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DIGITALISATION FOR A TERRITORIAL CIRCULAR ECONOMY: TOWARDS AN INTEGRATED PLATFORM

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Abstract: The digital transition and the ecological transition are happening simultaneously and transforming businesses and policies around the world. The exponential development of digital technologies generates unprecedented quantities of data and changes the way all societies function. Hence, significant opportunities are created for sustainability and circular economy strategies to be implemented. The concept of smart territories is emerging as one of the new paradigms for territorial management coupling the digital tools to sustainability and circular economy models. This new concept has not been fully exploited yet and many challenges on how to achieve smart territories are still to be identified and tackled. The present work explores the main building blocks of smart territories, data exploitation, digital technologies and digital twins and their synergies with the implementation of circular economy strategies. A systematic literature review is performed to analyse the precedent works and complemented by MERISE methodology to sketch the mock-up of a digital territorial platform. Through this work, potential contributions of digital tools to promote and accelerate the circular economy on a territorial level are shown. The findings are discussed and analysed, and then positioned and applied for the Paris-Saclay territory. After the current field is analysed, a mock-up of a platform is proposed through the MERISE methodology. There, simulations could be done by public authorities and the main actors to compare, test, and evaluate different scenarios.

Keywords: Territorial circularity, digital tools, decision-making support, data economy, Geographic Information System

1 INTRODUCTION

The continuing trends in population, policy, industry, economy, technology and human behaviour, known as the “business-as-usual” scenario is heading our world towards a climate catastrophe. The sixth assessment report (AR6) [1] of the Intergovernmental Panel on Climate Change (IPCC), highlights threatening increase in carbon dioxide emissions attributed to human and industrial activities. The IPCC finds that climate change is a threat to the well-being of humanity and the health of the planet. However, it is possible to decrease the effects of climate change by acting now, to preserve our future. In an effort to bring effective solutions to this problem, the COP26 agreement required countries and governments to reinforce those goals by the end of next year instead of the five-year period previously stipulated during the 2015 Paris Agreement [2], [3]. In this context, the European sustainable development report, 2021[4], enshrines the principle of the six SDG transformations for a clean Europe. The report also includes the SDG index for the European Union, its member states, and partner countries

targets to transform the European Union to achieve the Sustainable Development Goals (SDG). These principles include, but are not limited to, innovation, sustainable communities, circular economy (CE), zero pollution, and digital transformation [4]. As a matter of fact, doubling the circularity of the global economy could reduce by 39% the emissions of greenhouse gases, according to the circularity gap report (2021) [5]. The shift from a linear to a CE offers great potential for long-term sustainable development. Not only it reduces the waste of materials, goods and energy, but also it maximizes the utilization of all raw materials, minerals, energy and resources in its various forms. It also contributes to creating better economic and investment opportunities for companies and institutions, as well as environmental and social benefits for the different stakeholders [5].

The growth of digital technologies has impacted businesses and cultures around the world, creating more opportunities for circular economy strategies to be implemented [6]. The new digital technologies are expected to drive the CE and increase the efficiency of the actions and strategies that are implemented by both industrial firms and public authorities. Today, the world stands on the cusp of a new revolution, the “Fourth Industrial Revolution”. It is the application and the fusion of Artificial Intelligence (AI), the Internet of Things (IoT), robotics, biotechnology and 3D printing, and the revolution in the field of social networking sites and the digital world, quantum computing, and other technologies [7]. The breadth and depth of these changes herald a transformation of all production, management, and governance systems. The possibilities are endless for the billions of people communicating, and will be multiplied by new technological inventions in different areas [8]. Today, artificial intelligence is being increasingly adopted to support the decision-making process thanks to an impressive progress in computing power systems and the availability of vast amounts of data. The application of the artificial intelligence can today be achieved in various fields from software used to discover new drugs to algorithms used to predict long-term sustainable energy pathways at the level of the globe. Meanwhile, technology is constantly interacting with our real world. Engineers, designers, and architects combine computational design, 3D visualisation, artificial intelligence to make decisions concerning territorial planification and support effective actions and policies.

If at the heart of its agenda, the European Commission placed the ecological and digital transitions as the greatest challenge of our generation, a gap remains existing on the practical implementation of these strategies at many territories. There is, in fact, a lack of a consistent framework and supporting tools and methods that can guide the local authorities within the ecological and digital transitions, while meeting the needs of the involved and affected stakeholders. Hence, a territorial digital service platform is needed to centralize data and the computing process required to provide reliable information for public authorities. For instance, the “Communauté d'agglomération de Paris-Saclay” (CPS) is looking for deploying digitalisation in its territory to achieve circularity and to mitigate the effects of climate change by identifying the appropriate actions. The CPS is a French inter-municipal structure created in 2016, located in the Essonne department in the Île-de-France region. Alongside the Greater Paris Metropolis (at 20 km south of Paris), the territory constitutes a sector for the development of innovation on a regional and international scale. It is composed of 27 municipalities that share economic centres of influence, cluster of innovation, research and technological excellence. Those interact at the middle of an operation of national interest, lands and protected natural spaces. It is hence a territory of exception, being a centre of economic development and a world-class scientific area. Moreover, CPS hosts on its territory many higher education and research establishments making important companies to settle in the territory so they can carry out their research and development activities.

In these circumstances, the CPS aims for circularity on its territory. In concordance with the Territorial Climate, Air and Energy Plan (PCAET in French), CPS aims to develop a Territorial Digital Services Platform (TDSP) that enable real-time monitoring of cyclical indicators linked to the flows of household and green waste, mobility of people and flow of goods on the territory. Once these are integrated in a platform, data can be collected and centralized to enable their measurements. Subsequently, several scenarios could be studied through simulation and digital twin modelling. This will help the various stakeholders in their decision making by providing them with reliable information [9]. With this background, and in order to present a tool addressed for territorial actors, this study aims to investigate the potential contributions of digital technologies to support and accelerate the circular economy transition by answering the following research questions: What are the main digital

technologies and how do they support and accelerate the circular economy transition on a territory? On what information and data are they based? How can a territorial actor use a platform combining data and technologies – such as digital twins – in order to achieve territorial circularity?

