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DIGITALIZATION PROCESSES INVOLVING DIVERSITY FROM WORKERS. INSTITUTIONAL APPROACH

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Servitization and Industry 4.0 are considered two of the most recent trends transforming industrial companies. Servitization is mainly focused on adding value to the customer, while Industry 4.0 is frequently related to adding value to manufacturing process. On both ends heavy innovations have been introduced during the last few years, in particular to introduce automation in activities where regularity was high. However, such trend was somehow limited because of factors introducing high variability like processes involving key decision from operators, where no explicit knowledge was available or because of the high level of complexity due to the integration of different stakeholders with different interests. Therefore, this paper aims at discuss key factors being responsible for such generation of explicit knowledge on processes being driven by human decisions without specific standardization on activities, In particular two different contexts (intra and inter organizational cases) will be studied.

Keywords: digitalization; I4.0; BIM; worker integration; knowledge management

PROCESOS DE DIGITALIZACIÓN QUE IMPLICAN VARIABILIDAD DERIVADA DE LOS OPERADORES. UNA APROXIMACIÓN INSTITUCIONAL

Servitization e Industria 4.0 se consideran dos de las tendencias más recientes responsables de la transformación de las empresas industriales. La servitización se enfoca principalmente en agregar valor al cliente, mientras que la Industria 4.0 está frecuentemente relacionada con agregar valor al proceso de fabricación. En ambos extremos, se han introducido grandes innovaciones durante los últimos años, en particular para introducir la automatización en actividades donde la regularidad era alta. Sin embargo, dicha tendencia fue de alguna manera limitada debido a factores que introdujeron una gran variabilidad, como procesos que involucran decisiones clave de los operadores, donde no se disponía de conocimiento explícito o debido al alto nivel de complejidad debido a la integración de diferentes partes interesadas con diferentes intereses. Así, este artículo tiene como objetivo discutir los factores clave que son responsables de dicha generación de conocimiento explícito sobre procesos impulsados por decisiones humanas sin una estandarización específica de las actividades. En particular, se estudiarán dos contextos diferentes (casos intra e interorganizacionales) como fuente de reflexión para el mismo.

Palabras clave: digitalización; Industria 4.0; integración de trabajadores en datos de proceso; gestión del conocimiento

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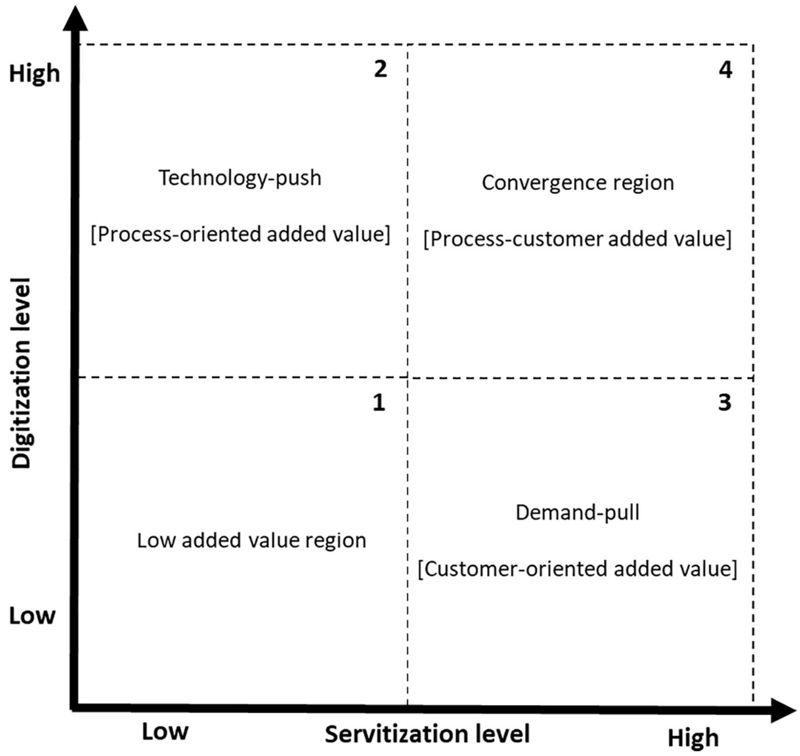
1. Introduction

Servitization and Industry 4.0 (I4.0) are considered two relevant topics capable of transforming companies. Servitization is mainly focused on adding value to the customer, while I4.0 is frequently related to adding value to the manufacturing process (Frank et al. 2019).

