Complexity and Adaptive Enterprise Architecture

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Abstract: In the current VUCA (Volatility, uncertainty, complexity and ambiguity) environment, enterprises are facing constant threats and opportunities due to internal and external factors. Those factors can impact various parts of the enterprise in the form of changes. Thus, Adaptive Enterprise Architecture (EA) is leveraged to assist the continuous adaptation to the evolving transformation. On the other hand, the complexity has been identified as one of the major challenges of the discipline of Enterprise Architecture. Moreover, one of the criteria of Adaptive EA is the ability to monitor and control the complexity of changes. Consequently, in this paper, we suggest a conceptualization of EA complexity measurement drilled down into factors and indicators. First, we begin with a brief summary of the criteria that we consider compulsory for Adaptive Enterprise Architecture and we give an overview of the model that we worked on in previous work. Then we investigate related work about complexity in a broader view. Finally, we describe our approach of assessment of complexity based on the proposed indicators.

1 INTRODUCTION

In current turbulent environment, enterprises are often required to adapt in the form of disruptive changes that impact its various parts. Thus, they need to become adaptive and agile by facing unique challenges that they encounter with the specificities of each of them (cycles, recurrence, frequency, etc.). They are required to recognize the impact of change, detect obstacles and facilitate decision-making. Also, they need to consider the uncertainty and the diversity of change and respond effectively to it.

In order to support the evolving requirements, Enterprise Architecture can be leveraged. As the watcher of changes and facilitator of adaptation, EA should focus on the methods and tools needed to move from an initial, detailed, complex, documentation-centred and prescriptive EA to an EA that focuses on principles of adaptation to expected changes and unforeseen ones. More importantly, EA should provide continuous improvement to proactively address development needs with the right level of complexity. In this regard, we introduced Adaptive Enterprise Architecture model (Daoudi et al. 2020a).

Adaptive EA takes into account the uncertainty of change and its diversity. It allows the proactive detection of change and responds to it efficiently. It also permits the management to make the adequate trade-offs between the components involved and that are sometimes competing. Most importantly it leads dynamic transitions, in the form of projects, from an "*as is*" to a "*to be*" by ensuring the right level of complexity.

On the other hand, the Cambridge Dictionary defines complexity as "*the quality of having many connected parts and being difficult to understand*". In the literature, the notion of complexity can be found in different domains and there is a lot of definitions and a lack of consensus on it or on how to measure complexity (Padalkar et al., 2016). In regards with EA, this concept can have many interpretations as there are many stakeholders involved in an EA and each one have a different perception of it.

In this paper, we explore the state of the art related to complexity and we define some factors that we consider as drivers of complexity in Enterprise architecture. Then, we introduce EA DDC (Degree of Dynamic Complexity) as a measure. In Section 2, we summarize the results of our previous work in regards with Adaptive Enterprise Architecture. Section 3 focuses on related work of complexity of change management. In Section 4, we define the factors and the metrics of Complexity in an elementary EA transition. Finally,

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in the last part, we conclude our work and present our perspectives.

2 ADAPTIVE ENTERPRISE ARCHITECTURE MODEL

In order to put into context our paper, we present in this part the main results than we achieved and that were published in previous work. We proposed a definition for Adaptation: Adaptation ensures that the EA is consistent with the changes, to maintain its normal functioning. It is a process of adjustment and of continuous improvement to reach an EA in harmony with its environment. Then, we defined some criteria that we consider compulsory ingredients for Adaptive Enterprise Architecture (Daoudi et al., 2020b).

First, we highlighted **multi-level of dynamics** factor as some types of change occur at different layers and impact the relations inter-layers and intra-layers. Then, we explained the s**ensing of change** part which is the ability to detect continuously the need for change proactively at internal and external levels. We also underlined the **process of adaptation** which is the core of the adaptive enterprise architecture. We pointed out the **complexity of change management** that is related to the degree of complexity of the different components and relationships in an EA. It is for example related to business diversification, geographic diversification or network interconnectedness. Moreover, a complex document-oriented framework will certainly fail to handle abrupt changes that happen at high pace. Then, we defined the ability of **handling unforeseen changes** which is the proactive definition of unexpected change specifities location, severity, probability and kinds of adaptations needed. Another criterion specified was related to the **explicit management of adaptability trade-offs.** It allows the archiving, tracking and knowledge sharing of trade-offs necessary when deciding of an architecture. Finally, we underlined the importance of **evaluation of adaptation** which allows the assessment of the improvements made through the adaptation process.