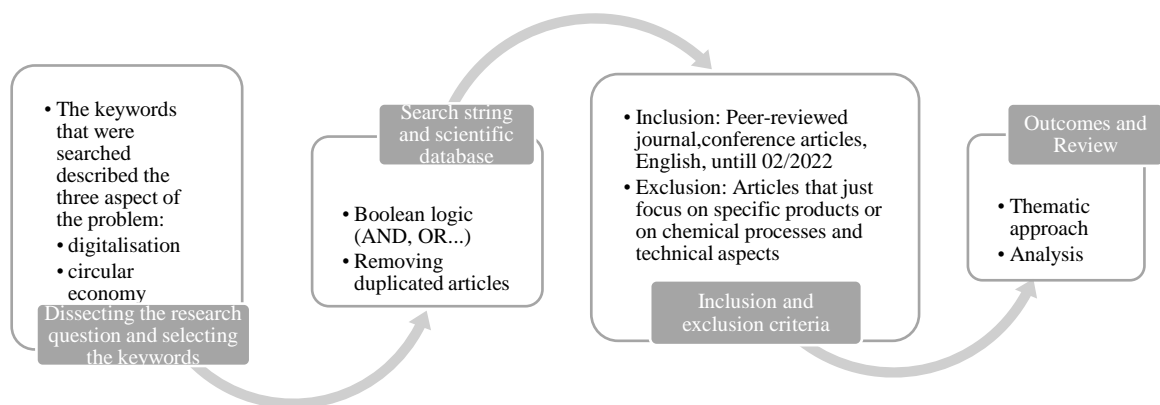
To answer the above settled research questions, a systematic literature review is carried out via Scopus and then the MERISE methodology is chosen to establish the mockup of the platform. MERISE is usually used in the field of information systems development, software engineering and project management to design and development a system. Then, the results are discussed by (i) presenting the data economy, (ii) presenting the identified digital tools, and (iii) linking the deployment of digital tools for a transition towards a circular economy of a territory by presenting the mock-up of the platform. Finally, a conclusion is made by joining perspectives and future propositions, while mentioning challenges and difficulties that should be tackled.

2 MATERIALS AND METHODS

2.1. Systematic Literature Review

This work was based on the systematic literature review methodology (SLR) [10]. It was detailedly described in a parallel work realised by Bouillass et al. [11]. This method is usually used since it is easy to be replicated by future scholars. The criteria used are summarized in this following figure. However, the full study was the pillar of another paper.

Figure 1. Systematic Literature Review steps



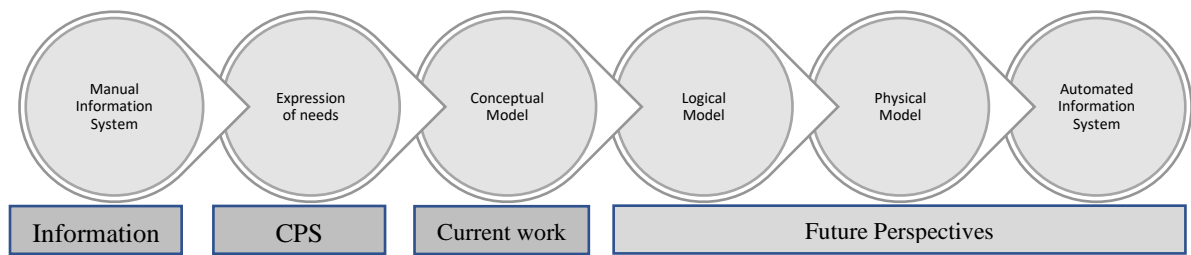
The analysis showed that digitalisation for CE is at the core of today’s world business strategies [12]. In fact, in summary, the SLT showed that new technologies could assist people in decision-making relating CE [12]. However, a study determined that research tackling digitalization and sustainability is still insufficient, by linking the digital economy to the indicators of the Sustainable Development Goals (SDG) [13].

2.2. MERISE method

After showing and presenting the results of the SLR, all the concepts will be integrated into one platform. This article presents the idea and links it with other works to present the mockup for the CPS.

Information systems require methods in the design phase to be able to set a model to rely on. A virtual representation of a reality in such a way as to bring out the points of interest is called analysis [14]. There are several methods of analysis, the method most used in France being the MERISE method MERISE, which is used for IT projects and is based on the separation of the data and its processing to be carried out into several conceptual and physical parts. This ensures the longevity of the model [14]. Here, the design of the platform and the information system follows the succession of several steps represented in the following figure.

Figure 2. MERISE Methodology steps



This succession of steps is called the abstraction cycle for the design of information systems [15];

- The steps of this method start with defining the objectives of the general system definition and a manual information system.
- Then, a preliminary study is done via the expressions of needs. The expression of needs is a step consisting in defining what is expected of the automated information system. This requires making an inventory of necessary elements for the information system and defining the system by asking future users about their needs. It is usually followed by a detailed study leading to the conceptual data modelling.
- Once the needs are defined, the conception model on which we will focus here will be created by taking the information flows into account.
- The logical model represents a software choice, and the physical model reflects a material choice for the information system. Once these are settled, an automated information system will hence be finalised. This happens when the technical study, the software production and its implementation are done.

In this paper;

- the manual information system is done through literature review and the data economy model
- the expression of needs is done in collaboration with the CPS
- the conceptual model is presented in the mock-up of the platform by showing the user interface and describing use cases.
- Logical, physical and hence automated information system are out of scope and could be done at a later stage.

