UNIVERSIDAD POLITÉCNICA DE MADRID
GRANT: PID2022-137748OB-C31

A1.D4.1 “Use case description: Challenges & technological requirements”

Digitalization As basic Driver for servitization in Industry and Basic Services” (DADIBAS)

Date: 08/01/2025
Doc. Version: 1.1

Document Control Information

Settings	Value
Document Title:	Delveirable A1.D4.1 “Use case description: Challenges & technological requirements”
Project Title:	Digitalization As basic Driver for servitization in Industry and Basic Services” (DADIBAS)
Document Author:	Joaquín Ordieres-Meré
Project Owner:	AEI
Project Manager:	Joaquín Ordieres-Meré
Doc. Version:	1.1
Sensitivity:	Public
Date:	08/01/2025

Document Approver(s) and Reviewer(s):

NOTE: All Approvers are required. Records of each approver must be maintained.
All reviewers in the list are considered required unless explicitly listed as Optional.

Name	Role	Action	Date
Miguel Ortega Mier	CoIP	*Review*	23/1/2025

Document history:

The Document Author is authorized to make the following types of changes to the document without requiring that the document be re-approved:

- Editorial, formatting, and spelling
- Clarification

To request a change to this document, contact the Document Author.
Changes to this document are summarized in the following table in reverse chronological order (latest version first).

Revision	Date	Created by	Short Description of Changes
1.0	07/12/2023	Joaquín Ordieres-Meré	First version of the Deliverable A1.D4.1
1.1	08/01/2025	Miguel Ortega Mier	Editorial improvements

Configuration Management: Document Location

The latest version of this controlled document is stored in the OneDrive repository of the project.

TABLE OF CONTENTS

1 INTRODUCTION

Project Title:	*“Digitalization As basic Driver for servitization in Industry and Basic Services” (DADIBAS)*		
Initiator:	*Joaquín Ordieres-Meré*	**Organisation / Unit:**	*UPM*
Date of Request:	*07/09/2024*	**Target Delivery Date:**	*08/01/2025*
Type of Delivery:	■ In-house ☐ Outsourced ☐ Mix ☐ Not-known		

2 CONTEXT

The focus of this WP is to consider the applicability in infrastructures, either refurbished or new construction, by selecting or developing an integrated building asset data management system that represents lifecycle phases. The design of the BIM-DBMS includes the design of data acquisition, data storage, and data processing modules along with the user interface.

The list of relevant tasks is,
T4.1.- Setup of a suitable context for BIM.
T4.2.- Asset modelling.
T4.3.- Connection with existing logic infrastructure.
T4.4.- Setup of additional sensors including wearables when needed.
T4.5.- Model creation with Data Integration.
T4.6.- Management dimension for servitization and forecasting.
T4.7.- Dissemination.
T4.8.- Reporting & Configuration Management.

The foreseen deliverables are:
D4.1 .- Use case description: Challenges & technological requirements [M10]
D4.2 .- Digital models (BIM and operational models) and process improvement [M45]
D4.3 .- Dissemination report and KPIs [M48].

The focus of this document is to address the first deliverable (D4.1). It took longer than initially foreseen, since negotiation with different agents, as well as discussions to find a suitable environment extended over several months.

However, we strongly believe that servitization can be extended further in many different sectors (including industry but also other business services such as finance, health, or education) from the technical point of view but also from the involved asset management perspective, which demands the integration of operations and maintenance policies. Therefore, a relevant research question to be addressed is, **how to articulate transparency on data from assets, performance, and degradation models to foster an increased servitization level at process or service levels?**

The different systems will handle a predetermined data model to generate an output. These outputs can be for different purposes: to identify risk in assets, to assess that risk, to mitigate the risk, etc. DT and BI apps can interact with IAM apps to allow the introduction of powerful data analytics and visualisation tools. In this scenario, the data model becomes critical to each one of the processes that the different applications support. This is even more critical when talking about the digitalisation of legacy assets, where data collection sometimes is a difficult task, Therefore, the need for comprehensive reference frameworks is evident, although some have already been proposed:

- BIM / AIM.- Building / Asset Information Modelling is a framework for the construction industry where the life cycle of buildings is considered from its digital dimension (from design to operation and maintenance).
- Cognitive DT (CDT).- Although it is not just a reference framework but a concept, it proposes to extend the DT throughout the life cycle, as BIM does.
- RAMI 4.0.- Is a well-known reference framework developed by the German Electrical and Electronic Manufacturers' Association (ZVEI) to support Industry 4.0 initiatives. It focuses on industrial production as the primary area of application, including discrete manufacturing for the process industries.

Then, **is it relevant to conceptualize the digital transformation of an asset**?

There is a highly significant challenge to build reference frameworks and methodologies addressing coherently the issues that arise at strategic, operational and also at component levels. Its importance becomes clear in the analyses of the opportunities and advantages to be gained when different processes requiring the usage of assets (maybe owned by different stakeholders) are considered, and decisions must evaluate not just the current operation but those coming soon. Asset health can impact on the delivered quality of products or services.