Then driven by those criteria, we tried to propose an Adaptive Enterprise Architecture approach based on agile methodologies (Daoudi et al., 2020a). The Figure 1 is a simplified diagram that shows the main elements of our Adaptive Enterprise Architecture Approach.

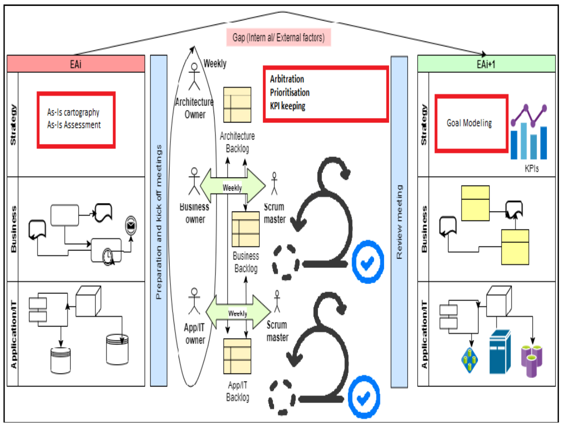

Figure 1: Simplified diagram of the proposed model.

Our approach allows having a dynamic architecture that is continuously evolving through time. Thus, in order to analyse the components of the EA we take a static snapshot at a certain time (EAi). We consider that during an enterprise lifecycle we move from an EAi ($i \in N^*$) to EAi+1 ($i \in N^*$) (Elementary transition). So as to ensure those continuous transitions, every elementary transition is a project with the main objective to close the gap between the “*As-Is*” and “*To-Be*”.

3 RELATED WORK

In the current VUCA (Volatility, uncertainty, complexity and ambiguity) environment, management approaches need to adapt to the new requirements and to manage complexity. In the literature, multiple papers and researches have shown the importance of complexity management as it impacts various project phases during its lifecycle, it hinders the identification of goals and objectives and it can affect different project outcomes in terms of time, cost and quality (Baccarini, 1996) and (Parsons-Hann et al., 2005). Also, the larger and the more complex a project is, the riskier it is. In fact, this type of projects face significant, unpredictable change, and are difficult or impossible to forecast (Taleb et al., 2009). If we focus only on the IT (Information System), complexity has been attributed as one of the causes of high failure rates in IT projects. So as to give some statistics, One in six IT projects is expected to be a black swan, with a cost overrun of 200% on average (Flyvbjerg et al., 2011). In general, complexity is taken as having negative impact on project performance (Bjorvatn et al., 2018). But in order to maximize the effectiveness of an architecture, some new concepts evolved recently like "*requisite complexity*". It shows that is important to find the right balance between complexity excess and deficit, that is, to find an optimal level of complexity (Schmidt, 2015).

On the other hand, limited research has been conducted on metrics and measuring IT complex projects and less in defining methods for managing them. Most research concludes that metrics and tools are required but not available or not reliable (Morcov et al., 2020). Specifically talking about complexity and Enterprise Architecture, complexity has been identified as one of the major challenges faced by the discipline of enterprise architecture (Lucke et al., 2010). But little research on complexity management in other areas is applicable to the field of enterprise architecture (Lee et al., 2014).

In addition to that, systems are increasingly exposed to hazards of disruptive events (Zio, 2016). e.g., new business requirements, unexpected system failures, climate change and natural disasters, terrorist attacks. Risk assessment is, then, applied to inform risk management on how to protect from the potential losses. It is a mature discipline that allows analysts to identify possible hazards/threats, understand and analyze them, describe them quantitatively and with a proper representation of uncertainties (Zio, 2018). Its principles are based on assessment of risk as a scientific activity depending on the available knowledge and the uncertainty inherent in risk, and decision making based on risk is regarded as a political activity. According to Qazi et al. (2016), in the current literature, some researchers are supporters of the existence of a relationship between complexity and risk. They argue that the adoption of a disintegrated approach of evaluating complexity and risks in silos raises the possibility of selecting sub-optimal risk mitigation strategies While others are detractors of this link and suggest that these two concepts are distinct.

In the following, we explore the broader state-of-the-art related to the definition of complexity with a focus on research papers related to IT, business and project management as, in our model, the elementary transition from EAi to an EAi+1 is a project. We also, identify the main contributions that discussed complexity measurement in Enterprise Architecture.

3.1 Definition of Complexity

The notion of complexity can be found in STEM (Science, Technology, Engineering, and Mathematics), social, economic and management disciplines. The main challenge is that there is a lack of consensus on the definition of complexity of a project (Padalkar et al., 2016). In the Table 1, we summarize the main definitions of complexity.

Table 1: Definitions of Complexity.