3 RESULTS AND DISCUSSIONS

3.1. Data Economy

The literature showed that data is the stimulus of societies that forms the basis for many critical decisions. However, organizations must have an extensive data quality process flow to ensure data validity, as accurate data can help deliver valuable results. Therefore, to take advantage of the explosive growth of big data, territories need to use a data quality management framework before they begin extracting actionable insights from information. The data quality management framework ensures consistency, accuracy, and validity. Data economy explains data quality management and data economy, identifies the criteria to ensure data quality, and classifies territorial data into categories. Territorial related data can help accelerate the broader transition to the CE – which is a complex and multifaceted system – by providing the financial community with the indicators on which to make investment decisions [16]. Several data scientists defined some key data quality dimensions to assess quality and value. (i) Completeness: Data collected is sufficient and there is no missing information. (ii) Consistency: Data is synchronized, unified, and standardized. (iii) Accuracy: Data is error-free and reliable. (iv) Timeliness: Data is available when expected. (v) Uniqueness: Data is not duplicated and is distinguished. (vi) Validity: Data meets the criteria or standards.

The report of IBM (2020) stated that the cost of data breach is \$3.86 million [17]. If this is a considerable number, it is because data became one of the most important aspects of our societies. This is unanimously recognized. In 2014, Xiao et al. predicted that data may be one of the most important trading commodities of the future [18].

Organisations are competitively structuring data to use it in decision making. The European Circular Economy Research Alliance presented a structural view of the data economy [19]. To reach the main digital technologies such as the Internet of Things (IoT), Big Data, Artificial Intelligence (AI), and Distributed Ledger Technologies (DLT), it is essential to start with a data-driven culture and then move the several stages of dissecting the data by integrating, collecting, analysing and sharing it.

- a) **Data-Driven Culture:** In the last decade almost, many of the major companies made the data a part of their culture. At a larger scale, societies are doing so. This means holistically embracing corporate data management in all its forms, basing its supply chain security on machine learning, boosting marketing through automated campaigns, offering customer support through artificial intelligence services...
- b) **Data capture** is the collection of all types of unstructured and structured information and transforming it into data that is read by computers. When all the data that come from several various sources are merged and linked together, data integration phase is reached. This will help us analyse data to make conclusions based on the available information. Finally, when individuals and organizations make sense of the information transformed into data, sharing will help multiple applications and users improve the process and making it more accurate with getting more and more data.
In terms of territories, a lot of information and data could be generated. Based on the literature survey, a classification of data by the main themes and categories was done (see Table 1).
- c) **Intelligence:** After data is captured, integrated, analysed and shared, room is made for intelligence and technologies that could be used for decision making and optimising choices while simulating scenarios. The mock-up of the platform that is developed in this current work, relies on this principle.

Table 1. Territorial data classified by the main themes and categories

Energy	Environment	Transportation, flows & Mobility	Territory and demographic data
<ul style="list-style-type: none"> ▪ Geothermal Networks ▪ Energy potential ▪ Consumption and types of energy ▪ Electric charging stations ▪ Heat loss 	<ul style="list-style-type: none"> ▪ Water ▪ Weather ▪ Carbon footprint and gas emission ▪ Chemical compounds in air (acidification...) ▪ Water or soil ▪ Pollutants 	<ul style="list-style-type: none"> ▪ Flows of human mobility: transport ▪ Bio-waste flows ▪ Mobility of goods ▪ Raw materials ▪ New facilities ▪ Raw materials ▪ Manufactured goods ▪ Food waste flow ▪ Flow of recycling and repairs ▪ Waste stream 	<ul style="list-style-type: none"> ▪ Cadastral data ▪ Municipal Division ▪ Communal division ▪ Population density ▪ Household expenditure

3.2. Digital Tools

In the recent years, digital tools have been playing a key role in terms of transforming societies and business [20]. Digitization is a logical consequence of technological evolution and more particularly of the Internet and IT. It allows processes to gain in efficiency by integrating various digital tools to tradition operations [21]. In this section, the different technologies and digital tools are presented while distinguishing between the levels of operations they can be integrated in, i.e., data collection, data analytics, data integration (digital twins, artificial intelligence, machine learning) and data sharing.

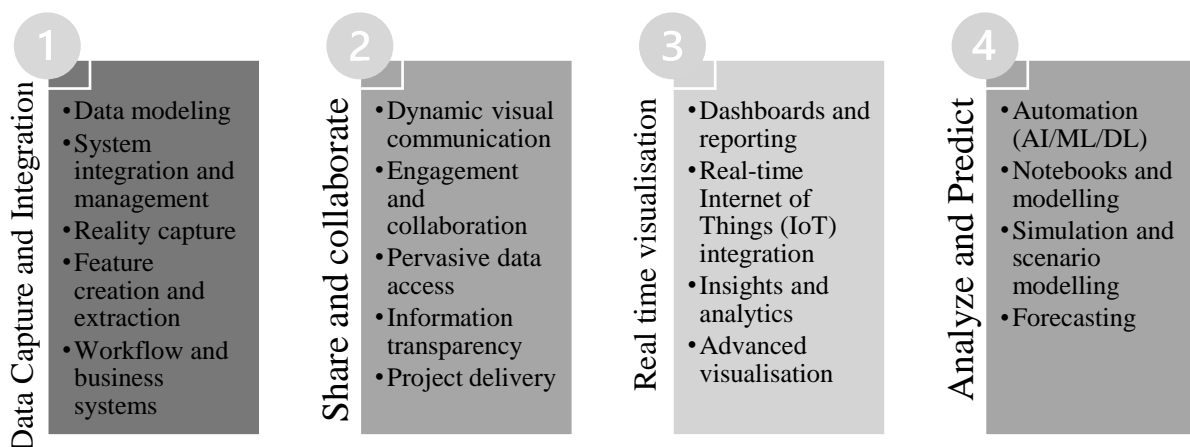
3.2.1 Data Collection: RFID, Sensors and Internet of Things