Looking to the successful implementation of such frameworks and methodologies, other challenges must be considered, such as: the integration of human operators, energy and environmental criteria and constraints; interoperability (data & systems) between and across levels; transparency in data and decisions when different stakeholders are involved.

3 EXPECTED OUTCOMES

Concerning the current market situation, Gartner distinguishes between three different types of asset management systems in the market: Enterprise Asset Management (EAM), Asset Performance Management (APM), and Asset Investment Planning (AIP) Solutions as indicated in Figure 1.

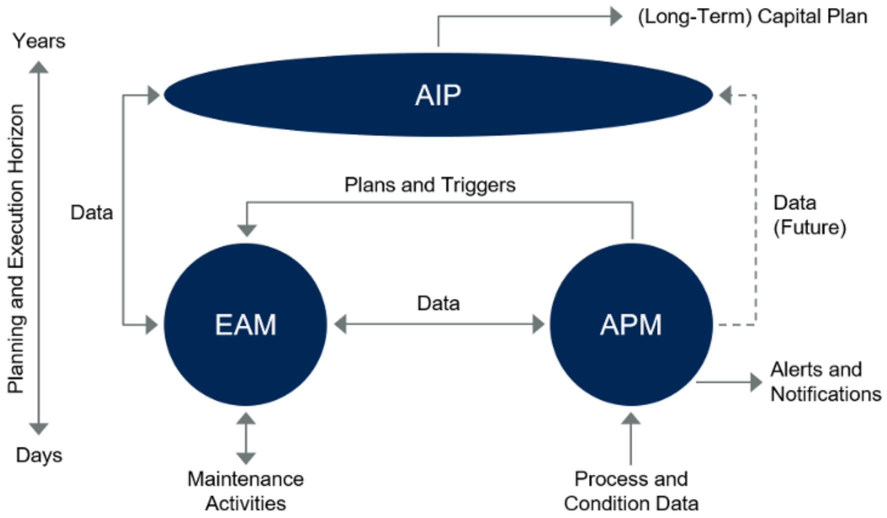


Figure 1.- The flow of data in advanced asset management systems

In this WP we will work mainly at the level of APM system, accepting services will be provided by the EAM subsystem and knowledge creation towards AIP subsystem is kept as goal.

4 USE CASE DESCRIPTION

To reach the established goals DADIBAS project proposes to adopt a mixed environment involving multipurpose building with some IoT devices already deployed and some outdoor context.

In this scenario the following areas will be addressed

- The definition of a scenario, deployment, and configuration of an IoT device network to improve the description of infrastructure conditions and O&M activities.
- The design and configuration of data management structures within big data architectures. This includes configuring brokering services, storing data in time-series databases, and setting up systems for analysing and visualizing collected data.
- Based on the collected variables, use cases will be defined to estimate the future behaviour of systems linked to O&M interventions. Both Machine Learning models and, where appropriate, Deep Learning models will be used, formalizing both their deployment and retraining processes based on improvements derived from systematic data collection during monitoring.

The selected spaces involve one part of the CeDInt building, allocated for a UPM research centre (*https://www.cedint.upm.es*), as well as some outdoor items and a greenlabs facility, as indicated in the following Figure 2:

