cities2030

D6.7 S2CP Final Report

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WP leader	UPM (P20)
WP co-leader	WIT (21)
Contributors and authors	SINNO(P19): Alejo Arias, Daniel Molina UPM (P20): Borja Bordel, Ramón Alcarria, Tomás Robles, Miguel Manso, Alejandro Leo ITC (P30): Tomaz Zadravec, Tomaz Bokan, Daniel Copot UNIL (P35): Aurel Machalek PRIM (P37): Pedro Caridade
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Abstract	This deliverable (D6.7, M48) describes the final version of the S2CP platform as the main outcome of WP6. The work methodology proposed in Task 6.1 is updated by including details of the last two phases (component

[1] R: document, report (excluding the periodic and final reports); DEM: Demonstrator, pilot, prototype, plan designs; DEC: websites, patents filing, press & media actions, videos, etc.; OTHER: software, technical diagram, etc.

	development and experimentation). A final version of the functional architecture of the solution is provided as well as the set of components that have been developed. In addition, the indicators co-defined in the framework of Task T3.7(D3.8) are reviewed and it is verified that the final levels show notable performance of the created platform. Deliverable D6.7 describes in detail the design and implementation decisions of each of the S2CP components and emphasizes the validation activities of these components. The integration of security functions and a user manual are shown in Annexes I and II.
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Legislation

Legislation H2020 Framework Programme – Regulation (EU) No 1291/2013 of the European Parliament and of the Council of 11 December 2013 establishing Horizon 2020 – The Framework Programme for Research and Innovation (2014-2020) (OJ 347, 20.12.2013, p. 104).

Euratom Research and Training Programme (2014-2018) – Council Regulation (Euratom) No 1314/2013 of 16 December 2013 on the Research and Training Programme of the European Atomic Energy Community (2014-2018) complementing the Horizon 2020 – The Framework Programme for Research and Innovation (OJ L 347, 20.12.2013, p. 948).

H2020 Specific Programme – Council Decision 2013/743/EU of 3 December 2013 establishing the Specific Programme Implementing Horizon 2020 – The Framework Programme for Research and Innovation (2014-2020) (OJ L 347, 20.12.2013, p. 965).

Rules for Participation (RfP) – Regulation (EU) No 1290/2013 of the European Parliament and of the Council of 11 of December 2013 laying down the rules for the participation and dissemination in Horizon 2020 – the Framework Programme for Research and Innovation (2014-2020) (OJ L 347, 20.12.2013, p.81).

Financial Regulation (FR) – Regulation (EC, Euratom) No 966/2012 of the European Parliament and of the Council of 25 October 2012 on the financial rules applicable to the general budget of the European Union (OJ L 298, 26.10.2012, p.1).

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Document history

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0.3	08/12/2024	Methodology	UPM	Drafted
0.4	08/31/2024	Main sections contributed by all partners	All partners	Drafted
0.9	09/09/2024	Draft final version	UPM	Drafted
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1.0	27/09/2024	PMO layout check and submission on SEDIA portal	P02 EPC	Completed

[2] As per the project's cloud storage if applicable, or per email date if applicable

[3] Drafted, completed or validated

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Glossary and abbreviations

AI	Artificial Intelligence
ANN	Artificial Neural Network
API	Application Programming Interface
BC	Blockchain
CI/CD	Continuous Integration and Continuous Delivery
CKAN	Comprehensive Knowledge Archive Network
CPU	Central Processing Unit
CRFS	City-Region Food Systems
CSV	Comma-Separated Values
D6.7	Deliverable 6.7
DNS	Domain Name System
GIS	Geographic Information System
HTTP	Hypertext Transfer Protocol
JSON	JavaScript Object Notation
JWT	JSON Web Token
KPI	Key Performance Indicators
MAA	Multi-Actor Approach
NLP	Natural Language Processing
No-SQL	Not only SQL (Structured Query Language)
OGC	Open Geospatial Consortium
OSM	Open Street Maps
REST	Representational State Transfer
SSL	Secure Sockets Layer
SSRI	Social Space for Research and Innovation
WFS	Web Feature Service
WMS	Web Map Service

WP6	Work Package 6
XLSX	Excel Spreadsheet (+XML)
XML	eXtensible Markup Language

1 Introduction

In this first section we analyze the context of Document D6.7 and describe its structure. We focus especially on the relationship of this document with the rest of the work packages and tasks of the Cities2030 project. This document is the main result of the WP6 for the period between M24 and M48 and aims to present the development and testing efforts regarding the S2CP digital platform. As well as analyzing the impact success of the delivered tools.

1.1 Short description of the CITIES 2030 project

The main goal of CITIES2030 is to create a future proof and effective UFSE via a connected structure centered in the citizen, built on trust, with partners encompassing the entire UFSE. CITIES2030 commit to work towards the transformation and restructuring of the way systems produce, transport and supply, recycle and reuse food in the 21st century. CITIES2030 vision is to connect short food supply chains, gathering cities and regions, consumers, strategic and complement industry partners, the civil society, promising start-ups and enterprises, innovators and visionary thinkers, leading universities and research across the vast diversity of disciplines addressing UFSE, including food science, social science and big data.

1.2 Short description of the WP6 Package

This work package will gather, design, and develop the main components and technological tools to establish a data-driven CRFS management platform for data collection, analysis and representation in multiple interfaces. An initial requirement acquisition will lead to the proposal of a common technical architecture for CITIES2030, for with supporting data set will be incorporated to be considered for data analysis and representation. Particularly, a service-based open collaboration space will be incorporated, to be used by CITIES2030 participants to improve their multistakeholder dialogue processes. In this space, blockchain technology will be employed to provide some proof of concepts of token-based monetization processes, and reflect multi-stakeholder interaction in a reliable and transparent way. Documentation and software repositories will be available for policy labs and living labs to develop their own solutions with assistance from WP6.

1.3 Purpose of D6.7 Report

The objective of document D6.7 is to introduce in a structured way the S2CP platform, as well as all their components and subsystems. Together with the final report for the KPI framework developed in task T3.7. Descriptions include a global overview of the architecture and a review of all previously delivered component (within the period M1 to M24).

Components are described with details, including those that have been developed from scratch, and those which are advanced versions of previously reported tools. We are focusing, besides, on the Scrum phase of the CDM methodology (see D6.1) guiding the entire S2CP development. In the Scrum phase, evaluation and product delivery are the most critical and essential tasks. Actions such as workshops, transference seminars and festivals are described, showing the impact and success of all planned and developed tools.

1.4 Relation of the Report with other WPs and deliverables

This deliverable has a direct relationship with WP6 and in particular with task T6.1 "Requirements and reference architecture" which will provide the CITIES2030 technical architecture, based on the experiences of participants from previous project platforms and compatible with other already established ecosystems. In this document we can find, finally, the technical report with all the implementations matching the original design and architecture described in T6.1. This document, moreover, can be understood as a closure report for documents D6.2, D6.3, D6.4 and D6.5. Those documents reported the technical works in the corresponding tasks, for the period M1 – M24. In this D6.7 document we are aggregating all the final reports for all those tasks in the period M24 – M48.

On the other hand, D6.7 is closely related to WP5. Specifically with Phase#3 "Experiments", described in the work methodology reported in D5.2. Living labs experiments were the usual frame for workshops and seminars, where the impact and usability of the S2CP tools were tested. Results were measured and fed the Scrum cycle in the CDM methodology.

Finally, regarding WP7, many tools and components identified in T6.1, developed in WP6 and reported in D6.7 have been employed as dissemination instruments and solutions to communicate the project results to stakeholders and society.

1.5 Deliverable 6.7 structure

The structure of this deliverable is as follows:

Section 2 describes the work and development methodology, but with an especial focus on the phases and actions taken during the period M24 – M48. Specifically, the CDM methodology described in D6.1 included three different stages and three development macrocycles. In previous documents, the first stage and the first macrocycle were described with details. As well as some aspects of the second macrocycle. In section 2, then we are focusing on the third stage: SCRUM, which includes the validation and productization actions.

Section 3 reviews the general architecture, proposed for the S2CP platform. This includes the original design described in D6.1, together with the small changes or adjustments caused by the different development macrocycles, where the users' needs are reevaluated and validated. All the components and subsystems in the platform are identified, with a special focus on its maturity level. Those components whose development was concluded in the period M1 – M24, and were reported in D6.2, D6.3, D6.4 and D6.5 are just briefly reviewed. While the rest of the document is aimed to report the works on the remaining components and subsystems.

Section 4 introduces, again, the KPI framework developed in Task T3.7, and reported in D3.8. This framework reflects the need and requirements of labs, Cities2030 users and stakeholders, and it was designed as an instrument to measure the impact of the S2CP platform. In document D6.1 it was reported the evolution of these KPI until M24. In section 4 we describe the final state and fulfillment of all these indicators by the end of the project.

Before describing with details all the components and tools developed, enhanced or validated in the period M24 – M48, in Section 5 we do a short review of all those components that were finalized before M24 and that were reported in documents D6.2, D6.3, D6.4 and D6.5. This includes components such as the sentiment analysis tool, the conformal learning platform or the confidential communications (privately) tool. The following section are finally dedicated to technical works in the period M24 – M48.

Section 6 presents a new component, developed from scratch in the period M24 – M48: the data mining component. This component is developed in the context of task T6.2 and offer to the labs a platform to really understand the opinions and evolution of users and stakeholders' thoughts about each CRFS in Cities2030 project.

Additionally, in Section 7, we introduce the S2CP data repository. This ecosystem allows Cities2030 participant to upload and share with all the society their open data and results from the project. The platform is open to all partners, so they can share the more appropriate data. There is a different space for each lab and partner. With this component all works in T6.2 are completed, and we align the Cities2030 project with the Open Research Data Pilot (ORDP)[4].

Section 8 introduces the real-time monitoring component. This component, developed from scratch in the period M24 – M48, provides a system for receiving events produced by sensors. This S2CP component can collect information generated in a city, farm or other food-related organization, so that information can be later represented for real-time visualization or monetization. The output of this component is a database containing all captured real-time information, expressed in a semantic and interoperable format (according to data models defined in T6.2), and also a visualization dashboard to facilitate date visualization, filtering and some

Section 9 describes the new development and enhancing effort on the Cities2030 Community component. This component aims to generate a communication space between the participants in the project and society. For this, the space includes customizable information (such as the lab space).

In Section 10, the Good Practices component, whose purpose is the dissemination and publicity of the good practices collected and developed in the context of the Cities2030 project, is revisited with a special interest on the new information and functionalities. The component is based on a web catalogue, whose edition can be collaborative among all the members of the project.

Section 11 is dedicated to the Spaces for Research and Innovation - Multi-actor Approach (SSRI-MAA) tool. A platform for managing innovation, experiments, and KPIs. It is focused on providing the different Labs that participate in the project with an ecosystem for the monitoring and follow-up of their innovation processes, with special attention to the measurement and follow-up of the indicators of success they have defined. The initial development was described in D6.3, but in this new document a full technical view, and evaluation with users, is provided.

Section 12 is dedicated to describing the implementation of a marketplace of the agri-food value chain: Blockchain for Short Food Supply Chains (SFSC). The platform handles data from different transactions developed at Urban Food System Environments (UFSE) and provides some proof of concept of token-based monetization processes, in a reliable and transparent way. In this section, we focus on the new functionalities and validation efforts developed in the period M24 – M48, as the initial technical descriptions were reported in D6.3.

Section 13 describes the Geospatial services component for the Cities2030 labs and the follower cities, from a technological point of view. This component, which includes two subcomponents, is employed as an engagement instrument for follower cities, and it is based on state-of-the-art technologies and common and standardized application interfaces in commercial products and in the world of research. This component shows the geographical distribution of the different agents throughout the different CRFS on a map system, helping follower cities to get a valuable service from Cities2030 project and improving their engagement. Section 13.1 focuses on the development of the solution, while Section 13.2 focuses on component validation through integration with S23CP platform and provision of Citeis2030 data.

Section 14 provides a detailed technical description of the operation of a Blockchain-enabled digital twin for the short supply chains within a CRFS. This twin helps users to understand all the processes involved and

[4] ORDP – OpenAIRE: https://www.openaire.eu/what-is-the-open-research-data-pilot

affecting the food handling in the region, as well as it offers an approach to its operation from the point of view of the end users.

In Section 15, we describe the new functionalities and validations regarding the S2CP dashboard (see document D6.5). This section is focused on user experience design (UX), developing an adaptive dashboard capable of integrating different web and mobile interfaces to serve as decision support systems in CITIES2030. The living and policy labs used this environment to compare the results of applying different processes or techniques to their data, and to monitor the performance of their solutions.

Finally, in Section 16, the conclusions of the document and future lines of work are presented.

As additional content, the Annexes I and II contain the user and integration manuals developed in the context of the task and delivered to end users to help integrate and transfer the technologies developed, according to the workshops carried out.

1.6 Roles and responsibilities

Lead partner UPM (P20) coordinates the activities, provide guidance, steer implementation and secure alignment, implement activities to deliver planned outcomes.

The rest of task participants: WIT(P21), Uni.lu (P35), ITC (P30), PRIM (P37) and SINNO(P19) develop the task simultaneously at EU level and beyond and contribute to the focus group.

2 CDM methodology for the final deployment and testing of the S2CP platform

The objective of S2CP platform is the provision of technological solutions to increase the collaboration between Cities2030 actors and improve the performance and precision in the decision making. For this, a set of technological components capable of providing users with the required services was designed and implemented. To carry out the implementation tasks, each one of the identified components was led by one of the members of the WP6. A joint meeting will be held every two weeks (or every four weeks, depending on the project's needs), in which the status of the developments were reviewed, those issues that must be transversal to the entire work package were harmonized, and the agenda for the next period was proposed. The following table shows those responsible for each one of the components that are part of the S2CP platform[5].

[5] The order of appearance of these components in the deliverable D6.7 does not meet any reason of relevance, development maturity or frequency of use by the Labs.

Table 1. S2CP Component and responsible partner in WP6

Component	Geospatial services	Cities2030 community	Good practices	Multi-actor approach tool	Blockchain enabled marketplace for SFSC	Blockchain enabled digital twin	Real-time monitoring
Responsible	UPM	UPM	UPM	SINNO	ITC	UNIL	UPM
Component	**S2CP dashboard**	**S2CP data repository**	**Data mining component**	**Private Communications**	**Sentiment analysis**	**Data integration and Management**	
Responsible	PRIM	UPM	UPM	UPM	UPM	WIT	

The components were developed in parallel, with several development cycles in accordance with the CDM methodology and the schedule planned for WP6 (described in D6.1). For the period M24 - M48, the CDM methodology stablishes the SCRUM phase is the most important and critical. Components, and this point, have a high technical maturity level, but validations and experiments with users are required to conclude the usability of the tools and complete their transference to the labs. In order to achieve the planned Development Objectives within the established times, the CDM methodology was structured in three basic phases that we briefly describe in the following subsections:

2.1 First phase

In the first phase, different actions are taken depending on the maturity level of the component.

For those components whose development was started from scratch, the requirements captured in T6.1 are considered to proceed with the specific design. The requirements identified within the general architecture (see D6.1) were analyzed among all the members in WP6 in order to identify, on the one hand, the software elements to be implemented, as well as their interrelationships, and on the other hand, the application interfaces to be integrated to allow the interaction with users and stakeholders.

But, for those components whose development was already initiated in the period M24 – M48, in this first phase, all the members in WP6 analyzed the results and reports form the workshops and seminars with users (see Section 2.2 in document D6.3). This feedback is part of the SCRUM phase in the CDM methodology and indicates the starting point for a new development and refinement macrocycle.

Section 3 offers and general view of the full S2CP architecture including all the components already released, the enhanced components and the newly developed tools.

2.2 Second phase

In the second phase, development work continues (or starts, depending on the components under consideration) in accordance with the general CDM methodology. To this end, an agile development scheme was followed (specifically Scrum methodology was mainly employed, as described in CDM methodology), in which Labs were interacted with on a regular basis, either through specific workshops for the general public or through individualized and personalized bilateral training meetings for each of the Labs.

As it was planned in the WP6 schedule, many workshops have been held with Labs. These workshops are the following:

- "Analyse your Lab with data". 23rd February 2023
- "S2CP Dashboard". 23rd February 2023
- "MAA Tool Workshop". 23rd February 2023
- "Arganda Lab and S2CP". 23rd de February 2023
- "Data in Cities2030". 25th January 2024
- "Demonstration of blockchain marketplace and digital twin". 20th June 2024
- "Measure the engagement and representativeness of the stakeholders in my Living Lab". 20th June 2024
- "Data mining for living labs and community platform". 20th June 2024
- "Blockchain-enabled marketplace. A use case". 26th September 2024.

Additionally, many bilateral meetings were held with Labs to help them adopt the technological tools. Without providing an exhaustive list of said meetings due to their high number, we would highlight the following:

- "Blockchain tools in Quart de Poblet". 30th May 2023
- "Blockchain-enabled marketplace in Latvia". 27th March 2023
- "Blockchain-enabled tools in Croatia". 15th February 2024

Sections from section 6 to section 15 offers a detailed description of all software developments.

2.3 Third phase and summary

Finally, once the final components are released, they are made publicly available to the entire consortium through the Cities2030 project website. In addition, specific user manuals for each of the components were made available to all Labs (see document D6.3 and document D6.5). The impact of the technology transference is analyzed in Section 4.

The following figure represents the methodology followed in WP6 for the period M24 – M48 and its relationship with the different sections of this document.

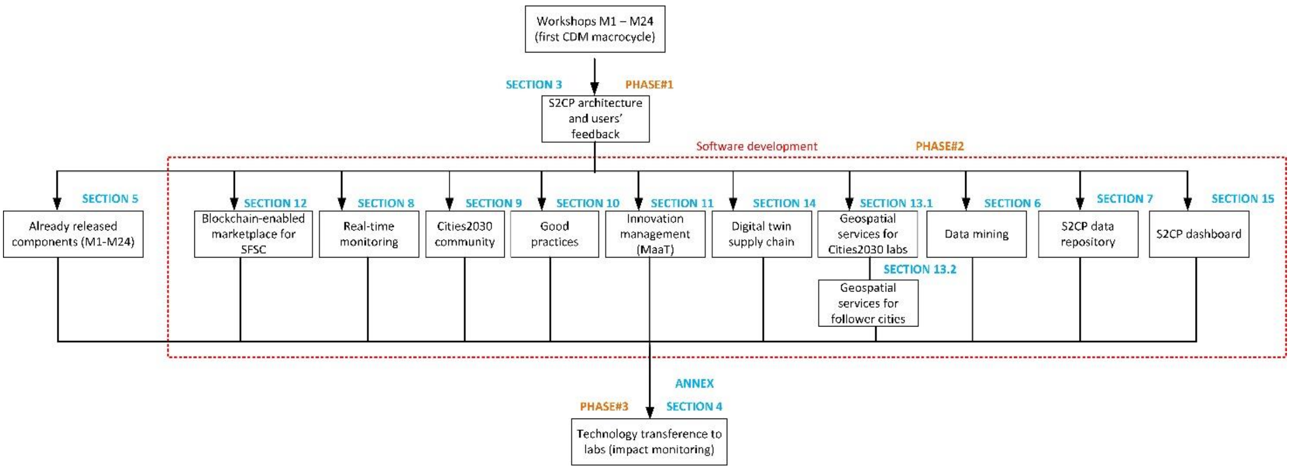


Figure 1. Relation between the work methodology and the deliverable structure

3 General architecture: final subsystems and components

The S2CP platform follows a component-based architecture, as can be seen in the figure below:

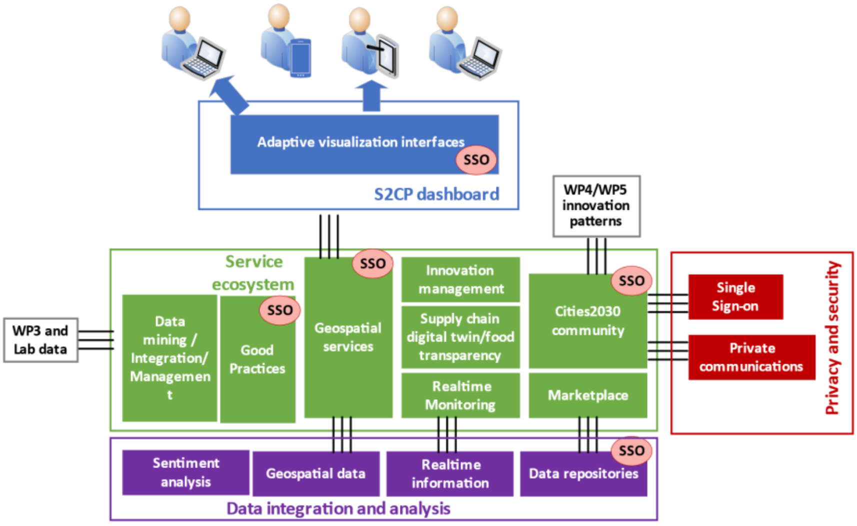


Figure 2. Component-based architecture of the S2CP platform

Each component was defined as an independent software unit, although all components may share common mechanisms that facilitate their use by Labs, such as a registration and login service with the same credentials (SSO).

The S2CP platform defines 13 components. From those, 3 components were previously released during the period M1 – M24 of the Cities2030 project (see Section 3.1); while the remaining 10 components have been developed from scratch (see Section 3.2) or highly enhanced (see Section 3.3) during the second half of the project. Additionally, the main shared mechanisms for all the components across the S2CP are described as well (see Section 3.4).