Servitization is understood as a strategic innovation of an organization's business model, shifting from selling products to selling a service that the product aims to provide. The organization at least extends the product to the combination of product and service that delivers value in use, i.e., a Product-Service System (PSS) (Leseure et al. 2010). The concept of PSS is just a case of servitization, because PSS is defined as a system of products, services, supporting networks, and infrastructure configured to satisfy customers' needs, and have a lower environmental impact than traditional business models (Frank et al. 2019). Relationships between network partners are enabling competitive performance as a result of a balance between cooperation and collaboration. Therefore, I4.0 brings increased flexibility, and customization capacities to the operating models and production. Under such a perspective, the I4.0 can be seen reinforcing the servitization phenomenon (see Figure 1).

Figure 1: Trajectories for Industry 4.0 and Servitization. Source (Frank et al. 2019)



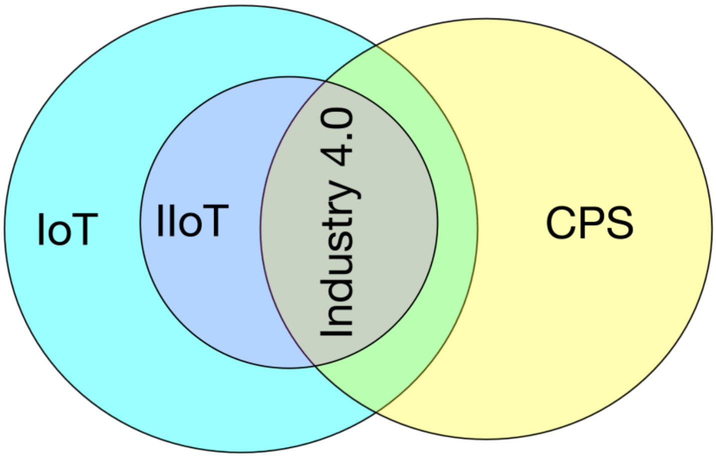
Note: The Y axis follows a technology-push innovation trajectory resulting in intra-organization value-added.The X axis follows a demand-pull innovation trajectory, where the value proposition looks to customers.

In the I4.0 era, items in a smart factory start to be equipped with communication systems, and embed data processing capabilities (edge computing), creating the Industrial Internet of Things (IIoT) concept. The IIoT will allow the direct interconnection of a set of devices to collect and transmit data, becoming aware of a broad context which better support smarter decisions. They will also cover the machine-to-machine (M2M) communication technologies with automation applications, supporting to share data for further intensive analysis.

The continuous technological innovations in the domains of information technology (IT), the Internet of Things (IoT), among others, have significantly changed production systems (Zheng et al. 2019)

The IIoT scenario enables a close connection between the physical and digital worlds, and the paradigm of cyber-physical equivalence or digital twin emerges (Glaessgen and Stargel 2012) (see Figure 2). It refers to a physical and functional description of a component, product, or system, which includes information that could be useful through its lifecycle (Schleich et al. 2017).

Figure 2: Relationship between related concepts. Source (Sisinni et al. 2018)



The rise of digital platforms supporting manufacturing operations plays a crucial role in supporting collaborative production, analysis, and forecasting processes. Then, the management dimension applies to these networks. Moreover, they provide flexibility to enterprises by fast orchestration of applications, where services are also offered to implement the decision-making process as well as the monitoring activities. Actually, the development of digitally enabled platforms for manufacturing will continue to evolve in the near future, which indicates that reference models behind them will be necessary to facilitate this evolution, providing reference approaches and guidance to their implementation and configuration. In this way, saving time and costs will be the provided value (Fraile et al. 2019).

