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Proposal of a sensing model in an Adaptive Enterprise Architecture

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Abstract

Nowadays, enterprises are evolving in an interconnected ecosystem mainly characterized by turbulence. They undergo unprecedented acceleration in transformations to survive in this highly dynamic and competitive landscape. This disrupts the osmosis between the various intertwined levels of abstraction of the organisation (Strategy, Business, and Information System). Enterprise Architecture and Adaptive Enterprise Architecture, especially, are used to catalyse successive changes and to ensure scalability over time. In this context, it is compulsory for companies to sense the change proactively or reactively in early stages to respond to uncertainty. They need to build their knowledge by continuously absorbing information and data from internal and external sources. Thus, a sensing model must be devised to face enterprise needs. In this paper we propose a meta-model that formalizes the sensing capability to make smooth adaptation. We also present a model that supports adequate future enterprise architecture adoption.

Keywords: adaptation; enterprise architecture; knowledge; sensing enterprise.

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1. Introduction

Technology and new strategic trends emerge continuously and rapidly in current world. Market uncertainties and global socio-economic issues tear up many plans and disrupt established ways of conducting the business. Evolving in these highly dynamic environments, many firms are not equipped with necessary models and competencies to face the new challenges [1]. Thus, to survive they need to adapt to turbulence. They are forced to undergo changes that, sometimes, can impact various levels of abstraction from strategy, business to information system. As the impact is multi-level, Enterprise Architecture is highly concerned.

In this context, Adaptive Enterprise Architecture was proposed to support adaptability requirements [2]. One of its essential pillars is the sense and response of changes. It enables a continuous sensing at all levels of abstraction by putting data in the center of the enterprise. The data can be captured from different internal and external sources. Then, thanks to the enterprise absorptive capacity, organizations take value decisions based on the information perceived and build their knowledge accordingly [3]. Over the literature, the research on the sensing enterprise in relation with Adaptive Enterprise Architecture is not overly developed.

Our objective is the modeling of the sensing capability in an adaptive enterprise architecture context to ensure self and context awareness for the enterprise. We suggest a meta-model that formalizes the sensing capability and integrates it in an adaptive enterprise architecture model. Most importantly it helps assess the absorptive capacity of the enterprise to balance the investment and the outcome while ensuring the competitive edge.

In this article, we start by presenting, in section 2, the literature on sensing enterprise with regards to adaptive enterprise architecture. Section 3 focuses on the knowledge enablement for an enterprise to sense and detect sources of change proactively/reactively. In section 4 we suggest a meta-model that is used to formalize the sensing capability in an enterprise, and we present a model of its integration within an adaptive enterprise architecture context. Then, section 5 presents an illustrative example of the proposed model and meta-model. Finally, we conclude our work and describe the future perspectives.

2. Related work

2.1. Enterprise Architecture

Enterprise Architecture was made popular in the late eighties and there is a lack of consensus on its definition [4]. It gives a holistic view on the enterprise sub-systems and their interactions. It allows moving from a current state (As-Is) to a Future State (To-Be) and catalyzes closing the gaps between them. There are various layers considered in an EA (Strategy Architecture, Business Process Architecture, Application Architecture, and Technical Architecture)[5]. It offers a coherent set of principles, models, and methods to design and realize these views [4]. Investments, risks and processes are assessed in a 360° way increasing efficiency and return on investment and reducing waste of resources. One of the most used definitions of Enterprise Architecture is ISO/IEC/IEEE 42010:2011 standard: “The fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution” [4]. Many Enterprise Architecture Frameworks are present in the literature and the industry [6]. Some of the most used ones are: Zachman framework and The Open Group Architecture Framework (TOGAF). However, those Frameworks are not agile [7,8]. This makes it a pain point in nowadays highly dynamic environment. Thus, an Agile or Adaptive Enterprise Architecture is needed. In the following we will share some adaptive enterprise architecture approaches and how they handle the specificities of nowadays context.