3.1 Previously released components: general overview

Three are the components that were released during the period M1 – M24, and they were considered concluded within the same period. Namely:

- Confidential communications tool: Privately is a decentralized blockchain-based app that allows communication between actors in a private manner, with the maxims of anonymity and integrity.
- Social network and sentiment analysis component: The aim of this component is to infer the opinion of consumers about various activities and actions taken by the LABs. To achieve this, the component gathers information related to the relevant actors from social network Twitter and performs sentiment analysis of the associated information (text of tweets and associated images).
- Data integration and management service: The operation of this component relies on having data owners for each data-source. Data owners are the ultimately the receivers of any value-exchange for use of the data.

3.2 New components (M24-M48)

In the third, and last, development macrocycle considered in the CDM methodology, the WP6 partners developed five new components (from scratch). These components were fully developed and validated within the period M24 – M48. Those components are:

- Data mining component: The fundamental purpose of this tool is to provide users with a detailed understanding of the sentiment and emotion expressed in restaurant reviews. With this information, users can make informed decisions about where to eat or what places to visit, based on an objective and analytical evaluation of the opinions of other users.
- S2CP data repository: This component allows Cities2030 participants to upload and share with all the society their open data and results from the Cities2030 project. The platform is open to all partners, so they can share the more appropriate data.
- Geospatial services: This component will show the geographical distribution of the different agents throughout the different CRFS on a map system. This component includes two subcomponents: geospatial services for Cities2030 labs and geospatial services for follower cities.
- Real time monitoring component: Real-time data monitoring component provides a system for receiving events produced by sensors. This S2CP component can collect information generated in a city, farm or other food-related organization, so that information can be later represented for real-time visualization or monetization.
- Digital twin supply chain: This component is designed to foster collaboration and data sharing among all actors in the value chain by incentivizing the exchange of information. Built on public blockchain technology, the component employs a unique approach called "Smart Digital Twins," creating digital representations of physical assets in the supply chain, such as products or resources.

3.3 Enhanced components

Finally, some components (five in total), although its initial version were developed within the period M1 – M24, were highly enhanced in the second half of Cities2030 as a consequence of the feedback received from user during workshops and seminars. Those components are:

- Cities 2030 communities: This component is a open collaboration space used by Cities2030 participants to improve their multi-stakeholder dialogue processes.
- Good practices component: This component is a map-based platform to allow the introduction of innovation activities by any Cities2030 partner, so that a catalog of information can be compiled, for filtering, searching and consulting (considering FAO pillars and MUFPP indicators).
- Blockchain-enabled marketplace for SFSC: This component is a blockchain-based data-driven UFSE (Urban food systems and ecosystems) marketplace solution. This component optimizes multi-stakeholder dialogue processes, in which blockchain will be employed to provide some proof of concepts of monetization processes or contract agreements, in a reliable and transparent way.
- Innovation management component (Multi-actor approach tool): This is a Web-based tool that aims to register and monitor the innovation at a well-defined Social Space. The main objectives of SSRI-MAA tool are (1) catalog and monitoring of SSRI actions and action plans; (2) catalog and monitoring of stakeholders and their representativeness; (3) monitoring of SSRI maturity levels and progress; and (4) context, Policy & Performance indicators catalog and monitoring (KPIs).
- S2CP dashboard: This component is a frontend (web and mobile) gathering all the available information from different sources and tasks. It is focused on user experience design (UX), developing an adaptive dashboard capable of integrating different web and mobile interfaces to serve as decision support systems in CITIES2030.

3.4 Shared mechanisms: Single Sign-On

The Single Sign-On (SSO) functionality has been provided in the scope of T6.4, as a way to integrate security and management of permissions and credentials following a single configuration for the S2CP platform.

SSO is a technique where-by one (or more) applications can automatically recognize a user as logged in when that user has logged in elsewhere. The Cities2030 Community platform has been selected as an authentication server, which can let a remote application recognize a user who has already logged in to the Community platform. A Single sign-on schema for the S2CP platform is described in the following figure:

Figure 3. SSO schema for the S2CP platform

Cities2030 Communities is chosen because it currently (at the writing date of this deliverable) has 129 registered members, both beneficiaries and alliance partners and other external stakeholders.

An SSO functionalities integration guide is established for S2CP component developers, which is included into Annex I.

The following components are currently interlinked with SSO capabilities: Cities2030 Community, Good practices, Data repository, Geospatial services and S2CP dashboard. The following sections describe the specific implementations for each of them: 9.2.4 Community as Single Sign-On server, 10.2 Good practices: Added functionalities, 13.2.1 Geospatial services: Integration with S2CP platform, 15.2 S2CP dashboard architectural design.

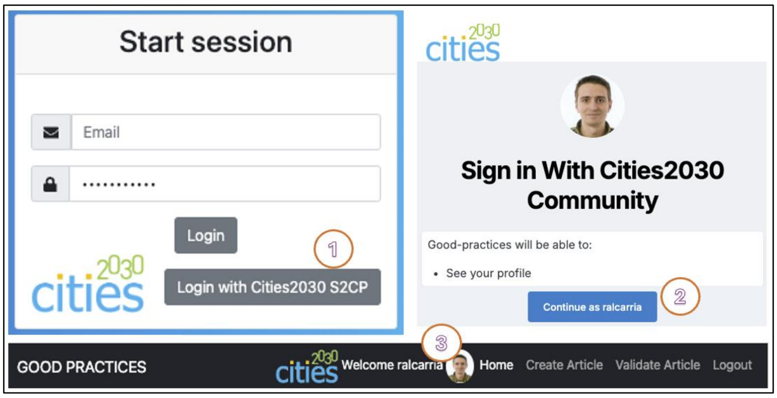


Figure 4. Example of SSO process in good practices component

4 Impact monitoring: final review

As a result of the continuous monitoring of the indicators foreseen in deliverable D3.8, and whose fulfillment is entrusted to WP6, it has been possible to determine the values defined in the following figure for all the KPIs of the framework created in WP3.

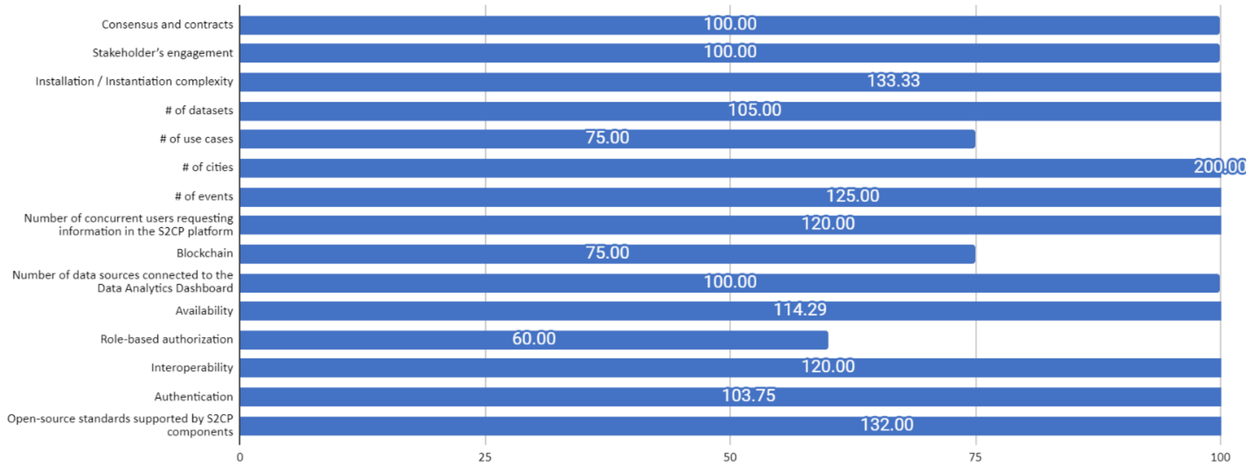


Figure 5. KPI completion at the time of writing D6.7

As can be seen in three of the indicators, the expected value has not reached. These indicators are: (1) Number of roles and categories with different authorization policies (producers, consumers, administrators, etc.) also considering regions.; (2) Number of use cases defined as framework for S2CP architectural design; and (3) Number of components using blockchain with benefits and usage in term of revenues, immutability, or consensus; show values.

In all these three cases, the motivation for this non-compliance is similar: Cities2030 labs did not demand any further effort. For example, three Blockchain-enabled components were considered enough to satisfy the labs' needs, although initially four different modules were planned. Similarly, the number of roles defined by labs when accessing to their data or communication spaces was just nine. Although from a technical point of view WP6 partners were prepared to define up to 15 different roles.

On the other hand, for all the other indicators, the expected value has been reached. In some cases, even the expected value has been greatly exceeded. For example, indicators: (1) Number Cities (Municipalities) incorporating S2CP enablers in pilots and living lab activities within the time period of the project; (2) Complexity in terms of IT knowledge required and local adjustments; or (3) Percentage of open standards implemented against the total number of protocols/technologies/models implemented; show values above 130% (even the first one, thanks to multiplier labs and flagship labs, achieves a 200% fulfillment).

Finally, for the majority of indicators, the fulfillment is closer (but above) to 100%. This is clear evidence of the success of WP6 in completing its objectives.

5 Previously released components

In this section we are briefly describing the components that were released, and whose development was concluded, within the period M1 – M24. As said before (see Section 3), three are the components in this situation. Next subsections analyze each one of them.

5.1 Confidential communications tool: Privately

A communication tool to enable distributed interactions among stakeholders is released. Privately[6] is a decentralized blockchain-based app that allows communication between actors in a private manner, with the maxims of anonymity and integrity.

The functional architecture of the tool for private communications is described below:

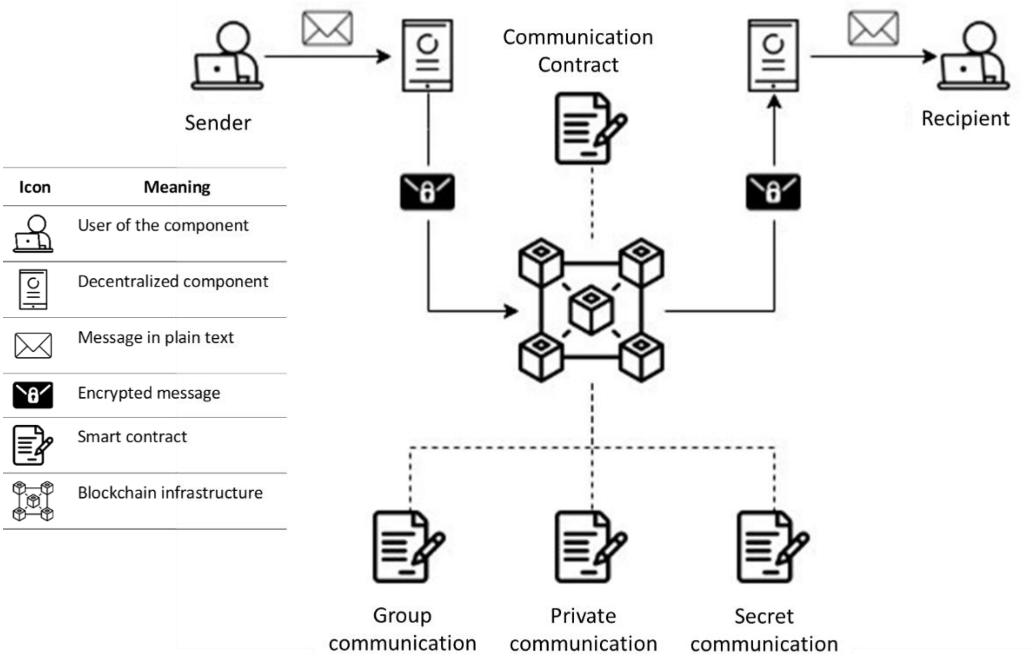


Figure 6. Tools for private communications architectural diagram

The core element of the architecture is the blockchain. After a technological study, a solution based on the implementation of the ***Ethereum*** blockchain is chosen. In addition to having a complete language for the implementation of smart contracts, Solidity[7], this blockchain implementation has recently changed its proof of work to a consensus protocol based on Proof of Stake[8], which makes its consumption is greatly reduced and thus its environmental impact, compared to other PoW-based implementations such as Bitcoin[9].

The Ethereum-based blockchain has three main features that solve an important part of the non-functional requirements for us:

- Decentralization: these networks can be made up of a large number of nodes, distributed geographically.
- Availability: Both the exchanged symmetric keys and the messages sent are stored in the blockchain as contract events, thus freeing users from the obligation to always be connected to avoid missing an event, as happens with technologies such as P2P. Thus, it would suffice to retrieve the events of the smart contract and check if there is any new conversation or any new message.

[6] https://cities2030.eu/single-click-crfs-platform/

[7] What Is Solidity? What Are Its Use Cases? https://topdigital.agency/what-is-solidity-what-are-its-use-cases/

[8] Why Ethereum's Merge Means Crypto That's Much Greener: https://www.bloomberg.com/news/articles/2022-08-23/what-are-crypto-proof-of-work-and-proof-of-stake-quicktake-l768gkg3

[9] Economic estimation of Bitcoin mining's climate damages demonstrates closer resemblance to digital crude than digital gold. https://www.nature.com/articles/s41598-022-18686-8

- Reliability: this technology guarantees that no transaction can be falsified using decentralized validation methods.

Although the characteristics mentioned are typical of any blockchain network, not all networks allow the creation of complex systems that take advantage of them. The Ethereum network or similar have an element called smart contract that allows you to integrate your own code fragments to carry out more complex transactions.

This component was uploaded to the Cities2030 website, S2CP[10] section. In addition, it was presented at the Third WP6 workshop "Analyze the challenge" that took place on June 10, 2022, on the occasion of the R113 milestone according to the WP6 Gantt diagram, which was incorporated into the deliverable D6.1, Section 2.3.

Labs attended a tutorial on the use of this component, in which its developers presented some installation instructions, and a demo of its use to enable private messaging in Cities2030. Video recordings and presentation materials were available to all Cities2030 participants through the official Cities2030 data management platform: Correlate.

5.2 Social network and sentiment analysis component

The aim of this component is to infer the opinion of consumers about various activities and actions taken by the LABs. To achieve this, the component gathers information related to the relevant actors from social network Twitter and performs sentiment analysis of the associated information (text of tweets and associated images). The data was collected from the Twitter Universe and further filtered to ensure the relevance to the studied question. Next, the sentiment analysis was performed with the help of the latest technologies available in NLP (Natural Language processing) and Image Processing domains, namely the Artificial Neural Network (ANN) -based algorithms. After that, the results were aggregated and summarized. Finally, they were presented in the form of plots and tables for further analysis by a user. This information can later be used *to understand the opinion of citizens about different topics, track the occurrence of certain projects on social networks, plan and correct action plans etc*.

The provided visualization of different granularity can include historical and geographical distribution of tweets of different sentiment (Positive, Neutral and Negative). Additionally, the component can perform the analysis of the images associated with the tweets to better target specific events/actions/discussions. The code of the component can be found at the following repository[11].

5.3 Data integration and management service

A micro-service-based design was used for building this component. The current envisioned micro-services are shown below, in the following Figure:

[10] https://cities2030.eu/single-click-crfs-platform/

[11] https://github.com/marharyta-aleksandrova/cities-sentiment

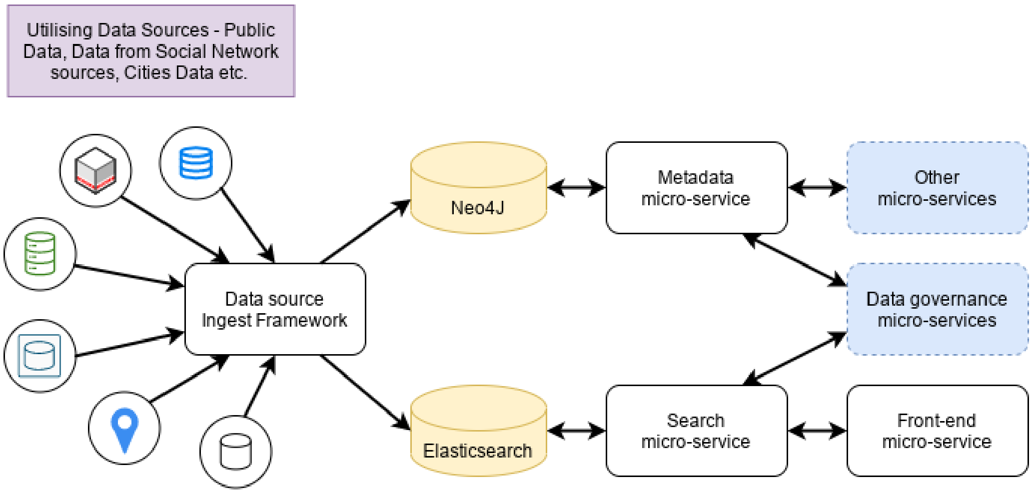


Figure 7. Data Integration, Discovery and Access Micro-services

- The Front-end micro-service offers a frontend UI for users which is web based. This allows end-users, data-scientists to discover available data-sources, query for different types of data available and through the use of Data Governance component, arrange data-sharing agreements.
- The search micro-service allows data source discovery, by servicing search requests from the Frontend micro-service. It allows searching based on the data-source / table descriptions, as well as by tagged keywords.
- The Metadata micro-service captures the essence of where particular data comes from, where (in the warehouse of data) it is stored, who is using it, and additional descriptions of its format and purpose. As expected the meta-data collected matches the meta-data collected for data sources, plus some automatically generated meta-data connections.
- The Data view micro-service provides access to the raw data contained in the warehouse. In line with the principles outlined for the Data Governance component, data can only be shared or made accessible once a data-sharing agreement is in place.
- The Datasource ingest micro-service focuses on taking the data-source definitions and using to ingest the corresponding meta-data from the data-source. Each data-source is equated to a database table, so this takes the data-source definition and generates a corresponding database schema to support data ingestion.

6 Data mining component

The data mining component retrieves a set of data on CRFS elements and analyzes them using natural language processing and sentiment analysis. In the following subsections we will detail a motivation for the development of this tool, the main functionalities, some keys about its development, and the processes of experimentation with it.

6.1 Introduction

This S2CP component is based on the use of various *python* libraries designed for sentiment analysis in text reviews, as well as data extraction using advanced web scraping techniques from recognized platforms such as Google Reviews, TripAdvisor and Yelp.

To guarantee accuracy in the evaluation of feelings and emotions, all texts must be in English, the language in which the analysis is carried out using Natural Language Processing (NLP). These tools allow us to automatically determine whether a text conveys a positive, negative or neutral sentiment within the specific context of restaurant reviews in this context.

In addition, the application identifies and analyzes the underlying emotions in the text, discerning emotional states such as happiness ("happy"), sadness ("sad") or anger ("angry").

The application's web interface offers users the ability to directly enter raw text for analysis or enter the URL of a specific restaurant, from which relevant reviews will be automatically extracted.

An additional component of the application deals with project management, where the results obtained from emotional analysis are stored and organized. This functionality allows users to compare and contrast the predominant emotions between different projects, and also provides a global analysis of the emotions captured in all projects.

The fundamental purpose of this tool is to provide users with a detailed understanding of the sentiment and emotion expressed in food-related contexts, such as restaurant reviews. With this information, users can make informed decisions about where to eat or what places to visit, based on an objective and analytical evaluation of the opinions of other users.

6.2 Architectural design

The architecture of this application has been designed to integrate the essential functionalities of both the backend and the frontend (see Figure 8). On the backend, an SQLite database hosted on a cloud-based environment is implemented, ensuring persistence and reliable data management. The backend components also include a FastAPI server that makes it easy to create a RESTful API[12], using technologies such as *Playwright*, *BeautifulSoup4*, and transformers for browser automation and web data analysis. On the other hand, the frontend is made up of a static web server that uses HTML, CSS and JavaScript to provide an interactive and visually appealing user interface. This architecture allows customers to interact intuitively with the application, accessing functionalities such as sentiment analysis and project management in an efficient and accessible way.

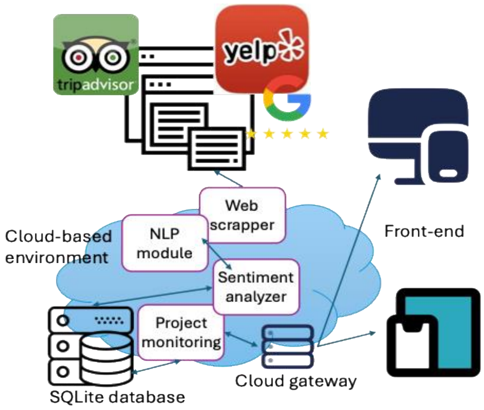


Figure 8. Diagram of the application architecture, showing the interaction between the cloud-based environment and frontend components.

6.2.1 Application backend

The application backend constitutes the operational core responsible for managing the project logic, processing data and facilitating interaction with key external services. Built on FastAPI, a Python framework

[12] FastAPI. https://fastapi.tiangolo.com/.

that facilitates the creation of web APIs, it guarantees both operational speed and comprehensive platform security.

Regarding the components that make it up, there is the previously mentioned framework, tools for data scraping, as well as tools for sentiment analysis. Starting with FastAPI, the main framework, it is used to develop a RESTful API. Thanks to its static typing system and automatic generation of interactive documentation using OpenAPI, FastAPI significantly simplifies the development and maintenance of the programming interface. Continuing with the Playwright and BeautifulSoup4 tools for web data scraping, Playwright is used for browser automation, facilitating the structured extraction of data from various web sources such as Google Reviews, TripAdvisor and Yelp. BeautifulSoup4 complements this process by efficiently analyzing the HTML data obtained, ensuring an extraction adaptable to variations in the structure of the pages. Likewise, to facilitate the task of validating input and output data within the API, there is the Pydantic tool, which ensures consistency and security in information processing. Finally, the use of transformers for sentiment analysis provides an adequate tool to capture long-term relationships in text sequences, and therefore demonstrate great effectiveness in tasks such as those presented in this project.