The main two principles of I4.0 are interconnection and information transparency. Different approaches have so far been tested by scientists and management who invariably face the challenge of shared understanding between the actors involved. Reference models represent a standard structure and language to describe and specify system architectures and, by bringing frameworks, helping to promote a common understanding among stakeholders, and supporting interoperability between components. They provide a framework for the standardized definition of relevant technical systems, where the ambition is to observe the whole life-cycle, from development, to operation.

Reference models enable different stakeholders to interact in such a way that interoperation between them is supported. As standards, they become regionally adopted; they represent a common understanding of terms for a wide range of practitioners from the industry. The level of coverage for such reference models is diverse. Therefore, some reference models describe the enterprise as a whole, and some others have a focus on specific problems. Among these ones, it is possible to find PLC programming, unique identification, AutomationML for mechatronic data modeling, and OPC UA(OPC 2009) for machine-to-machine communication, etc..

According to Kiel et al. (2017), the foreseen benefits of implementing such reference models are, attending to the four most common references,

- to promote strategic differentiation and competitive advantages based on innovative offerings,
- to enhance value creation and growing sales,
- to optimize product and process quality, and
- to increase productivity, machine availability, and output robustness.

However, such expectations can become somehow jeopardized because of factors introducing high variability like processes involving crucial decisions from operators, where no explicit knowledge was available or because of the high level of complexity due to the integration of different stakeholders with different interests.

Therefore, this paper aims at discussing key factors being responsible for such generation of explicit knowledge on processes being driven by human decisions with low specific standardization on activities. In particular, two different contexts (Intra and inter-organizational cases) are under analysis. For the Intra organizational dimension, information by process and product levels need to be collected and integrated into the appropriate digital twins to deliver the expected value. For the inter-organizational aspect, timely information needs to be shared among the relevant stakeholders, looking to provide them with the required information, keeping at safe the IT infrastructure, no matter how frequent the stakeholders vary.

2. Literature Review

Different conceptual frameworks have been introduced, covering different perspectives for reference models, in all the cases looking to create a shared understanding among diverse stakeholders. It is worth to mention the Reference Model for Industrie 4.0 (RAMI 4.0) (Adolphs et al. 2015) because it represents the life cycle of products and systems (following the IEC 62890 standard). The product life-cycle model differentiates between product type and product instance as an individual instantiation of a product type. RAMI 4.0 includes the hierarchical representation of the different functional levels of the factory, (based on the IEC 62264 and IEC 61512 standards) (Fraile et al. 2019). Some other standards like the Advanced Manufacturing Series (AMS) from NIST (Lu, Morris, and Frechette 2016), which emphasizes the landscape by identifying three main dimensions (Product Life-cycle Management, Production System Life-cycle, and Business Cycle for Supply Chain Management).

The goal of this section is not to present state of the art for the existing framework proposals for smart manufacturing, while more in-depth analysis can be found in the literature (Fraile et al. 2019; Li et al. 2018). However, there are some of them created after RAMI 4.0, which are relevant, like the Industrial Internet Integrated Reference Model (I3RM). Actually, it can be seen as a proposal integrating features of IIRA, AMS, and RAMI 4.0 reference models, to facilitate the definition of the system configuration from different perspectives of such digital platforms.

Despite the extensive work carried out for promoting general reference models and frameworks, they remain very conceptual, and they introduce limitations at different levels, like regarding the exact positioning of different technologies, perspectives, and functions as well as the connectivity between them. For instance, the planners of a smart factory must know where to place and how to interconnect some of the different kinds of digital twins and digital agents. These limitations can become an essential challenge for all the planners of smart factories, and they can hinder the adoption of such standards.

To address the aforementioned limitations is worth keeping in mind the general perspective provided by RAMI 4.0, but more specific frameworks are needed. Therefore, Resman et al.

(2019) proposed the introduction of the LASFA reference model, which presents the individual systems that need to be combined to configure a smart factory. It includes several layers, as well as a technical and management process that result in a product in the production site.

Even for these more detailed reference models like LASFA, the focus relies on systems and components and their communication. Still, an essential dimension discussed in the introduction, which is the operator or worker role, has not been considered. Therefore, this paper will promote an update for LASFA in the next section.

Another relevant aspect not clearly addressed by existing reference models is the competitive advantage and the value creation for customers that Kiel et al. (2017) found it their research. This aspect is relevant when the two different contexts (Intra and inter-organizational cases) are considered.