2.2. Adaptive Enterprise Architecture

Based on [9], an enterprise architecture is considered adaptive when it can sense and react to change appropriately, adapts to expected or unexpected changes at any time taking into consideration rapid change, reduces waste and cost without compromising on quality and focuses on enterprise fitness, improvement, transformation and innovation. In [10], we suggested a definition of an Adaptive Enterprise Architecture approach based on the selected criteria summarized in: Multi-level of dynamics, sensing of change, complexity of change management, handling

unforeseen changes, explicit management of adaptability trade-offs, adaptation process and evaluation of adaptation. Some contributions of adaptive enterprise architecture are the Adaptive EA framework (known as the Gill framework). Gill proposal is a meta-framework that supports continuous adaptation. It uses concepts from system of systems (SoS) and service science approach [7]. On top of it, the authors, in [11], proposed an integration of TOGAF existing Framework with an adaptation cycle. The adaptive EA cycle in the proposed model begins with the Context Phase, the Defining Phase, the assessment / architecture review, Rationalization Phase and Realization Phase. Moreover, in [12], we proposed an adaptive enterprise architecture approach that inherits some of the agile principles coming from Agile Software development. It is based on iterations (Elementary transition) or small EA projects. This approach ensures adaptation horizontally at each layer and vertically between the various layers. In the above one important criterion in Adaptive Enterprise Architecture is the sensing part. In the following we will present related work to the sensing enterprise.

2.3. Sensing Enterprise

Among the criteria used to define an Adaptive Enterprise Architecture [2], we highlighted the “sensing” criterion. It is the ability to detect proactively or reactively the need for change at internal and external levels. Besides capturing selective information, the Sensing Enterprise needs also to integrate decentralized intelligence into its decision-making process [13]. The Sensing Enterprise is described as: “an enterprise making use of the sensing possibilities provided by interconnected 'environments', anticipating future decisions by using multi-dimensional information captured through physical and virtual objects and providing added value information to enhance its global context awareness” [13].

In response to digital transformation, the authors, in [1], proposed a vision statement, defined and designed a Sensing, Smart and Sustainable (S^3) Enterprise. They considered the sensing part as described above. By “Smart”, they refer to the ability to create and use knowledge in favour of new opportunities. Finally, “Sustainability” refers to all social, environmental, economic and ethical concerns for an enterprise. They considered the S^3 enterprise as a complex adaptive system and proposed a model-based and service-oriented enterprise architecture. In interconnected environments, as described in the Internet of Things vision, a Sensing Enterprise would benefit from the concepts of sensors with mobile technology and distributed intelligence to open up to new development areas [14]. This would support analysis and decision-making. In fact, acting as a radar making use of the “Things” as sensors and private area networks (PANs), a Sensing Enterprise would be gather a big amount of unstructured data that can be converted into useful information for the business and then Knowledge [13]. In fact, data is the fuel of enterprises in current world [15]. Also, according to the DIKW reference model published by [16] in the domain of Knowledge Management data converts into information, which converts into knowledge, which converts in wisdom. We consider that the sensing elements that an enterprise gathers are in the form of data or information. Those constitute the building blocks of the enterprise knowledge that allows constant innovations and competitive edge maintenance.

3. Knowledge Enablers

Based on the definitions, previously, presented, we consider that a sensing enterprise is self-aware of its components internally and context-aware of what is happening in its environment externally. Internally, when an enterprise knows its capabilities, resources, and weaknesses, it can self-criticize and turn pain points into opportunities. Externally, the enterprise has this ability to capture and analyze the ecosystem where it evolves which supports its innovation, competitive advantage, and prediction of future situations. It encompasses business, social, economic, ethical, and environmental dimensions.

To allow a concrete comprehension of our proposed model to for a sensing enterprise, we propose a case study of a medium company (ABC) that provides and sells a large portfolio of IT solutions through Business-to-Business channel. It targets its local and national market. In its initial state, (ABC) is acting reactively on a top-down basis, following the enterprise architect and the management guidance. It doesn’t have any structured model to analyzing inputs from employees, existing processes, tools… Decisions on business and information systems transformations

are top-down and are based on management knowledge. Before presenting our proposed model, we will analyze what enables knowledge in an enterprise.

"Knowledge enablers" (KE) are components dependent or independent of the enterprise that allow the enterprise to build its knowledge and adapt accordingly after assessing the risks and the gains. Knowledge enablers can be categorized based on their sources: internal and external [17,18].

External Knowledge enablers exist outside the boundaries of the enterprise. First, we consider customer's cooperation which gives an outside of the box interpretation of the product and/ or the service offered by the enterprise. There is, as well, inter-firm collaboration where business partners or competitors can exchange on technical knowledge, market requirements, and trends. Another external KE is partnerships with public, semi-public, and private institutions which allows the enterprise to get updates on the market, technologies theoretically and industrially. We consider, as well, suppliers and manufacturer's cooperation. They are continuously interfacing with the supply chain having insights regarding availabilities of raw materials and environmental events impacting them. They are, also, the first ones to scale up technologies and elaborated products. Moreover, Internet Of Things and interconnected sensors relay data about end users and channel users' behavior in a near real time manner [19]. We consider, as well, Information and Communication Technologies (ICT) intelligence solutions which have the ability of capturing a huge amount of unstructured data from the cyberspace and possess high computational abilities [20]. They support foresight in an enterprise. Finally, E-Communities enable knowledge externally through Internet as a channel to engage discussions and interactions about a common matter of interest. Even more, large communities can propose services about specific topics creating what is called crowdsourcing for a targeted enterprise.