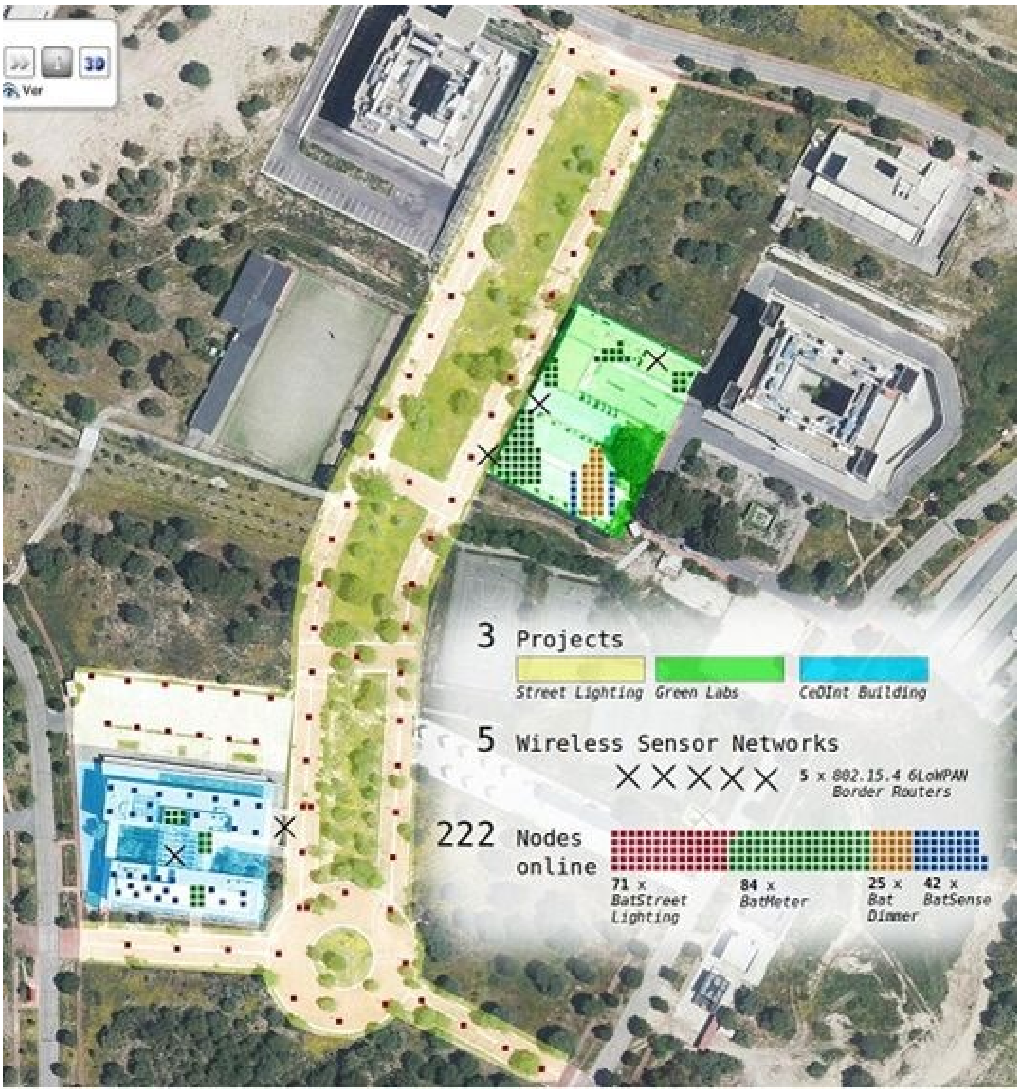


Figure 2.- Planimetric view of the use case study area . (Image provided by CeDInt)

The big advantage is that some IoT devices are already deployed and a basic collection system covering five OSI models are in place.

Table 1.- OSI model layers already in place

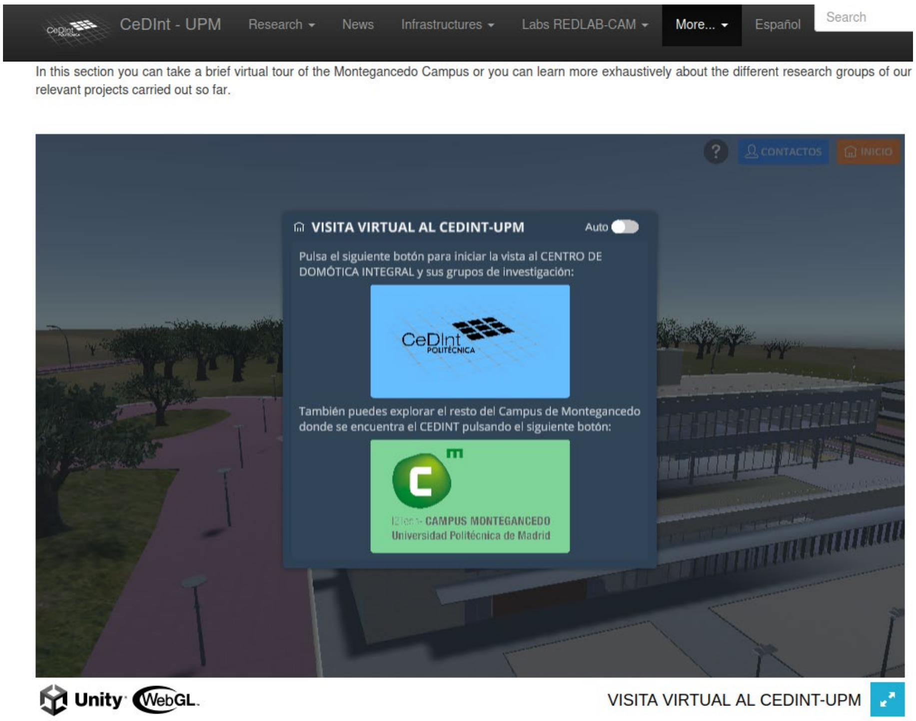
LAYERS	**IMPLEMENTED PROTOCOL**
Transportation Layer	UDP
Network Layer	IPv6/RPL
Data Link Layer	6LoWPAN
Physical Layer	IEEE 802.15.4

As distilled all the media layers have been addressed and the host layer interface (transport) were addressed. Based on them session, presentation and application can be established accordingly to the interesting interoperability scenarios.