For the Intra-organizational case, Sun et al. (2020) introduced the Healthy Operator 4.0 (HO4.0) concept. They show that advances in IoT, like wearable technologies, provide new opportunities for real-time monitoring of operator's activities, locations, etc., including the status of the surrounding environment. They also introduce a four-layer framework to develop the concept, where the different data streams were semantically annotated.

Yang et al. (2019) show that in complex Industrial Internet of Things (IIoT) application systems, there may exist a variety of functional sub-systems that provide divergent services to the users and the relationship among these services could be strong, which is very common in practice. To properly handling such services and their data flows, several challenges hit: system structure, personal privacy, and communication compatibility, while the context is mainly decentralized. Therefore, the reference model should also consider the added value for allowing such services to distribute immutable information over public databases by using Distributed Ledger Technolog (DLT). This particular feature can allow a productive potential of further development for different stakeholders, will also be addressed in the extended reference model being proposed in this paper.

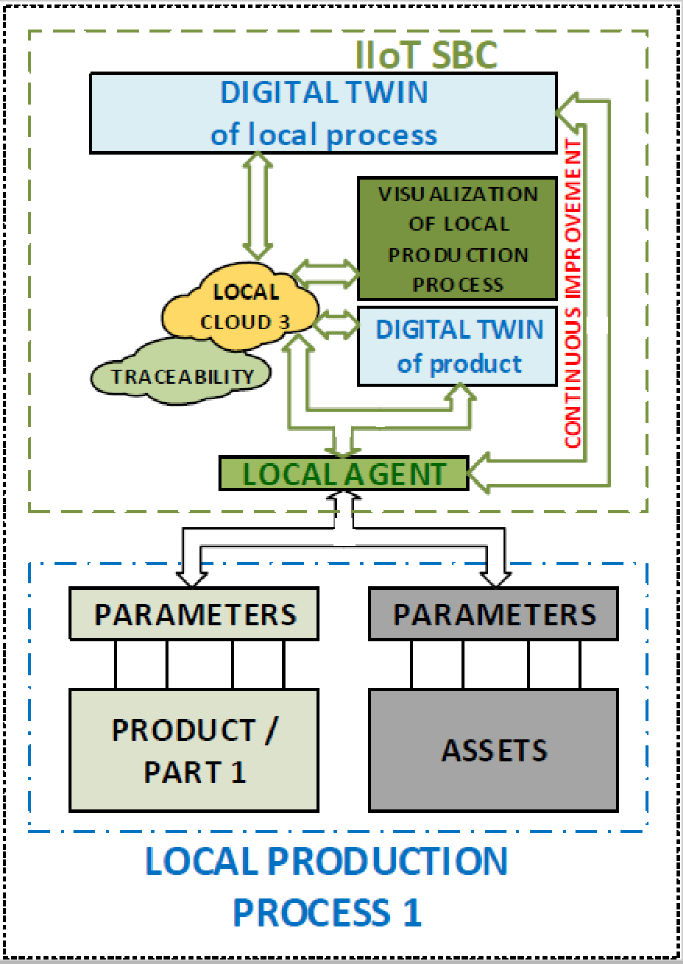
3. Update for LASFA reference model

The interest in this section is to promote an extension for the atomic component of the LASFA reference model, as depicted in Figure 3. There, it can be possible to identify both the production asset and the product are the starting point. They both are represented by their parameters, which are 'managed' by a local agent, responsible for storing them in a local cloud and for feeding them into the product and the process oriented digital twins. Visualization of process and product parameters come from such a local cloud, where it can be understood in terms of local data storage. It is supposed that those local agents are stored into single-board computers (SBC) to provide the IIoT context. It is the process digital twin which sends information to the Manufacturing Execution System (MES).

Although such architecture can be possible, it becomes hard to understand how to integrate into such classical definition the contribution of web service-oriented IIoT systems or operators being tracked through personal wearable devices. It is also difficult, except for new or heavily overhauled factories, to enable the interface with the MES, over the process digital twin, as probably the MES system was designed earlier than such concepts. Therefore, a more resilient and integrative architecture is needed, and because of it, it is proposed a different configuration as presented in Figure 4.