The RFID (Radio Frequency Identification) system offers the possibility of automatic management of the large amount of information to be processed. The equipment makes it possible to automatically synchronize the physical flows with the information flows. The term RFID encompasses all technologies that use radio waves to automatically identify objects or people. It is a technology that makes it possible to memorize and retrieve data remotely using a tag that emits radio waves [22]. The RFID system works as follows: The RFID tag is itself equipped with a chip connected to an antenna, the antenna allows the chip to transmit data (serial number, weight, etc.) which can be read using a transceiver reader. Once the information has been transmitted to the RFID reader - which is usually equipped with an antenna, - the radio waves are converted into data, read by RFID software [23].

RFID and sensors form an essential part in the field of Internet of Things known by IoT [22]. IoT is a computer concept that expresses the idea of various physical devices connected to the Internet and the ability of each device to identify itself to other devices. It is a virtual network that combines various things classified within electronics, software, sensors, and actuators and connects them via the Internet, which allows these things to exchange data with each other [24]. It is worth noting that the term “thing” on the Internet of Things is not limited to inanimate objects and small devices only, the “thing” may be a person carrying a heart rate monitor, for example, a child carrying a tracker, a car equipped with sensors, lighting systems in homes and shopping centres. The world of the Internet of Things is very complex and difficult to define in a specific sentence. On a technical level, it means the process of collecting huge amounts of random data from various things connected to the Internet, analysing it, and then predicting its behaviour in the future [25]. This includes many protocols (EPC C1G2) and programming languages (PHP).

3.2.2 Data integration and Digital Twins (DTs)

DTs elements are linked with data in several steps. However, since the main part is the integration of all the data in the system, DTs are presented in this section. DT is the replica of an object, a system, an implementation, or a process in digital form [26]. DTs have truly revolutionized the industrial world by changing not only the phase of product development or the use of equipment, but also large-scale project development such as territorial planification and infrastructure development. Before the emergence of the DT concept, a company physically created an object to subject it to a set of tests, make changes. With the DT, the data collected on the evolution of the object makes it possible to anticipate it and optimize its technological and sustainability performance [27]. The concept of DT was applied in several areas in order to model and simulate some problems. It was usually linked with IoT, AI and Industry 4.0 [28], [29]. Benefits of DT are many. Not only it improves the reliability of products, but once applied, it could improve the safety level, build consumer confidence and most essentially, reduce repair costs by anticipating future failures and risks. The way how organisations capture information, visualize and analyse data, and integrate them into systems and networks was enhanced and improved with the boom of DT. The following figure helps us visualise the several elements of DTs. Figure 3. Elements of Digital Twins



Since the study tackled the territorial aspect, in our case, the study presents a Geographic Information System (GIS) that will be the DT that will be created to integrate several models. GIS is a system designed to map, analyse, store, process, present and manage all types of geographic data that are mapped on different layers. For instance, it can display the territorial data (table 1), allowing people to see different data patterns and relationships [30]. Once these are visualized, organizations and public authorities can make better informed decisions based on analysis and predictions. This improves information sharing and collaboration across the various stakeholders [31]. For instance, agriculture, urban and town planning, oil spill, disaster management, mapping and navigation, business, marketing, and sales, are some of the several applications of the GIS.

3.2.3 Data Analytics: Big Data, AI and Machine Learning

- a) **Big data:** The arrival of big data is sometimes presented by many articles as a new technological revolution similar to the discovery of steam (early 19th century), electricity (late 19th century) and computing (late 19th century), qualify this phenomenon as the last stage of the third industrial revolution, which is in fact that of "information". In any case, big data is considered to be a source of profound upheaval in society [32]. Big data is a set or sets of data of various classifications that have unique characteristics (such as size, speed, diversity, variance, data validity). These characteristics cannot be efficiently processed using current and traditional technology to achieve benefit from it. The technological creations that have facilitated the arrival and growth of big data can broadly be categorized into two families: on the one hand, storage technologies, particularly driven by the deployment of cloud computing. On the other hand, the arrival of adjusted processing technologies, especially the development of new databases adapted to unstructured data and the development of high-performance computing methods. The 3V model shows the features of the big data and identifies the three main characteristics, i.e., Volume, Variety, and Velocity,: [33].
- b) **Artificial Intelligence and Machine Learning:** In order to process all the data more efficiently, an additional technological layer has been added to big data. This layer is called Artificial Intelligence (AI). To define it, we must first remember that today there are only weak AIs which are machines that reproduce human intelligence (without awareness of what they are doing) [34]. AI is hence a process of mimicking human intelligence that relies on the creation and application of algorithms executed in a dynamic computing environment. Other recent definition given for AI is the artifacts that detect situations and respond to those circumstances with actions [35]. Its purpose is to enable computers to think and act like human beings. Advances in deep learning (machine learning methods based on the learning of data models) have allowed AI to become an essential technology in data processing. AI and ML were shown to increase productivity and improve business processes at several levels [36].

3.2.4 Data Sharing: Cloud Technology, Cyber Systems and Supply Chain integration

Data sharing is the fact of making data used available to other and different users and stakeholders operating within the same perimeter, in a win-win logic. Data sharing requires rigorous supervision in order to avoid any risk of data leakage. This is where main technologies are deployed:

- a) **Cloud technology:** In cloud computing, companies no longer use their computer servers, but access online services from an infrastructure managed by the supplier. Applications and data are no longer on the local computer, but in a cloud made up of interconnected remote servers. This makes data sharing simpler.
- b) **Cyber Systems:** In parallel, in the same context of data sharing, a cyber-physical system is a system where computer elements collaborate for the control and command of physical entities in a high level of security.
- c) **Supply Chain integration:** Moreover, one main application of collaboration and data sharing is the supply chain integration where businesses are linked together by sharing their data and using it. Data sharing sometimes takes the form of a partnership between two companies that offer complementary but non-competitive products or services, for example, a tour operator and a transport company.