Regarding the IoT devices, there are sensors deployed to monitor the power and energy consumption of the greenhouses at CBGP (Center for Plant Biotechnology and Genomics) located on the Montegancedo Campus of UPM. Sensors and actuators have also been installed in one greenhouse module to assess improvements in energy efficiency resulting from the use of these devices:

- 2 BatLinks
- 70 single-phase BatMeters to monitor energy consumption across 420 independent circuits
- 10 BatSenses, which measure temperature, humidity, and light intensity in the greenhouse module
- 25 BatDimmers to control the light intensity emitted by each LED

Regarding the BIM definition it must be done but the starting point can be some digital models existing for the VR application (https://www.cedint.upm.es/en/more/montegancedo-campus-and-cedint-virtual-tour) created with Unity and WebGL



In this section you can take a brief virtual tour of the Montegancedo Campus or you can learn more exhaustively about the different research groups of our relevant projects carried out so far.

VISITA VIRTUAL AL CEDINT-UPM

Pulsa el siguiente botón para iniciar la vista al CENTRO DE DOMÓTICA INTEGRAL y sus grupos de investigación:

También puedes explorar el resto del Campus de Montegancedo donde se encuentra el CEDINT pulsando el siguiente botón:

Figure 3.- 3D Model based on Unity 3D blocks. (Image provided by CeDInt)

Specific research will be developed to identify how to start from the current geometry o when it is better to scan the objects by using lidar and point clouds.

Several targets are identified within this use case.

First how to articulate the BIM models with IoT devices making it possible to integrate managerial information about sensors as well datasets related to the geometrical and spatial elements side by side in a seamless manner.

Figure 4.- Example of sensors already deployed. (Image provided by CeDInt)

To this end, it is relevant to achieve solutions which are integrative and not very expensive in such a way that they limit the practical usage for different stakeholders. In our particular use case, interfaces to the current collection system will be required.

After addressing the needed integration and interoperative exchanges between the BIM and IoT systems, attending the usability and configuration of elements, by using different solutions will be explored as first target.

The second target is to elaborate models helping to estimate the energy consumption for different operating scenarios, such as smart heating and cooling systems driven by demand prescriptions instead of based on time-oriented rules. In 2018, traditional cooling systems accounted for 15% of global electricity consumption and contributed 10% of CO_2 emissions. This share is expected to rise to 45% by 2050. To this end, geometric information provided by the BIM model as well as estimated usage and energy consumption can bring the proper contexts to estimate operational conditions and, therefore, to use such models as predictors. Long term tracking can help also in assessing the maintenance condition of the subsystems, which will be targeted as well.

Other usage significant context will be explored, including the integration with mobile or wearable sensors to develop more complex scenarios or product/service-oriented ones. There are multiple cases of application that fall within the scope defined as the objective of this study. To illustrate a few of them, without intending to be restrictive, we will outline one related to mobility and another concerning emergency healthcare.

For the first example, the rising prevalence of private car usage in urban regions, driven by rapid economic growth, outdated policies, and subsidies, stands as a primary factor contributing to the global concern of car parking in transportation and traffic management. The absence of effective management of downtown parking spaces in cities with high demand leads to inefficient utilization of parking areas and illegal vehicle parking. This situation causes wasted time and effort, exacerbating traffic congestion (Parmar et al., 2020).

A significant 35% loss in productive time was recorded due to the search for parking spots. Statistics from the USA indicate that this wasted time costs drivers approximately $345 in fuel expenses. The requirements for parking, including for autonomous vehicles, must be carefully examined (Usharani & Karmel, 2022).

Smart parking research has been conducted by different authors proposing alternative layers of technology (Usharani & Karmel, 2022), with different alternatives focused on cloud-based solutions (Yun & Yuxin, 2010). Most of the contributions presents the generic concept of using cloud-based intelligent car parking services in smart cities as an important application of the Internet of Things (IoT) paradigm (Ji et al., 2014).

Many works have addressed the location at convenient places proposing solutions based on radar technology (Tiwari & Singh, 2016). It is ideal for outdoor detection over long distances, this solution becomes particularly relevant as European nations increasingly embrace electric shared cars to combat emission pollution. Given this trend, it becomes imperative to regulate recharging stations located around parking areas. To optimize their utilization, radar sensors are installed to deter unauthorized vehicles from occupying these spaces. Once a car parks in one of these spaces, the radar sensor can ascertain whether the vehicle has connected to the charger.

Other proposals include wireless ultrasonic sensor is powered by the wireless network to collect the information through high-frequency ultrasound waves (Jeon et al., 2014). However, a more integrative proposal is required, covering a variety of use cases, from street parking to handicap parking places, load/unload special areas, or even construction & demolition containers placed at the street, among others.

Given the critical importance of emergency response, extensive research has been conducted to enhance the efficiency of emergency response centres, particularly through digital transformation. Studies have focused on how digital technologies can improve each component of the emergency response chain (Yang et al., 2013). For instance, the development of Emergency Response Information Systems (ERISs) has been pivotal in supporting first responders by enhancing their situational awareness, thereby facilitating better decision-making (Betts et al., 2005). Furthermore, the architectural models of these systems have been explored to optimize their operational efficacy (Turoff & Chumer, 2004).