The new proposal not only considers the contribution/impact explicitly for the process and the product of assets but also of operators, as well as of other different IIoT devices installed. It is supposed that such IIoT devices transmit their information to the integrator cloud, in case there is no option to embed the technology into the factory cloud. This situation has been represented by a cloud crossing the company boundaries, as it could happen. In the case of the operator wearables or similar devices, the information will be transmitted to the provider's cloud, which is external to the factory boundaries.

Figure 3: Description of production process item in LASFA. Source (Resman et al. 2019)

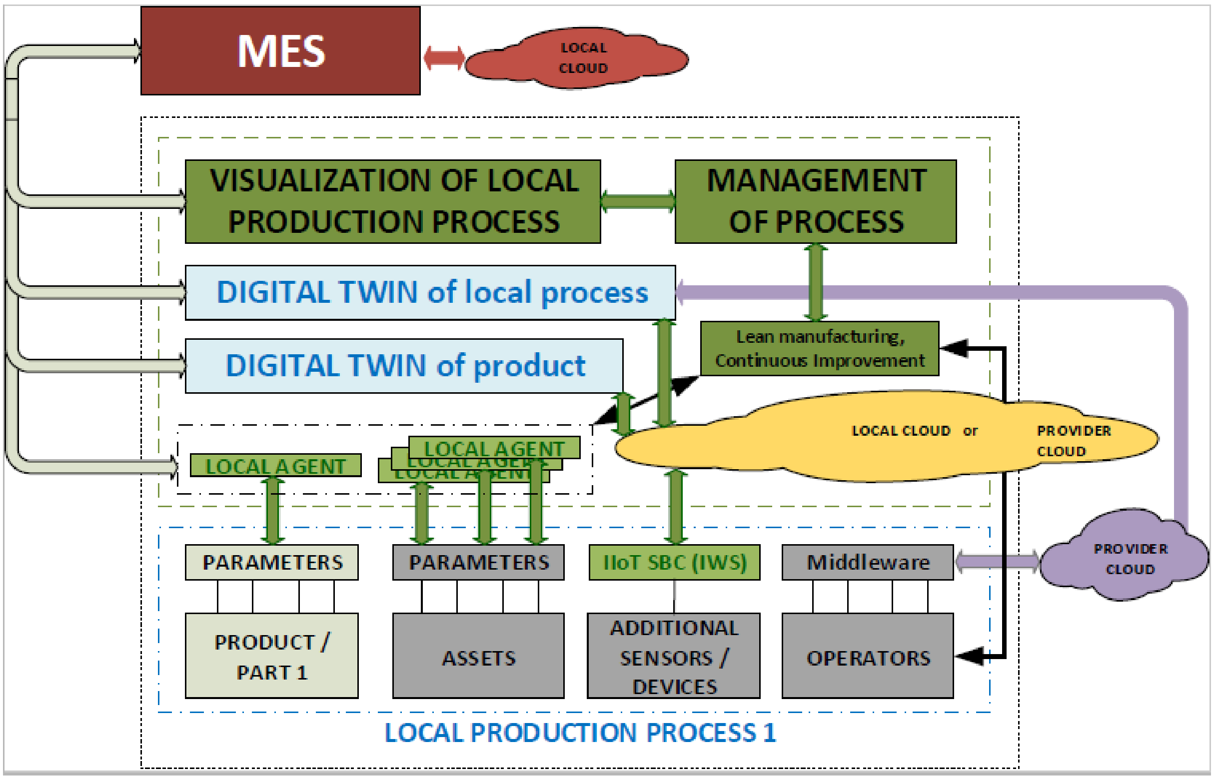


Local agents are software components making it possible to send to the MES system the relevant information, which will be in charge of presenting timely and reliable information about the process. Implementation of digital twins for process and product will capture data from the MES, as well as from the IIoT through web service consumption and from the wearable devices from their middleware. In this way, the digital twins will extend the data sets from those currently being stored into the MES system.

