Success and hindrance factors of AHA-oriented Open Service Platforms

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Abstract. In the past years, there has been a flourishing of platforms dedicated to Active Assisted Living (AAL) and Active and Healthy Ageing (AHA). Most of them feature as their core elements intelligent systems for the analysis of multisource and multimodal data coming from sensors of various nature inserted in suitable IoT ecosystems. While progress in signal processing and artificial intelligence has shown how these platforms may have a great potential in improving the daylife of seniors or frail subjects, there are still several technological and non-technological barriers that should be torn down before full uptake of the existing solutions. In this paper, we address specifically this issue describing the outcome and creation process of a methodology aimed at evaluating the successful uptake of existing platforms in the field of AHA. We propose a pathway (as part of an overarching methodology) to define and select for Key Performance Indicators (KPIs), taking into account an extensive amount of parameters related to success, uptake and evolution of platforms. For this, we contribute a detailed analysis structured along with the 4 main actions of mapping, observing, understanding, and defining. Our analysis focuses on Platforms, defined as operating environments, under which various applications, agents and intelligent services are designed, implemented, tested, released and maintained. By following the proposed pathway, we were able to define a practical and effective methodology for monitoring and evaluating the uptake and other success indicators of AHA platforms. Besides, by the same token, we were able to provide guidelines and best practices for the development of the next-generation platforms in the AHA domain.

Keywords: AAL · AHA · Open Service Platforms · KPI Analysis · Data analysis.

1 Introduction

One of the most critical socio-economic emergencies that all the countries in the world face today and will deal with soon is ageing [1]. A European Union statistic in 2019 [9] estimated that people of 55 years or more in the EU-28 would reach 40.6 % of the population by 2050, thus potentially putting the countries health systems at serious risk. To prevent this scenario, the European Union government has set aside a high level of resources for Information and Communication Technologies (ICT) projects in the AHA field. The principal idea has been to provide adaptive services to the citizens by using intelligent systems for the processing of data of various nature acquired directly from people, in their home or on the move, thanks to a wide range of sensors, including wearable as well as contact-less sensors. Following the trends in IoT, the emphasis has then shifted to the coordinated collection of information from disparate embedded devices, to the processing and correlation of multidimensional data and, finally, to the orchestration of services for the provision of superior assistance and effective guidance. In this context, computational intelligence on single-modality data has already given excellent results. To name a few, accidental falls can be automatically detected by cameras as well as mobile devices accelerometers [20], while wearable sensors might be sufficient to compute an index with very relevant prognostic value, i.e. the heart rate variability [13]. Analysis and integration of multidimensional and multimodal data may lead to advanced and smarter services in different situations ranging from the management of chronic conditions [3] to the promotion of healthier lifestyle and, in turn, to Active and Healthy Ageing (AHA) [4, 15]. Considering the added value of data correlation and service orchestration, the creation of open and interoperable platforms for the integration and aggregation of data has become of growing importance. To this end, the scientific and technological community developed numerous open-source innovative platforms in AHA domain, such as universAAL [14] and FI-WARE [10]. Further, during the last years, the European Union government has financed many ICT projects, such as ActivAge [12], permitting integration and interoperability across existing AHA platforms. While promising, such platforms (or meta-platforms) have not yet fully uptaken, but there still exists a mixture of technological and non-technological barriers that prevent a larger diffusion. This is a relevant issue since it jeopardizes the possibility to take advantage of the recent developments in intelligent system and artificial intelligence and use them in favour of the ageing population. The work presented here try to analyze this issue and to identify success and hindrance factors, focusing on EU funded platforms in the AHA domain. The approach consists of four main actions that define the path leading to the definition of a methodology: map, observe, understand and define. The first action was to *map* an ecosystem by collecting existing open-source platforms in the AHA domain, their end-users and related stakeholders. The next step was to *observe* common and differentiating features and characteristics of existing platforms that can act as success or hindrance factors in their uptake. Subsequently, the aim was to *understand* the links among all the information collected by running interviews and other types of consultations with platform developers to identify further hidden factors affecting their uptake and evolution. The last action was to *define* strategic KPIs to be tracked for evaluating uptake, interoperability, synergies and cost-benefit analysis of open service platforms. After all these steps, we were able to define a practical methodology for monitoring and evaluating the uptake and other success indicators of a platform in the AHA domain. In the future, the methodology will be applied to existing platforms for its validation; at the same time best practices will be identified, also using quantitative analysis, providing new input for the next-generations AHA platforms.