Once you have the skeleton of the application, it is of interest to have a database to store and manage the data necessary for the complete operation of the application. In this sense, an SQLite database is implemented, protected against vulnerabilities such as SQL injections, using queries prepared with placeholders "?". This practice guarantees the integrity and security of the stored data, crucial for the reliable operation of the application in production environments.

6.2.2 Application frontend

The frontend deploys the user interface (UI) through which users interact with the functionalities offered by the backend, providing an intuitive and easy-to-use user experience.

The user interface is developed using technologies such as HTML, CSS and JavaScript. These technologies allow the creation of a visually attractive and functional interface, which makes it easier to navigate and understand the various features of the application. HTML provides the basic structure of the page, while CSS takes care of the layout and visual presentation. On the other hand, JavaScript is used for dynamic interactivity, improving usability by allowing real-time updates and responses. The developed frontend interacts closely with the backend by using HTTP requests through the API provided by FastAPI. These requests perform communication between the frontend and the backend, thus allowing the exchange of data and the execution of the required operations.

API Requests made from frontend to backend include various types of requests, such as sending raw text for sentiment analysis. This functionality allows users to directly enter text they wish to analyze, obtaining instant results on the tone and emotion of the evaluated text. Additionally, the frontend can send the URL of a specific restaurant to the backend, requesting automatic extraction and analysis of the reviews available on that web page. On the other hand, the user interface also facilitates project management and visualization of results. Users have the ability to create new projects, allowing them to organize and categorize different sets of review data for specific analysis. The frontend created is responsive, that is, once a new project is created, the graphs are automatically updated to reflect the data of the selected project. Additionally, the interface allows users to resize the web page without affecting the content[13], ensuring a consistent experience on both mobile devices and laptops or desktops. Therefore, the frontend design ensures that user interaction with the application is clear and fast, providing an easy-to-use platform for the analysis of sentiments and emotions in restaurant reviews.

[13] Bootstrap 5 web site: https://getbootstrap.com/docs/5.0/getting-started/introduction/

6.3 Development of solution

The data mining and sentiment analysis component is based on two main techniques, being data mining and the use of natural language processing (NLP) techniques to extract and analyze restaurant reviews from various web platforms.

6.3.1 Data mining

Data mining in this context aims to extract restaurant reviews from different websites. For this, use is made of the aforementioned Playwright and BeautifulSoup, as well as Asyncio. The latter is a library to handle asynchronous I/O operations in Python, allowing the execution of multiple concurrent tasks.

6.3.1.1 Web scraping architecture

The scraping process is structured into several asynchronous functions, each one responsible for extracting reviews from a specific platform. The general workflow and specifics of each function are described below.

Initially, a validation of the URL and the selection option of the page to be analyzed is carried out. In this step, it is verified that the URL provided corresponds to the website of interest (Google, TripAdvisor or Yelp). Continuing with the execution flow, a scraping attempt is made with retries, that is, up to three scraping attempts are made in case of errors, implementing exponential backoff logic to handle transient errors.

The scraping process, using Playwright, begins with the creation of a simulated browser, which accesses the specified URL and accepts the cookie dialog if necessary. Next, we proceed with extracting reviews by waiting for the review elements to be visible, ensuring that the correct information is captured. Finally, the content of the reviews is extracted using BeautifulSoup, storing said content in a list of texts.

In case of extraction failures, a diagnostic screenshot is taken, and scraping is retried after an incremental wait in time. This allows you to detect and diagnose what the problem could be with the poor execution of web scraping.

6.3.1.2 Extraction Features

Each extraction function is designed to work with the specific HTML structure of the corresponding platform. When accessing the web page, not all of them use the same structure of elements, which implies the need to analyze different HTML codes associated with each web page. In this way, the required parameters are correctly accessed, in this case, the content of the customer reviews of the restaurant in question. Using methods such as soup.select(), elements of interest are identified and extracted.

Google Reviews

```
async def extract_google_reviews(page):
        await page.wait_for_selector('.MyEned', timeout=10000)
        html = await page.inner_html('body')
        soup = BeautifulSoup(html, 'html.parser')
        review_elements = soup.select('.MyEned')
        reviews_text = [review.text.strip() for review in review_elements]
        return reviews_text
```

TripAdvisor

```
async def extract_tripadvisor_reviews(page):
        await page.wait_for_selector('.JguWG', timeout=10000)
        html = await page.inner_html('body')
        soup = BeautifulSoup(html, 'html.parser')
        review_elements = soup.select('.JguWG')
        reviews_text = [review.text.strip() for review in review_elements]
        return reviews_text
```

Yelp

```
async def extract_yelp_reviews(page):
    await page.wait_for_selector('.comment_09f24_D0cxf.y-css-h9c2fl', timeout=10000) await asyncio.sleep(randint(1, 5))
    html = await page.inner_html('body')
    soup = BeautifulSoup(html, 'html.parser')
    review_elements = soup.select('.comment_09f24_D0cxf.y-css-h9c2fl') reviews_text = [review.text.strip()
    for review in review_elements] return reviews_text
```

6.3.2 Natural language processing models

Natural Language Processing is a branch of artificial intelligence that focuses on learning human language patterns. In the project, advanced NLP models are used to analyze feelings and emotions in restaurant reviews, allowing users to obtain meaningful insights into other users' experiences.

That is why a transformer architecture is used, proposed by Vaswani et al.[14] (see new Figure).

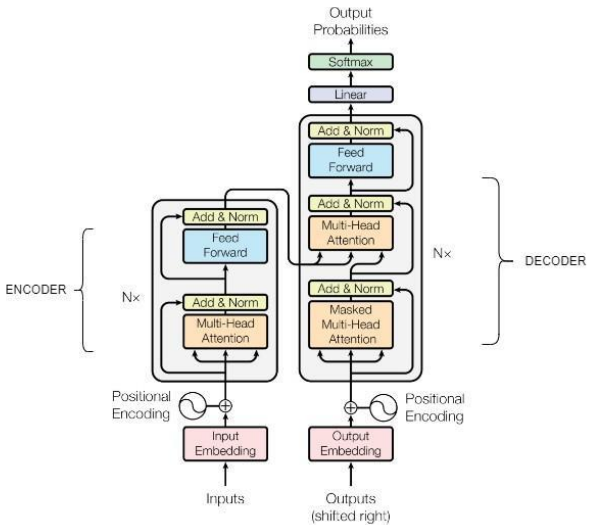


Figure 9. Diagram of the transformer architecture, where the blocks are detailed encoder and decoder

As can be seen, the transformer is made up of two main components: the encoder and the decoder. Both components employ positional encodings to preserve information about the position of elements in the input and output sequence, thus allowing efficient handling of long-term dependency in sequences.

6.3.2.1 Encoder

The encoder in the Transformer architecture processes the input sequence to generate contextual representations through a series of encoding layers, each with a self-attention mechanism and a feed-forward network. The self-attention mechanism allows each token to attend to itself and all other tokens in the sequence, capturing global contextual dependencies. The feed-forward network applies complex transformations to each position in the sequence independently. Each layer includes residual connections and layer normalization to facilitate optimization. Finally, the output of the encoder is a sequence of high-level representations that encapsulate the contextual information of the input.

---

[14] Ashish Vaswani et al. «Attention Is All You Need». En: CoRR abs/1706.03762 (2017). arXiv: 1706.03762. URL: http://arxiv.org/abs/1706.03762.

6.3.2.2 Decoder

On the other hand, the decoder generates the output sequence using the contextual representations of the encoder through decoding layers that include a masked self-attention mechanism, an encoder-decoder attention mechanism and a feed-forward network. The self-attention mechanism ensures that each token attends only to previous tokens to maintain causality. The encoder-decoder attention mechanism allows output tokens to be attended to input tokens, facilitating the transfer of relevant information. As in the encoder, each layer of the decoder has residual connections and layer normalization. The final output of the decoder is passed through a linear layer and a *softmax* function to produce the probabilities of the next words in the output sequence.

6.3.3 Trained models

In the sentiment analysis task, a model trained with a Kaggle data set was initially developed. For this, Google Colab was used. This document details the preprocessing applied to the data from the set used. Likewise, various models were trained with the pre-trained *BERT* and *RoBERTa* architectures, responsible for generating the embeddings. Another extra layer was added to these models as a classifier. By training this final layer for the corresponding task, results were obtained with a precision of up to 0.74. This can be due to several reasons, one of them being the available computing capacity. That is why the next step was to opt for a model already pre-trained on the sentiment analysis task.

6.3.4 Selected final model

Analyzing the results of the manually trained models, these were not what was expected, and since the objective was to be as accurate as possible, other alternatives were tested. These alternatives include continuing to use the transformers architecture but with more powerful models. In this case, the Yelp Restaurant Review Sentiment Analysis model available at [15] was used for the classification of sentiments, and the Bart-Large model[16] (after being trained on the MultiNLI[17] dataset) for the classification of emotions. The model used for sentiment classification was trained with a data set of thousands of Yelp reviews. This model is capable of classifying a text into three categories: positive, negative or neutral. Classification is performed using a text classification pipeline provided by the Transformers library.

```
model_name = "mrcaelumn/yelp_restaurant_review_sentiment_analysis"
sentiment_pipeline = pipeline("text-classification", model=model_name)
```

This pipeline takes a text review as input and returns a sentiment label along with a confidence percentage. To facilitate the interpretation of the labels, a mapping function is used that translates the model labels into more understandable sentiment categories.

- LABEL_2 = POSITIVE
- LABEL_1 = NEUTRAL
- LABEL_0 = NEGATIVE

On the other hand, for the identification of emotions, a classification model without specific labels is used, known as zero-shot classification. This model is capable of classifying text into a variety of predefined

[15] Hugging Face – MrCaelumn: https://huggingface.co/mrcaelumn/yelp_restaurant_review_sentiment_analysis

[16] https://huggingface.co/facebook/bart-large-mnli

[17] https://huggingface.co/datasets/nyu-mll/multi_nli

categories without requiring specific training for those categories. In this case, the target emotions are happy, sad and angry.

```
classifier_pipeline = pipeline("zero-shot-classification", model="facebook/bart-large-mnli")

def analyze_emotions(review_text: str):
    result = classifier_pipeline(review_text, candidate_labels=["happy", "sad", "angry"])
    return result
```

This approach allows for great flexibility and adaptability, as the model can be reused to classify different emotions as needed. Regarding the process of analysis of feelings and emotions, this is carried out in several steps, adapting according to the type of input. If a single review is received, it is directly analyzed to determine its predominant sentiment and emotion. On the other hand, if a URL is received, all reviews are first extracted using the scraping functions described above. Each individual review is then analyzed for sentiment and emotion. Finally, results are aggregated, and averages are calculated to provide an overview of the dominant sentiment and emotion in the set of reviews analyzed.

6.3.5 Functionalities

This S2CP component offers a variety of features designed to meet the needs raised in the project. One of the main functionalities is the ability to create new projects. This feature allows users to organize and manage different sets of review analysis. When creating a project, a dedicated space is assigned where all the reviews associated with that project are stored and processed, facilitating an orderly and segmented analysis. In addition, the UI allows users to easily switch between projects. This functionality is crucial for comparing and contrasting results from different data sets. The ability to switch between projects helps users identify patterns and trends in review data, thus improving the quality of decisions based on these analyses.

Another key feature of the app is the option to analyze raw text directly entered by the user. This functionality allows users to perform analysis of individual text fragments. Raw text analysis is especially useful for personalized evaluations, where an understanding of the sentiments and emotions expressed in a particular text is needed. In addition, the app allows entering the URL of a specific restaurant to automatically extract and analyze all the reviews available on that page. This feature provides an automated way to obtain and analyze large volumes of review data, saving users time and effort.

The following figure shows the two review mining options. Option (a) "Analyze raw text", which allows you to analyze a single review entered by the user, Option (b), to analyze the reviews of a specific restaurant.

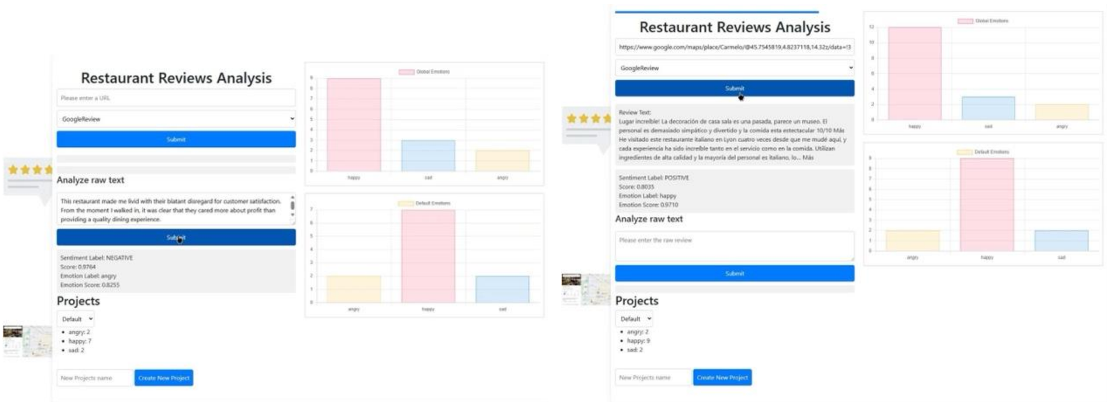


Figure 10. (a) Analysis of an individual review. (b) Analysis of reviews of a restaurant

6.3.6 Limitations

The system has several limitations that must be considered to ensure its proper operation and maintenance.

Firstly, the structure of web pages can change with updates, which can modify the review fields, i.e. the name of the containers associated with the reviews in the HTML of the page. Therefore, it is crucial to periodically review the functioning of the code to ensure its correct performance. In case of failures, it must be verified whether these are caused by updates to the web page and, if so, update the extraction functions mentioned in Section 6.3

In addition, review pages periodically adjust their policy to allow or deny web scraping[18], which can affect the automation of the collection of user reviews in various applications. A concrete example is the TripAdvisor platform, where a blocking system has recently been incorporated that has prevented the operation of automated collection systems. It is important to take this limitation into account and to adhere at all times to the data collection policy of the website.

Finally, a limitation present in sentiment analysis is the language of the analyzed texts. Although it is possible to analyze texts in various languages, the current model is not optimized for this, which can result in inaccurate predictions. This limitation could be mitigated by training language-specific models or by using a more universal model that effectively supports multiple languages. In any case, it is necessary to consider this restriction when interpreting the results of sentiment analysis.

As can be seen, these limitations require constant monitoring and periodic adjustments to ensure the effectiveness and accuracy of the system.

6.4 Experiments

This section describes the experiments carried out to evaluate and demonstrate the operation and capabilities of the application of sentiment and emotion analysis in restaurant reviews. Details are provided on how to run the system and the features available in the application. Additionally, information is included on how to access the project source code.

6.4.1 Deployment

Public deployment

The backend is deployed on a public Internet server to ensure global accessibility. Using Uvicorn as an ASGI server, the FastAPI application runs locally on port 8000 of cloud virtual machine. This port must be mapped to an available public port, allowing the API to process incoming requests from any web client using the full URL.

Local deployment (for testing)

To run the system locally, it is essential to clone the project repository from GitHub. UPM (P20) will give access to the *github* repository by providing the <Cities2030_Data_Mining_Sentiment_Analysis> url.

```
git clone https://github.com/<Cities2030_Data_Mining_Sentiment_Analysis>.git
```

Once the repository is cloned, the next step is to navigate to the project directory and ensure that all the necessary dependencies are installed. This can be achieved by running pip install -r requirements.txt

---

[18] Techopedia. Web Scraping: https://www.techopedia.com/definition/5212/web-scraping

With all dependencies installed, the backend server can be started using Uvicorn. This server handles application logic and user requests. The command to start the server is *uvicorn sentimentAnalysisApp:app*.

In parallel, the frontend can be run locally by navigating to the project's static files. This can be done by adding /static/index.html to the URL, or using Live Server or another similar tool, allowing continuous display and testing of the user interface. During development, the typical path to access the frontend is http://127.0.0.1:8000.

6.4.2 Experiments with Cities2030 labs

The data mining component was developed between the second and third phases of the Combined Development Methodology (see Section 2) and was presented at the workshop "Data mining for living labs and community platform", part of the General Assembly in Marseille, on 20th June 2024. At this workshop, the attendees, representatives of the Cities2030 CRFS labs, tested the operation of the application by suggesting places they knew, such as restaurants and review sites, and played at anticipating the result of the application after carrying out the sentiment analysis.

Figure 11. Showcase of Data mining component in Marseille's GA

6.5 Conclusions

In conclusion, a complete and functional system for sentiment analysis of reviews of food-related places has been developed. Using state-of-the-art techniques in natural language processing (NLP) and web scraping, the system allows users to gain a detailed understanding of the emotions expressed in customer reviews. This ability to discern positive, negative and neutral sentiments, as well as specific emotions such as happiness, sadness or anger, provides a solid basis for decision making in the gastronomic context.

Despite its effectiveness, the identified limitations provide a clear roadmap for future improvements, including continuous adaptation to changes in the web structure, understanding of scrapping policies, and expanding the linguistic capabilities of the model.

The application has been brought to the attention of CRFS Labs, which has positively valued the information generated on sites of interest.

7 S2CP data repository

Publishing and consuming open data is a cornerstone for the development of applications and the creation of an innovation ecosystem. In this regard, this section explains how Cities2030 data repository has been created, and how users can expose their data publishing it in this S2CP component.

Cities2030 data repository is an open-source solution based on the well-known Open Data Publication network CKAN (Comprehensive Knowledge Archive Network), most widely used by cities, public authorities, and organizations. This repository enables the publication, management, and consumption of open data, usually, but not only, through static datasets (CSV, XLSX, etc.). This allows to catalogue, upload, and manage open datasets and data sources, while supports searching, browsing, visualizing, or accessing open data.

7.1 Goal and requirements

The technological choice of this component was based on the following objective:

Provide a tool to facilitate access to the data generated and used within the project. Provide a dedicated environment that improves searches and organizes information in a coherent manner following the structure defined within the project.

To meet this objective, the following requirements were stated and discussed at the regular meetings of the WP6 members:

- Creation of organizations and projects in which the organizations participate (which in our case is the concept of a lab).
- Possibility of generating permanent URLs to facilitate the public dissemination of data and the capture of this information by other S2CP tools.
- Use of a free software environment that has the latest data storage and publication standards (to meet the project KPIs).
- Ease of deployment of the system in a Cloud environment (to meet the WP6 KPIs discussed in Section 4) and integration with the S2CP authentication system.

7.2 Technology choice

CKAN[19] has been chosen as data repository software, as it offers the following advantages:

Easy data access

This component incorporates a central keyword search, that can be faceted by tags, location, format, license, publishing organization, etc. The embedded browser allows searching by groups, keywords, and publishers, enabling a standardized interface for viewing datasets and downloading them through links and direct access. Preview and data explorations is possible with some data formats.

Private Datasets

This S2CP component allows users to control the visibility of their datasets, enabling the creation of private datasets that only certain users can access. This is core to support the access control and GDPR compliance.

Geospatial Information

Data repository has advanced geospatial features, covering data preview, search, and discovery. Where structured data with location information is loaded into the Data Store, it is possible to plot the data into an interactive map. The screenshot shows a map view of a sample dataset, with markers showing individual data points and full details shown for records as they are selected. A user searching for datasets can filter the results by geographical location, specifying a bounding box to limit the interesting areas. Different coordinate geometries and formats are supported. To integrate datasets with other systems, metadata can be coded in INSPIRE standard and major metadata schemas (ISO19139 and GEMINI 2.1), including OGC's CSW standard. The architecture is extensible, making it easy to support other standards and distribution services.

[19] CKAN: Open-source data management system website: https://ckan.org/

As an example, in the following figure it is possible to see a dataset containing Community Gardening sites in Salford, UK, and its previsualization in the Data Repository component.

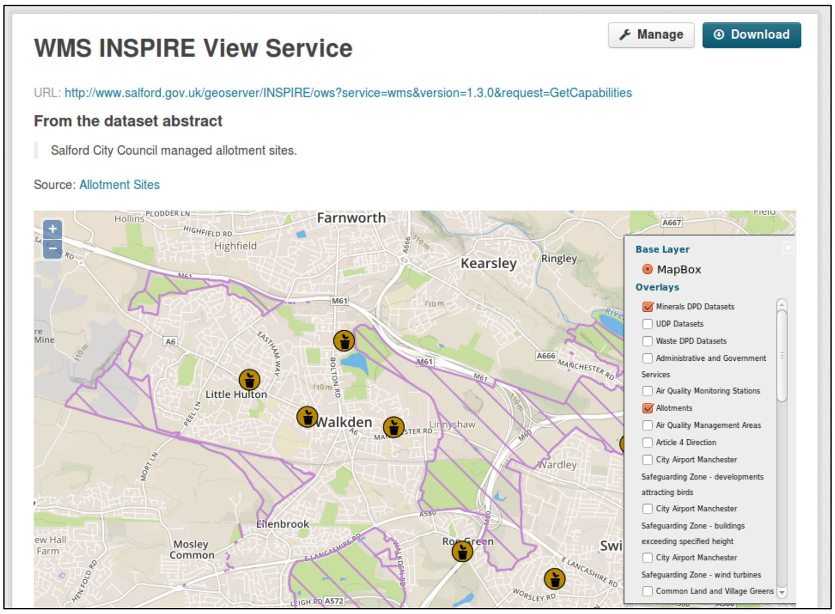


Figure 12. Previsualization of point-based data in Data Repository

Single Sign On

The OAuth2 extension allows site visitors to login using an authentication server. In this way, other S2CP component such as Cities2030 Community can be used as the identify provider leveraging the single sign-on approach required for the access control management of CKAN datasets.