Regarding internal Knowledge enablers, firms acquire internal knowledge through internal Research and Development where an enterprise initiates innovation discussions between the dedicated teams. It also pushes them innovate and share their knowledge with their peers and their managers through programs and incentives [21]. It can also be enabled by employee's knowledge as they are the ones to note limitations and areas of improvements daily in enterprise resources. Their experience within or coming from outside the enterprise is valuable as it brings various insights. Another internal enabler is the continuous improvements in processes and systems that generate historical data and pinpoints weaknesses and strengths. We also note in nowadays digital environments ICT Solutions as knowledge enablers as they contain a big amount of unstructured data and metadata that can be turned into knowledge through analytics helping companies to make right decisions in the right time (internal knowledge management tools, libraries, wikis, customer relationship management tools, portals, log files, files, emails…) [22]. Finally, we mention embedded sensors in products that allow the monitoring of the systems and their health checks. This leads to near real time valuable information about the products themselves without the need to be near the machines or to run fastidious diagnosis.

Moreover, another categorization of the knowledge enablers is related to the nature of those sources [18]. They can be Technocratic related to Information Systems and Information and Communications Technologies (ICT) or Behavioral related to interactions among individuals as knowledge creators and holders. We summarize in Table 1 the categories and the various Knowledge Enablers that we consider in our paper.

Table 1. Knowledge enablers categorization.

Knowledge Enablers	Behavioral /Socio cultural	Technocratic /Techno structural
Internal	Proprietary Research and Development activities	ICT Solutions
	Employees Knowledge	Embedded sensors
	Continuous improvements in processes	Continuous improvements in systems
External	Customer's cooperation	Internet Of Things and Interconnected sensors
	Inter-firm collaboration	ICT intelligence solutions
	Partnerships with public, semi-public, and private institutions	E-Communities
	Suppliers & Manufacturers cooperation	

In our paper, we consider that in current VUCA (volatile, uncertain, complex, and ambiguous) world, each enterprise needs to have a unique position resulting from the synergy created by the combination of its resources

and capacities and the external factors detected. In fact, the current context is highly dynamic leading to a very quick time to obsolescence for many kinds of knowledge. Also, the scanning and analysis of each captured data can be highly expensive without any certain outcome. The best strategy is to find its own equilibrium between its resources, investments, risks, and external and internal knowledge enablers without imitating competitors. We would say that in current context the absorptive capacity as described by [23] as "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends." It is not a straightforward approach. It needs to be monitored, filtered and decisions need to be taken quickly, continuously, and efficiently.

Initially in (ABC) we conclude that the there is a lack of analysis of technocratic/techno structural knowledge enablers. Data are gathered and logs are existent but analyses are barely performed. Behavioral/Socio cultural enablers are used implicitly without a formal process.

4. Proposed model of sensing in an Adaptive Enterprise Architecture

4.1. Meta-model of the sensing layer

The meta-model suggested shows the need of the integration of a sensing layer to the current layer EA model. This layer allows the continuous listening of the enterprise to the environment externally and a sensing of internal events. To ensure the validation of the sense and respond criteria in adaptive enterprise architecture [2], a deeper insight into the core concepts of this layer is required. A meta-model of the sensing layer is presented in Fig.1. We provide below its various components.