Sources	Definition of complexity
Aristotle	He Defined complexity as "the whole is something else than the sum of its parts"
Smuts et al. (1927)	The theory of holism reintroduced complexity notions. It highlighted that the ultimate sources of knowledge derive from a reference to the system's broader context.
Pich et al. (2002)	They defined complexity as information inadequacy when too many variables interact.
Ward et al. (2003)	They viewed the number of influencing factors and their interdependencies as constituents of complexity.
Bertelsen (2004)	He considered that complex society is characterized by open systems, chaos, self-organization and interdependence.
Cooke-Davies et al. (2007)	In relation with complex systems theory, they highlighted the following attributes of complexity : Emergence and Unpredictability
Brokmann et al. (2007)	The Luhmannian system theory, defined complexity as the sum of the following components: differentiation of functions between project participants, dependencies between systems and subsystems, and the consequential impact of a decision field.
Vidal et al. (2008)	They qualified project complexity as that property that makes it difficult to understand, foresee, and keep under control its overall behaviour.
Remington et al. (2009)	They linked complexity to the severity of project specificities in relation with the difficulty of control, management and predictability.
Schütz et al. (2013)	They defined complexity as the number and the heterogeneity of the components and relations of an EA.
Custovic (2015)	He considered that a project is complex when it is difficult to formulate its overall behaviour in a given language, even with reasonable complete information about its atomic components and their interrelations.
Efatmaneshnik et al. (2016)	They calculated the distance of an architecture from a reference simplicity.
Abankwa et al. (2019)	They defined 'structural complexity' as the relation of project elements to the structure of the project.
Trinh et al. (2020)	They considered that the attributes of project complexity are parts of the following groups : organizational complexity, technical complexity and environmental complexity.

In our paper, we consider that complexity of an Adaptive Enterprise Architecture involves many unknowns and many interrelated factors as explained by the previous criteria. In fact, complexity is related to the different parts of an enterprise with their specificities, to the interrelation between layers and to the environment. Moreover, we also have the dynamic aspect between EAi and EAi+1. This means that the complexity is not applied to a static approach but has a dynamic part. Thus, our reasoning tends towards the definitions given by Vidal et al. (2008), Schütz et al. (2013), and Trinh et al. (2020).

3.2 Complexity Measurement

As shown in the previous part, complexity can have many interpretations sometimes even in the same field. In the following, we focus on papers that discussed the measurement of complexity.

According to San Cristóbal et al. (2018), in order to comprehend project complexity concept can be drilled down into factors and characteristics. They identified the main factors that are considered in the literature: Size, Interdependence and Interrelations, Goals and Objectives, Stakeholders, Management Practices, Division Labor, Technology, Conccurent engineering, Globalization and context dependence, Diversity, ambiguity, Flux.

Also, with a focus on IT projects, Morcov et al. (2020) identified the below characteristics of complexity : Multiplicity, ambiguity, uncertainty, Details (Structural), Dynamics, Disorder, Instability, Emergence, Non-Linearity, recursiveness, irregularity, randomness, Dynamic complexity, uncertainty of objectives and methods, varied stakeholder and competing views, changing objectives, adaptive evolving, explanation states of stability-instability, Size, Variety, interdependence, context, innovation, difficult to understand, Difficult to foresee and difficult to control.

Lagerström et al. (2013) applied Design Structure Matrices. They classify applications based on their dependencies into core, control, shared and periphery applications and calculate the propagation costs.

In Schneider et al. (2014), the authors identified eight aspects frequently examined in complexity science literature and proposed a conceptual framework that aims to unify views on complexity through four dimensions : Objective vs Subjective / Structural vs Dynamics/ Quantitative vs Qualitative/ Ordered vs Disordered.

Kahane's approach to complexity used a process called the U-process. Basically, the project managers try to sense the current reality of the project, then analyse it and propose action items, and finally they implement those actions (Kahane, 2004).

Cynefin Decision-Making Framework originated from Snowden‟s work in knowledge management. It is a sense-making framework that sorts systems into five domains that require different actions based on cause and effect relationships: simple, complicated, complex, chaotic and disorder (Kurtz et al., 2003).

In relation with Enterprise Architecture, Iacob et al. (2018) worked on the conceptualization of EA complexity measurement, including the variables and the metrics to measure them. Through an analysis of the state-of-the-art, they proposed a measurement model that integrated existing complexity metrics and introduced new metrics.

Janssen et al. (2006) considered enterprises as complex adaptive systems and attributed to them properties like emergence and self-organization. In addition, they provided concrete architectural guidelines.

Mocker (2009) provided one of the first empirical evaluations of complexity measures including interdependencies of applications, diversity of technologies, deviation from standard technologies and redundancy.