Multilingualism

Thanks to widely stablished CKAN framework, the Cities2030 data repository is translated by into over 10 languages, supporting all international characters and supporting multilingual search, string translations & more for the European Commission Open Data Portal.

7.3 Construction of structure based on Cities2030 model

The information recording methodology is based on the three phases of the Combined Development Methodology (see Section 2). Linked to the CDM: As we obtain data from the geospatial services for the cities2030 labs and for the follower cities (see Figure 1), this data is stored in the Data repository. The Geospatial sections component (see section 13 of this deliverable) is used for the intercommunication of this data with other entities such as the S2CP dashboard.

In contrast, the Cities2030 Repository component offers a better distribution of the resources, sorted by lab and publishing organization. To align the publication structure in this component with the Cities2030 model and its participating actors, the following entities are defined: Organizations, Datasets, and Groups:

- Organizations are entities that control who can see, create, and update datasets in Data Repository. Each dataset can belong to a single organization, and each organization controls access to its datasets.
- Dataset is a collection of data. Datasets can be marked as public or private. Public datasets are visible to everyone. Private datasets can only be seen by logged-in users who are members of the dataset's organization. Private datasets are not shown in general dataset searches but are shown in dataset searches within the organization.

- Groups: Groups are created to manage collections of datasets. This is used to catalogue datasets considering the CRFS locations such as Labs. This is a very simple way to help data consumers to find and search published datasets.

In the following Figure you can see the content created around *Groups* and *Organizations*:

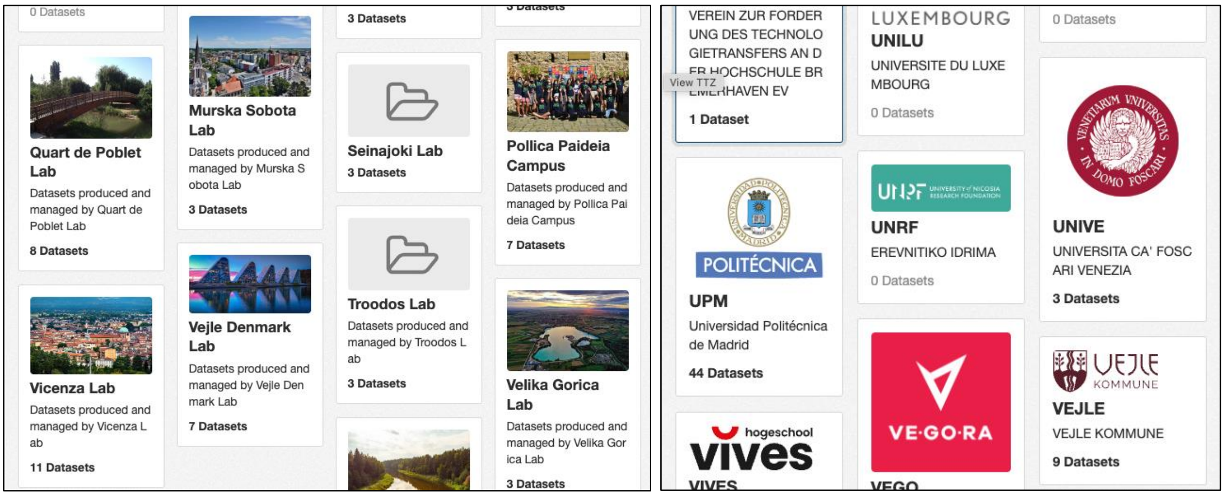


Figure 13. Created groups and organizations in Cities2030 repository

7.4 Implemented functionalities

Below are the functionalities that have been implemented in phase #2 of the CDM: Data API, Geospatial extension, secure cloud provision and single sign on integration.

7.4.1 Data interoperability through Data API

As discussed in D6.5 Section 6 "Interconnection with other S2CP components", the data repository has been integrated into the S2CP platform by establishing connection links with the Geospatial CRFS Services and the S2CP dashboard. Specifically, regarding the data repository, we take advantage of the use of the CKAN Datastore and Data API, available in CKAN Open-Source repository since v1.7. The DataStore provides a database for structured storage of data - together with a powerful Web-accessible, JSON-based, Data API. Data can be automatically inserted into the DataStore from spreadsheet files in .csv or .xls (MS Excel) format that are uploaded or linked to in the Repository.

When datastore is enabled, datasets the Data repository gives an interactive preview onto the file, and by accessing to the "Data API" it is possible to consume the information from other S2CP components. This displays useful information about using the API for this resource, including the endpoints, some examples, and links to further information.

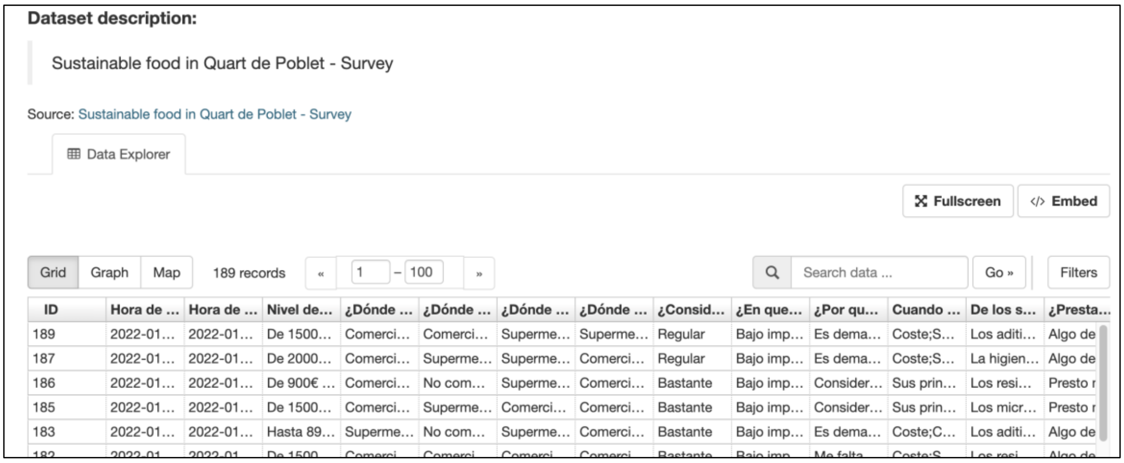


Figure 14. Data repository preview of sustainable food consumption survey generated within the scope of Quart de Poblet lab

7.4.2 Geospatial extension

We have integrated a geospatial information viewer as an additional feature. To do this, we have used the CKAN GeoView extension[20], which allows different views with different libraries (OpenLayers, Leaflet) and map providers (OpenStreetMaps, Mapbox, etc.).

The view supports a representation of point information (markers) and also polygons, which allows the representation of administrative boundaries, or polygonal points of interest, as can be seen in the following figure:

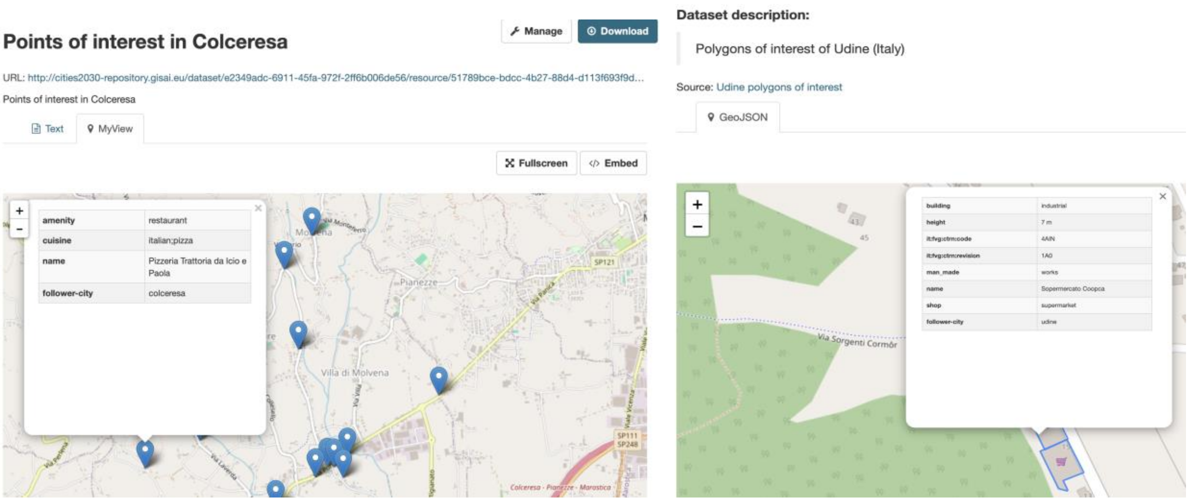


Figure 15. Geospatial visualization of point-based (left) and polygon-based (right) information

7.4.3 Secure cloud provision

For integration with the S2CP platform security ecosystem, the Data Repository component is provided via a secure HTTPS address and hosted on the gisai.eu domain provided by partner P20.

[20] https://github.com/ckan/ckanext-geoview

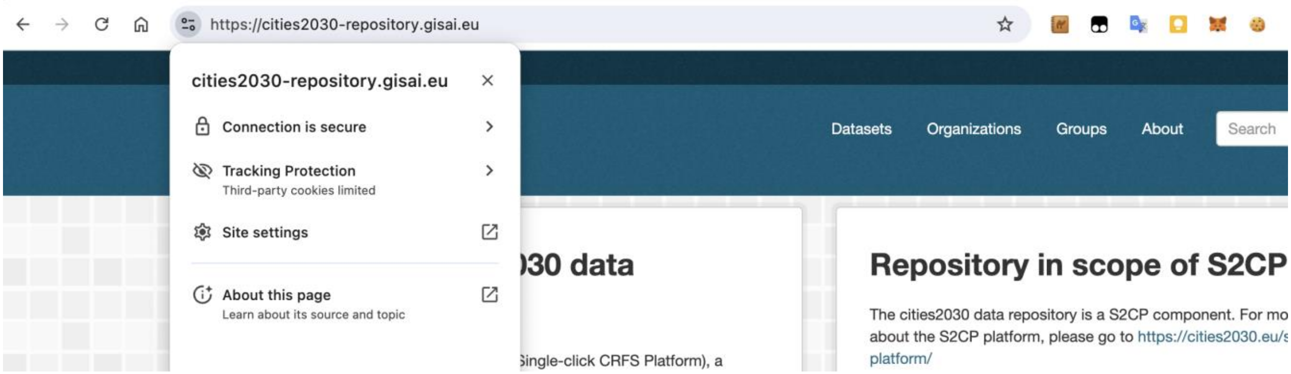


Figure 16. Data Repository: Secure cloud provision

This functionality is also necessary to achieve data interoperability with other S2CP components that are hosted on secure sites, and to provide the Single Sign On functionality described in the next section.

7.4.4 Single Sign On integration

For the integration of this application into the S2CP authentication/authorization ecosystem, the guide prepared by P20 has been followed, and which is included in Annex I.

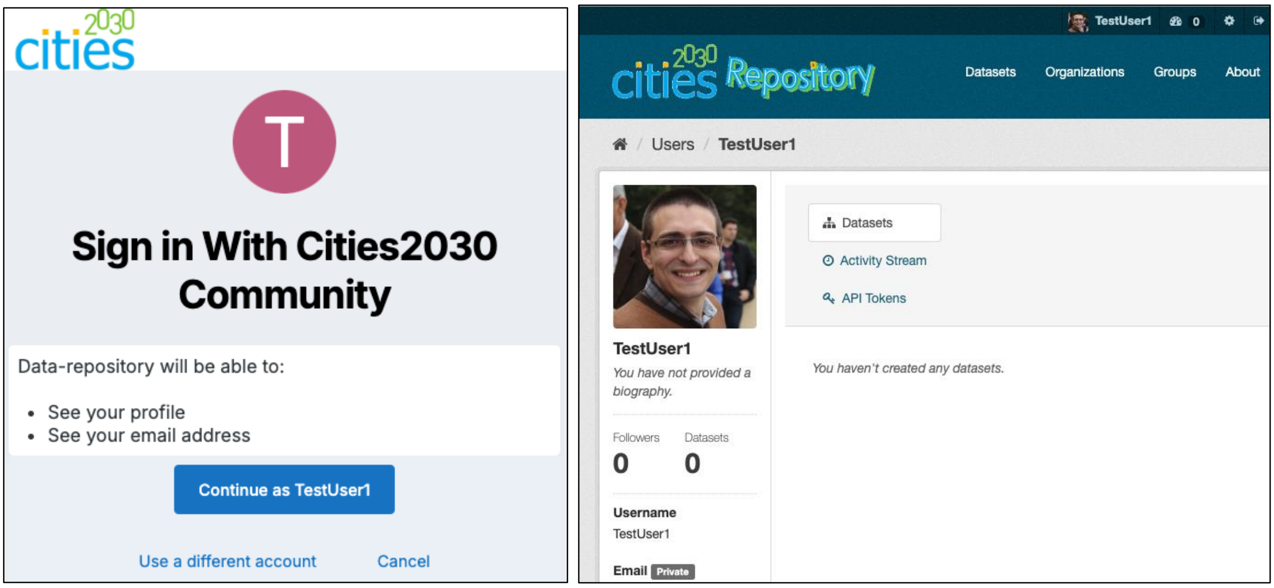


Figure 17. Data Repository: Sigle Sign On with Cities2030 Community

7.4.5 Platform validation

Thanks to the provision of single sign on, we have provided the platform with 163 users (cities2030 partners and alliance partners) as of the date of writing this deliverable.

The Data repository currently has 64 datasets provided by the project organizations. Below is a summary of the types of data included.

Table 2. Types of data and dataset for each lab or follower city

Lab (number of DS)	Uploading account	Formats (number of DS)	Licences
Vicenza (11)	UNIVE (3), UPM (3), VIZ (3), EPC (2)	XLS (8), GeoJSON (3)	Other Open (7), Open Data Commons (3), Public Domain (1)
Quart de Poblet (8)	UPM (7), QUAR (1)	GeoJSON (3), XLS (3), XLSX (2)	Other Open (4), Open Data Commons (4)
Pollica Paideia (7)	UNIVE (3), EPC (2) VIZ (2)	XLS (7)	Other Open (7)
Vejle (7)	VEJLE (7)	CSV (7)	Other Open (4), Open Data Commons (3)
Bremerhaven (6)	UPM (3), BIOZ (1), BRH (1), TTZ (1)	CSV (3), GeoJSON (3)	Other Open (3), Open Data Commons (3)
Arganda (4)	UPM (4)	XLS (3), XLSX (1)	Other Open (4)
Follower cities (4)	UPM (4)	GeoJSON (4)	Creative Commons Non-Commercial (4)
Murska Sobota (3)	UPM (3)	GeoJSON (3)	Open Data Commons (3)
Brugge (3)	UPM (3)	GeoJSON (3)	Open Data Commons (3)
Food for Iasi (3)	UPM (3)	GeoJSON (3)	Open Data Commons (3)
Haarlem (3)	UPM (3)	GeoJSON (3)	Open Data Commons (3)
Seinajoki (3)	UPM (3)	GeoJSON (3)	Open Data Commons (3)
Troodos (3)	UPM (3)	GeoJSON (3)	Open Data Commons (3)
Velika Gorica (3)	UPM (3)	GeoJSON (3)	Open Data Commons (3)

As can be seen in the table, most labs present information in GeoJSON that corresponds to points of interest in the region (OSM Nodes, OSM ways and administrative limits). In addition, there are other xls and xlsx files with statistical information about these regions. This information comes from official repositories such as Eurostat, but it is also information generated by the partners through surveys of their population (see Figure 14. Data repository preview of sustainable food consumption survey generated within the scope of Quart de Poblet lab).

7.5 Conclusions

Cities2030 data repository is an open-source solution based on the well-known Open Data Publication network CKAN (Comprehensive Knowledge Archive Network), most widely used by cities, public authorities, and organizations. The choice of this tool and its coexistence with other services of the S2CP ecosystem responds to a need to offer a better distribution of resources, sorted by lab, contributing organization, format, license, aligning the publication structure to the Cities2030 entity model and its participating actors (Organizations, Datasets and Groups).

The functionalities implemented during phase #2 of the CDM have been the implementation of the Data API, to consume information from other S2CP components, the geospatial extension for the preview of data in Maps, and the secure cloud provision, for a seamless integration with the rest of the S2CP services.

In phase #3, the platform is validated through the introduction of 64 datasets and the creation of 163 users (Cities2030 partners and alliance partners), associated with Labs and Cities2030 organizations.

8 Real-time data monitoring

Real-time data monitoring component provides a system for receiving events produced by sensors. This S2CP component can collect information generated in a city, farm or other food-related organization, so that information can be later represented for real-time visualization or monetization.

8.1 Functional architecture

In the following figure the functional architecture of the solution is represented:

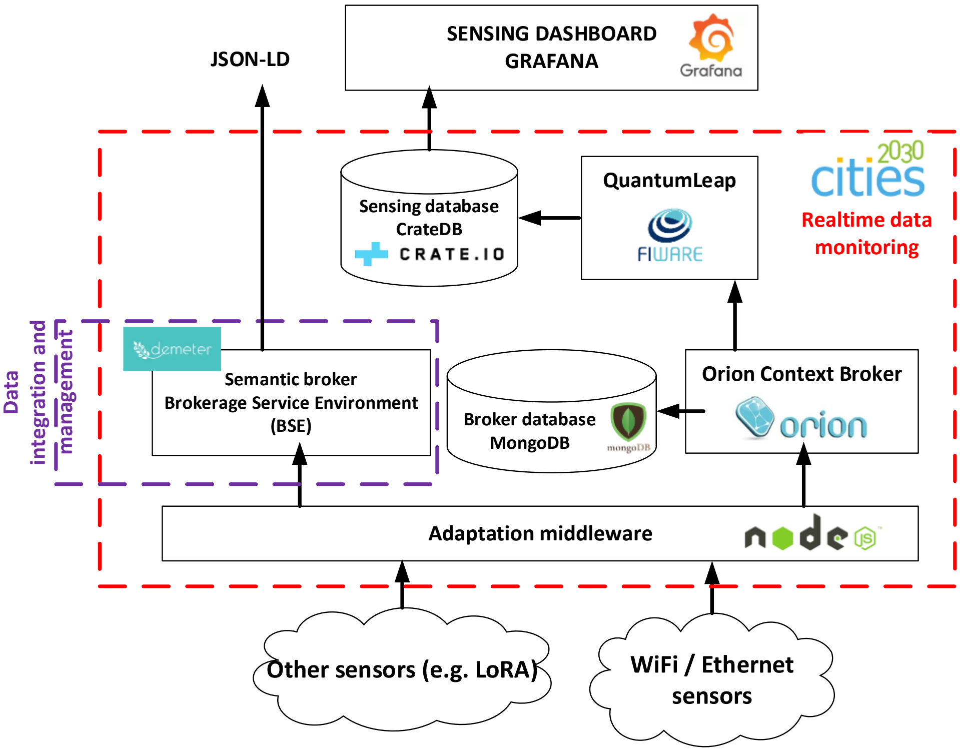


Figure 18. Functional architecture of real-time data monitoring component

The functional architecture shows that different types of sensors can supply data to real-time data monitoring, such as WiFi/Ethernet sensors, and other sensors that communicate with well-stablished technologies such as LoRA or SigFox. A connector-based adaptation middleware serves as a communication proxy and transmits information to two types of brokers:

- The semantic broker BSE publishes the interfaces for data consumption through a semantic model compatible with the data integration and management tool, and based on semantic models from previous projects such as DEMETER.
- The Orion Context Broker is a FI-WARE component optimized for sensor data communication, which supports the NGSIv2 protocol.

To provide persistence to the information received by the sensor infrastructure, the QuantumLeap module is used, another FI-WARE component that saves all sensor updates in a CrateDB sensing database.

Finally, this database can be used as a source of information for the representation of the information received in a dashboard, for subsequent analysis, filtering and as a decision support system.

8.2 Deployed sensorization infrastructure

A sensorization infrastructure has been deployed in the scope of Arganda Lab. Three smart sensor nodes have been installed in a food processing facility thanks to the associated partner CODAN S.A. (member of the Cities2030 alliance). Data has been captured by smart sensor nodes (powered by an Arduino Mega architecture with an Ethernet W5100 shield), combining various sensors:

- DTH-11 module to measure environmental temperature and humidity
- CCS811 module to monitor the air quality (equivalent CO2 -eCO2- and total volatile organic compounds - TVOC-).

Data structure is expressed in JSON-LD format, by following DEMETER's Agricultural Information Model and FI-WARE's NGSIv2 standard communication protocol.

In addition, the real-time monitoring component has been deployed in a cloud environment. For this, Docker technology was used, an open platform for developing, shipping, and running applications. Docker enables to separate the applications from the infrastructure so software can be delivered more quickly.

8.3 Component validation in workshops with labs

The described component has been validated within the framework of the Arganda Lab. Arganda Lab describes an Industry 4.0 use case, where data brokering solutions should be provided to improve food transparency and more information related to the food processing scenario, including environmental worker conditions.

An experiment in this lab has been defined using the innovation handbook of Task 5.2, which goal is:

- Improving the production efficiency and workers wellbeing through an Industry 4.0 sensing platform. Continuous and automatic monitoring should help companies to reduce resource consumption, waste, and improve the wellbeing and working conditions.

The real-time data monitoring component has been used to achieve this goal, considering the sensing platform, sensing database and middleware, the semantic broker, and the sensing dashboard. Through the information displayed in this dashboard, food processing companies may make decisions to improve their indicators.