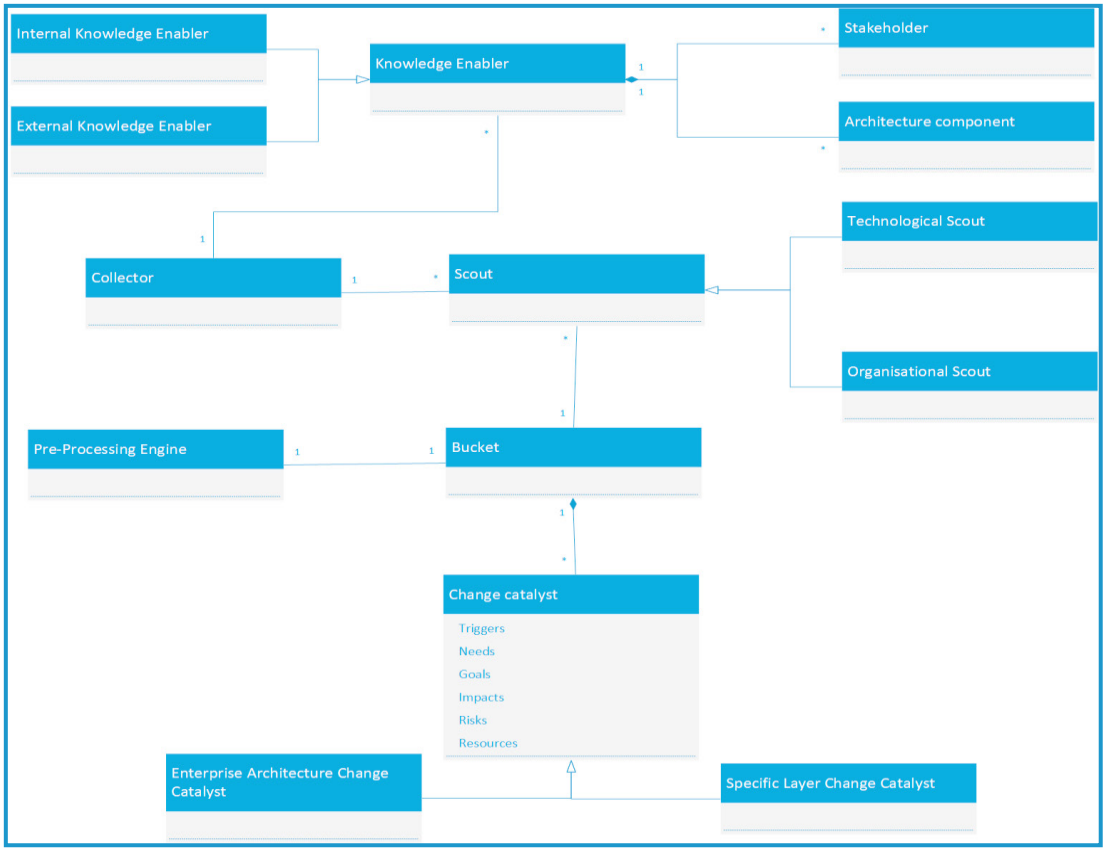

Fig. 1. Metamodel of the sensing layer.

First, we cite the **Collector** that is a centralized interface between strategy, business and information system layers, and the sensing layer. It gathers all the inputs like keywords, pain points, topics, innovation proposals and suggestions of improvements, coming from internal knowledge enablers. Internal Knowledge Enablers to not interact directly with the collector but transits through their respective representative who plays a filtering role. Second is the **Scout** which is a continuous observer or listener that can access the outside of the company looking for knowledge enablers. It also gathers internal data, information, and knowledge. The scout can be a technological system or organizational (person or group of people). Third is the **Bucket** that gathers inputs from external knowledge enablers and from the collector directly. It contains data and information that were cleaned from duplicates and errors. It adds attributes ranks to highlight the importance of some elements. Fourth we present the **Pre-processing engine** which allows a categorization of inputs depending on the trigger layer and pre-processes the elements in the bucket to redirect them to the strategy layer for assessment and prioritization. The representative of the strategy layer is the Enterprise Architect. The sensing layer interacts with **Knowledge Enablers**, **Stakeholders** which are individuals or groups that affect the enterprise somehow and **Architecture components** that can be components of the strategy, business, or information system layer. Finally, **change catalysts** are constituted of diverse change initiators for Enterprise Architecture projects or specific layer projects. Their attributes are triggers, needs, goals, impacts, risks, and resources.

4.2. Proposed Model

In our previous research [12], we highlighted the importance of an Adaptive Enterprise Architecture that takes into consideration a sense and response in a lightweight manner. Fig.2. presents the proposed model based on previous formal meta-model of the sensing layer.