The MES system itself can have its own cloud, and it can contribute to a more sophisticated digital twin, which will be covering different cells or production units, to reflect the factory digital twin. This level can be reached as probably different MES systems will be in operation as per production cells groups.

Regarding the other relevant aspect, to provide convenient access to the information for different stakeholders, with compromising any of the factory IT systems, is to have a distributed database providing support to data access for different agents, with the convenient privacy levels. The proposal here is to adopt the IoTA protocol, which is an example of DLT technology, and it was designed to be lightweight and serving for data communication between IoT devices. It is different from traditional blockchain-based distributed ledger protocols by solving two major relevant points: latency and fees. IoTA does not utilize the concept of blocks of transactions and mining to have the right to sign the blocks. Instead, transactions wanting to be added to IoTA's distributed ledger (the tangle), must validate two unconfirmed transactions on the ledger by solving a low-cost computational proof of work (Brogan, Baskaran, and Ramachandran 2018).

Figure 4: Description of UPDATED production process item in LASFA.



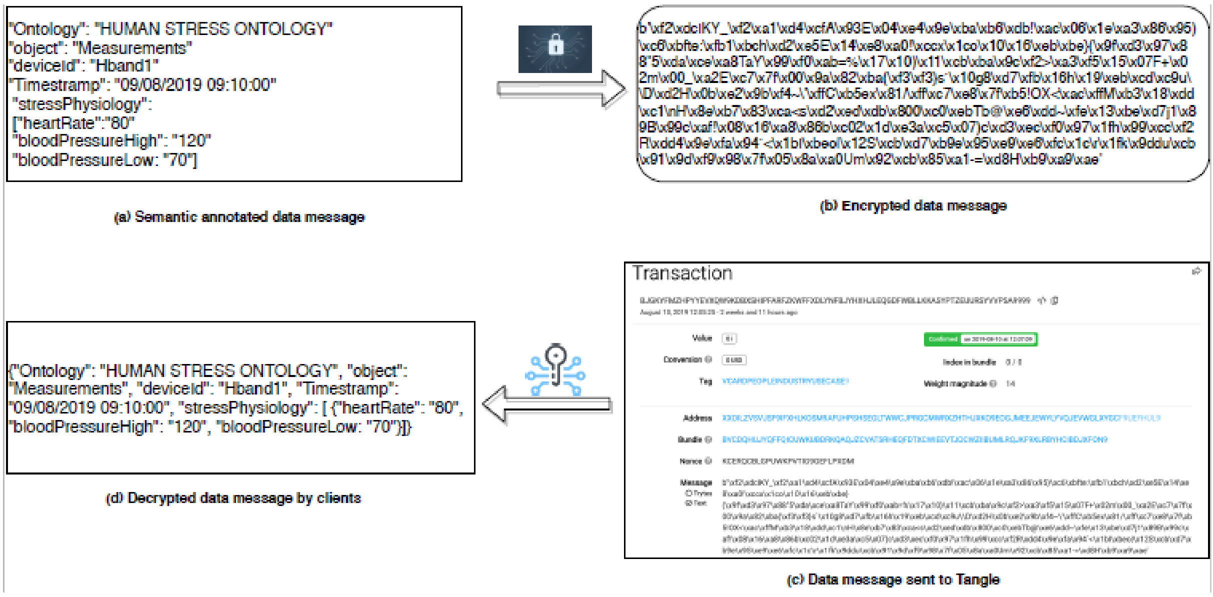
From the theoretical point of view still, it is possible to accept those external clouds the reference model defines to be the public DLT database. Practically, it is proposed to get them configured as transactions, encrypted, and headed to the owner's IoTA wallet, and finally sent to them through the tangle (see Figure 5). Therefore, the factory owner can always have centralized access to the information through time.

The second relevant aspect is to enable the collection and or use for data being produced dynamically for the facility service or agent during its life. Fortunately, the same protocol can be used to handle data streaming from different sensors as well as from service providers of various commodities, as far as they want to implement such an option. In this case, full traceability about what and when the use of such services can be obtained by using the Masked Authenticated Messaging (MAM). IOTA offers the MAM extension, acting as a second layer data communication protocol (Brogan et al. 2018; Zheng et al. 2019). Therefore, sensors and services can broadcast encrypted, authenticated data streams being transmitted through the tangle as transactions without transmission value.