Kandjani et al. (2013) presented a co-evolution path model, which is based on the idea of Ashby's law of requisite variety. The model shows that each time the complexity of an enterprise's environment changes, the enterprise itself has to adjust its complexity.

According to the IEEE Standard 1471-2000 in IEEE Architecture Working Group (2000) and Schütz et al. (2013), we can consider EA as a system, consisting of its components and its relations to each other. Zio (2016) stated that systems are increasingly exposed to hazards of disruptive events. Thus, risk assessment is applied to act proactively to those events and prevent eventual losses.

The International Risk Governance Council (2012) defined risk as an uncertain (generally adverse) consequence of an event or activity with respect to something that human beings value. As for the risk description, the focus is on the accident scenarios, their possible consequences and likelihoods, and the uncertainties therein (Bjerga et al., 2016). The post-accident recovery process, is not considered. As the accuracy of scenarios and of estimations are evaluated against the available knowledge which is limited, risk needs to take into account the uncertainties associated to the risk assessment (Kaplan, 1981). Aven et al. (2010) integrated knowledge as an explicit component in the definition of risk. The challenge is to have under analysis all the knowledge from experts observations and model prediction about rare but potentially disastrous accident events (Zio, 2018). The relatively recent discussions on the concept of risk, have clearly stated the outcomes of risk assessment are conditioned on the knowledge available on the system and/or process under analysis (Aven, 2016). This means that there is inevitable existence of a residual risk related to the unknowns in the system, and/or process characteristics and behaviors.

For a specific project, the identification and the tracking requirement are not sufficient as they are based on unconstrained plans. Thus, Perera et al. (2005) proposed to integrate 7 pillars of risk management (Schedule, people, technical, configuration management, Safety, Environment, and cost/Budget) with the three major areas of emphasis of project management which are project control, systems engineering, and safety and mission assurance.

Recognizing the common framework used to describe the uncertainties in the assessment stands on probability theory, and particularly on the subjectivist (Bayesian) theory of probability, as the adequate framework within which expert opinions can be combined with statistical data to provide quantitative measures of risk (Kelly and al., 2011).

According to Perera et al. (2005), NASA's (National Aeronautics and Space Administration) risk management strategy is a continuous and iterative process performed to reduce the probability of adverse threats. It includes also an approach of knowledge archiving and sharing as a basis for future mitigation activities. It focuses on the following activities. First the identification of potential problems. Then the analysis of those threats by understanding the nature of the risks, cleaning by merging elements and eliminating duplicates, classifying and prioritizing them which help with the creation of the mitigation plans. The next step is risk planning (action plan). After that is the tracking part. Finally, risk control which is the decision making in relation with each risk and the actual action plan. One Other contribution of this paper is the measure of effectiveness of the risk management process though four dimensions: Input (documentation hinders), Speed (time to get from source to right destination), Fidelity (risk input changes) and Synthesis (view of correlated input from different sources).

In addition, Dynamic Risk Assessment (DRA) is defined as a risk assessment that updates the estimation of the risk of a deteriorating system according to the states of its components, as knowledge on them is acquired in time (Yadav et al., 2017). Most existing DRA methods, only use statistical data that require the occurrence of the accidents or near misses (Zio, 2018).

4 COMPLEXITY IN ADAPTIVE ENTERPRISE ARCHITECTURE

In this paper and in relation with our approach, we propose the assessment of one of the criteria of "Adaptive Enterprise Architecture" that were proposed in Daoudi et al. (2020b): the **complexity of change management.**

Before tackling the core of this part we consider EA as a system, consisting of its components and its relations to each other. This consideration is aligned with IEEE Standard 1471-2000 in IEEE Architecture Working Group (2000) and Schütz et al. (2013) work. In regards with the tools of modelisation, we suggest the use of Archimate notation. ArchiMate is a modeling language that provides a uniform representation of diagrams describing enterprise architectures. This provides an integrated architectural approach that describes the different domains of architecture, their components and their relationships and dependencies. As such, we suggest considering the complexity of change management or the complexity of moving from an EAi to an EAi+1 as a function of time that has multiple factors that we will define later. We named this metric: EA Degree of Dynamic Complexity (DDC).

$$DDCi,i+1(t) = \sum_{j=1}^{n}(fj(t) + fj) \quad \text{where } n \in N$$

Where i the indicator of the EA version, $f_j(t)$ the values of dynamic factors and f_j the values static factors.