Significant attention has also been paid to the methods of communication between citizens in distress and emergency dispatchers. Research in this area includes the use of live video to improve the quality of communication and the efficacy of the response (Bergstrand & Landgren, 2009). Additionally, studies have examined the technological and deployment architectures of such communications, including cloud services, machine-to-machine communications, and ad hoc networks (Gonzalez et al., 2017).

The breadth of topics within emergency management has led to various applications of IoT technologies in enhancing emergency response and management. (Damaševičius et al., 2023) have considered numerous innovative applications, though this paper specifically focuses on designing an integrated emergency response system. This system aims to enhance the management of emergency services as a public asset by improving connectivity between users and emergency centres and optimizing the data transmitted to these centres through mobile applications and cloud service technologies.

For another example, emergency management and response are critical aspects of ensuring public safety and security (Firoozabadi et al., 2017). It is estimated that 320 million emergency calls are made every year in the European Union, enabling emergency services to assist citizens in all sorts of difficult situations (NENA, 2013). The significance of emergency management lies in the unpredictable nature of emergencies, which often necessitate swift action. Therefore, the efficient operation of emergency centres becomes crucial, potentially saving lives by providing timely guidance and allocating resources judiciously.

Effective emergency management involves receiving accurate and complete information about the emergency, providing accurate instructions and recommendations to individuals requesting assistance and the efficient allocation of resources. The decisions made by Public Safety Answering Point (PSAP) staff—based on the information they receive and their training and experience—are pivotal. Proper advice from an expert via video call, for instance, can resolve certain medical emergencies on the spot, eliminating the need for dispatching response teams.

This optimized resource allocation ensures that only necessary teams and equipment are deployed, reducing unnecessary costs, time, energy, and even noise pollution. It also prevents the misallocation of resources, such as sending a full firefighting team to an incident that does not require it, which could delay response to other critical situations.

Prioritizing emergencies becomes more manageable when the information received by the PSAP is clear and detailed. Not all emergencies require the fastest response, and efficient use of resources, especially during peak times, depends on accurate prioritization. Thus, the communication between the PSAP centre and the individual in distress, along with the continuous and up-to-date information provided, is of utmost importance. Research conducted on the Norwegian helicopter emergency medical service (HEMS) demonstrates that video communication can significantly improve dispatch precision, serving as a promising and feasible tool for complex emergency medical communication centre (EMCC) operations (Ulvin et al., 2023).

Given the complexity of managing emergencies through a central PSAP, the integration of digital assistants and machine learning (ML) models becomes essential. These technologies can aid PSAP agents in making informed decisions, providing accurate instructions to users, or even autonomously making decisions under supervision.

While the completeness and accuracy of information provided to the PSAP center are critical for effective emergency response management, continuous updates of this information are equally important until the response team arrives on the scene. The European Emergency Number Association (EENA) emphasizes the necessity of maintaining a permanent link with the caller, ensuring that the PSAP centre has real-time access to evolving situations.

The quality, completeness, and continuity of information received from the caller are crucial for PSAP centres to manage emergencies effectively with optimal resource use. The digitalization of traditional systems, such as monitoring real-time health data through wearable devices, sending different type of data like image and video as well as direct voice or video communication can significantly enhance the quality of emergency services. A qualitative study involving 100 emergency medical communication centre (EMCC) calls revealed that the effective assessment of emergency calls by emergency medical dispatchers (EMDs) plays a vital role in identifying critical medical conditions and providing essential instructions. However, barriers such as contradictory information, unclear primary problems, or poor call structure can impact the quality of emergency call assessments (Lindström et al., 2014)

In addition to the quality of information, the knowledge and experience of PSAP agents are critical in perceiving incidents accurately and making appropriate decisions. This includes providing proper advice to the caller or dispatching the correct resources, such as deciding whether to send an Emergency Physician (EP) with paramedics in an ambulance (Chappuis et al., 2021). This need for specialized knowledge has led some countries to maintain separate emergency centres for different services, such as medical, fire, and police, where operators possess specialized knowledge to provide expert advice and services. For instance, in Norway, the emergency medical centre can be reached through 113, the police through 112, and fire rescue through 100 (Spjeldnæs et al., 2023). While this specialization ensures high-quality service, it can be confusing for users, especially in crisis situations, compared to countries with a single emergency number.

In countries with a unified emergency number, like the 112 in Europe, there is broad agreement on the benefits of a single number for handling all emergencies within a country or even internationally (Marin & Pop, 2009). With the vast amount of data received daily at PSAP centres, artificial intelligence (AI) has significant potential to assist. Machine learning models, trained on historical data, can analyse emergency requests and provide valuable recommendations to PSAP operators. These models can process and analyse both labelled and unlabelled data, including images, videos, and voice recordings, by training different deep learning models. AI can also classify emergencies, providing crucial support for PSAP operators responsible for managing various types of emergencies, thereby reducing error rates and saving time and costs.