4. Proof of Concept

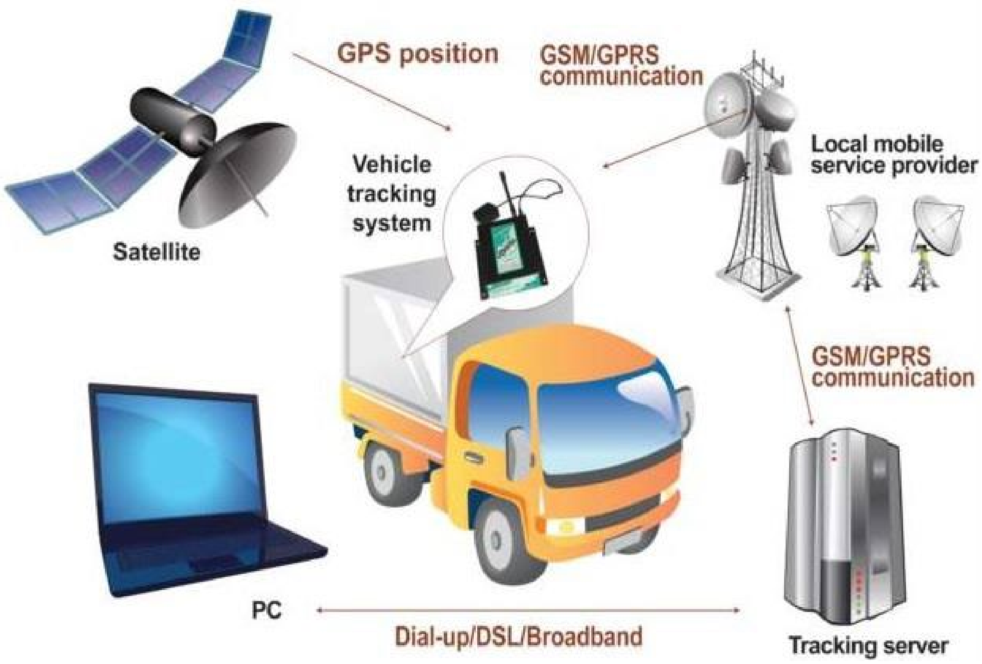
Looking to validate the proposed updated reference model, including the distribution of messages through the DLT solution, it was selected a conventional business able to collect and to prepare steel-based scrap from different providers and delivering it to a steelmaking facility. It has different production units, some in charge of scrap collection, some of the scrap sort out, some of the packaging and some of the “product delivery.”

Figure 5: Example of submission and recovery of data to the tangle.



Without a lack of generalizatization, one of the units dealing with scrap collection is selected. It is composed of one truck with onboard crane, the driver, as well as the industrial weighting systems at both ends, the provider and the owner scrapyard. The mock-up of the concept is presented in Figure 6, where the different elements of the production cell involving assets are the industrial scales, and their local agents are the software programs loading the truck id and the weights, before and after the process, which is stored at the MES based database. Indeed the third asset is the truck itself, which provides information about its status.

Figure 6: Example of submission and recovery of data to the tangle.



The product is in this particular case is the collected scrap, where the local agent is the camera collecting pictures and uploading them into the MES system, because of traceability reasons. There are two more data streams in this application. The first is one IIoT system, which, in this case, provides tracking for the location of the asset through time. It is located onboard and delivers data to the service provider cloud by means of a 4G data link, and a web service accesses it under SOA description. There is another data stream providing environmental conditions in the cockpit of the truck (CO2, T, HR, light, sound levels). In this case, the local agent running in a SBC (raspberry pi 3B) delivers such data as per minute to a cloud belonging to the owner. The latest data stream is related to the heart rate and blood pressure for the driver, where the ambition is to keep the stress levels under control, as well as, to give such information to the driver timely (not when he is driving, but later on). It is carried out by wearing the driver with a smart-band and using an android mobile phone as a middleware (see Figure 7).

Figure 7: Capture of the middleware screen for the smartband.