2 Map

The *Ecosystem Map* creation started with identifying the most representative platforms in AAL/AHA domains in the last ten years. During the selection of the platforms, we did not limit ourselves to the ones explicitly belonging to our interest domains; instead, general-purpose platforms applicable in AHA solutions were included. We found 48 platforms that meet the two main identification criteria: the extensive experience in previous projects and the in-depth research through numerous European channels, including the *eHealth Hub Platform* [6], the *DHE Catalog* [5] and specific official reports of the European Union [8]. Out of the 48 identified platforms, we selected 18 of them, discarding projects:

- with a low impact on the development of AAL / AHA technologies;
- completed ten years ago or more and no longer maintained (obsolete);
- without impact or reports on other subsequent projects;
- without the European coverage;
- aimed at specific solutions, either by type of pathology or by end-user.

However, we also included obsolete platforms that have been fundamental to developing other important selected platforms like Activage or UniversAAL. Our Ecosystem Map consists of a set of views belonging to four different domains:

- *Geographic*: the European countries (Figure 1) involved in the selected platforms.
- *Relationship*: how different projects are related to each other. Figure 2 shows the main dependencies between the platforms. Four types of relationship are considered: *Derived from* indicates that the receiving platform was partially created using a previous platform as a basis, typically inheriting some characteristics; *Allow interoperability* indicates that the platform allows interoperability between the platforms from which the arrow starts; *Physical layer from* indicates that the receiving platform inherits the design and implementation of the layer indicated by the source platform; *Standalone platforms* are those that have no relationship with other platforms examined;

- *Application*: projects mapping according to their main domain of application. They are general-purpose, AAL and AHA.
- *Temporal*: years in which the individual projects were developed. The analysis allowed us to define three macro generations, the first from 2004 to 2010, the second from 2010 to 2015 and the third from 2015 to 2020.

3 Observe

This activity aimed to furnish a more in-depth analysis of the selected platforms to identify possible success and hindrance factors. In this task, we analyzed the eight remaining platforms of the 18 initially included in Ecosystem Map, after applying additional selection criteria regarding the development timeline and current status of the platforms and their final scope and outputs (Figure 4).

For each project, the analysis focuses on three dimensions:

- *Technical dimension*, aiming at describing and characterizing the provided features, functionalities and services, taking into account six significant aspects of an IoT system:
  - device management capabilities, i.e. how the platform maintains the list of connected devices and track their operation status;
  - integration/interoperability, concerning the API permitting access to operations and data to expose outside of it;
  - information security, to characterize the vulnerabilities to which the data is exposed;
  - types of protocols i.e. the main used operational communication protocols;
  - data analytics, with particular concern to the way agents and intelligent services process data to produce results. It can be real-time, batch, predictive and interactive analytics;
  - visualization capabilities, the collection of human-machine interfaces supported by the platform to visualize results of the computations and analysis;
- *Contextual dimension*, aiming at the description of:
  - legal and administrative context, mainly related to administrative burdens for entry and growth, safety, health and environmental regulations, product regulation, labor market regulation, court & legal framework, procurement and reimbursement;
  - ethics and privacy, about the type of data collected and information provided;
  - data sharing and governance, dealing with the models (e.g. Economic, Citizenship, trusted 3rd party, collective) and data management;
  - Intellectual Property Register (IPR), taking into account patents, trademarks, copyrights, and trade secrets, and open access, open-source or close access;

Fig. 1. Representation of the geographic distribution of the surveyed platforms in AAL/AHA domains i

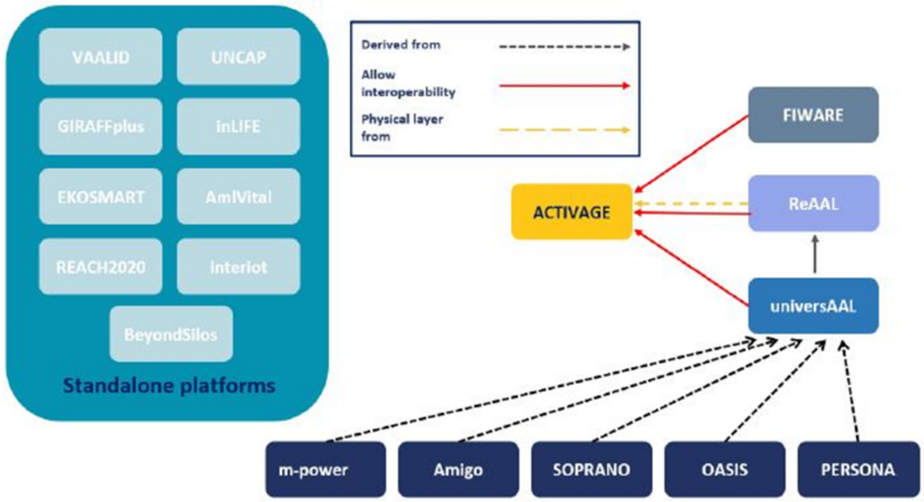

Fig. 2. View of the relationship domain. Besides standalone platform, several other have dependencies and/or interoperability features.