An engagement plan has been stablished within the scope of Arganda Lab to result in the final validation of the S2CP component. This plan consisted of several phases:

- Establishment of an expert workshop for the detection of technological needs.
- Co-definition of an experiment for Arganda Lab with the S2CP platform
- Conducting the experiment and collecting data
- Dissemination and publication of results

8.3.1 Detection of technological needs with an expert workshop

To align the objectives of the lab with the technological capabilities of the components of the S2CP platform, the organization of a meeting in the format of an "expert workshop" was considered. In an expert workshop, participants are usually professionals from one of the food system links, who are used to dealing with food production systems, traceability, waste management, packaging, labeling, among others. The objective of this type of workshop is to obtain a more detailed opinion on some specific aspect of the proposed innovations, so that they can improve day-to-day work in these food systems. An example may be presenting factory workers with a new application that manages incidents that may occur in the manufacturing process, in order to obtain recommendations to improve this application and adapt it to real food production scenarios. These workshops are usually held in expert's facilities.

One expert workshop was held on 8th of July 2021 in a processing company facility (Arganda municipality) where experts in food processing exchanged ideas of how technology can help process automation in Industry 4.0. Some images of the workshop, with 10 participants, as seen below.

Figure 19. Expert workshop in CODAN facilities

The workshop concluded that the real-time data monitoring component was useful for collecting and monitoring the variables that define the working conditions in the factory. It also concluded that a results dissemination component such as Cities2030 community (which we will detail in Section 9) is useful for displaying information about the experiment that was going to be carried out.

8.3.2 Co-definition of experiment for Arganda Lab

The CODAN company which operates the food processing factory is currently transforming the factory from a traditional model to a Smart Factory model. The experiment co-defined in the scope of the Arganda Lab aims to monitor the conditions of workers in a food processing facility. Gas emissions, temperature and humidity have to be measured in real-time and represented in a dashboard. S2CP components will be used.

Considering this general goal (monitoring of relevant environment parameters of food production processes), Arganda Lab co-defines with WP6 a system for receiving events that can be produced by sensors. Thus, it can collect information produced by sensors that may be deployed in a city or on a farm and generate information repositories for real-time visualization or monetization. Therefore, this goal is in turn subdivided into two specific goals:

Table 3. Indicators of Arganda Lab's experiment with S2CP platform

Goal ID	Indicator	Types	Target value
#1	Thermal discomfort reduction	Productivity, behavior, gender equity	Reduction in unitary annual number of thermal discomfort episodes in 10%.
#2	Real-time alert notification	Productivity, delivery and time	Generation of alerts related to real time information in less than 30 seconds since error detection.

8.3.3 Conducting the experiment

The hypothesis to validate is that by using the S2CP platform, GOALS #1 and #2 can be achieved. That is, it is possible to reduce the number of thermal discomfort episodes of food processing personnel by 10%, and it is possible to generate alerts related to realtime information in less than 30 seconds since error detection.

Variables such as temperature, humidity, power consumption and air quality were monitored through sensor nodes. A framework of performance and economic indicators is generated, and we analyze their changes and envisioned evolution after the Industry 4.0 paradigm adoption.

To achieve that, the real-time data monitoring component developed by UPM-P20 was used, as it can receive events produced by sensors and represent the mesaures for real-time visualization or monetization. As stated in Section 8.2 this component requires some data input coming from an Internet of Things (IoT) hardware platform, which must be defined and deployed in the pilot site. The output of this component will be a database containing all captured real-time information, expressed in a semantic and interoperable format (according to data models defined in T6.2), and also a visualization dashboard to facilitate data visualization, filtering and some simple analysis.

The following figure shows the deployed platform.

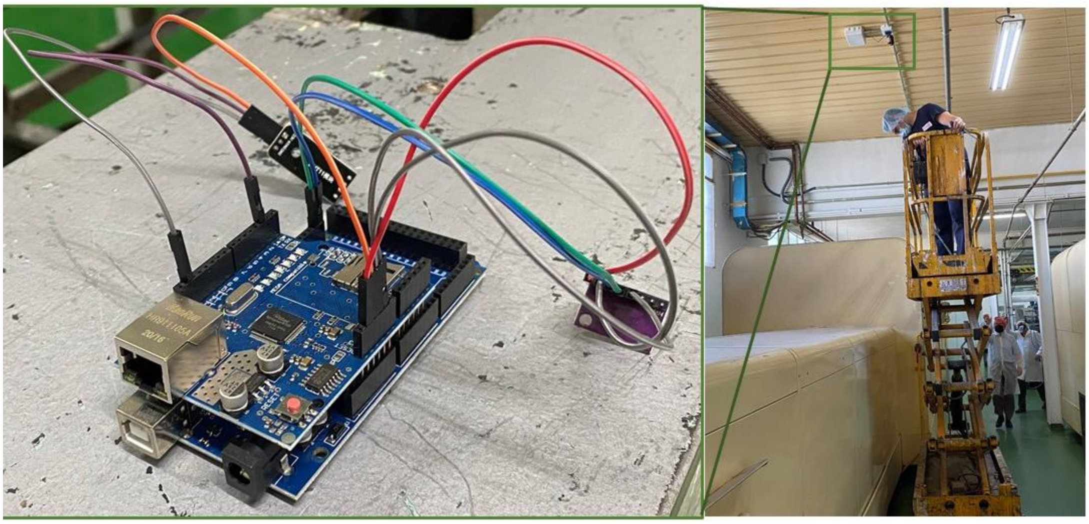


Figure 20. Deploying sensorization infrastructure

All software components were deployed in a private cloud in the Universidad Politécnica de Madrid. The underlying server was a Linux architecture (Ubuntu 20.04 LTS) with the following hardware characteristics: Dell R540 Rack 2U, 96 GB RAM, two processors Intel Xeon Silver 4114 2.2GHz, HD 2TB SATA 7,2K rpm.

In order to analyze the evolution of all indicators in the KPI framework, the following methodology was designed and implemented. Data was collected for six months and all indicators were evaluated.

In the following figure it is possible to see the collected information:

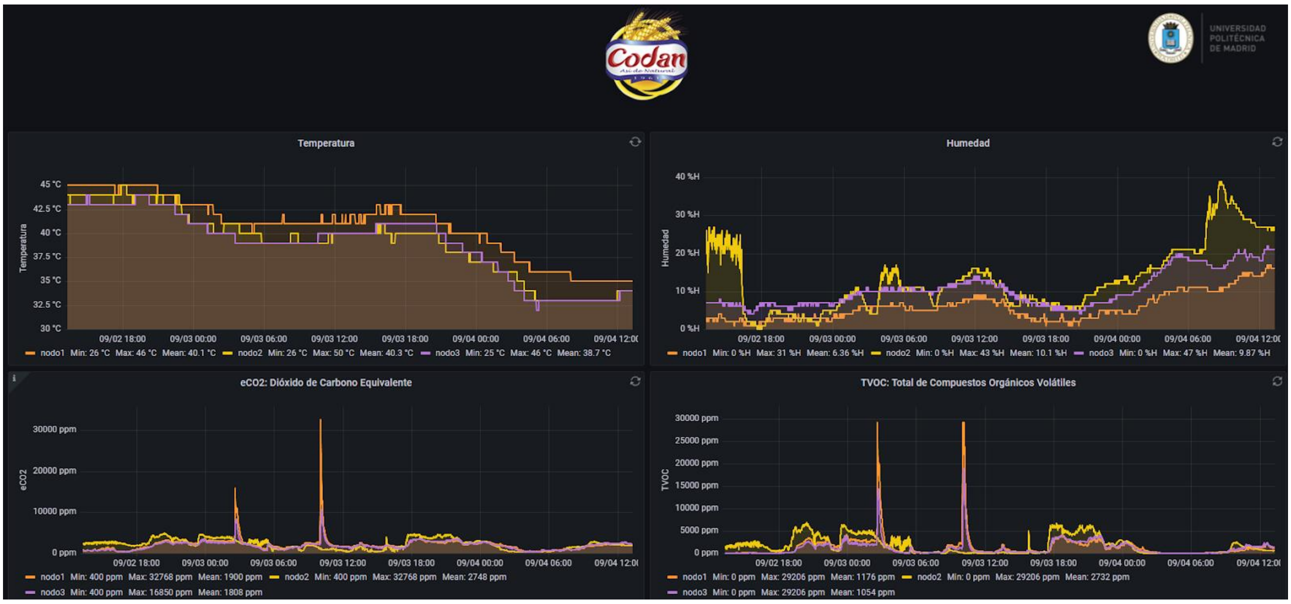


Figure 21. Validation of real-time data monitoring component

8.3.4 Dissemination and publication of results

The following dissemination actions were carried out on the operation of the real-time data monitoring component and its validation within the framework of the Arganda Lab.

Creation of Arganda Lab communities page

Arganda Lab has been created in Cities2030 Communities:

https://cities2030-community.gisai.eu/labs/5-arganda-lab/

Below it is seen an screenshot of this integration:

Figure 22. Profile of Arganda lab in Cities2030 Community platform

As it can be seen, pages regarding Context analysis, initial reflections, communication plan, indicators and discussions are created. Information that is already provided in the Handbook (T5.2) is also provided and disseminated by using the S2CP component.

Presentation of results in Cities2030 workshops

Arganda Lab’s deployment results were presented to other Labs and other Cities2030 partners in “Lab Festival” event, part of the Cities2030 GA in Haarlem, on 23rd of February 2023. At this event, the operation of the component and the results obtained after the implementation of the experiment were demonstrated.

8.4 Conclusions

Real-time data monitoring component provides a system for receiving events produced by sensors. This S2CP component can collect information generated in a city, farm or other food-related organization, using temperature, humidity and air quality sensors, and aligned with latest standards such as JSON-LD and FI-WARE's NGSIv2.

Expert workshops within the scope of the Arganda Lab indicated that this component was useful to achieve their goals on thermal discomfort reduction and real-time alert notification. Finally, the real-time data monitoring component deployment results in Arganda were presented to other Labs and other Cities2030 partners in "Lab Festival" event, part of the Cities2030 GA in Haarlem.

9 Cities2030 Community

This section describes the Cities2030 Community component, the open collaboration space used by Cities2030 participants to improve their multi-stakeholder dialogue processes.

9.1 Extending data sources

The information used for the creation of this component comes mainly from the processes established in WP4 and WP5 to create an open innovation structure around the CRFS Labs objectives and capabilities.

In the first version of this component (up to M24) the data sources detailed below were mainly used:

- Innovation methodology for policy labs (WP4): The innovation methodology of the policy labs has been launched in the framework of WP4. This methodology defines a series of phases for policy co-creation, which are listed below: Phase #0: Get the information about your CRFS (agents, relations, etc.) from different sources, Phase#1: Analyze the current state of your CRFS, Phase#2: KPI selection and action points.
- Extended Innovation Pattern (EIP), proposed in Task 5.2. EIP makes a Handbook available to Labs, through which Labs can advance in the processes of creating their collaborative ecosystem following the open innovation paradigm. From the Communities component, a structure has been created so that the Labs can follow up on the EIP according to the following phases proposed by WP5: #0 CRFS Living Lab for Developments and Innovations, #1 Understand CRFS and #2 Analyze the Challenge.

For this second version of the platform (M24 to M48) we have focused on the following data sources:

- Lab festival, 23 February 2023, Koepelhal, Haarlem. This event collects the Policy Action Plans of the labs, indicating initial objectives and activities to achieve these objectives. Figure 23 shows the format of the lab festival and the information collected in the form of posters, structured according to (i) Context, (ii) Lab vision, (iii) Current activities, (iv) future activities that has been subsequently processed.
- Extended Innovation Pattern (EIP), #2 Analyze the Challenge: step 2, innovation action plan. The results of the phase are a shared and improved understanding of the challenge through the establishment of an action plan. The Action Plan is a milestone that urges living labs to summarize their understanding of CRFS vision towards 2030 and challenges into an actionable series of experiments and measures for the second half of the project (up to M48). The gained knowledge gives a good basis for setting the SMART Goals for the forthcoming experiments.
- Extended Innovation Pattern (EIP), #3 Experimenting. The main purpose of the Experimenting phase is that CRFS-LLs carry out experiments in a systematic, goal-oriented and participatory manner. The results of a series of experiments are evolved for business purposes or other exploitable assets to implement beyond the project time span.

- D4.5 Deployment Program Plans & Tools to Engage with Follower CRFS Labs: application of the business canvas model to the preparation of deployment plans for CRFS labs. Provision of Goal Attainment activities to reach SMART Goals included in EIP.

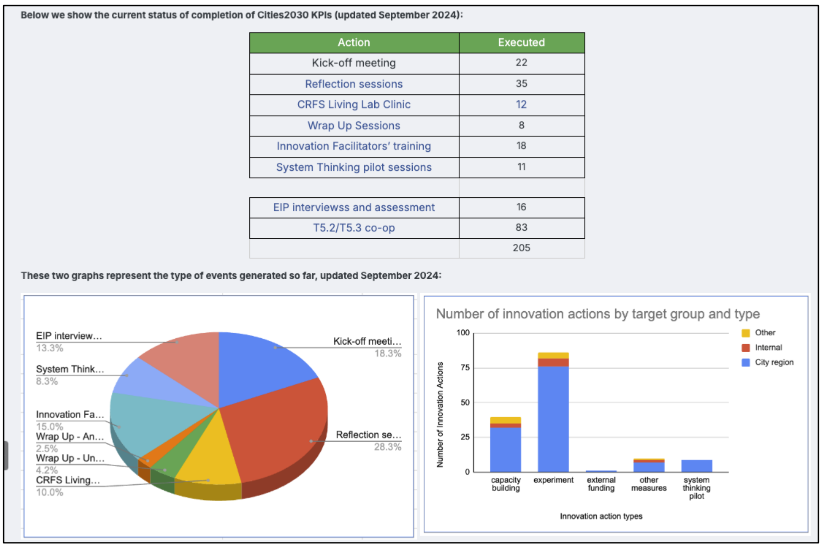
Figure 23. Lab festival poster presentation in Haarlem

9.2 New functionalities

In this section we describe the new features that have been enabled in the Cities2030 Community portal.

9.2.1 General pages for project monitoring

As planned functionalities, to help in the management and dissemination tasks and to connect with the efforts that are taking place in other workpackages, it is proposed the creation of general pages that shows overall indicators on the performance of Cities2030 labs. The following figure shows a general page created in communities with indicators on the number of innovations produced by the labs, classified according to different typologies (labs, type of innovation, location, etc.).



Below we show the current status of completion of Cities2030 KPIs (updated September 2024):

Action	Executed
Kick-off meeting	22
Reflection sessions	35
CRFS Living Lab Clinic	12
Wrap Up Sessions	8
Innovation Facilitators' training	18
System Thinking pilot sessions	11
EIP interviewss and assessment	16
T5.2/T5.3 co-op	83
	205

These two graphs represent the type of events generated so far, updated September 2024:

Figure 24. General KPI page in Cities2030 community

9.2.2 Improved calendar

A calendar is implemented to disseminate and share information on events, activities and results. In a new improved version of the calendar, the following features are included:

- Hovering over an event produces a pop-up with a preview. Users can subscribe to calendar events to receive email notifications when there are new events, or events occurring near their city.
- Events allow comments so users can answer questions about the event or interact with the organizers.

The following figure shows a sample of the new calendar features for the month of November 2023.

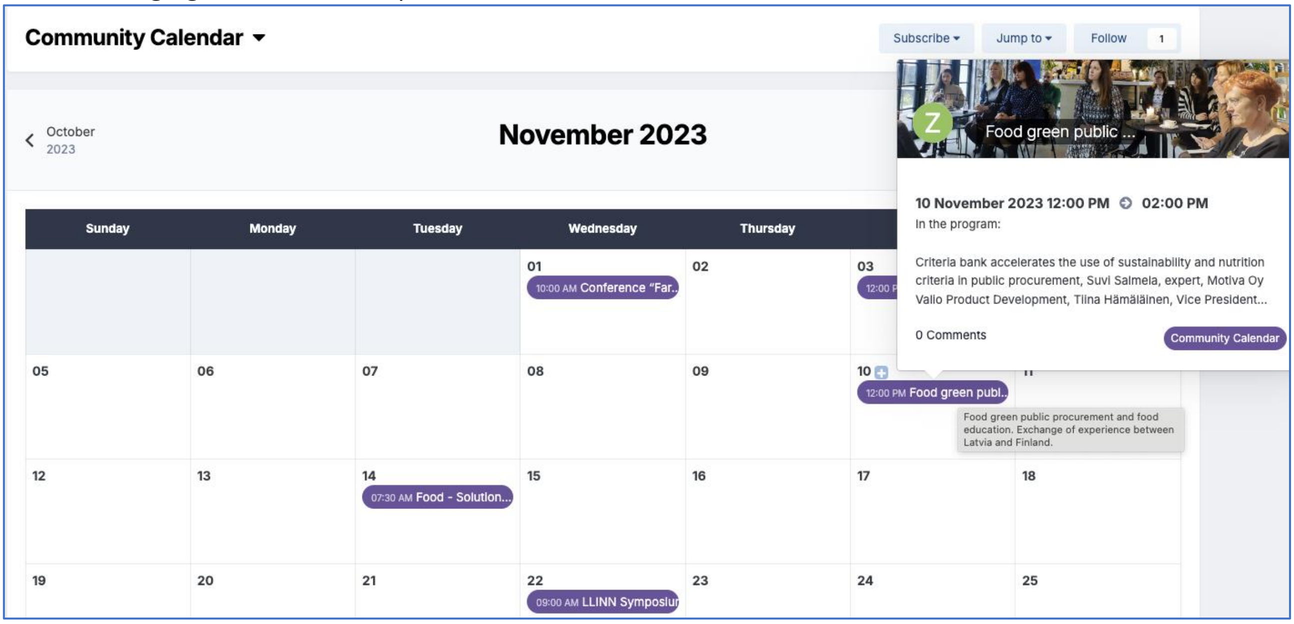


Figure 25. Calendar in Cities2030 Community platform

9.2.3 Classification de Labs

The page that displays information about the Labs additionally includes information about the type of lab it is, according to their definition by Cities2030:

- ***Pilot***: Original labs that started the Cities2030 Project. They have initially defined objectives and follow the methodologies defined in WP4 and WP5 for the development of their innovation actions.
- ***Flagship***: Also called lighthouse, these are labs that have recently joined the project, and which, due to their achievements and experiences, can serve as an example of good practices for others.
- ***Multiplier***: New labs that are interested in launching initiatives already explored in other labs (pilots or flagship) but applied to their circumstances and problems, depending on the region of study.

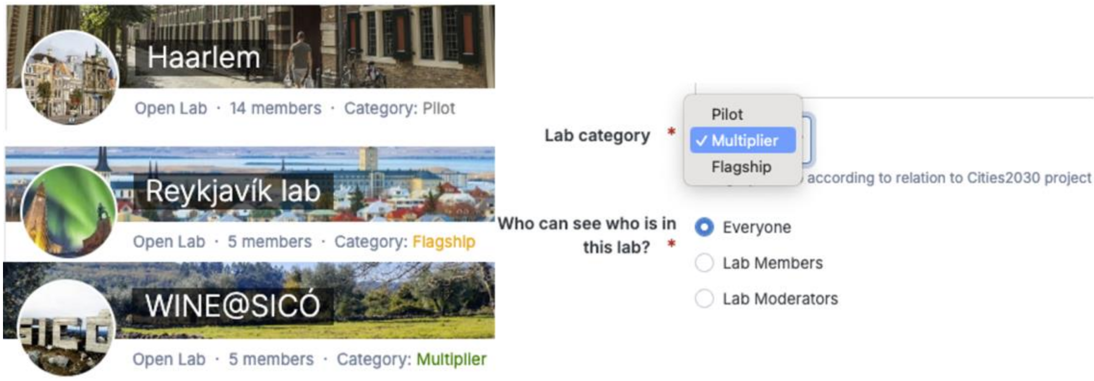


Figure 26. Lab classification in Cities2030 Community platform

9.2.4 Community as Single Sign-On server

As explained in other sections, the possibility of the Community platform acting as a Single Sign-On server has been implemented. This functionality is detailed in section 3.4 Shared mechanisms: Single Sign-On.

9.3 Validation: Workshop with labs and user registration

We present two points of view on platform validation. On the one hand, the platform is made known to stakeholders through workshops where the main functionalities are presented and feedback is collected (section 9.3.1) and on the other, the demonstration of the use of the platform through the actions that have been carried out on them (section 9.3.2).

9.3.1 Community workshops

This second version of the Cities2030 Community application has been validated through various workshops and presentations:

- "Analyze your Lab with data". GA in Haarlem, 23rd February 2023
- "Data in Cities2030". Event: "Complexity and Food System – Tools and Policies to support CRFS and the food supply chain", Venice, 25th January 2024
- "Data mining for living labs and community platform". GA in Marseille, 20th June 2024

Below are some photos from the presentations of the first two workshops. Photos from the third workshop "Data mining for living labs and community platform", as it was also used to present the Data mining component, are included in the section describing this component (Section 6).