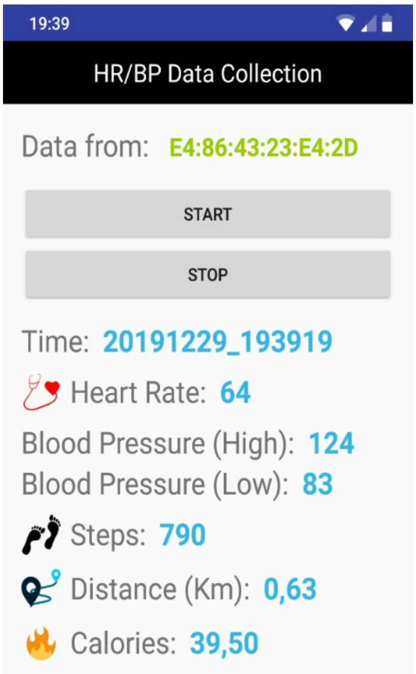
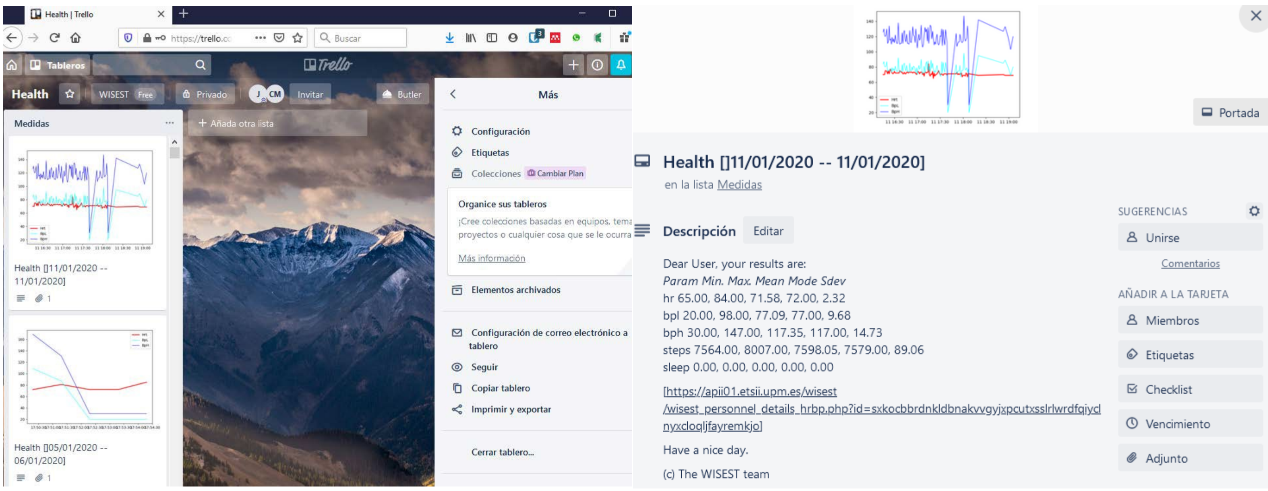


Figure 8: Trello interface of a user.



At the other end, regarding the data sharing employing the presented method, the driver's personal information collected is delivered encrypted to the IoTA tangle. The user can utilize an application to register its interest and the certificate to unencrypt its related data transactions. S/he can also decide to see them or just to send them to its own Trello account to have under his/her domain the information (see Figure 8).

5. Conclusions

This paper has quicky reviewed the relationship between servitization and Industry 4.0, making it possible to realize the importance of the reference models for innovation. Several popular reference models were reviewed, looking to understand their strengths and limitations.

From the analysis, it became clear that RAMI4.0 provides a very abstract and general model based on automation standards, where more specific reference models are needed. Some limitations were found, and a proposal for improving one (LASFA) has been carried out, able to accommodate the existing infrastructure of MES, with hybrid configuration based on web services. Indeed, it accommodates to gather information from operators, including personal wearables.

A proposal enabling to share divergent information to specific stakeholders in an encrypted way was configured. It considers both transaction or streaming, using DLT.

To validate the figured out proposal, it was defined as a real context, and a proof of concept was set up, which provides evidence of the value for the proposal made.

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Communication aligned with the Sustainable Development Objectives