.brighttalk.com/webcast/12231/538625?utm_source=brighttalk-portal&utm_medium=web&utm_content=UAF%20Summit&utm_term=search-result-4&utm_campaign=webcasts-search-results-feed
[25] O. C. Eichmann, S. Melzer, and R. God, "Model-based development of a system of systems using unified architecture framework (UAF): A case study," in *Proc. IEEE Int. Syst. Conf. (SysCon)*, Orlando, FL, USA, Apr. 2019, pp. 1–8.
[26] R. León-Soriano, M. J. Muñoz-Torres, and R. Chalmeta-Rosaleñ, "Methodology for sustainability strategic planning and management," *Ind. Manage. Data Syst.*, vol. 110, no. 2, pp. 249–268, Mar. 2010.
[27] M. J. Pour, Z. K. Zadeh, and N. A. Zadeh, "Designing an integrated methodology for knowledge management strategic planning: The roadmap toward strategic alignment," *VINE J. Inf. Knowl. Manage. Syst.*, vol. 48, no. 3, pp. 373–387, Aug. 2018.
[28] F. Kitsios, M. Kyriakopoulou, and M. Kamariotou, "Exploring business strategy modelling with ArchiMate: A case study approach," *Information*, vol. 13, no. 1, p. 31, Jan. 2022.
[29] T. C. Niday, "Enabling disruptive innovations in high growth organizations when architecting an enterprise," M.S. thesis, Dept. Syst. Des. Manag. Program, Massachusetts Inst. Technol., Cambridge, MA, USA, May 2022.
[30] M. A. Benzaghta, A. Elwalda, M. Mousa, I. Erkan, and M. Rahman, "SWOT analysis applications: An integrative literature review," *J. Global Bus. Insights*, vol. 6, no. 1, pp. 55–73, Mar. 2021.
[31] Y. Hongxiong and W. Huiming, "Background analysis of digital transformation of automobile enterprises based on SWOT analysis method," in *Proc. IEEE Int. Conf. Electr. Eng., Big Data Algorithms (EEBDA)*, Feb. 2022, pp. 386–389.
[32] A. Sarsby, *SWOT Analysis*, 1st ed. Berlin, Germany: Spectaris, 2016. [Online]. Available: https://books.google.com/books?id=Yrp3DQAAQBAJ
[33] S. K. White. (2018). *What is SWOT Analysis? A Strategic Tool for Achieving Objectives*. [Online]. Available: https://www.cio.com/article/219603/swot-analysis-defined.html
[34] K. Almutairi, S. J. Hosseini Dehshiri, S. S. Hosseini Dehshiri, A. Mostafaeipour, A. X. Hoa, and K. Techato, "Determination of optimal renewable energy growth strategies using SWOT analysis, hybrid MCDM methods, and game theory: A case study," *Int. J. Energy Res.*, vol. 46, no. 5, pp. 6766–6789, Apr. 2022.
[35] M. F. Gholami and R. Ramsin, "Strategies for improving MDA-based development processes," in *Proc. Int. Conf. Intell. Syst., Model. Simul.*, Jan. 2010, pp. 152–157.
[36] *User Guide, UAF Elements*. Accessed: May 13, 2022. [Online]. Available: https://docs.nomagic.com/display/UAF12P2021xR2/Driver
[37] M. Hause and L.-O. Kihlstrom, "Tilting at windmills: Drivers, risk, opportunity, resilience and the 2021 texas electricity grid failure," in *Proc. INCOSE Int. Symp.*, vol. 32, 2022, pp. 545–564.
[38] A. Morkevicius, "Past, present, and future of the unified architecture framework (UAF)," presented at the 32nd Annu. INCOSE Int. Symp. Detroit, MI, USA: INCOSE, Jun. 25–30, 2022. [Online]. Available: https://www.linkedin.com/feed/update/urn:li:activity:6960220185249095680?utm_source=share&utm_medium=member_desktop
[39] S. Friedenthal, A. Moore, and R. Steiner, *A Practical Guide to SysML*, 3rd ed. Boston, MA, USA: The MK/OMG Press, 2015, doi: 10.1016/C2013-0-14457-1.
[40] A. D. Brucker and J. Doser, "Metamodel-based UML notations for domain-specific languages," in *Proc. 4th Int. Workshop Lang. Eng. (ATEM)*, Zürich, Switzerland: Eth Zürich, 2007, pp. 1–15.