Based on Schneider et al. (2014) and as shown in the formula, we proposed a first dimension of classification of our factors. Thus, we have "Dynamic" one who can have many values overtime. Those factors can allow us to study their trends and to assess their evolution during the elementary transition. On the other hand, we have "Static" ones that have the same value overtime during the elementary transition. Those factors can be picked by the management in collaboration with the Architecture owner. In our proposition, we won't consider any static factor.

The second classification dimension is Objectivity. Thus, we consider that we have factors that are assessed based on expert judgment and available knowledge. Those are "Subjective" Factors. In opposite, we define "Objective" factors that can be calculated using mathematic formulas based on the characteristics of the components of the architecture.

Trinh et al. (2020) considered that the attributes of project complexity are parts of the following groups: organizational complexity, technical complexity and environmental complexity. Also, Schütz et al. (2013) introduced a system theoretic conceptualization of complexity in enterprise architectures. Similarly and in application to EA, we also propose a third dimension of classification that is based on the below EA sub-systems. The first one is "Architecture". It encompasses the factors that are drivers of complexity of the whole project of transitioning from an EA_i to an EA_{i+1}. It contains also factors that are related to multiple layers of the EA. Then, we have “Strategy”, “Business”, “Organisation” and “Information System”. The factors in these categories translates the specificities of complexity at respectively each level. We added “External” category, it is not a sub-system of EA but it is worth mentioning as some environmental requirements may have an impact on the complexity studied. The Table 2 shows the factors that we consider as drivers of the complexity of each increment or elementary transition (project) in our proposed approach. The list is not exhaustive.

Table 2: Proposed complexity factors in EA transition project.

	Factors	Subjectivity	Indicators
Architecture	Context awareness	Subjective	Scoring of the observer and adaptability capability
	Ambiguity	Subjective	Scoring of ambiguity in the overall project
	Uncertainty	Subjective	Scoring of uncertainty in the overal project
	Security	Subjective	Scoring of the degree of safety and security required at each level
	Risk assessment	Subjective	Scoring Approach
	Interdependencies between different layers	Objective	Number of impacted relations between different layers
	Number of delivrables estimated of the project	Objective	Estimated number of delivrables at each level and overall
	Effort estimated of the project	Objective	Man days at each level and overall
	Cost/Budget of the project	Objective	Scoring of the estimated cost and budget of the project
	Duration of the project estimated	Objective	Scoring of the duration of the project
Strategy	Context awareness	Subjective	Scoring of implication of priorities and of management support
	Competing Soft Goals	Subjective	Number of competing goals
	Interdependences and interrelations between hard goals	Objective	Number of relationships between Hard goals implicated in the elementary tansition
Organisation	Variety of stakeholder and competing views	Objective	Organisational Entropy
	Team Size	Objective	Number of collaborators implicate in the project team
	Variety of skills needed	Objective	Entropy of skills
Business	Interdependences and interrelations between Business Processes	Objective	Number of impacted relations in the same layer
	Business KPIs	Subjective	Scoring of the degree of definition of business KPIs
IT	Variety of systems and applications	Objective	Entropy of applications and systems
	Infrastructure and material resource availibility	Objective	Cost of the infrastructure investment estimated
	Interdependences and interrelations between IT components	Objective	Number of impacted relations in the same layer
	Quality of service (QoS)	Objective	Qos level required
External	Environment limitations and compliance	Subjective	Scoring of the environment limitations

The selection of the factors was mainly based on the interrelations between layers and the heterogeneity of elements (Schütz et al., 2013). In addition, it is also related to the characteristics of the dynamic aspect in our approach: elementary transition EAi to EAi+1 and also sprints and weekly vertical alignment in each transition (Daoudi et al., 2020a).

In the following we will define each complexity factor. For objective factors we used quantitative metrics. As for subjective factors, we adopted a scoring methodology to translate the expert judgment in numbers Perera et al. (2005).

First at architectural level for subjective factors, we proposed **“*context awareness*”** which expresses the ability to catch internal changes and to adapt the project details accordingly at architectural level. Then we have **“*ambiguity*”** that shows to which extent the decisions and the communication are traceable and clear to all the stakeholders. There is also **“*uncertainty*”** that shows the level of uncertainty in project estimations according to the owners (Architecture, Business and IT) and the assumptions taken for the unconstrained plans. Another factor is **“*Security*”**. It describes the degree of complexity of security requirements in the whole project. Finally, we have **“*Risk assessment*”** which shows the assessment of risks in the elementary architectural transition. Then, we have objective factors at architectural level. We considered in those the **“*Interdependencies between different layers*”** which is the different relationships interlayers. We also identified some factors related to the project of moving from EA_i to EA_{i+1}: **“*Number of deliverables estimated of the project*”**, **“*effort estimated of the project*”**, **“*Cost/budget of the project*”** and **“*Duration of the project estimated*”.**

At strategy level, we identified two subjective factors. **“*Context awareness*”** is the first one it and it expresses the degree of integration of strategic priorities and the level of support from management. Then, we have **“*Competing soft goals*”**. As we proposed the use of goal modelling (Doumi, 2013), the assessment of soft goals and the identification of the competing ones gives an outlook over the trade-offs that will be needed. The other objective factor is related to **interdependencies** and the number of interrelated had goals.