- *Financial & business dimension*, taking into account financial and exploitation aspects. It studies the platform's business models based on the available information acquired through existing social and professional networks as well as desk research targeting data openly accessible on the internet.

Identifying Critical Success Factors (CSFs) is a crucial step as it allows companies to focus their efforts on building their capabilities to meet those aims. By following John Rockart [22], the focus was put on industry, strategy, environmental and temporal CSFs.

Each CSF should be measurable and associated with a target goal. A critical success factor is not a KPI, but these indicators will quantify the objectives and enable the measurement of strategic performance. Evaluating the outcomes and the in-depth analysis of the examined platforms, we have identified four success criteria for an AHA platform. These are efficiency, effectiveness, fulfilment of functional requirements and stakeholder satisfaction. These criteria are formulated based on the three considered dimensions: technical, contextual and financial & business. Further, one extra dimension is considered as overarching or transversal: the resources. Stakeholders are also considered, and all areas are represented in Figure 3.

4 Understand

The work carried out so far has allowed us better to understand the various platforms' characteristics and differences. The purpose of this activity is to deepen the knowledge about the poll of platforms by directly questioning the professionals who took part in the creation, management, development and maintenance

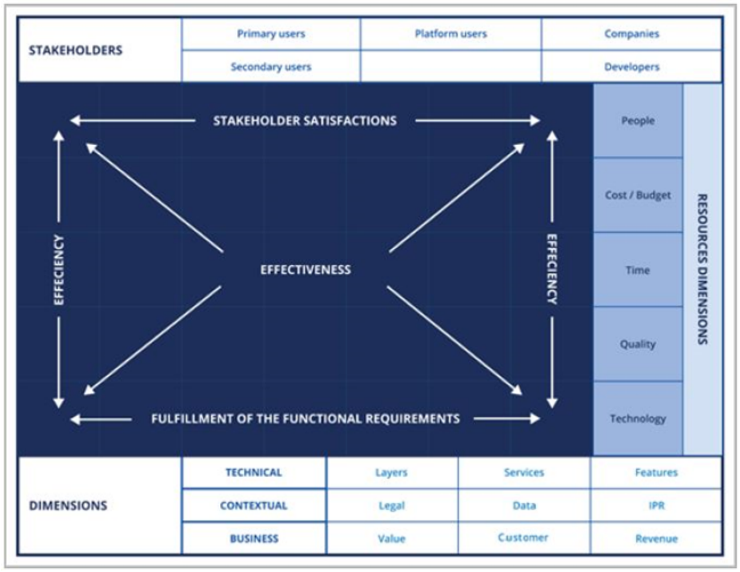

Fig. 3. Schema describing the critical success factors for open AHA platforms, their dimension and interrelation.

phases of these platforms, to try to obtain information that is hard to elicit from the official documentation. The Technical, Contextual and Business dimensions have been mapped using two questionnaires: one relating to the technical dimension to be sent to platform developers (Section 4.1), the other one about the contextual business dimension, dedicated to executives (Section 4.2).

4.1 Technical questionnaire

The technical questionnaire is aimed primarily at platform developers and is divided into three main sets of questions. The first addresses *Development, services and devices* with the goal of collecting an overview of the platform focusing on interoperability, monitoring capabilities, real-time diagnostic, usage analytics, minimum resource requirements and communication processes between all those developing the platform. Then, *End-users and privacy* are considered since the involvement of end-users and privacy and security issues in the processing and transmitting sensitive data are of utmost importance. Finally, other miscellaneous questions are proposed regarding e.g. management or recruiting assignments, difficulties and problems encountered during development, and general knowledge of other AHA oriented platforms.