MOHAMMADREZA TORKJAZI (Member, IEEE) was born in Gorgan, Golestan, Iran, in 1988. He received the B.S. and first M.S. degrees in industrial engineering from the Mazandaran University of Science and Technology, Babol, Mazandaran, Iran, in 2010 and 2013, respectively, and the second M.S. degree in industrial engineering from West Virginia University, Morgantown, WV, USA, in 2020. He is currently pursuing the Ph.D. degree in systems engineering and operations research with George Mason University, Fairfax, VA, USA.

From 2017 to 2020, he was a Graduate Research and Teaching Assistant at the Department of Industrial and Management Systems Engineering, West Virginia University. Since 2020, he has been a Graduate Research and Teaching Assistant with the Department of Systems Engineering and Operations Research, George Mason University, Fairfax, VA, USA. His research interests include system of autonomous systems, model-based systems engineering, decision support systems, and multi-criteria optimization.

Mr. Torkjazi is a member of the International Council on Systems Engineering and an Elected Member of the George Mason University Chapter of The Honor Society of Phi Kappa Phi.

ARTURO J. DAVILA-ANDINO (Member, IEEE) was born in Caguas, Puerto Rico, in 1991. He received the B.S. degree in physics from the University of Puerto Rico, Mayaguez, in 2015, and the M.S. degree in systems engineering from the University of Maryland, College Park, in 2018. He is currently pursuing the Ph.D. degree in systems engineering and operations research with George Mason University, Fairfax, VA, USA.

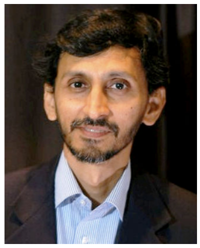
From 2018 to 2022, he has held various positions as a Model-Based Systems Engineer at BAE Systems, Johns Hopkins University Applied Physics Laboratory, and Booz Allen Hamilton. Since 2022, he has been practicing as a Model-Based Systems Engineering Specialist at McIntire Solutions, Chantilly, VA, and Founded Bungean, Greenbelt, MD, USA, to provide digital engineering education and consulting services. His research interests include digital engineering, model-based systems engineering, systems engineering education, simulation optimization, and non-stationary queueing theory.

Mr. Davila-Andino is a member of the International Council on Systems Engineering. He is certified as an Associate Systems Engineering Professional by the organization. He is also certified by the Object Management Group as an OMG Certified Systems Modeling Professional–Model Builder Intermediate.

AHMAD ALGHAMDI (Member, IEEE) was born in Jeddah, Saudi Arabia, in 1983. He received the B.S. degree in industrial engineering from King Abdulaziz University, Saudi Arabia, in 2006, and the M.S. degree in engineering management from the University of Melbourne, Australia, in 2009. He is currently pursuing the Ph.D. degree in systems engineering and operations research with George Mason University, Fairfax, VA, USA.

From 2012 to 2016, he was a Lecturer with the Industrial and System Engineering Department, University of Jeddah, Jeddah, Saudi Arabia. Since 2019, he has been a Teaching Assistant with the Systems Engineering and Operations Research Department, George Mason University. His research interests include system architecture design and evaluation, adaptive complex system resilience, and model-based systems engineering.

Mr. Alghamdi is a CAB member of the International Council on Systems Engineering.



ABBAS K. ZAIDI (Senior Member, IEEE) was born in Karachi, Pakistan, in 1965. He received the B.E. degree in electrical engineering from the NED University of Engineering and Technology, Karachi, in 1988, and the M.S. degree in electrical and computer engineering and the Ph.D. degree in informational technology and engineering from George Mason University, Fairfax, VA, USA, in 1991 and 1994, respectively. He is currently a Professor at the Department of Systems Engineering and Operations Research, George Mason University.

From 1999 to 2002, he worked as an Associate Professor with the Department of Electrical Engineering and Computer Science, and the Dean of the Faculty at Mohammad Ali Jinnah University, Karachi. He has been affiliated with the System Architectures Laboratory, George Mason University, since 1990, first as a Graduate Research Assistant (Ph.D.) and then as a Research Faculty. He has also served as the Director of research at the System Architectures Laboratory, George Mason University. His research interests include digital engineering, evaluation of architectures, multi-modal simulations, and discrete-event systems.

Dr. Zaidi was a recipient of the several research grants from the government and private sector organizations. He is a member of the International Council on Systems Engineering (INCOSE) and an Elected Member of Sigma Xi.