Figure 27. Community workshop (Analyze your Lab with data) in GA in Haarlem (23rd February 2023)

Figure 28. Data in Cities2030 workshop in Venice (25th January 2024)

9.3.2 Platform usage

Below we present some data that reflects the use that has been given to the platform, such as data accumulated since its launch. First we will talk about the number of registrations and the use of categories for user groups. At the time of writing this deliverable there are a total of 129 registered members, who are divided into the categories expressed in the following figure:

GROUP NAME	MEMBERS
Administrators	2
Alliance Partner	28
Cities2030 partners	82
Guests	1 guest (Online)
Moderators	0
Registered	17

Figure 29. Registered users in Cities2030 Community, by category

As for the number of page views, some statistics can be seen in the following graph:

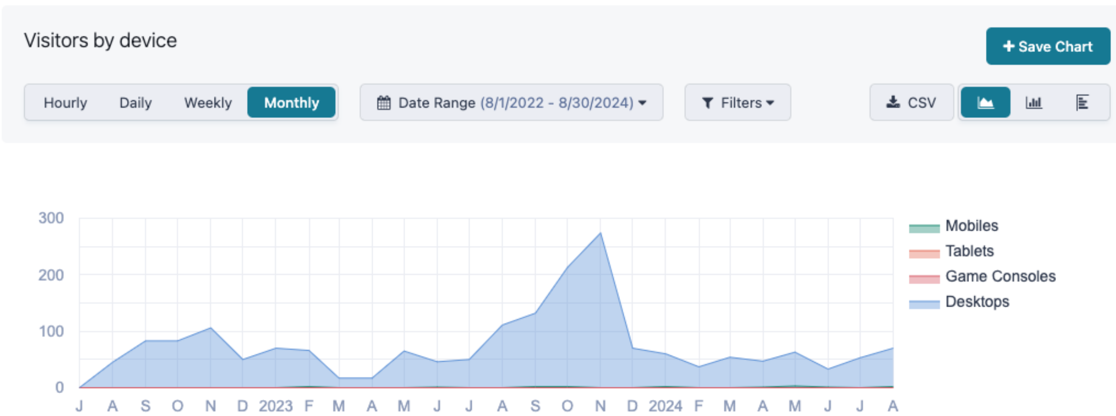


Figure 30. Visitors by device in Cities2030 Community

It shows that in the last two years there have been about 60 visits on average, reaching 270 visits by the end of 2023.

Finally, in terms of lab registrations, 24 labs have been created on the platform: 12 Pilots, 9 multipliers, and 3 flagships. The API provided by Google Maps is used to represent users and labs, as can be seen in the following figure, where all registered labs are represented.

Figure 31. Use of Google Maps API for map of labs

9.4 Conclusions and future work

The Cities2030 community component is a communication environment between project participants and social agents. In this second version of the platform, new data sources have been added in accordance with the innovation action collection methodologies carried out within the framework of WP4 and WP5. Specifically, we have focused on the development of the action plans and the experiments defined by the labs (pilots, multiplier and flagship).

The new functionalities facilitate the publication of results related to the activities carried out within the framework of the Labs. They complement the functionalities already tested to deploy static information, mechanisms for asynchronous communication between the different registered people (forums), and calendar systems.

Finally, it has been demonstrated that sufficient actions have been carried out to make the platform known to the stakeholders, through workshops, and that the platform has been used by them, thanks to the content editing features, and the login functionality, which also offers a single interface for authentication in the rest of the S2CP components.

10 Good practices

This section describes the updates made to the Good Practices component during the period M24 to M48. Good practices tool is a map-based platform to allows the introduction of innovation activities by any Cities2030 partner, so that a catalog of information can be compiled, for filtering, searching and consulting (considering FAO pillars and MUFPP indicators).

10.1 Information collection methodology

The main data source for this component is T3.6, which results in "The 100 Innovation Framework". This framework aims to explore and map the novel trends in several applicable spheres of the food system, identifying emerging digital and technological solutions, start-ups, practices of local communities, findings of international research projects and other initiatives that promote positive transformation in CRFS.

This task has collected 140+ innovations and good practices from more than 20 countries (e.g., the EU countries, Iceland, North Macedonia, Turkey, the USA, Canada and other). Innovations were clustered in Cities2030's 10 key thematic: food production, processing, distribution, markets, consumption, waste, food security, social inclusion & equality, ecosystem services, and livelihood & growth.

A Google Form survey was created by P25 for Cities2030 partners to collect innovations from their network. These innovations were introduced by several partners (P25, P20, P5, P2, among others) in the Good practices component. This action was already described in D6.3 "Service-based open collaboration space development report".

In February 2024, the Latvijas Lauku forums team (P25), on the occasion of the M47 version (final version) of the 100 innovation frameworks of CRFS D3.7, launched a survey again where they asked about the following parameters:

- Partner collecting the innovation
- Innovation title
- Description of the innovation. (What is it? What problem or issue it helps to solve in the CRFS? Who are the main beneficiaries or users? How is it implemented?)
- Thematic area (from Cities2030's 10 key thematic)
- Impact on CRFS (What positive impact innovation has on CRFS?)
- Innovation potential for learning or transfer (How and why the innovation potentially could be interesting for other cities or regions to learn from?)
- Source of information on innovation: 1) organization name (developer or implementor), 2) website or active social media account (Facebook, Twitter, Linkedln, etc.)
- Location of innovation (city, region, country)
- Representative picture

The theme of this new collection process was the activities promoted by the project labs. The following partners (among others) were the main contributors: 23 FFI, 27 AGFT, 40 CITAG, 14 SLEAN. 33 new good practices were collected and an equivalent number of old practices were updated. Using the methodology promoted in WP6, some of these good practices were selected for incorporation into a second version of the tool. The criteria followed to carry this out were the following:

- The originator of the Good Practice proposal has the category of Cities2030 lab (pilot, flagship or multiplier lab), according to roles defined in KPI "role-based authorization" (see Section 4 Impact monitoring: final review).
- Location of innovation corresponds to a country represented in the Citeis2030 partnership. The location defines a region precisely.
- The description of the innovation is sufficiently detailed, including Impact on CRFS and Innovation potential for learning or transfer.
- Additional information is presented in the form of images that can be used and linked publicly.

Using these criteria, 42 new initiatives were introduced to existing ones, making a total of 84 complete descriptions of Good Practices.

10.2 Added functionalities

In addition to the functionalities already analyzed in section "5.2 Detailed functionalities" of D6.3, new functionalities have been incorporated in this new version of the application:

- Securing the virtualization server (cloud system) for its connection through a *.eu domain and HTTPS connection.
- Improved display of markers and geospatial clustering of information.
- Facilitating the introduction of coordinates to improve the user experience when registering new Good Practices (using the interactive map).
- Integration with the S2CP authentication server for sharing access profiles. Graphic evidence of this integration can be seen in Figure 4.
- Improved image display to avoid distortion due to oversize height or width.

The validation of these new functionalities has been carried out through the study of Section 10.3.

10.3 Good practices validation: Usability study

The application's usability impact has been analyzed using two criteria. From a theoretical point of view, in Section 10.3.1 we analyze how the application aligns with the ten usability principles[21] established by Jakob Nielsen. This analysis allows us to identify strengths and weaknesses in the application design, facilitating a detailed understanding of how the implemented features meet usability expectations and where there are opportunities for significant improvements.

In Section 10.3.2, and to complement the theoretical analysis, a usability survey is designed and distributed. The purpose of this survey is to collect direct feedback from users about their experience with the application, ranging from ease of navigation and clarity of information presented, to overall satisfaction with the platform.

10.3.1 Usability principles assessment

Next, we will analyze whether the usability principles described by Jakob Nielsen in the application of Good Practices are met. These principles provide a framework for evaluating critical aspects of the user experience, including the simplicity of the design, the effectiveness of communication of the system status, and the ease with which users can complete their tasks and correct errors.

1. *Visibility of system status:* The web system should always keep users informed about what is happening, through appropriate feedback within a reasonable time. **Result:** This principle could be improved. When the user performs a search by name and no results are found, it would be useful to add a message indicating that there is no search with that name so that the user understands what has happened.

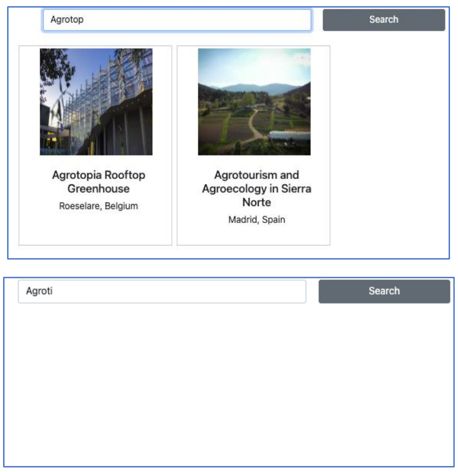


Figure 32. Search with results (top) versus search without results (bottom)

[21] Nielsen, J. (2005). Ten usability heuristics.

2. *Correspondence between the system and the real world:* The system should speak the language of the users, with words, phrases and concepts familiar to the user, rather than system-oriented terms. It should follow the conventions of the real world, making information appear in a natural and logical order. **Result:** This principle is satisfactorily fulfilled. The system is verbally understandable, that is, it speaks the same language as the users. In addition, the symbols included, such as the clock to indicate the duration or the location icon, are easily recognizable.

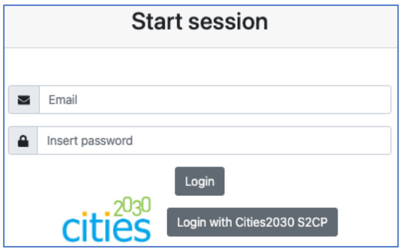


Figure 33. Login details in good practices component

3. User control and freedom: Users often choose system functions by mistake and will need a clearly marked way to exit the undesired state without having to go through an extensive process. **Result:** This principle is met. Users can easily return to previous views using a back button.

4. Consistency and standards: Users should not have to wonder whether different words, situations or actions mean the same thing. Follow the platform's conventions and standards. **Result:** This principle is also fulfilled. The map follows a standard model used on other websites. Markers indicate the place where innovation actions are carried out. If we click on one of these markers we will be redirected to the information about that innovation activity.

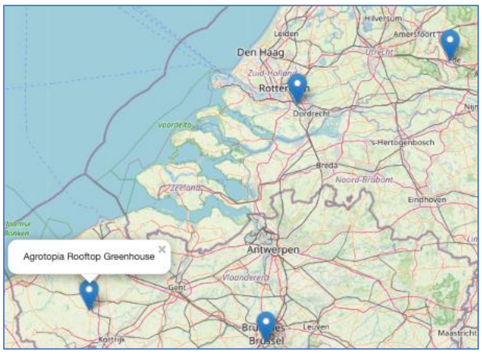


Figure 34. Login details in good practices component

5. Error prevention: It is better to prevent errors than to have good error messages. Careful design can avoid problems. **Result:** Clear and logical arrangement of elements helps prevent errors during navigation.

6. It is better to recognize than to remember: Minimize the cognitive load on the user by making objects, actions and options visible. The user should not have to remember information from one part of the dialog to another. **Result:** This principle is fulfilled. The system includes descriptive icons that complement the information. In addition, detailed information about the different activities can be consulted in the same way, by clicking the button to see more details.

7. Flexibility and efficiency of use: Accelerators, invisible to the novice user, can often speed up the interaction for the expert user so that the system can cater to both novice and expert users. Allow users to customize frequent actions. **Result:** To improve this principle, a section could be added listing activities added in the last few weeks. This would allow users to discover new opportunities more efficiently, avoiding repeatedly reviewing the same activities.

8. Aesthetic and minimalist design: Dialogs should not contain information that is irrelevant or rarely needed. Each piece of extra information competes with the relevant information and decreases its relative visibility. **Result:** This principle is fulfilled. The design of the website is clean, without any extra information that is not useful. The minimalist approach evident in the pages presenting the detailed information of each good practice is noteworthy.

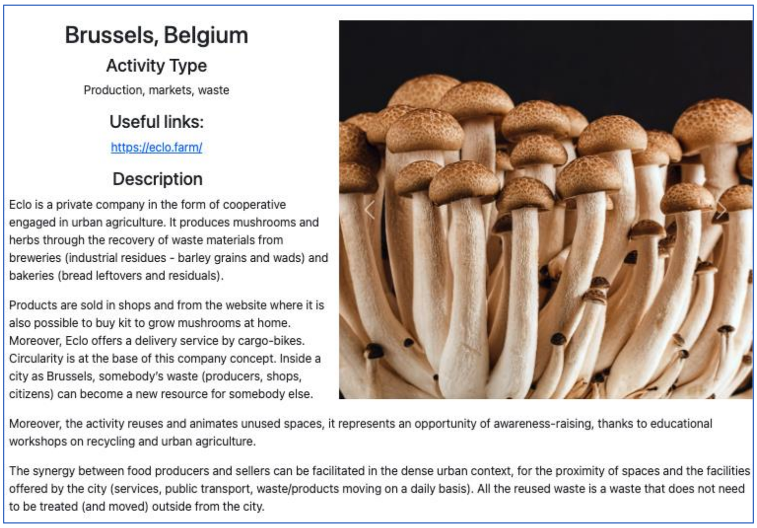


Figure 35. Good practices description detailed view

9. Help users recognize, diagnose, and recover from errors: Error messages should be expressed in plain language (no codes), accurately indicate the problem, and constructively suggest a solution. **Result:** A robust platform is presented where causing a user error is relatively difficult, thanks to an intuitive design and a user-friendly interface.

10. Help and documentation: Although it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any help information should be easy to find, focused on the user's task, list concrete steps to be carried out and not be too extensive. **Result:** This principle is partially fulfilled. There is documentation on the official cities2030 website on the use of the Good Practices component, as well as in the corresponding deliverables, as can be seen in the following figure. To improve the help and documentation offered, a section could be provided where the user can contact the website owners. Other components such as Cities2030 Community do have this functionality.

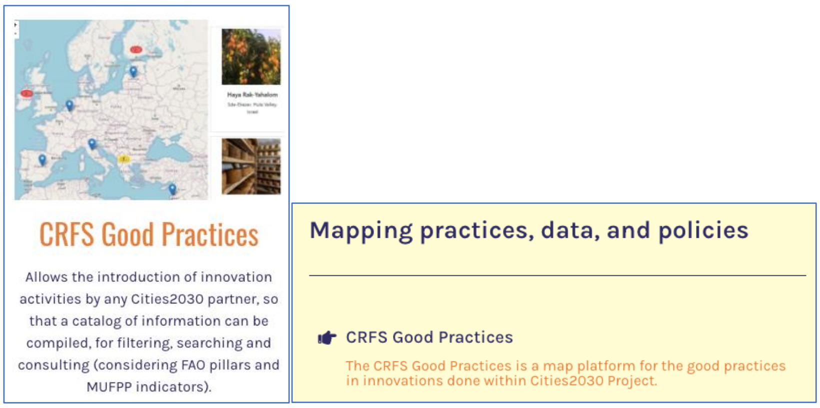


Figure 36. Description of good practices component in S2CP webpage

10.3.2 Usability survey

10.3.2.1 Motivation

The decision to use a survey as the main data collection instrument is justified by the following reasons:

- Flexibility and scope: The survey allows reaching a wide audience of users in an efficient manner, as it facilitates the collection of a significant volume of data in a relatively short time.
- Combination of methods: By integrating quantitative and qualitative questions, the survey offers a powerful combination of research methods. This mixed approach allows not only to quantify aspects of usability, but also to explore in depth the experiences and motivations of users.
- Comprehensive analysis: The structure of the survey facilitates a comprehensive analysis of usability, allowing the identification of areas of strength and opportunities for improvement. The combination of statistical analysis of closed responses with content analysis of open responses ensures a detailed understanding of how and why certain aspects of the application impact the user experience, providing a complete view of the user's interaction with the application.
- Pressure-free environment: Unlike in-person usability testing or interviews, surveys allow users to provide their opinions and feedback in a pressure-free environment, which can lead to more honest and thoughtful responses.

10.3.2.2 Methodology

The methodology used is as follows:

After selecting the survey as the optimal data collection instrument and Google Forms as the platform for its implementation, the development and structure of the survey have focused on maximizing the quality and relevance of the information collected. The survey is made up of a total of 30 questions, divided into 5 sections. The average response time has been estimated to be between 10 and 15 minutes, in order to ensure that detailed information is collected without overloading users. The survey begins with general questions about the user experience and progresses to more specific questions about individual functionalities and design aspects. The sections and main questions are described below:

- Section 1: Demographic Information and Technological Experience: The first section of the survey is dedicated to collecting basic demographic information and assessing the level of technological experience of participants:
  - Age: allows segmenting the data according to age groups
  - Gender: seeks to capture gender diversity among participants, allowing open questions and optional response.
  - Educational level: provides insights into cultural and socioeconomic background
  - Technological experience level: assesses users' knowledge and ability to use technologies
- Section 2: Evaluating Usability and Website Content, integrating the following questions:
  - *What's your opinion about the website?* This question offers three options to measure how easy it is for users to understand and become familiar with the website.
  - *Is the website navigation intuitive?* Measures how users perceive the ease of navigation within the website.
  - *Does the website have an attractive design?* This question seeks to assess the aesthetic perception of the website among users.
  - *Does the website have relevant and detailed content?* Constantly updating the content is crucial to keep the website dynamic and attractive to users.
  - *Is the website suitable for all types of audiences?* Seeks to understand whether the website is inclusive and accessible to a wide range of users, regardless of their level of technological experience or prior knowledge about volunteering.

- Section 3: Navigation Preferences, Layout, and General Feedback, integrating the following questions:
    - *What is the easiest method to find an interesting initiative?* This question identifies the tool or feature preferred by users to search for initiatives on the platform.
    - *How do I find the size of the map?* It assesses the user's perception of the size of the interactive map, a crucial element for the search experience.
    - *How do I find the size of the images?* This question collects opinions on the size of the images on the website, which is important for the visual appeal and clarity of the information presented.
    - *How do I find the color scheme of the website?* This question seeks to understand how users perceive the color scheme of the website, contributing to the overall visual design and user experience.
    - *Do you have any additional comments?* Suggestions or constructive criticism about the website and user experience.

10.3.2.3 Selected distribution channels

To avoid familiarity bias[22], that is very present in research projects, as indicated by several authors[23], we tried to avoid having the Cities2030 participants themselves, experts in food systems, and familiar with the work of WP6, answer the questions to evaluate the impact and ease of use of the Good Practices component. Instead, general distribution channels were selected, to ensure wide participation, based on their popularity and effectiveness in reaching the target audience, such as social networks. Instagram and X, formerly known as Twitter, have been the main channels used, given their popularity among young and adult audiences and their ability to facilitate rapid dissemination of the survey.

To increase the reach and participation in the survey, users were provided with a direct link to the website along with the survey invitation, allowing them to interact with the application beforehand. This ensures that the answers are based on current and genuine user experiences, enriching the quality of the data collected.

10.3.2.4 Ethical and privacy considerations

Throughout the survey distribution and collection process, important ethical and privacy considerations have been taken into account.

- Informed Consent: It has been ensured that all participants are duly informed about the purpose of the survey and how their responses will be used, guaranteeing their informed consent. To this end, the first question in the questionnaire implies accepting that the data will be processed for research purposes within the framework of the project.
- Anonymity and Confidentiality: The anonymity of the responses has been guaranteed to protect the identity of the participants, and measures have been taken to ensure the confidentiality of the information collected. To this end, the email addresses from which the surveys are conducted are not collected.

[22] https://www.thebehavioralscientist.com/glossary/familiarity-bias

[23] Greul A, Schweisfurth TG, Raasch C (2023) Does familiarity with an idea bias its evaluation? PLoS ONE 18(7): e0286968. https://doi.org/10.1371/journal.pone.0286968

10.3.2.5 Result analysis

Following the distribution of the survey, a total of 61 responses were collected, which is in line with the objective established in the selection of the population to reach a representative sample of between 50 and 75 participants.

Below are the results by section. Starting with Section 1 (Demographic Information and Technological Experience):

- The demographic distribution of the sample reveals a predominance of young people, with 81% of participants falling in the age range of 18-34 years.
- From a gender perspective, there is a slight bias towards women, who represent 54% of participants, while men make up the remaining percentage.
- Regarding educational level, an impressive 75% of respondents hold a university degree, indicating a high level of education among participants.
- When exploring the professional and technological experience of participants, we found that 27.9% report having professional experience. 39.3% identify themselves as having advanced technological experience. The remaining 32.8% of participants describe themselves as having basic technological experience. This finding is particularly relevant, as technological competence can significantly influence how users interact with and perceive the application.

In relation to Section 2: Evaluation of the Usability and Content of the Website, we highlight the following results:

- Almost all respondents find the website intuitive, with 98.4% of them stating that the platform is quite easy to use. Only a scant 1.6% mentioned that it took them some time to figure out how to navigate the site.
- Regarding the design, most users have a positive opinion: 49.2% strongly agree that the design of the page is attractive, while 42.6% only agree with this statement. Only 8.2% remain neutral, suggesting that the visual aspect of the page is generally well received.
- The navigation of the page also receives high marks, with 62.3% of users rating it as completely intuitive and 36.1% agreeing with this perception. This indicates that users can move around the website and find what they are looking for with ease.
- The relevance of the available content is also highly valued, with 57.4% of participants considering it to be totally relevant to their interests and 36.1% agreeing. This shows that the information provided on the platform is considered useful and pertinent.
- The majority acknowledges that the website has detailed content, with 52.5% strongly agreeing and 36.1% agreeing. 11.5% remain neutral, which may indicate opportunities for improvement in its content.
- The adaptability of the page is highly valued, with 50.8% of users considering it to be totally adaptable and 41% considering it sufficiently adaptable. This suggests that the website manages to be inclusive and accessible to a wide audience.

In relation to Section 3: Visual aspects of the website and preferences, we highlight the following results, also reflected in the following figure:

- The most popular way to search for initiatives is by scrolling through the full listing, with 54.1% preferring it. This suggests that many users like to have an overview of all available options before making a decision.
- Browsing on the map is the second most popular method with 37.7%, indicating that a significant portion of users value the ability to search for initiatives based on geographic location.

- Using the search engine by name is less common with only 8.2% preferring it, which could reflect a lower interest in searching for specific opportunities.
- The majority of users, 91.8%, find the size of the map on the website to be adequate, indicating that a good balance has been achieved that meets the viewing needs of most users. A small percentage do not fully agree, with 6.6% finding it large and 1.6% finding it small.
- Similarly, the size of the images is considered adequate by a large majority of users, 93.4%. A small group thinks that the images are too small, 4.9%, while only 1.6% consider them too large. This reflects an effective visual design that effectively communicates information through images.
- The color scheme of the website is very well received, with 90.2% of users rating it as attractive. This suggests that the color scheme contributes positively to the user experience, making navigation through the platform visually pleasing. Only a minority, 3.3%, considers the color scheme to be overdone or excessive 6.6%.