Research indicates that the high accuracy and sensitivity of machine learning models can significantly support medical care providers in diagnosing conditions, thereby saving time and resources. However, due to the potential for errors, AI-driven diagnoses must be verified by doctors (Aleksandra et al., 2024)

Currently, the emergency call handling process begins when a person involved in an emergency dials the emergency number, reaching the PSAP and an available call taker. The call taker collects information about the incident's nature, location, and sometimes the caller's identity, then decides on the appropriate resources to dispatch (EENA, 2020). The sequence of actions in emergency response highlights the importance of knowing the emergency number, particularly for tourists, and the availability of call takers to process the call. The decisions made are based on the data provided by the caller, such as location and incident details, which, if incomplete or inaccurate, can lead to suboptimal responses and resource allocation. This underscores the need for improving emergency response management through digital means, ensuring fast, resilient, and continuous communication between the distressed individual and the PSAP, along with accurate and complete data.

5 REQUIREMENTS

For the foreseen targets it will be needed to:

a) Digitize and elaborate a convenient BOD BIM model.

b) Adopt a platform able to exhibit seamless the built BIM models

c) Provide a hardware infrastructure capable of delivering services for data storage.

d) Adopt a convenient IoT Platform enabling management of IoT devices with multiple tenants, etc.

e) Design procedures to capture current data coming from the physical sensors.

f) Enable API based requests to get access to the collected data.

g) Design procedures to get access to the existing data structures stored in different environments.

h) Determine the convenient features and prepare learning-oriented datasets.

i) Build and test prediction capabilities of models.

j) Determine whether maintenance conditions can be derived from existing features, or virtual sensors relaying of combination of features or features and model's outcome.

k) Provide convenient interface to the created models.

6 METHODOLOGY

The design principles adopted in this research were shaped by the contributions of (De Sordi, 2021; Gregório et al., 2021; Peffers et al., 2007; Venable et al., 2017). Their design approach encompasses a structured methodology involving problem identification, objective definition, solution development and evaluation, and ultimately, result communication. This method is instrumental in guaranteeing that the resultant artifacts are effective, beneficial, and pertinent to the requirements of stakeholders within a given context. The context may include people, businesses, organizations, and existing technologies that are relevant to the problem. The

Design science methodology also helps to identify any potential limitations or challenges that may need to be considered when developing an artifact.

There is a need for a more thorough conceptualization of wearable data within the complex semantic framework of industrial processes. This is especially crucial for understanding interactions between discrete equipment states and human operators, with the goal of reducing discrepancies in comprehending the entire process flow (Ordieres-Meré & Ortega-Mier, 2024).

7 REFERENCES

Abadi, M., Barham, P., Chen, J., Chen, Z., Davis, A., Dean, J., Devin, M., Ghemawat, S., Irving, G., Isard, M., Kudlur, M., Levenberg, J., Monga, R., Moore, S., Murray, D. G., Steiner, B., Tucker, P., Vasudevan, V., Warden, P., … Zheng, X. (2016). TensorFlow: A system for large-scale machine learning. Proceedings of the 12th USENIX Symposium on Operating Systems Design and Implementation, OSDI 2016.

Aedo, I., Díaz, P., Bañuls, V. A., Canós, J.-H., & Hiltz, S. R. (2011). Information Technologies for Emergency Planning and Training.

Aldahdouh, K. A., Darabkh, K. A., Al-Sit, W., & others. (2019). A survey of 5G emerging wireless technologies featuring LoRaWAN, Sigfox, NB-IoT and LTE-M. 2019 International Conference on Wireless Communications Signal Processing and Networking (WiSPNET), 561–566.

Aleksandra, S., Robert, K., Klaudia, K., Dawid, L., & Mariusz, S. (2024). Artificial Intelligence in Optimizing the Functioning of Emergency Departments; a Systematic Review of Current Solutions. 12(1), e22. https://doi.org/10.22037/aaem.v12i1.2110

Bat-Erdene, B. O., & Saver, J. L. (2021). Automatic Acute Stroke Symptom Detection and Emergency Medical Systems Alerting by Mobile Health Technologies: A Review. In Journal of Stroke and Cerebrovascular Diseases (Vol. 30, Issue 7). https://doi.org/10.1016/j.jstrokecerebrovasdis.2021.105826

Bergstrand, F., & Landgren, J. (2009). Using live video for information sharing in emergency response work. 6(3), 295. https://doi.org/10.1504/IJEM.2009.031567

Burges, C. J. C. (1998). A tutorial on support vector machines for pattern recognition. Data Mining and Knowledge Discovery, 2(2). https://doi.org/10.1023/A:1009715923555

Carreras-Coch, A., Navarro, J., Sans, C., & Zaballos, A. (2022). Communication Technologies in Emergency Situations. In Electronics (Switzerland) (Vol. 11, Issue 7). https://doi.org/10.3390/electronics11071155

Chappuis, V. N., Deham, H., Cottet, P., Gartner, B. A., Sarasin, F. P., Niquille, M., Suppan, L., & Larribau, R. (2021). Emergency physician’s dispatch by a paramedic-staffed emergency medical communication centre: sensitivity, specificity and search for a reference standard. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine, 29(1). https://doi.org/10.1186/s13049-021-00844-y