Regarding organisation, we suggest three objective factors. **“*Variety of Stakeholders and competing views*”** allows the calculation of the concentration of the business units, the geographic dispersion, the division labor, the competing stakeholders views and the implicated contingent companies. Then, **“*team size*”** which is the number of collaborators implicated in the project. Finally, the **“*Variety of skills*”** that shows the distribution of skills that are needed in the project.

At business layer, we propose the calculation of **interdependencies** that are impacted by the elementary transition. We will deep dive into the method of calculation of this objective factor in the next parts. The other factor is the existence of **“*Business KPIs*”** to monitor the transition or the necessity of creation of new ones. This one is subjective and assessed by expert judgment.

At IT layer, we proposed the assessment of "***Infrastructure and material resource availability***" so as to identify the needed acquisitions, leasing and partnerships. Then, we identified the "***variety of systems and applications***" that shows the heterogeneity of applications and systems and the number of their types. Another important factor is the "***Quality-of-Service***" required in the IT systems and the network. We also have the **interdependencies** between the impacted components in IT layer.

Moreover, we added the external perspective which is an outlook over the environment of the EA. It is mainly focused on the analysis of external limitations, compliances and regulations.

Regarding the factor "***interdependence and interrelations***" in different sub systems and between them, we suggest the use of matrix notation based on ArchiMate 2.0.

This representative matrix $XY_{n,m}$ n,m $\in N^2$ will be constituted of n rows representing one layer and m columns representing the other layer. Also, X and Y belongs to {S,B,A,I}. We propose then six representative matrices: SS, SB, BB, BA, AA, AI. SS has soft goals in rows and Hard goals in columns, SB has hard goals in rows and Business process in columns, BB represents the intra-relations inside the business layer, BA has business processes in the rows and applications in the columns, AA represents the intra-relations in the application layer and AI has applications at rows and infrastructure components at columns. The elements of the representative matrices are couples $(a_{ij},w_{ij}) \in \{0,1\}xN$ i, j xN^2 where a_{ij} represents the existence of relationship between rows and columns and w_{ij} represents the weight of this relationship.

Based on this definition, we can automatically find impacted entities in the business layer, application layer and in the infrastructure layer through dependency chain. We use for this purpose the following operator "x":

We suppose : i, j, l, n, m $\in N^5$

$A =\{(a_{ij},w_{ij})\}_{n,m}$ where $(a_{ij},w_{ij}) \in \{0,1\}xN$

$B=\{(b_{ij},p_{ij})\}_{m,l}$ where $(b_{ij},p_{ij}) \in \{0,1\}xN$

$R = \{(r_{ij},k_{ij})\}_{n,l}$ where $(rij,kij) \in \{0,1\}xN$

The resulting matrix is then

$$R= A \text{ x } B = \{(\cup_{k=1}^{N} aik * bkj, \cup_{k=1}^{N} wik * pkj)\}_{n,l}$$

Where ∪ is the OR operator.

The number of interdependences is then the sum of the first part of elements impacted. Based on the resulting matrix, we select the set of elements impacted and sum its elements. The value is couple represented by the number of relations and the weight of the relations.

Regarding the variety of applications and systems and the variety of stakeholders we suggest the use of Entropy.

The term entropy was introduced in 1865 by Rudolf Clausius. He developed the concept based on the formulation of the second law of thermodynamics. The entropy of a system is determined by the number of states accessible to the system, and the probability of occurrence of each of those states.
Its formula is :

$$S= - \sum_{i=1}^{N} pi \ln(pi)$$

Where S is the entropy and pi the probability of each state of the studied system.

According to (Martínez-Berumen, 2014), we can consider the organisational aspect as a system and thus apply Entropy to it. We will use his definition of organisational entropy. For the variety of applications and systems, we will also use entropy so as to assess the heterogeneity of the landscape.

Regarding risk assessment, we suggest the use of a matrix that contains the risks based on expert knowledge, to assess them and characterize their impact using a scoring notation. The risk of the project then can be categorized from 1 to 3 (High risk, medium risk and low risk).