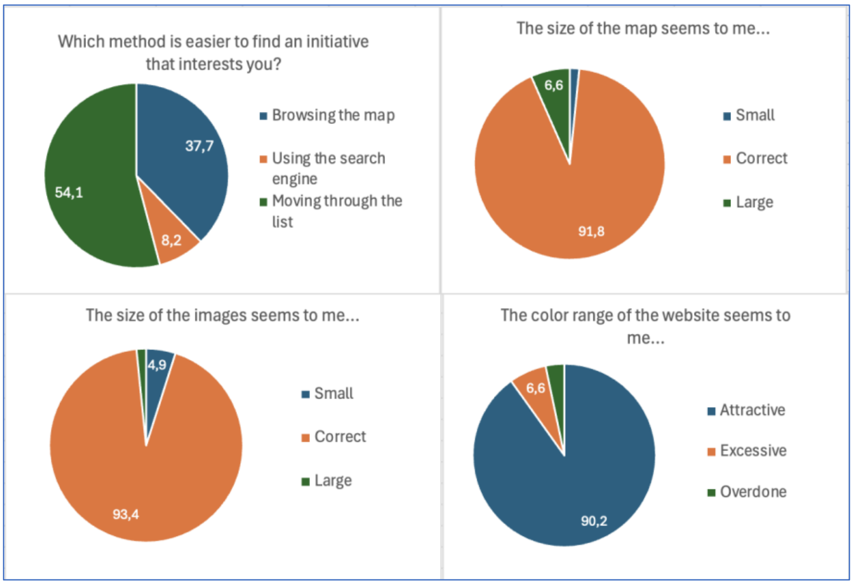


Figure 37. Pie chart of usability survey Section 3

10.3.2.6 Limitations of the analysis

The proposed methodology aimed to carry out a sufficiently representative analysis. However, it is important to recognize certain limitations of the study that could be considered in future research.

- Sample size and diversity: Although 61 responses were collected, this number limits the ability to generalize the findings to the entire future user population. In addition, the concentration on a specific demographic segment, primarily young people between 18 and 34 years old with a high level of education, may not fully reflect the diversity of experiences and opinions of all potential users.
- Self-selection of participants: Since participation in the survey has been voluntary, a self-selection bias may have been introduced, where those who chose to respond may have different experiences or attitudes towards technology or food systems, compared to those who chose not to participate.
- Limitations in the depth of questions: Although the survey was designed to cover a wide range of topics related to usability and user experience, the survey format limits the depth of responses that can be obtained.
- Limitations in question depth: Although the survey was designed to cover a wide range of topics related to usability and user experience, the "survey" format limits the depth of responses that can be obtained.

10.4 Conclusions and future work

The good practices component has been improved with a second version, which has incorporated new data sources, improved functionalities and a usability study, which has detected shortcomings and future proposals for improvement, indicated for the post-project period of cities2030.

In relation to new data sources, collaboration with other innovation research tasks (T3.6) and with the cities2030 labs (through WP4 and WP5) has allowed us to increase the database of new practices, focusing, in this second version, on the practices detected by the labs in their study regions. At the time of preparation of this deliverable, the set of new practices included in the component amounts to 84.

The second and third phases of the combined development methodology have been used to improve the functionalities of this component, including improvements in security and profile-based access management, as well as in the visualization of information (positioning of images and introduction of location through the map).

These features have been analyzed using Jakob Nielsen's 10 usability principles with positive results in most indicators, but also extracting recommendations for improvement, such as a section of recently added new entries, or increasing the information on the navigation status of the page. The study, extended by using a survey, also concludes that the users' experience with the website is very positive (with adjectives such as "interesting", "intuitive", "effective", "simple", "clear", "useful" and "practical"). The users surveyed find the website attractive, which plays a crucial role in their decision to use it as an innovation analysis tool, contributing to a pleasant user experience. In addition, they highlight the ease of navigation of the site, allowing them to quickly find the information they are looking for, which is key to simplifying access and potentially increasing the number of users of the platform.

11 Multi-Actor Approach Tool

11.1 Introduction

The MAATool is designed to aggregate information from various teams involved in a program that employs the multi-actor approach methodology. It estimates stakeholder representativeness using a customizable set of indicators and tracks the progress of Key Performance Indicators (KPIs).

11.2 Architectural design

This section will describe the main functional units defined in the MAATool.

11.2.1 System overview

The MAATool is deployed by *Docker Compose*, both in development and production environments. They integrate the SSL service for HTTPS protocol, an *Angular 17*-based website hosted on *Nginx*, a mail server utilizing the *Node Mailer library*, a *MariaDB database*, and an API developed using the *NestJS* framework on *NodeJS*.

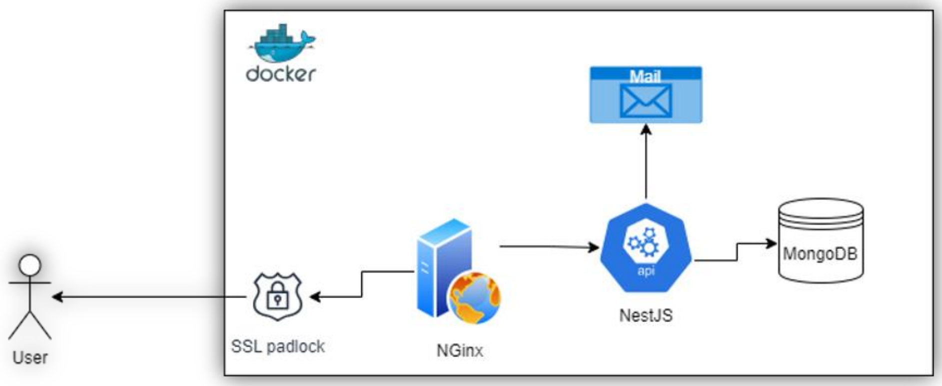


Figure 38. Subsystem design of MAATool

The primary language for both the backend and frontend of this project is TypeScript. This choice aims to ensure cohesive development and facilitate rapid understanding of the business domain elements during coding. The application's main server is hosted on a Google Cloud virtual machine, with access secured through SSH protocol using username and password credentials.

To enhance version control management, all components related to the system's functionality are stored in separate repositories on GitHub. They are:

- *MAATool:* This is the primary repository, which is public. Its main purpose is to host the project's wiki, detailing its functionalities.
- *maatool-app:* Here hosted the Angular 17 application.
- *maatool-api:* In this repository is the Nest JS application based on NodeJS.
- *maatool-deploy:* This repository contains the configuration main files at the time the system is deployed and the docker-compose file.
- *maatool-development:* The site where the project files, assets and graphics are located.

11.2.2 System architecture

A diagram including functional units and how the exchange data is presented in the following Figure:

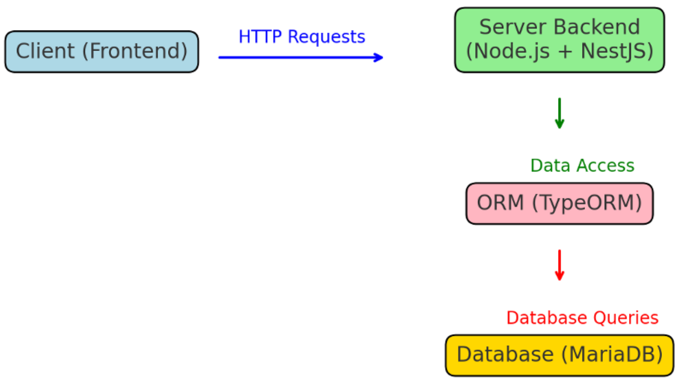


Figure 39. MAATool system architecture

11.3 Technology selection

In this section the selection of technologies is described from the point of view of the two main parts of this component, the frontend and backend.

11.3.1 Frontend

The frontend part has been developed using Angular 17. But it has been updated to Angular 18 to ensure that the latest functionalities and security updates are present on the website. Apart from that there are no plugins other than bootstrap, Apexchart or Pluralize installed.

The application is structured into separated modules that bring stability and cohesion to the development. The development has followed the principles of Clean Architecture to ensure a robust, maintainable, and scalable codebase. This approach separates the concerns of the application making it easier to manage and test. Despite being a single standalone application, it has a detailed lazy loading implementation that let the parts of the application be loaded more quickly.

The website is hosted using Nginx with a reverse proxy configured on the "/*api*/*" endpoint. The connection to the API is almost direct because it is hosted on the same virtual machine as the Nginx server.

11.3.2 Backend

The backend has been developed using Node.js on the NestJS framework. The API architecture uses TypeORM for the Object Relational Mapping (ORM) utility. It's connected to a MariaDB database.

The solution is REST API that generates a JSON Web Token (JWT) for making all requests except the login, register, recover password and viewing images requests.

All the API image requests have a half-hour cache system to prevent DDoS attacks.

The API calls are modularly secured: All accesses are done with hierarchical calls, starting with the main responsible component until the concerned element that the user is manipulating. For example, if we call the users of the work entity with ID "x" we should add the program ID "x" too in this request too in this request.

With this methodology, it's not necessary to check if the user has access to some work entity because the backend checks if the user has permissions in a program and if they do, the query uses the program ID in the process of obtaining the users of a work entity.

Vertical and horizontal scalability are considered. The first is implemented by enhancing the resources allocated to the Docker container, such as increasing CPU and memory limits. The second, is achieved by replicating containers across multiple instances, thanks to Docker Compose. This replication enables load balancing and distributes the incoming traffic evenly among the instances, ensuring high availability and improved performance.

11.4 Deploy

The deployment is done by Docker Compose. It's automated and scripted for CI/CD purposes. There are three main processes in this automation.

1. **The Let's Encrypt certificate obtention**: The process of obtaining an SSL certificate with Let's Encrypt involves using Certbot to automate the certificate request and validation. Certbot places a temporary file on the web server to verify domain control via the HTTP-01 challenge, or it uses a DNS-01 challenge

by adding a specific DNS TXT record. Once validated, Let's Encrypt issues the certificate, which Certbot stores and configures for the web server to enable HTTPS. Certbot also sets up automatic renewal tasks to ensure continuous certificate validity.

2. **Updating the website**: This process consists of stopping the web service and starting it again.
3. **Updating the API**: In addition to stopping and starting the web service, it involves rebuilding the image. The script first runs a "*docker-compose down*". Then, it deletes the API generated image created by a Dockerfile (this process is necessary because NestJS should be built on the same machine that is going to be used for the JWT plugin needs). Finally, the compose services are started again forcing the generation of a new API build.

11.5 Solution implementation

The MAATool has been migrated from a basic initial deployment solution to a new one that fits the variety of the current development methodologies applied in modern web development. The previous tool version was static and didn't support the reuse and variability of data. The solution underwent a total refactor process. It began with defining who the main actors in a multi-actor approach methodology are.

11.6 Entity modeling

A project is composed of different types of actors.

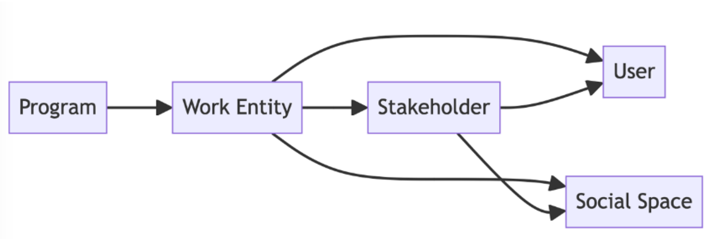


Figure 40. MAATool: Entity modeling

11.6.1 User

The user has been defined as the person that performs every action on the platform. They are linked to email and can manipulate all the other actors. Every action on the platform is executed by a user. It is not an essential piece of the application of the methodology, but it is a necessary element.

A user can have different states:

- **Deleted**: this is the state of a user who has been deleted either by an administrator or moderator or by themselves when deactivating their account.
- **Pending**: A user is in a pending state when the system needs the user to confirm an email that has been sent to them.
- **Representative**: This is an important state. It indicates that the user has been created for representative purposes by another user for another element. In this state the user can be invited by receiving an email or a notification to their account.
- **Active**: An active user that can enter the website and perform actions.
- **Administrator**: A user that can enter any element and define pillars.

11.6.2 Stakeholder

A stakeholder is any person or group of people that represents an interested party in the project. They can belong to users, social spaces and programs. A stakeholder is a key part of the tool because they are a part of the objective equation process. In addition, a stakeholder is quantified at the moment that they enter a social space. This quantification process is based on a set of pillars predefined in the tool. Based on this quantification the MAATool estimates the reality of the stakeholder representativeness in the platform ecosystem. It helps to ensure an effective way of sharing stakeholders between projects. A stakeholder can be private or public. Being public allows the stakeholder to be searched and invited by social spaces or programs.

11.6.3 Social Space

A living lab is a user-centered, open-innovation ecosystem that integrates research and innovation processes within a public-private-people partnership. It operates as a social space where users can design and experience their own future, encouraging co-creation and real-life experimentation to address societal challenges and innovate solutions.

11.6.4 Program

Programs are initiatives that integrate social spaces, users, and stakeholders to achieve targeted innovation goals. They ensure that various elements work together harmoniously for effective and inclusive outcomes. A program includes work entities.

Figure 41. MAATool program example

Work entity

Work entities are flexible, user-defined components within a program that can represent various levels of work, from individual tasks to comprehensive action plans, enabling adaptable and scalable management.

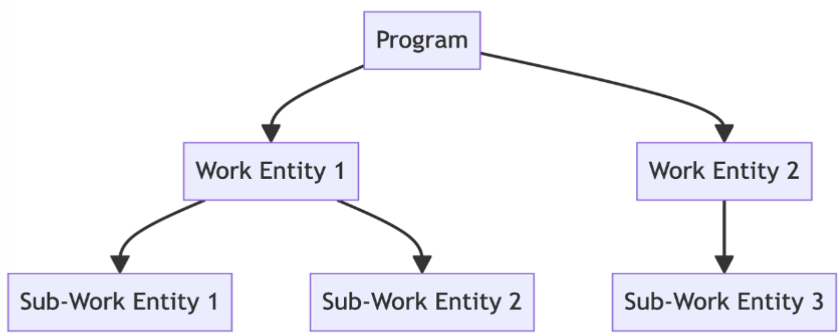


Figure 42. MAATool "program" data model

Thanks to this methodology it is possible to define different levels of depth in a program. For example, we have a project where the levels of depth are as follows:

1. Work packages.
2. Actions plans.
3. Actions.
4. Tasks.

But let's assume that in WP5, the WP leader does not want Action Plans in the next aggregation level but wants Pilots and then Activities. So, its depth level will be: (1) Work packages, (2) Pilots and (3) Activities.

This level of personalization is possible, because the Tool enables the definition of new levels of depth in each work entity.

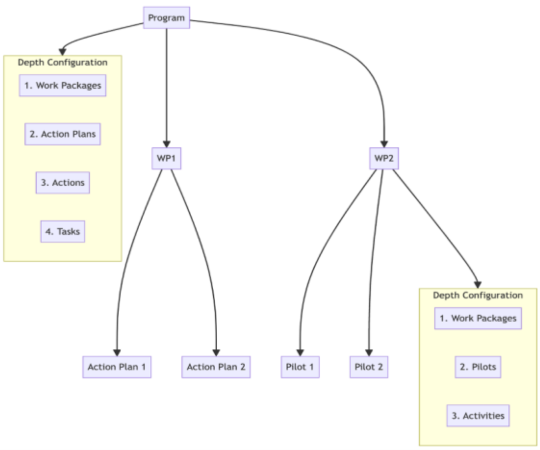


Figure 43. MAATool entity level configuration

11.7 Objectives

The objectives represent another pillar for the MAATool. They are responsible for the accomplishment of different objective types. Such as KPIs, goals, milestones and an undetermined set of definitions.

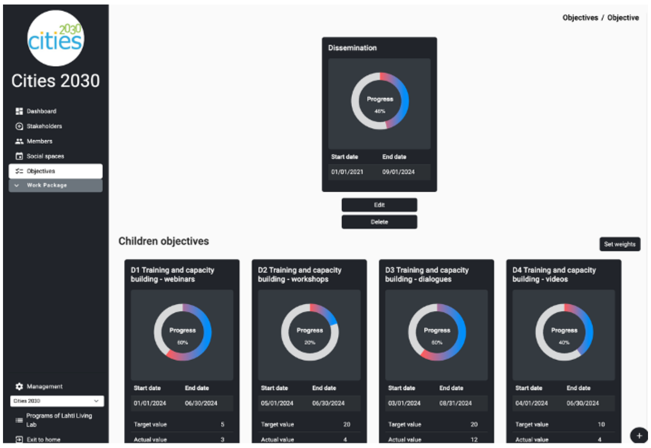


Figure 44. MAATool representation of objectives

The objectives are created inside the programs, and they can be assigned to specific work entities. An objective should be linked to an objective type, and it can be linked to an indicator. Also, an objective can be of two types:

- Normal objective.
- Aggregated objective.

11.7.1 Indicators

Unless an objective is aggregated it should have an indicator linked to it. An indicator is the way of quantifying the value that the user is going to track. It has, apart from name and description attributes, an objective has three values that define its purpose and tracking method.

- **Datatype**: it's used for defining if the numeric value of the objective will be an integer or a float value.
- **Order type**: it's used to define the direction of the indicator, whether it is increasing or decreasing.
- **Value type**: it represents if the value is static or variable, in the case of being static the latest added value to the objective is the current value of it. On the other hand, being variable implies updating the value constantly based on the current value of the objective.

Lastly, an indicator is linked to a pillar. This is necessary to correlate the value of objective completeness linked to a stakeholder versus the pillar estimations done by the social spaces.

11.7.2 Inputs

The objective values are updated based on inputs. The inputs are new values added to an objective that should have a date and an optional comment on it.

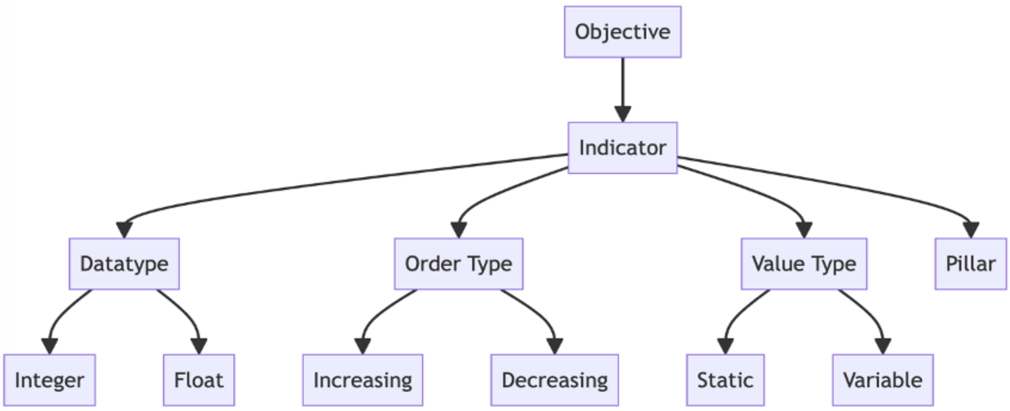


Figure 45. MAATool: relation between objectives, indicators and inputs

11.8 Extra attributes system

One of the main goals of the tool was to make it customizable. This wouldn't be possible if the MAATool entities' attributes weren't customizable based on projects or work entities.

The customization currently is performed only in the programs. Where it is possible to add extra attributes to stakeholders, users, and work entities. The setup of the extra attributes is not static within the program environment. It follows, just like work entities, a hierarchical methodology.

Programs and work entities contain a set of extra attributes for each of its contained entities and a set of children extra attributes for their children work entities. In the case of the work entities extra attributes within a program only the children set exists.

In addition, the application allows personalizing the validation of the extra attribute values that the user is going to create.

11.9 Experimentation: Workshops and monitoring activities

In the context of the MAATool there have been many workshops, and the tool has been used for monitoring and tracking activities in the context of Cities2030.

11.9.1 Workshops

11.9.1.1 Marseille workshop, 20th of June 2024

This workshop consisted of speaking a bit about the general purposes and the refactorization of the MAATool and showing its usage. The meeting was organized in the Cities 2030 final meeting.

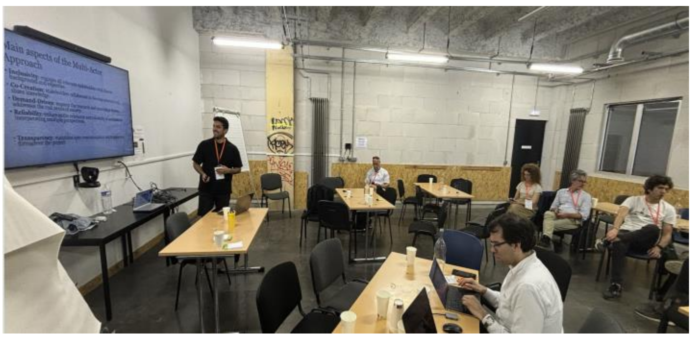


Figure 46. Experimentation with MAATool in Marseille workshop (20th June 2024)

11.9.1.2 Cuenca workshop

This workshop focused on discussing the usability and purposes of the MAATool in a rural environment, including its potential for monitoring stakeholders and quantifying objectives.

Figure 47. Experimentation with MAATool in Cuenca workshop

11.9.2 Monitoring activities

Cities2030 activities in the form for Tasks and WPs have been implemented on the tool. There is a program with its name and a WP decomposition with its corresponding Action Plans linked to it.