Chen, Y. (2020). IoT, cloud, big data and AI in interdisciplinary domains. 102, 102070. https://doi.org/10.1016/j.simpat.2020.102070

Constant, N., Cay, G., Ravichandran, V., Diouf, R., Akbar, U., & Mankodiya, K. (2021). Data analytics for wearable IoT-based telemedicine. In Wearable Sensors (pp. 357–378). Elsevier. https://doi.org/10.1016/B978-0-12-819246-7.00013-9

Damaševičius, R., Bacanin, N., & Misra, S. (2023). From Sensors to Safety: Internet of Emergency Services (IoES) for Emergency Response and Disaster Management. 12(3), 41. https://doi.org/10.3390/jsan12030041

De Sordi, J. O. (2021). DSR as an Innovation Accelerator Strategy. Design Science Research Methodology, 1–5. https://doi.org/10.1007/978-3-030-82156-2_1

NENA. (2013). NENA NG9-1-1 Transition Plan Considerations Information Document.

EENA. (2013). Next Generation 112 Long Term Definition.

EENA. (2020). Emergency call handling service chain description. EENA.org

Eisenkraft, A., Goldstein, N., Fons, M., Tabi, M., Sherman, A. D., Ben Ishay, A., Merin, R., & Nachman, D. (2023). Comparing body temperature measurements using the double sensor method within a wearable device with oral and core body temperature measurements using medical grade thermometers—a short report. 14, 1279314. https://doi.org/10.3389/fphys.2023.1279314

Firoozabadi, S. M. K., Soleimani, G., Amiri, M., & Moradian, M. (2017). Review of Emergency Response Methods in Disaster Management, Dispatch and Control of Forces in Emergencies. 11(3).

Friedman, J. H. (2001). Greedy function approximation: A gradient boosting machine. Annals of Statistics, 29(5). https://doi.org/10.1214/aos/1013203451

Gardett, I., Clawson, J., Scott, G., Barron, T., Patterson, B., & Olola, C. (2016). PAST, PRESENT, AND FUTURE OF EMERGENCY DISPATCH RESEARCH: A SYSTEMATIC LITERATURE REVIEW. Emergency Medicine Journal, 33(9). https://doi.org/10.1136/emermed-2016-206139.13

Gonzalez, E., Peña, R., Avila, A., Vargas-Rosales, C., & Munoz-Rodriguez, D. (2017). A Systematic Review on Recent Advances in mHealth Systems: Deployment Architecture for Emergency Response. In Journal of Healthcare Engineering (Vol. 2017). https://doi.org/10.1155/2017/9186270

Gregório, J., Reis, L., Peyroteo, M., Maia, M., Mira da Silva, M., & Lapão, L. V. (2021). The role of Design Science Research Methodology in developing pharmacy eHealth services. Research in Social and Administrative Pharmacy, 17(12), 2089–2096. https://doi.org/10.1016/J.SAPHARM.2021.05.016

Hochreiter, S., & Schmidhuber, J. (1997). Long Short-Term Memory. Neural Computation, 9(8). https://doi.org/10.1162/neco.1997.9.8.1735

James, J. G., & Nair, S. (2017). Efficient, real-time tracking of public transport, using lorawan and rf transceivers. TENCON 2017-2017 IEEE Region 10 Conference, 2258–2261.

Jeon, S., Kwon, E., & Jung, I. (2014). Traffic Measurement on Multiple Drive Lanes with Wireless Ultrasonic Sensors. Sensors 2014, Vol. 14, Pages 22891-22906, 14(12), 22891–22906. https://doi.org/10.3390/S141222891

Ji, Z., Ganchev, I., O’Droma, M., Zhao, L., & Zhang, X. (2014). A Cloud-Based Car Parking Middleware for IoT-Based Smart Cities: Design and Implementation. Sensors 2014, Vol. 14, Pages 22372-22393, 14(12), 22372–22393. https://doi.org/10.3390/S141222372

Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2017). ImageNet classification with deep convolutional neural networks. Communications of the ACM, 60(6). https://doi.org/10.1145/3065386

Lafioune, N., Desmarest, A., Poirier, É. A., & St-Jacques, M. (2023). Digital transformation in municipalities for the planning, delivery, use and management of infrastructure assets: Strategic and organizational framework. Sustainable Futures, 6, 100119. https://doi.org/10.1016/J.SFTR.2023.100119

Lindström, V., Heikkilä, K., Bohm, K., Castrèn, M., & Falk, A.-C. (2014). Barriers and opportunities in assessing calls to emergency medical communication centre - a qualitative study. 22(1), 61. https://doi.org/10.1186/s13049-014-0061-3

Marin, G., & Pop, D.-P. (2009). THE EUROPEAN EMERGENCY NUMBER 112.