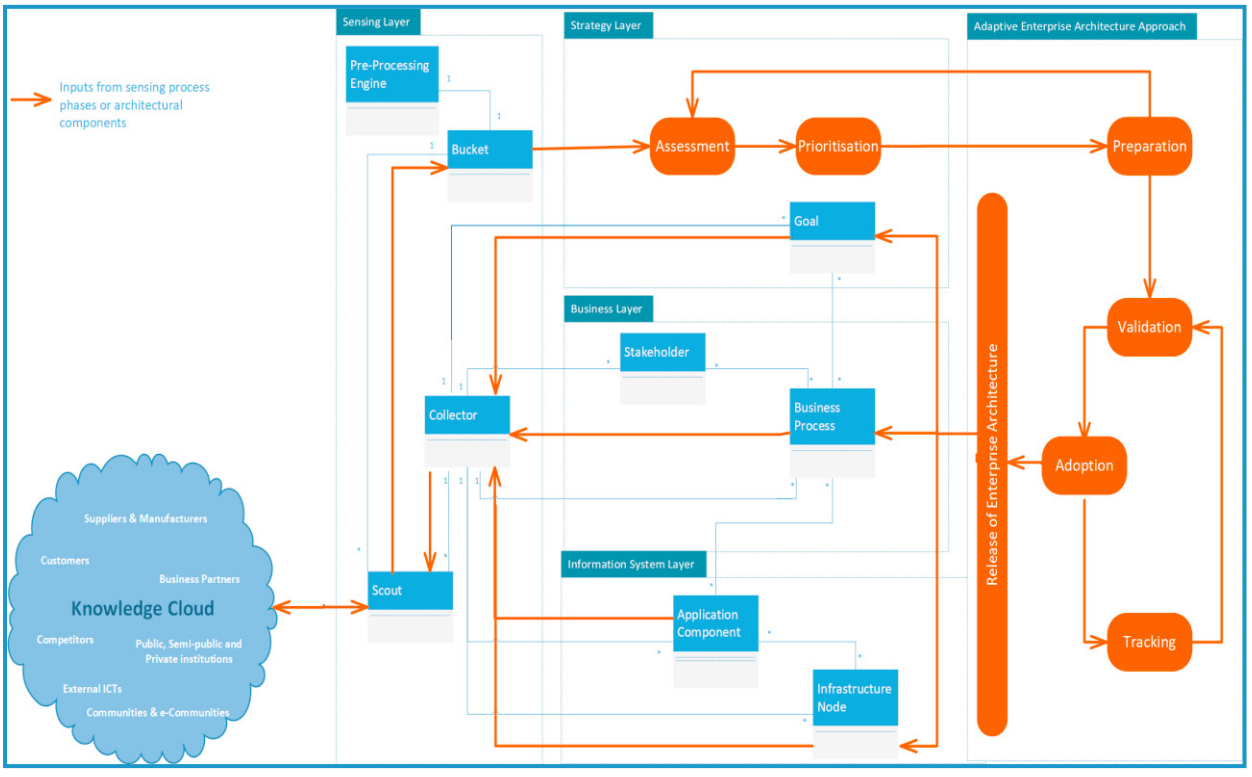

Fig. 2. Model of the sensing layer.

The sensing layer is fed by data from strategy, business, and information system (Application/Technical) layers. It then turns this data to information to give it to strategy layer. All the changes in an enterprise architecture lead to a

decision that needs to be Top Down even if the trigger is related to a specific business or information system topic. The data gathered is then extracted in the collector into keywords that allow the Scout to search for information related to those keywords. The collector is also constituted of suggestions coming from the business and information system stakeholders gathered during their horizontal alignments. It is also fed by data from the different systems and sensors. The scout then comes into play. The results are then fed into a bucket categorized depending on the layer that it impacts the most and redirected for assessment in the strategy layer. Once the EA project identified and prioritized, it is an input to our approach described in [12]. We also summarizes our Adaptive Enterprise Architecture Approach into a lifecycle: Preparation, validation, tracking, and adoption of the new enterprise architecture (incremental change). It leads to changes at different levels that are feeding again the sensing layer with new elements identified at each layer. The evolving aspect of each architecture component is then modeled by inputs coming from the new architecture and outputs to sense what is externally happening. This allows the components to be communicative components and ensure dynamic proactive collaboration at runtime. Using this approach, they have insights about context awareness and are dynamically configurable to attain WYSIWYG (What You Sense is What You Get) at design-time. The idea is not to absorb all new trends but to be rather a listener of its own and of the market so that it increases context and self-awareness, pinpoints the elements to be improved and discusses the strategies against the market. The below model shows the sensing layer and highlights the sensing process. The red arrows model inputs coming from and feeding two types of elements: architectural components or process phases.