3.3. Data and the emergence of smart sustainable territories

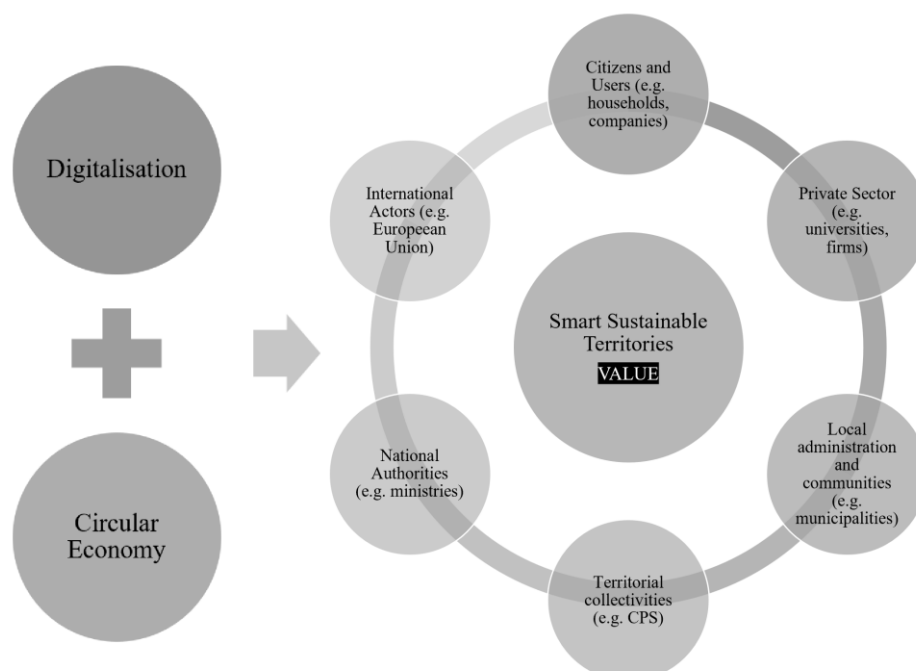
The following table illustrates the potential use and application of the main digital tools on a territory. Concrete and tangible examples for each item are listed. These digital tools are inter-connected since after data is collected, it is integrated and combined to be analysed. After these steps, sharing could happen between the several stakeholders to reach common results. To conclude, when combining these main technologies and digital tools together with the commonly used tools such as LPWAN, Wi-Fi, fibre network, and 5G. Moreover, smart circular object and supply chain integration accompanied with cyber-security strategies will play a huge impact on businesses and societies in general.

Table 2. Application of main digital tools on a territory

	Digital tools	Applications or territories
Data Collection	<ul style="list-style-type: none"> ▪ RFID ▪ Sensors ▪ Internet of Things 	<ul style="list-style-type: none"> ▪ Track mobility and transportation of goods and people. ▪ Measure the energy consumption. ▪ Inventory management. ▪ Waste and recycling rate.
Data Integration	<ul style="list-style-type: none"> ▪ Digital twins ▪ Data systems 	<ul style="list-style-type: none"> ▪ Visual representation of data on maps. ▪ Virtual replica of a territory. ▪ Assess renewable energy potential such as solar irradiation potential of buildings.
Data Analytics	<ul style="list-style-type: none"> ▪ Big data ▪ Artificial Intelligence ▪ Machine learning 	<ul style="list-style-type: none"> ▪ Reuse and recycling parameters (efficiency, rate) ▪ Optimisation of circular supply chain performance ▪ Monitoring of circularity indicators ▪ Increase automation, autonomous connected vehicles, collaborative robots, ▪ Global pollution control
Data Sharing	<ul style="list-style-type: none"> ▪ Cloud Technology ▪ Cyber-physical Systems ▪ Supply Chain integration 	<ul style="list-style-type: none"> ▪ Information transparency. ▪ Integration of capabilities. ▪ Share information and enhance collaboration. ▪ Deployment model in which the hosting and all the processing carried out on data by a cloud service are physically carried out within the limits of the territory.

Once we apply digitalisation for the territory and we reach the CE, we can talk about Smart Sustainable Territories (SST) that merge the idea of smart territories with the idea of sustainability and CE. “Coupling”, a term in computer science that describes the automatic exchange of information between software components was used to describe the interaction that could be done between LCA and GIS [37], we extend this idea and make the coupling between digitalization in general and CE. Value can be captured for SSTs by linking the several stakeholders together. Services offered through data sharing could be used by several actors at different scales as shown in the following figure.

Figure 4. Value created when digitalisation and CE are applied towards Smart Sustainable Territories



3.4. Integrating data: The platform's mockup

This research and work were done in order to be implemented for the Communauté d'Agglomération de Paris-Saclay. As developed in the previous section, data is integrated and exploited through digitalisation for a circular economy of the territory. In this section, a recap of the actual state and already existing platforms is presented. Then, the model created and developed in a group project of several master's students is briefly presented through the MERISE Methodology.

3.4.1. Actual State

In this case study of the CPS and for any other territory that wishes to develop the circular economy, it is crucial to know all these data through regional platform tools that go beyond the quantification of mass. In 2013, the Environmental Conference encouraged the Regions to develop flow knowledge platforms in order to visualize the progress gap between low and high performance in the use of resources mobilized in the territories while producing knowledge and the governance of these flows. This following table represents the main existing platforms at CPS and their characteristics.