4.2 Contextual/Business questionnaire

The contextual/business questionnaire is primarily aimed at platform executives and is divided into these three main sets of questions. First, a *platform overview*

PLATFORMS TO BE ANALYSED IN FULL	PROJECTS THAT LED TO MORE RECENT ONES	ONLY SUMMARISED WITH CRITERIA FOR EACH GROUP
UniversAAL	Mpower | Soprano Persona | Amigo | Oasis	Out of Europe: - IoTvity
Activage_AIOTES	InterIoT ReAAL	Platforms already closed: - AmIVital - Inlife - Vaalid - SeniorSome
Ekosmart		
Reach 2020		
Sensinact		Out of scope: - Beyond Silos - OpenThings
UNCAP		
FIWare		Only a project: - Giraff
Onesait		

Fig. 4. List of the platforms that were selected or disregarded after thorough observation.

is sought from a a high level point of view considering aspects such as competitive advantages and weaknesses of the platform, impact of the services in the AHA domain and costs related to the installation and maintenance of all the services offered. *End-users and privacy* are considered also in this questionnaire focusing on relationship with end-users and the treatment of the feedback received, security, data processing and data sharing. Finally, other miscellaneous questions are proposed concerning e.g. statistical data regarding the actual use of the platform (active or passive users, registrations, growth rates, earnings, etc.) and possible success stories.

4.3 Questionnaire analysis and essential characteristics

The analysis of the information collected allowed us to establish, from an insider point of view, the characteristics of an ideal platform and to identify the main issues that might be critical and capable of compromising its functionality and purposes. In total we analyzed 14 questionnaires, completed by 12 professionals who worked on the development of the platforms examined. Table 1 reports the essential characteristics that we were able to elicit.

5 Define

In this task, a set of KPIs were defined for tracking the successful uptake and evolution of existing platforms [18, 19, 7, 17, 11, 25, 24]. These KPIs will serve as input for the revaluation and development of the final methodology. Considering the results of an analysis conducted on Google Scholar, we obtained that the current literature is mainly focused on evaluating the performance of platforms from the technical point of view. There is no related work attempting to provide KPIs or other metrics to measure the uptaking of largely diffused platforms

Characteristic	**Description and remarks**
Microservices	service-oriented and distributed architecture permitting to structure applications as independent agents, each focused on a particular aspect
Open source	inherently guarantees advantages such as reliability, transparency, cost savings and collaboration, without having to depend on licenses
Support of standards	since these are systems intended for large segments of the population, it is necessary to support the existing primary standards to guarantee full compatibility with most of the devices on the market
Object-oriented	provides natural support for software modelling of real-world objects or the abstract model to be reproduced and allows easier management and maintenance of large projects
Interoperability through semantic	expresses the meaning of terms and concepts and finds the right relationships between them
Correct dimensions definition	it is vital that the three identified dimensions, technical, contextual and business, are thought of as separate modules but dependent on each other. The design of a platform should start from the setting of these three dimensions and their dependencies
Focused documentation	correct documentation and its constant updating are the basis for the success of a platform over time
Tools for diagnostics and usage analytics	fundamental both for proper maintenance and for the creation of new metadata
End-users engagement and feedback	end-users need to feel involved, they should perceive that the platform's functionalities are beneficial for improving their lives
Full GDPR compliance	improves the protection of European data subjects' rights and clarifies what companies processing personal data must do to safeguard these rights

Table 1. Essential characteristics.

such as FIWARE or universAAL. As a second step, we analyzed the International Consortium for Health Outcomes Measurement (ICHOM), who has developed a group of standard sets for different health conditions and diseases to measure health-related outcomes that matter the most to patients. Based on the methodology from ICHOM [21, 2, 16], the process to define the KPIs has been based on a number of iterative steps: (i) the *perspectives* have been defined according to the definition of stakeholders, including Primary End Users (assisted persons, caregivers), Technology Providers (including platform developers, 3rd party developers, etc.), End-User Customers (healthcare providers, social and well-being organizations, etc.) and Government (Authorities / Policy Makers); (ii) an *initial KPI list* was collected to have an exhaustive set of potential KPIs related to the uptake and success of platforms, coming from different sources such as literature search, projects/platforms specific KPI, own authors' experience and KPI coming from benchmarking, and procedures like MAST, MAFEIP, OPEA, GLOCAL; (iii) a *revision of the initial list* of KPIs was performed, clarifying initial doubts and providing clear definitions to those KPIs that were confusing; (iv) in order to set up a priority of the initial list of KPIs, it was given a *priority* (low, medium, high) to each KPI; (v) *first analysis of KPIs*, performing an in-depth revision of the KPIs definition and measurement proposals, obtaining a clean list of KPIs; (vi) *KPI clusterization* of the clean list of KPIs, according to the perspectives defined in step (i); (vii) *Assessment of partners experts* to finalize definition and prioritization of the KPIs; (viii) *second analysis of the KPIs* by redefinition and merging of similar KPIs, new priority computation based on the average score of the initial prioritization and two partner expert assessments, approval or rejection of KPIs; (ix) *final list of KPIs* was organized per cluster according to priorities, having some KPIs shared among different clusters; (x) *partners experts' prioritization*, by rating the priority of all the KPIs per cluster with values between 1 and 10 according to the importance of this KPI per the corresponding target stakeholder of the cluster; (xi) *top-10 KPIs per cluster* were finally selected by computation of the average priority rate and the standard deviation.