5. Illustrative example integrating the proposed model

In our previous example, we integrated the sensing layer in “ABC” enterprise architecture. The company collected data and information streams from the external and internal spaces continuously feeding its centralized bucket. It decided that on quarterly basis the Enterprise Architect assesses the bucket content and identifies the needs for EA projects. In recent years, the Information System owner continuously fed the collector with “Cloud Solutions” and the external scout as well detected this Information System technology. It climbed the ranks and was positioned recently as a hot suggestion. Last two quarters a new signal from internal and external knowledge enablers highlighted that a new player started its activities in the country. This new company intersects with ABC portfolio on some solutions. It offers approximately the same products but in the form of cloud solutions. Being in an investment mode, they did activate aggressive plans. The fear of losing market share, big labels, and competitive advantage was felt on long term strategies. By adapting to the current situation and not adopting blindly the concept, the enterprise architect assessed “Cloud Solutions” as impacting the whole enterprise architecture and not only the Information System layer. The illustrative example is summarized in Fig.3. where the implemented process is highlighted in red, and the green elements are related to the chosen “Cloud” architecture.

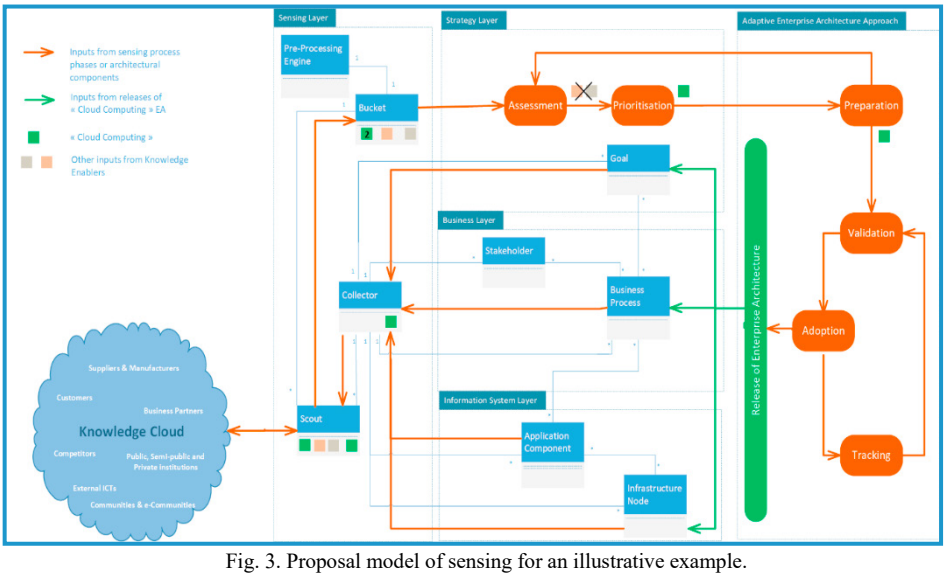

Fig. 3. Proposal model of sensing for an illustrative example.

(ABC) Enterprise Architect focused on “Cloud Solutions”. He prioritized it and formulated two Adaptive Enterprise Architecture projects: The acquisition of the new player and the integration of “Cloud Offerings” in their current model. He ran an impact analysis using the method in [12] simulating the two scenarios, highlighting the competitive advantages, goals, impacted business process and Information System (IS) components, risks, and supporting resources. After alignment with management and the committee of owners (Strategy, business, and information system) during a preparation meeting, they decided to go with a hybrid mode of offerings on some specific solutions as pilots. The adoption of this decision led to the implementation of a new EA through the adaptive enterprise architecture approach. While the new EA is being built, the layers views are updated, and they feed the collector continuously.

6. Conclusion

In current highly dynamic environments, enterprises face many disruptive changes that need to be undergone to keep the competitive advantage and avoid abrupt failures. Those changes impact various levels of abstraction (Strategy, business, and information system). Their proactive detection and right assessment versus the enterprise strategy are pivotal in bringing value and ensuring sustainability. More than ever, the need to build knowledge about self and context awareness is required. The Covid-19 pandemic accelerated this urge.

In this paper we explored the literature regarding sensing enterprise in relation with adaptive enterprise architecture. We deeply analyzed the sources of knowledge inside and outside the boundaries of an organisation. They constitute the fuel of the strategic planning. Then we proposed our approach to integrate the sensing capability in the enterprise architecture. We presented a formal meta-model and integrated it into a model. Finally, we concluded with an illustrative example to materialize the model.

In future work, we target to deep dive into the multi-dimensional prioritisation indicators of new enterprise architectures. We also aim to propose a prototype that aggregates sensed data from various knowledge enablers and supports predictions and foresight of the most adequate enterprise architecture to adopt.

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