Table 3. Recap of Existing Platforms

Platform	Created	Goal	Pros	Cons
Cartoviz	By ESRI France, in 2017	Identification and Visualization of Data	GIS, Data shown, Maps downloaded and printed	No superposition and links between Data
SIOM Direct	By SIOM, in 2019	Waste Management	Communication	No filter of information
OPALIS	By ROTOR, in 2017	Professional operators and sellers of deconstruction materials	Information of waste management	Lack of geographic information
ACTIF	By CCI Occitanie, in 2016	Identification and Matching for a recovery of waste from companies	Visualisation of companies on a map	Lack of alimentation of information
ECLIPSE	By Orée, in 2016	Evaluation of performance of ecology and territorial strategies	3 users' interface: visitor, animator and observator	Only addressed to EIT and professionals. Inscription required.
INEX Circular	By Inex Circular, in 2017	Characterization of actors and resources of a territory through AI	Complete service, cost anticipating	Paid, focuses mostly on companies
Info Chantiers	By Université Paris-Saclay, in 2017	List of worksite activities	Open source and calque system	Update of information, verification to be done
System X	By Institut de Recherche Technologique	Merging, visualising and analysing heterogeneous data, focusing on Energy	Simulating Strategies	Not exhaustive
Decarbonized City	By CosmoTech	Energy Planning	Territorial Data and Digital Twin	Covers on aspect
Cartofiches	By the French Government	Wastelands information (industrial, commercial, residential)	Official sources	Limited for data
Plateforme maMob'	By the Agglomération Paris-Saclay	Transportation and mobility	Information from the community itself	Still need more development
Data Enedis	By Enedis	Consult and compare data on the themes of Electricity Production and Consumption with the geographical mesh	Territorial aspect: municipalities, departments and regions...	Only one aspect is tackled: the electricity

As represented in the tables, the platforms are many. A single platform that joins and regroups all the information and data and helps in the decision making is not available. However, in order to reach circular economy for a territory, the several factors and data should be combined and studies together. Another issue is that the different stakeholders should interact together and be able to visualise and analyse real time data.

3.4.2 The Proposed Platform - Future State

Having a systemic view of data sets allows all actors and stakeholders to have an alignment on the current state of organizational systems and makes room for improvement. Therefore, a complete, clear and centralized visualization would allow all stakeholders to align themselves on a common language. The challenge of this data centralization tool is to make complexity intelligible.

It merges flows, information and data into a digital twin and a GIS where several technologies were deployed in the model. The goal is to create a tool for simulating decision-making scenarios. It focuses on the principle of interoperability. This is illustrated in figure 5.

The mock-up of the platform is developed by highlighting the main ideas behind its design, showing its main representation, and presenting its functional diagram, and architecture. This would be a tool offered for the CPS as a solution for their needs. Future work could consist of developing the whole platform by following the requirements needed.

The mock-up platform is created following the MERISE methodology.

- a) The manual information system is the fact of collecting all the data and information available on the territory (through RFID and technologies mentioned), as well as the various available flows.
- b) The expression of needs was done by CPS. Creating a circular economy development tool that would include the flows of the territory and develop a decision support tool to reduce the impact of activities on CPS. This platform could: (i) Collect data. (ii) Measure/visualize (raw data). (iii) Build and understand (indicators). (iv) Compare and interpret. (v) Track and predict. (vi) Analyse the causes. (vii) Set targets. (viii) Define actions. (viii) Propose action plans. (x) Simulate action plans. (xi) Decide on, recommend/optimize action plans. (xii) Follow action plans. (xiii) Assess business performance. (xix) Evaluate citizen/user performance.
- c) The conceptual model is the mock-up of the platform created that helps the users visualise data, and flows, and focus on simulation of scenarios with the evaluation based on the indicators. The platform interface is made up of several panels and bars organized around a workspace, in order to make the interface ergonomic. The interface is made up of 4 main areas:
 - **The menu bar:** through which you access the tool and the type of indicators you want to apply.
 - **The toolbar:** offers the navigation tools needed to select and move around the interface. It also includes the functions that allow you to print, save, choose (decision support) an optimal simulation. –
 - **The space or viewing area:** on which the different layers of data corresponding to the panes are visible. The data related to the sectors, actors and flows are based on historical data of the territory while the last layer makes it possible to illustrate the simulations on data which can be speculative. It is possible to switch each space in satellite view, or in Data view (3D elevation) according to the desires of the users. There is a modularity of the visualization to visualize the data in different dimensions.

Figure 5. The platform: A digital twin for the territory.