The methodology described in this section can be used to identify and prioritize indicators in other domains and for different stakeholders. Moreover, the final list of KPIs can serve as a reference for current and future platforms with a focus on AHA, AAL and social health care.

6 Conclusions and Future Works

The pathway for the creation of the methodology considers all the performed work throughout the tasks of Map, Observe, Understand and Define. Monitoring can help the project's team to identify and solve problems and to keep track of project inputs and outputs such as activities, reporting and documentation, finances and budgets, supplies and equipment.

The monitoring methodology is based on the collection of KPI results between each dimension or platform statistics during their monitoring frequency.

It keeps track of inputs and outputs of the projects according to technical, business and contextual dimensions. The evaluation seeks to understand why and how the uptake of platforms is going. Our evaluation methodology is performed by an expert jury panel, considering the monitoring results performed by the platform providers. There are 5 evaluation criteria that basically can conduct a project evaluation [23] consisting in relevance, effectiveness, efficiency, impact and sustainability.

The methodology pathway began with the identification and analysis of the existing project and open platforms in the field of AHA. More refined evaluation criteria were added in the next step, when performing the in-depth analysis, namely the combination of the technical, contextual and business analysis with the CSF model, as well as their final scope and outputs, presented in the scheme in Figure 8. From the firstly identified 18 platforms, 8 cooperated by responding to the questionnaires undertaken in Section 4 *Understand* of this document. The KPIs addressed different Open Service Platform aspects and features, mostly through validated questionnaires, according grouped in four clusters. After all the several iterations described above, including desk research, analysis of several methodologies and good practices, the pathway of our methodology was simplified and revised (Figure 5).

The monitoring and evaluation methodology thus combines the work performed in the previous activities, using the instruments (questionnaires, platform statistics and technical features) defined for the KPIs for Open Service Platforms Evaluation and the different layers previously defined for analysis. The results feed the technical, business and contextual dimensions of the platform monitoring and evaluation report. The monitoring and evaluation methodology presented here aims to be user-friendly, applicable and to support and collect the necessary indicators necessary to monitor and evaluate the successful uptake of an open platform in the AHA domain.

Currently, the proposed methodology is being applied to the set of available platforms (and to new ones) and is producing quantitative values with respect to different perspectives by effectively returning meaningful and consistent indicators, thus increasing our insight in success and hindrance factors.

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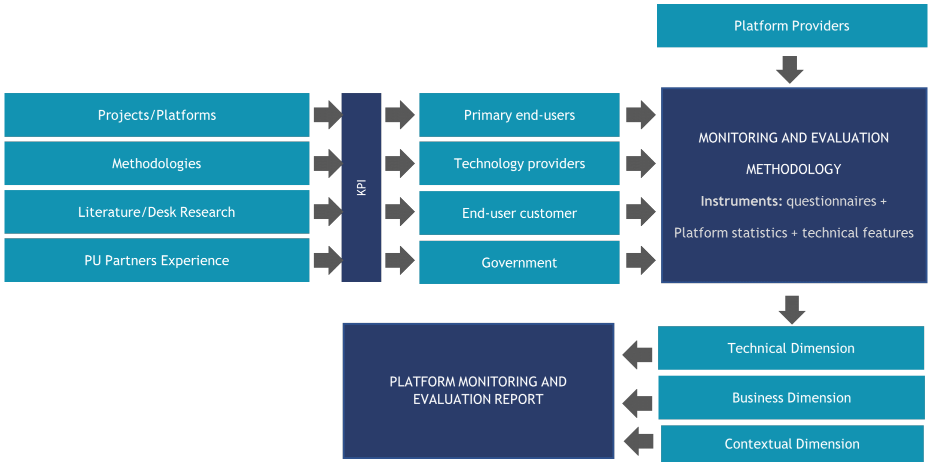

Fig. 5. Graphic representation of the proposed methodology for monitoring and evaluation of open AHA platforms.

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