For other factors, apart from the calculation of the estimations proposed in the Table 1, we suggest the use of a scoring notation from 1 to 10. This will allow us to sum all the values gathered and define classes of complexity of an elementary transition project.

5 CONCLUSION

In this paper we explored the literature regarding complexity in general and in relation with Enterprise Architecture. Then we outlined and formalized our methodology based on factors and indicators to monitor complexity when doing an elementary transition (project) in the Adaptive EA approach. We also managed to categorize those factors based on the implication of an expert stakeholder (Subjective/ Objective) and the perspectives targeted

(Architecture, Strategy, Business, Information System and External). The main contributions in this paper are to provide the project managers (Architecture owner, Business owner, IT owner and management stakeholders) with a set of indicators to monitor complexity and also to stimulate discussion about complexity in Enterprise Architecture context.

In subsequent work, we aim to propose a prototype that integrates the complexity factors and apply it to a case study. We will also deep dive into the definition of some factors and metrics that can add more concreteness to the other criteria and also explore the use of data driven analysis in our model.

REFERENCES

Abankwa D.A., Rowlinson S.,and Adinyira E. (2019). *Conceptualizing team adaptability and project complexity: A literature review.* International Journal of Innovation, Management and Technology

Aristotle*. Metaphysics,* Book VIII, 1045a.8–10

Aven, T., and Renn, O. (2010). Risk management. In *Risk Management and Governance*, pp. 121-158. Springer, Berlin, Heidelberg.

Aven T. (2016). *Ignoring scenarios in risk assessments: Understanding the issue and improving current practice.* Reliability Engineering & System Safety. pp. 215-220

Bertelsen S. (2004). *Construction management in a complexity perspective.* International SCRI Symposium

Baccarini D. (1996). *The concept of project complexity—a review. International Journal of Project Management,* vol. 14. pp. 201–204

Bjerga T., et Aven T. (2016). *Some perspectives on risk management: A security case study from the oil and gas industry.* Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability, pp. 512-520

Bjorvatn T. and Wald A. (2018). *Project complexity and team-level absorptive capacity as drivers of project management performance.* International Journal of Project Management, vol 36, pp. 876–888

Brockmann C. and Girmscheid G. (2007). *Complexity of Megaprojects,* in: CIB World Building Congress: Construction for Development

Cooke-Davies T., Cicmil S., Crawford L., and Richardson K. (2007). *We're not in Kansas anymore, Toto: Mapping the strange landscape of complexity theory, and its relationship to project management.* Project Management Journal, vol. 38, pp. 50-61

Custovic E. (2015). *Engineering management: old story, new demands.* IEEE Engineering Management Review, vol. 43, no. 2, pp. 21–23

Daoudi W., Doumi K., et Kjiri L. (2020a). *An Approach for Adaptive Enterprise Architecture.* International Conference on Enterprise Information Systems ICEIS, pp. 738-745

Daoudi W., Doumi K., and Kjiri L. (2020b). *Adaptive Enterprise Architecture: Initiatives and Criteria.* International Conference on Control, Decision and Information Technologies (CoDIT), vol. 1, pp. 557-562

Doumi K. (2013). *Approche de modélisation et d'évaluation de l'alignement stratégique des systèmes d'information Application aux systèmes d'information universitaires.* PhD Thesis

Efatmaneshnik M., and Ryan M.J. (2016). *A general framework for measuring system complexity.* Complexity. pp. 533–546

Flyvbjerg B. and Budzier A. (2011). *Why Your IT Project May Be Riskier Than You Think.* Harvard Business Review

Iacob M. E., Monteban J., Van Sinderen M., Hegeman E., et Bitaraf K. (2018). *Measuring Enterprise Architecture Complexity.* IEEE International Enterprise Distributed Object Computing Workshop. pp. 115-124

IEEE Architecture Working Group (2000). *IEEE Recommended Practice for Architectural Description of Software-Intensive Systems*

International Risk Governance Council (2012). *An introduction to the IRGC Risk Governance Framework.* ISBN 978-2-9700772-2-0

Janssen M., and Kuk G. (2006). *A Complex Adaptive System Perspective of Enterprise Architecture in Electronic Government.* Hawaii International Conference on System Sciences

Kahane A. (2004). *Solving Tough Problems: an Open Way of Talking, Listening, and Creating New Realities.* Berrett-Koehler Publishers

Kandjani H., Bernus P., and Nielsen S. (2013). *Enterprise Architecture Cybernetics and the Edge of Chaos: Sustaining Enterprises as Complex Systems in Complex Business Environments.* Hawaii International Conference on System Sciences. pp. 3858–3867