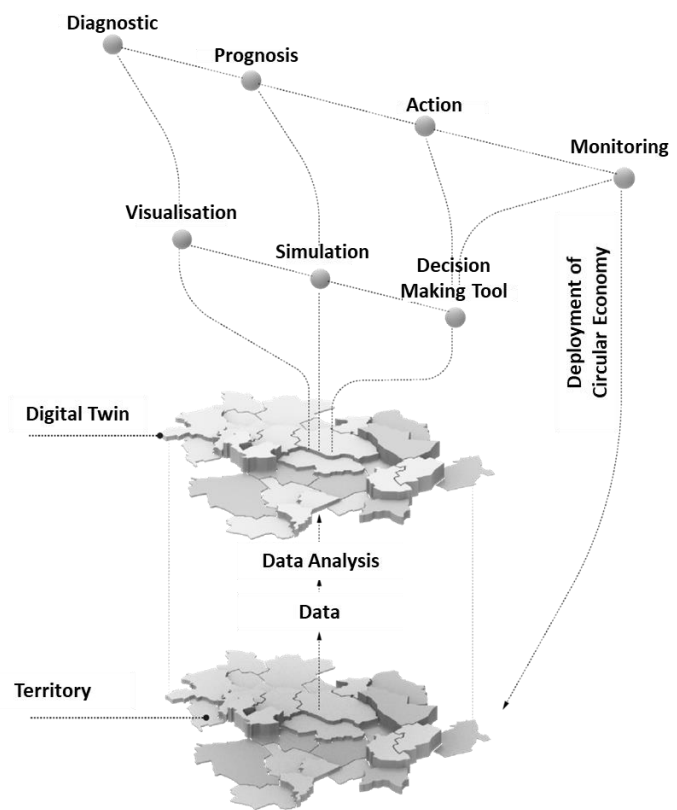


Figure 6. Platform main representation

- **The filters panel:** allows to focus on specific, temporal, geographical, text or informative data. Applying a filter on one or more data makes it possible to target information and generate data combinations. This panel has 4 panes: (i) "Sectors - Territories" which offer different cartographic views according to cadastral data, minimum distances, partnership zones... (ii) "Stakeholders - Activities" which offers the different views of CE stakeholders and the different activities of recovery, recycling, repair, reuse. (iii) "Flows" which allows you to filter the different data concerning the waste streams, available, recovered, collected, etc. on the territory according to the selected actors. (iv). "Simulation" which allows testing of data hypotheses through interactive graphs. All sections have their circularity indicators. The indicators are on the scale of the territory, but also on the scale of the actors, and flows.



Adding multi scales data, combining them, visualising them and generating scenarios for getting help in decision making is the main objective of the platform. The scenarios are evaluated and compared. Other than the cost estimation, indicators for evaluation of Circular Economy could be used. An inventory of the latter was done by the Organisation for Economic Co-operation and Development [38]. Impacts of a solution could be evaluated by checking the impact that generates ecological damage (e.g., Climate change and the greenhouse effect, acidification), the impact that generates health damage (e.g., Radiation) and the impact that generates a decrease in resources (e.g., depletion of natural resources, energy consumption.)

d) The logical model and the platform programming are out of the scope of this project. This could be done after the full validation and the decision to implement the project. However, the functional diagram and the architecture of the platform show that the main part of the tool is the data that we identified and collected in previous sections. Not only they are visualized on this platform, but they are interpreted and analysed to create simulations where stakeholders can compare and test hypothesis to visualize their impact on the territory. Results would then be shared for the several actors of the CPS. The later will be working on a common cloud. This could enhance alimentation, maintenance, verification and use of the information and data present.

Figure 7. Architecture of the Platform

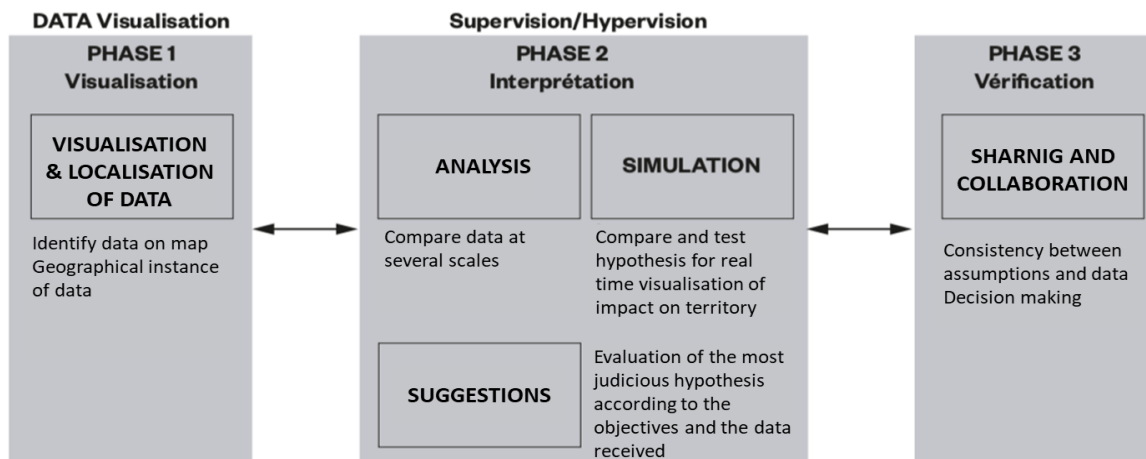
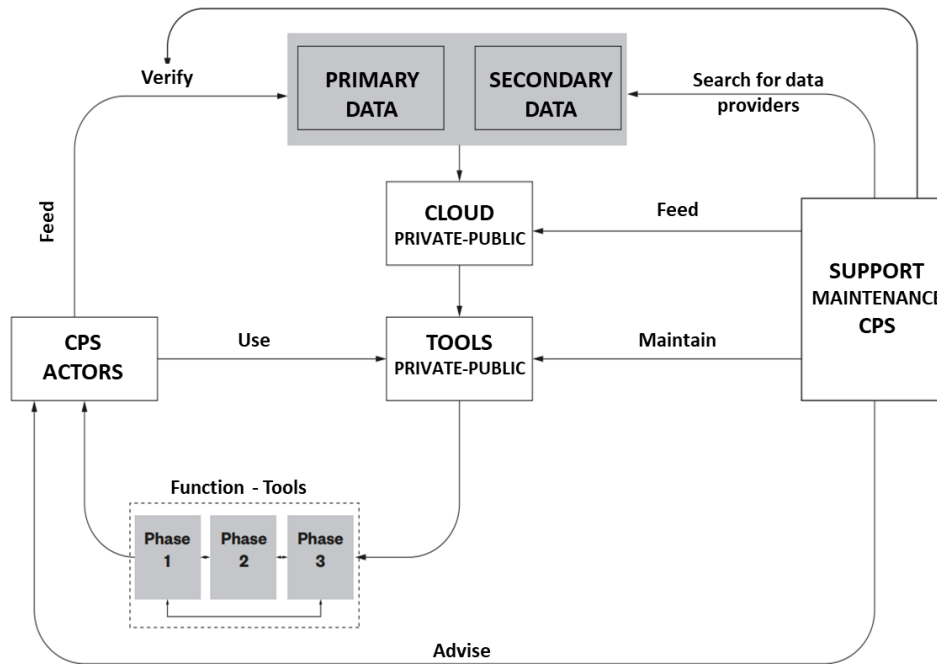


Figure 8. Functional Diagram



3.4.3. Applications and Scenarios

To better understand the principles and make the ideas more practical and pragmatic, some use cases are developed in this section. Five different ways of applications are presented through scenarios.