Namkoong, M., McMurray, J., Branan, K., Hernandez, J., Gandhi, M., Ida-Oze, S., Cote, G., & Tian, L. (2024). Contact Pressure-Guided Wearable Dual-Channel Bioimpedance Device for Continuous Hemodynamic Monitoring. 9(3), 2301407. https://doi.org/10.1002/admt.202301407

Noble, W. S. (2006). What is a support vector machine? In Nature Biotechnology (Vol. 24, Issue 12). https://doi.org/10.1038/nbt1206-1565

Ordieres-Meré, J., & Ortega-Mier. Miguel Ángel. (2024, May 15). Challenges in Industry 5.0: Human behavior integration. Manufacturing.

Palmieri, F., Ficco, M., Pardi, S., & Castiglione, A. (2016). A cloud-based architecture for emergency management and first responders localization in smart city environments. 56, 810–830. https://doi.org/10.1016/j.compeleceng.2016.02.012

Parmar, J., Das, P., & Dave, S. M. (2020). Study on demand and characteristics of parking system in urban areas: A review. Journal of Traffic and Transportation Engineering (English Edition), 7(1), 111–124. https://doi.org/10.1016/J.JTTE.2019.09.003

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A Design Science Research Methodology for Information Systems Research. Journal of Management Information Systems, 24(3), 45–77. https://doi.org/10.2753/MIS0742-1222240302

Prajapati, P. H., & Darji, A. D. (2022). Hardware Efficient Low-Frequency Artifact Reduction Technique for Wearable ECG Device. 71, 1–9. https://doi.org/10.1109/TIM.2022.3208262

Qiu, M., Ming, Z., Wang, J., Yang, L. T., & Xiang, Y. (2014). Enabling Cloud Computing in Emergency Management Systems. 1(4), 60–67. https://doi.org/10.1109/MCC.2014.71

Repanovici, R. M., Nedelcu, Șerban, Tarbă, L. A., & Busuioceanu, S. (2022). Improvement of Emergency Situation Management through an Integrated System Using Mobile Alerts. 14(24), 16424. https://doi.org/10.3390/su142416424

Rodriguez-Labra, J. I., Kosik, C., Maddipatla, D., Narakathu, B. B., & Atashbar, M. Z. (2021). Development of a PPG Sensor Array as a Wearable Device for Monitoring Cardiovascular Metrics. 21(23), 26320–26327. https://doi.org/10.1109/JSEN.2021.3064219

Sebillo, M., Vitiello, G., Paolino, L., & Ginige, A. (2016). Training emergency responders through augmented reality mobile interfaces. 75(16), 9609–9622. https://doi.org/10.1007/s11042-015-2955-0

Siagian, P., & Fernando, E. (2020). LoRaWAN Intelligent Outdoor Smart Street Lighting. 2020 IEEE International Conference on Communication, Networks and Satellite (Comnetsat), 198–203.

Spjeldnæs, T. B., Nilsen, K. A. V., Myrmel, L., Sørnes, J.-O., & Brattebø, G. (2023). “Calling for help: I need you to listen” - A qualitative study of callers’ experience of calls to the emergency medical communication centre. 31(1), 94. https://doi.org/10.1186/s13049-023-01161-2

Tiwari, V. K., & Singh, V. (2016). Study of Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions. | International Journal of Advanced Research in Computer Science | EBSCOhost. International Journal of Advanced Research in Computer Science. https://openurl.ebsco.com/EPDB%3Agcd%3A3%3A7865907/detailv2?sid=ebsco%3Aplink%3Ascholar&id=ebsco%3Agcd%3A121071482&crl=c

Turoff, M., & Chumer, M. (2004). The Design of a Dynamic Emergency Response Management Information System (DERMIS).

Ulvin, O. E., Skjærseth, E. Å., Krüger, A. J., Thorsen, K., Nordseth, T., & Haugland, H. (2023). Can video communication in the emergency medical communication centre improve dispatch precision? A before–after study in Norwegian helicopter emergency medical services. BMJ Open, 13(10). https://doi.org/10.1136/bmjopen-2023-077395

Usharani, S., & Karmel, A. (2022). Smart Parking System and Its Applications. 75–99. https://doi.org/10.1007/978-981-19-2184-1_4

Venable, J. R., Pries-Heje, J., & Baskerville, R. L. (2017). Choosing a Design Science Research Methodology. ACIS 2017 Proceedings. https://aisel.aisnet.org/acis2017/112

Windmill, E. (2020). Flutter in Action. Manning Publications.

Yang, L., Yang, S. H., & Plotnick, L. (2013). How the internet of things technology enhances emergency response operations. 80(9), 1854–1867. https://doi.org/10.1016/j.techfore.2012.07.011

Yun, M., & Yuxin, B. (2010). Research on the architecture and key technology of Internet of Things (IoT) applied on smart grid. 2010 International Conference on Advances in Energy Engineering, ICAEE 2010, 69–72. https://doi.org/10.1109/ICAEE.2010.5557611

Zhang, T., Lu, J., Hu, F., & Hao, Q. (2014). Bluetooth low energy for wearable sensor-based healthcare systems. 2014 IEEE Healthcare Innovation Conference (HIC), 251–254. https://doi.org/10.1109/HIC.2014.7038922