Kaplan S., et Garrick B. J. (1981). *On the quantitative definition of risk. Risk analysis.* pp. 11-27

Kelly, D., et Smith, C. (2011). *Bayesian inference for probabilistic risk assessment: A practitioner's guidebook.* Springer Science & Business Media

Kurtz C.F.et Snowden D.J. (2003). *The New Dynamics of Strategy: Sense-making in a Complex and Complicated World.* IBM Systems Journal, vol 42, no. 3, pp. 46

Lagerström R., Baldwin C.Y., Maccormack A.D., and Aier S. (2013). *Visualizing and Measuring Enterprise Application Architecture: An Exploratory Telecom Case.* Harvard Business School Working Paper, pp. 13-103

Lee H., Ramanathan J., Hossain Z., Kumar P., Weirwille B., and Ramnath R.. (2014). *Enterprise architecture content model applied to 122 complexity management while delivering IT services.* IEEE International Conference on Services Computing. pp. 408–415

Lucke C., Krell S., and Lechner U. (2010). *Critical issues in enterprise architecting: A literature review.* Americas Conference on Information Systems

Martínez-Berumen H. A., López-Torres G. C., et Romo-Rojas L. (2014). *Developing a Method to Evaluate Entropy in Organizational Systems.* CSER, pp. 389-397

Mocker M. (2009). *What is Complex about 273 Applications? Untangling Application Architecture Complexity in a Case of European Investment Banking.* Hawaii International Conference on System Sciences.

Morcov, S., Pintelon, L., et Kusters, R. J. (2020). *Definitions, characteristics and measures of IT project complexity-a systematic literature review.* International Journal of Information Systems and Project Management

Padalkar M. and Gopinath S. (2016). *Are complexity and uncertainty distinct concepts in project management? A taxonomical examination from literature. International* Journal of Project Management, vol. 34, pp. 688–700

Parsons-Hann H. and Liu K.. (2005). *Measuring requirements complexity to increase the probability of project success.* International Conference on Enterprise Information Systems, pp. 434–438

Perera, J., et Holsomback J. (2005). *An integrated risk management tool and process.* IEEE Aerospace Conference, pp. 129-136

Pich M. T., Loch C. H., and Meyer A. D. (2002). *On uncertainty, ambiguity, and complexity in project management.* Management Science, vol. 48, no. 8, pp. 1008–1023

Qazi, A., Quigley, J., Dickson, A., et Kirytopoulos, K. (2016). *Project Complexity and Risk Management (ProCRiM): Towards modelling project complexity driven risk paths in construction projects.* International journal of project management, pp. 1183-1198

Remington K., Zolin R., and Turner R. (2009). *A model of project complexity: distinguishing dimensions of complexity from severity.* International Research Network of Project Management Conference

San Cristóbal, J. R. Carral, L., Diaz E., Fraguela, J. A., et Iglesias, G. (2018). *Complexity and project management: A general overview.* Complexity

Schmidt C. (2015). *Business architecture quantified: How to measures business complexity.* Business Architecture Management, pp. 243–268

Schneider A., Zec M., and Matthes F. (2014). *Adopting notions of complexity for enterprise architecture management.* Americas Conference on Information Systems

Schütz A., Widjaja T., and Kaiser J. (2013). *Complexity in enterprise architectures – Conceptualization and introduction of a measure from a system theoretic perspective.* European Conference on Information Systems

Smuts J. C. (1927). *Holism and Evolution.* 2nd Edition. Macmillian and Co

Taleb N. N., Goldstein D. G. and Spitznagel M. W. (2009). *The Six Mistakes Executives Make in Risk Management.* Harvard Business Review

Trinh M. T., and Feng, Y. (2020). *Impact of project complexity on construction safety performance: Moderating role of resilient safety culture.* Journal of Construction Engineering and Management

Vidal L.-A. and Marle F. (2008). *Understanding project complexity: implications on project management.* Kybernetes, vol. 37, no. 8, pp. 1094–1110

Ward S. and Chapman C. (2003). *Transforming project risk management into project uncertainty management.* International Journal of Project Management, vol. 21, no. 2, pp. 97– 105

Yadav V., Agarwal V., Gribok A.V., and Smith C.L. (2017). *Dynamic PRA with Component Aging and Degradation Modeled Utilizing Plant Risk Monitoring Data.* International Topical Meeting on Probabilistic Safety Assessment and Analysis

Zio E. (2018). *The Future of Risk Assessment.* Reliability Engineering and System Safety

Zio, E. (2016). *Challenges in the vulnerability and risk analysis of critical infrastructures.* Reliability Engineering et System Safety, pp. 137-150