Scenario 1: A year and a half ago, the SIOM opened the yellow bins to a lot of other waste, the problem is that there are a lot of sorting errors, and the collection trucks no longer make suitable routes: there is an excess of empty trucks, transport is inoperative.

The platform would be useful for citizens who want to have better support on sorting in order to limit waste, do better sorting. The platform would also be useful for rippers so they can see the filling rate of the bins and find the best route to collect the waste without spending too much energy.

The SIOM and the CPS deploy connected trash cans that allow visualizing and hence monitoring the filling rate. This optimized collection rounds and helped with decision-making, especially in terms of adding or removing containers.

Scenario 2: A young entrepreneur wants to develop an activity in the territory that will allow the recycling of a certain number of waste streams. However, he does not know if his upgrading activity will help create or maintain jobs. The platform would be useful for companies. It would make it possible to assess the costs of setting up and the upgrading activity that has the most potential in order to be able to generate an activity that can create jobs. The platform indicates the upgrading activities present in the territory and highlights the activities as well as the flows thanks to this representation it is easy to represent the potential deposit and thus the deployment of one or more revaluation activities. Through the platform, CPS can guarantee the homogeneity of the data.

Scenario 3: A company is managing a destruction site in Saclay. Usually, people do not want to buy back the lumber that was salvaged, but since the company does not have any storage space, it has to get rid of it quickly. The platform would be useful to find a buyer as soon as possible. It would also allow the company to post an ad thanks to its “matching” viewing mode. It would also make it possible to find resource centres or other recovery companies that could recover them. Through the directory and waste filters in the platform this could be achieved.

Scenario 4: In Courtabœuf area, a company wishes to enrol in an industrial and territorial ecology approach, but the decision makers do not know the maturity of the company compared to other companies or even the potential they could have. The platform would be useful to assess the maturity

according to an indicator sheet to be completed. It would also make it possible to visualize potential partners to limit the loss of value and why not generate gains. It would make it possible to observe the interactions that already exist as well as their density. Through the platform, visualization of potential actors could be done.

Scenario 5: A facilitator wants to identify a potential company to join the symbiosis. He realises that he is one of the missing resource players within the ecosystem, but he does not know which company could join us. The directory platform categorizes the companies and offers sufficient detail of the companies so that the facilitator can decide on the best decision by coming into direct contact with the subjects. This could be done through the visualization and the monitoring of the actors on the platform.

4 CONCLUSION

Conceived as an operational approach to managing the resources of a territory in a loop, circular economy requires a sufficient knowledge on the resources flows and actors as well as their connectivity. In parallel, the shift to digitization concerns all territories and public authorities are challenged by a growing need for data and digital tools. The territorial actors have many assets to take the initiative on these subjects. They will be able to take advantage of the rapid coverage of the territory through networks. This will help them integrate a logic of connected objects and data collection. This research work contributes to the exploration of these concepts and proposed some avenues for research on the issues of the territorialization of CE through digitalisation. Based on a SLR, this work answered the main research question by providing a model, a concept and then a mock-up of a platform that could be used by a public or private territorial actor that acts as a decision-maker.

In fact, if the value of accumulated information is generated in the data economy model, digital technologies are needed to handle this data. The main tools technologies that support and accelerate the circular economy transition were found to be RFID and sensors, and IoT for the data collection, digital twins for the data integration, big data, AI and machine learning for the data analytics, and cloud technology, cyber systems and SC integration for the data sharing. Digital tools were found to be a momentum for the transition towards territorial circularity. Examples and applications of the digital tools and their effect on the CE of the territories were developed. Hence, digitalisation and CE for Smart Sustainable Territories were followed by a model of the infrastructure of a Smart Sustainable Territory.

In parallel, in order to fill the gap of the actual state where several non-sufficient initiatives are created, a mock-up of a platform having centralized visualization is presented. This would allow all stakeholders to align themselves on a common language. Through MERISE methodology, adding multi scales data, combining them, visualising them and generating scenarios for getting help in decision making is the main objective of the platform would be possible. A territorial actor like the CPS, would be interested in establishing strategies, making decisions, and simulating scenarios based on data like the flows of household and green waste, the mobility of people and the energy consumption. All over this study, a roadmap was proposed, the main titles were established. Accordingly, the territorial digital platform could be developed. Based on the created model, territorial actors could tackle on several challenges and cross the limitations that existed.

Finally, the mock-up done, confirms that, indeed, digitalization and data deployed for the various circular economy approaches make it possible to reduce the production of waste and better use of resources, which meets the initial objectives. One of the contributions of the CE, is the collaboration of the various actors of the territory. Whether at the level of communities and companies for industrial and territorial ecology approaches, or between citizens and communities for the functional economy, there is a need for knowledge of the specific needs of the people involved. Understanding each other not only makes it possible to pool skills and resources, but also to create relationships of trust. These links thus created are necessary both for the sustainability of the projects but also to stimulate new dynamics of collaboration that can give rise to other innovations. Hence, if other researchers came up with several alternatives, these remains to be converged towards a common goal via a common tool. A roadmap was presented here. Even though MERISE method is not new, its

capacity to understand the background and define the needs, while including and embracing all of them, makes it interesting. Remains to be seen what actors on the CPS are ready for the collaboration and for the development of the platform.

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