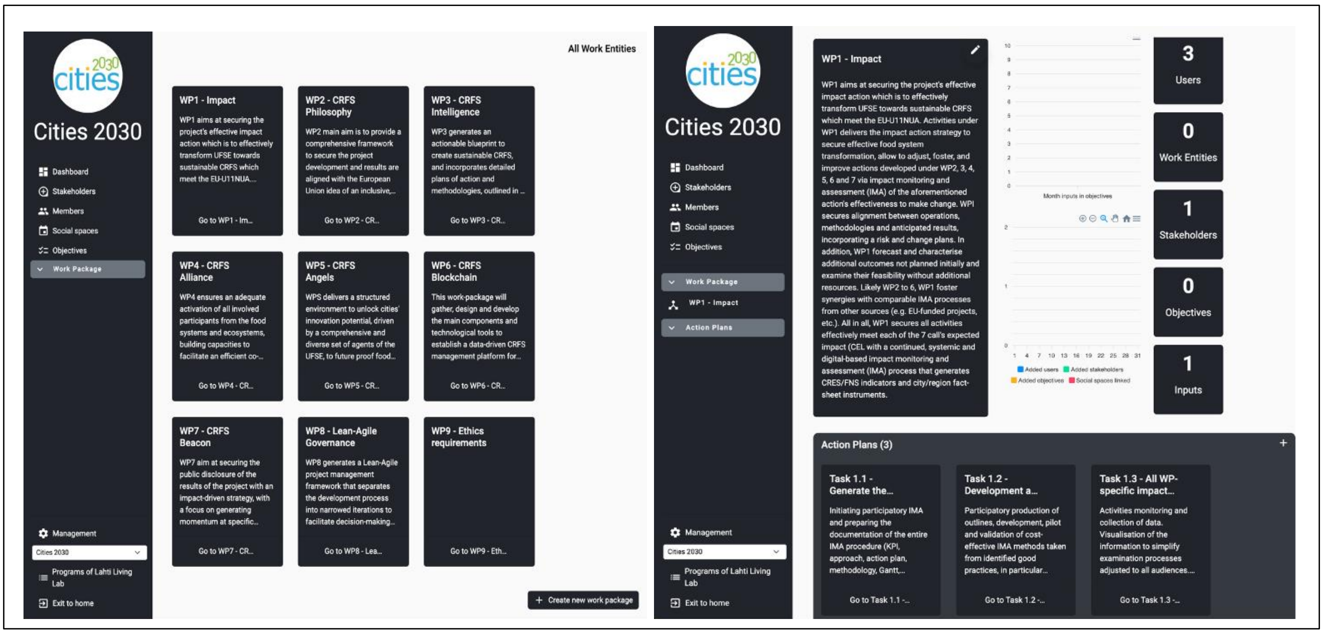


Figure 48. Monitoring activities in MAATool

11.10 Conclusions

The development and implementation of the MAATool within the Cities2030 project have demonstrated the tool's capability to enhance collaboration and efficiency across multiple actors involved in urban innovation initiatives. By employing the multi-actor approach methodology, the MAATool has successfully aggregated diverse information streams and provided a robust framework for monitoring and tracking Key Performance Indicators (KPIs).

The architectural design, which leverages modern web technologies such as Angular for the frontend and Node.js with NestJS for the backend, ensures that the tool is both scalable and maintainable. The use of Docker Compose for deployment facilitates seamless updates and enhances the tool's reliability and security.

The customization features, including the ability to define new levels of depth and add extra attributes, have made the MAATool highly adaptable to the unique needs of various programs and work entities. This flexibility is crucial for addressing the dynamic requirements of urban development projects.

Moreover, the tool's application in workshops and real-world scenarios, such as the monitoring activities in Cities2030, has validated its practical utility and impact. The feedback from these workshops has been instrumental in refining the tool, ensuring it meets the users' needs effectively.

To conclude, the MAATool proves to be an all-encompassing solution for managing and monitoring urban innovation projects. Its strong architecture, customizable features, and effective use within Cities2030 demonstrate its capability to foster significant advancements in urban planning and enhance stakeholder collaboration.

12 Blockchain-enabled marketplace for SFSC

12.1 Introduction

Blockchain-enabled marketplace for SFSC (short food supply chain) is an infrastructure and traceability solution which uses a Consortium Type Blockchain (BC) network based on Hyperledger Besu solution. Hyperledger Besu is an Ethereum client that can be used with both public and private networks. Although the initial nodes are provided by the ITC and DIH AGRIFOOD partner institutions, every stakeholder participating in supply chains is able to set up its own node.

The solution is enabling farmers, food producers, food processors and other actors to automatically generate digital BC-certificates for specific food types in the form of non-fungible ERC 721 tokens, while consumers are able to verify the SFSC-related food, its origin, and journey simply by scanning relevant QR codes placed on products. Each BC transaction is able to handle basic BC-related information (i.e., timestamp, digital identity, signature), as well as specific food (i.e., type, harvest region, harvest date/time, etc.) and logistics-related information (i.e., LOT number, type, etc.). The solution also enables storing digital proofs (i.e., harvest or delivery photos etc.), which can be stored on a related IPFS or Swarm network and other rich data, such as certificates, nutritional data, farmer/producer data, farming practices related data, environmental footprint related data, etc.

12.2 Architectural design

Detailed functionality with interfaces and user interaction is explained in document D6.3, while here we are only providing a summary of work done and changes and adaptations to the system we implemented, to ensure the shelf solution is generally suitable to any supply chain.

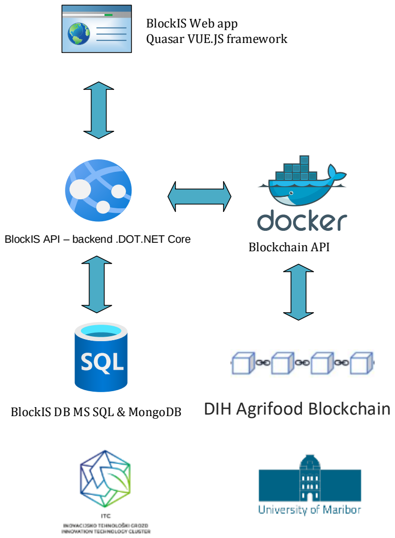


Figure 49. Component functional architecture

In the picture above, we have presented the schematics view of the system architecture of the solution. The diagram is constructed with the layered approach, with four layers.

- The front end is built with the Quasar, open-source Vue.js based framework for building apps with a single codebase.
- The Backend of the web application is built with .NET open-source computer framework.
- The Backend for accessing the Blockchain is implemented in a Docker container provided by the University of Maribor, which ensures a transparent interface to the blockchain infrastructure in the form of simple REST API endpoints
- The database layer consists of Microsoft SQL Server, which ensures real-time access to data stored in the system. MongoDB is being used to store blockchain-related data (e.g., wallet addresses, private and public keys, etc.). The blockchain infrastructure is being used for verification of the records of the activities stored in SQL database.

The architecture of the data storage layer is the biggest change of the design and implementation of the solution compared to the first version of the traceability solution.

In new version the SQL database is being used for storing data. The blockchain stores only the hash of the records in the structured database. So, the data, stored in the SQL database can be verified for the proof of the immutability of the timestamp, description, pictures, etc., of the records.

With this approach, we ensured two main new functionalities of the traceability solution:

- The user experience is much better because of the much better responsiveness of the application. Namely, when blockchain is used as a main storage for data, the application starts working slowly when we have large amounts of data. This is due to the nature of the blockchain, which has to be confirmed by multiple nodes when storing and changing data.
- The data model is model of the solution is generalized, so it can be adapted to any Short Food Supply Chain, while the data model of the first version was specifically tailored to the requirements of the Green Point supply chain. In that way we can provide of the shelf traceability solution for any interested supply chain.

12.3 Development of solution

Throughout the development process, a series of workshops were conducted that employed a multi-actor approach, actively involving various stakeholders, including farmers who expressed a willingness to collaborate in the development of the solution. These farmers are integral members of the short food supply chain and demonstrated a commitment to dedicating their time and resources to ensure the creation of a fully operational service that would not only assist them with their day-to-day activities on the farm but also streamline the management of their products within the broader food supply chain operations.

The initial concept for this project was inspired by the existing framework of the Green Point short food supply chain and its ongoing processes. During one of the inaugural meetings in 2022, ITC developers met with the Green Point team to thoroughly analyze and map out all relevant processes to determine how blockchain-based traceability could be effectively integrated. In this session, several key processes and actors were identified as crucial components that would benefit from enhanced traceability via blockchain technology. These included:

- Farmer Activities: Encompassing all on-farm operations from planting to harvesting, and the initial stages of processing.
- Logistics: Covering the transportation and handling of goods between different points in the supply chain.
- Food Processors: Involving the transformation of raw agricultural products into final consumable goods.
- Distribution Center: Where goods are aggregated, stored, and prepared for further distribution.
- Retail Activities: The process of making the products available to consumers through various retail channels.
- Consumers: The end-users who purchase and consume the products, and who would benefit from enhanced transparency and trust in the supply chain.

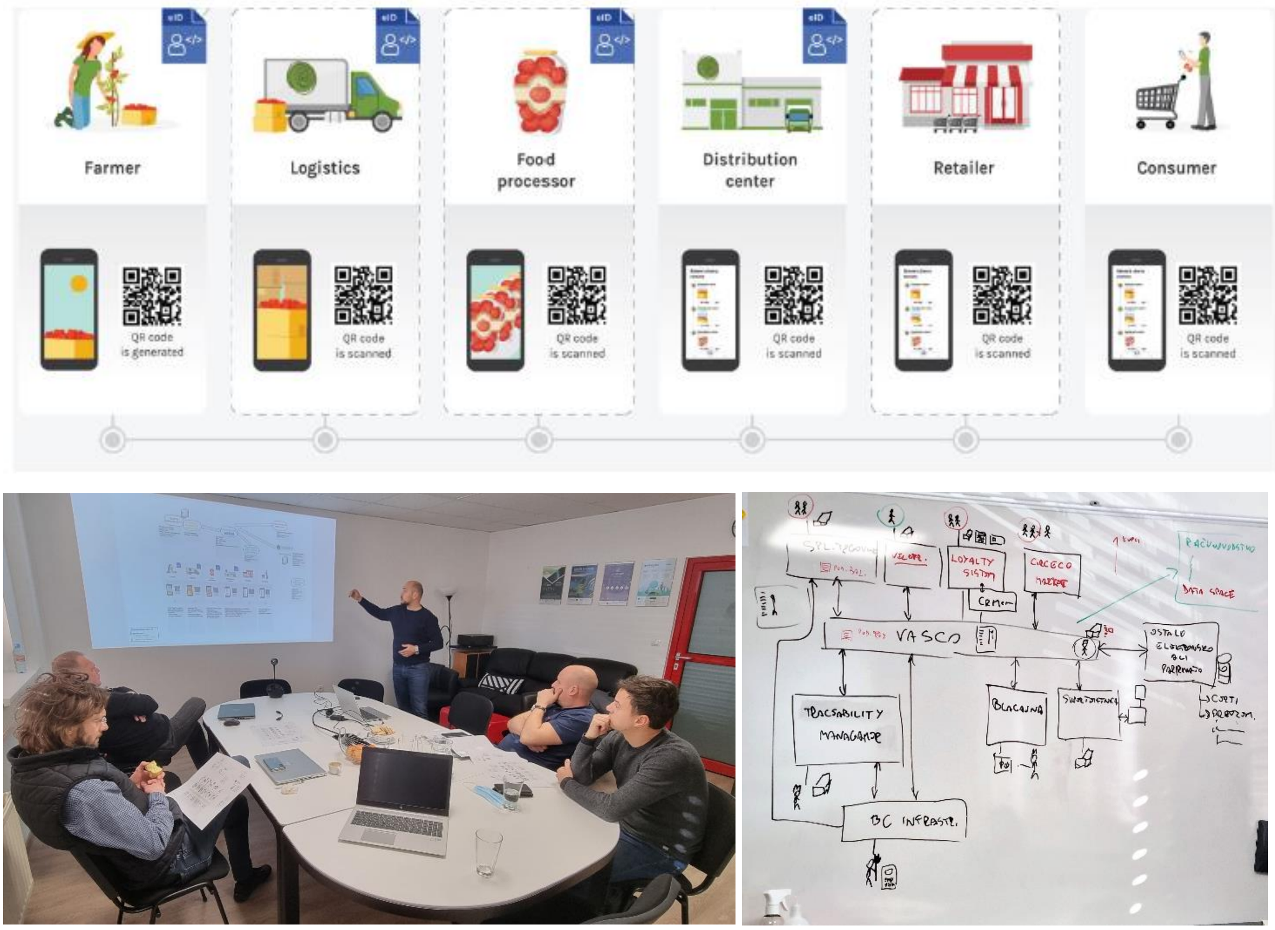


Figure 50. Co-creation of first version of Blockchain-based marketplace

Based on the discussions and the detailed analysis of these processes, the ITC team embarked on the development of the first version of the application. The initial development phase was completed by September 2022.

In September 2022, the ITC team held one of the first workshops specifically with farmers, during which they presented the concept and the initial version of the application. However, the feedback from the farmers was not entirely positive. The farmers expressed concerns that the application, in its initial form, added to their workload without providing commensurate benefits. The additional tasks required by the application were seen as burdensome, and the perceived advantages did not justify the extra effort and resources needed to engage with the system.

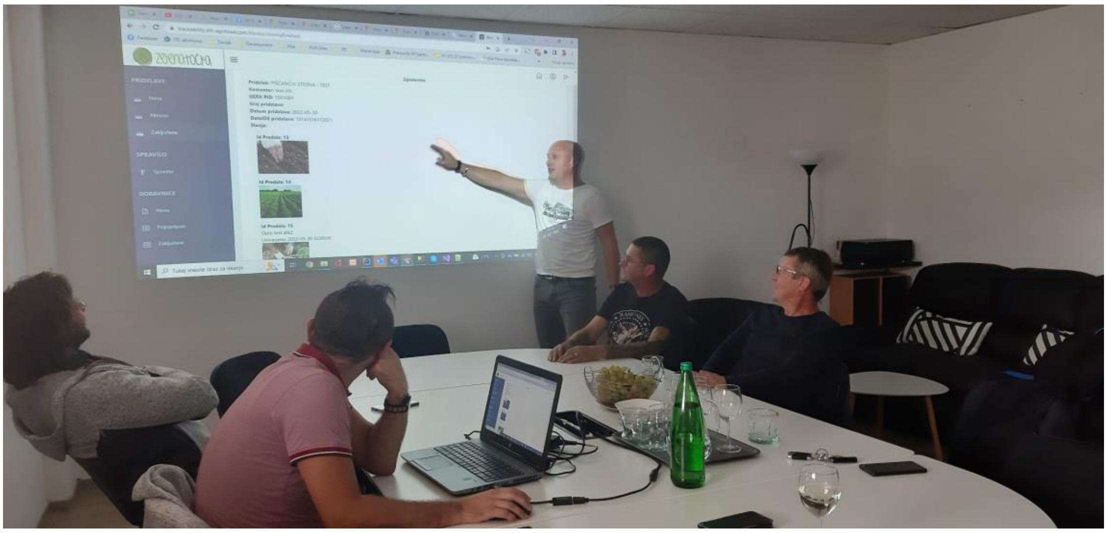


Figure 51. Validation of first version of Blockchain-based marketplace

In response to this feedback, it was agreed that the application would undergo significant upgrades to better meet the needs of the farmers. The goal was to ensure that the application would not only support the traceability aspect but also reduce the administrative burden on farmers. The upgrades focused on integrating functionalities such as the preparation of electronic delivery notes and supporting all processes via mobile devices and QR codes. These enhancements were specifically designed to automate paperwork, thereby saving time and resources for the farmers. The ITC team engaged in several additional meetings with the farmers during this phase to present the updated functionalities and to gather further feedback. These iterative consultations ultimately led to the development of a more refined and user-friendly application, that is called version 2, for the purpose of the deliverable.

Figure 52. Schematic view of the activities performed in the supply chain

In the above picture, we have the schematics view of the activities performed in the supply chain, where the hash of the records is stored in the Blockchain to ensure the proof of the immutability of the records.

By July 2023, version 2 was ready for a broader rollout. It was presented to additional farmers who were active participants within the supply chain. A dedicated workshop was organized to provide comprehensive training on how to use the application, demonstrating its functionalities and operational workflow. During the workshop, the ITC team explained the process of tracking the production phases and how this traceability would be seamlessly integrated into the existing supply chain activities. The workshop also highlighted the benefits that this traceability would bring to the consumers, such as increased transparency and confidence in the origin and handling of their food.

Figure 53. Workshop for validation of second version of Blockchain-based marketplace

After successfully finalizing the version of the application tailored to the specific needs of the Green Point short food supply chain in the Pomurje region, ITC experts embarked on the next phase of development: creating an off-the-shelf solution, or version 3. This new solution was designed to be adaptable and ready for deployment across a wide range of food supply chains, beyond just the initial context of Green Point.

The development of this versatile, standardized solution involved refining the core features and functionalities that had proven effective in the Pomurje region. ITC focused on ensuring that the system could be easily customized to meet the specific requirements of different food supply chains with minimal modifications. This adaptability was crucial, as it allowed the solution to be integrated into various supply chain environments, each with its unique processes and existing systems.

By the end of 2023, ITC had finalized the development of this version 3. The result was a robust, flexible platform that could be integrated into other food supply chains with only minor updates or upgrades to the process flow. Furthermore, the integration process was designed to be seamless, requiring only straightforward adaptations to ensure compatibility with any existing systems operated by the supply chain stakeholders.

This off-the-shelf solution represents a significant advancement in supply chain management technology, offering a scalable, efficient tool that can enhance traceability and streamline operations across diverse food supply chains.

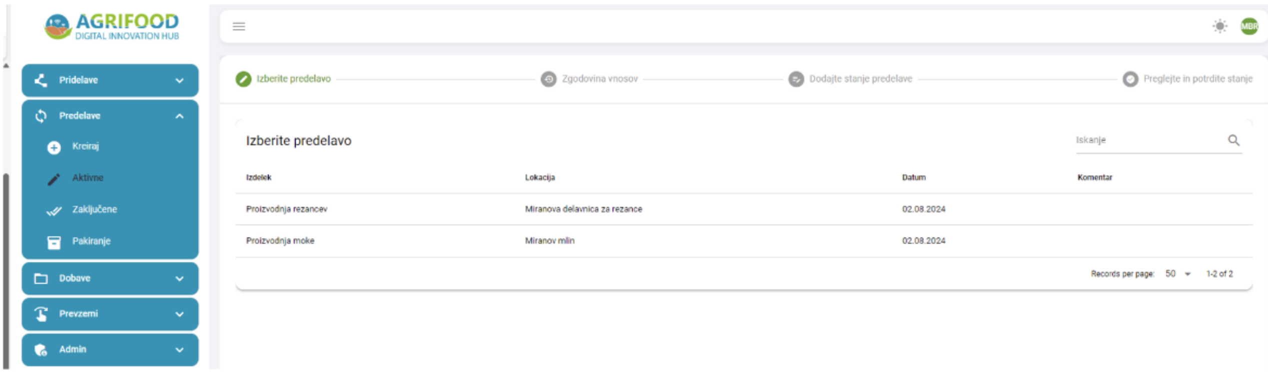


Figure 54. Screenshot of blockchain-based marketplace, version 3

12.4 Experiments: Workshop with labs, feedback and impact for the project

The initial phase of the experiment was conducted using the blockchain-based marketplace version 1, within a fully developed short food supply chain in Murska Sobota, with the targeted development efforts focused on the Murska Sobota living lab as part of the project. The experiment pursued multiple directions, all centered around the primary objective of increasing the proportion of locally sourced food in the region and highlighting the critical importance of home-grown produce. A key component of this initiative was the integration of a blockchain-based marketplace for short food supply chains (SFSC). Through this integration, P30-ITC, in collaboration with P34-MOMS, successfully demonstrated the transparency and authenticity of the food supply chain, ensuring that the food was indeed grown locally and eliminating any concerns about fraud within the system.

To promote the service and the activities carried out within the scope of the project, several workshops were conducted involving various stakeholders. These workshops were crucial for educating and engaging different actors in the supply chain, fostering a deeper understanding of the system's benefits, and encouraging widespread adoption.

As early as June 2021, ITC and MOMS organized a press conference to introduce the service and present the initial concept of the application to the public. This event attracted significant attention, with key participants including representatives from the Ministry of Agriculture, Forestry, and Food. The press conference served as an important platform to showcase the potential of the application and its alignment with regional and national goals related to food security and sustainability. Through these efforts, the project not only advanced technological solutions but also reinforced the value of local food systems in promoting regional development and consumer trust.

Figure 55. Press conference (June 2021) organized by ITC and MOMS

This press conference became an annual event, where ITC provided updates on the ongoing development and enhancements of the application. Each year, these conferences served as a platform to share progress, gather feedback, and reinforce the commitment to improving the short food supply chain through innovative technology.

In 2023, the endpoint of these efforts was showcased at the press conference, where the fully operational service (version 3) was officially presented. This event held particular significance as it took place within the premises of the Green Point short food supply chain, which was celebrating its 10th anniversary. The celebration was marked by this major milestone—the introduction of the enhanced application—underscoring the progress and innovation within the Green Point network.

The introduction of the fully functional service was not just a technological upgrade; it represented a significant advancement in the efficiency, transparency, and integrity of the supply chain. The integration of the application into Green Point's operations highlighted its role in supporting the continued growth and sustainability of the local food system. This event also symbolized Green Point's ongoing commitment to embracing cutting-edge solutions to ensure the highest standards of quality and trust in their supply chain, reinforcing its position as a leader in the short food supply chain movement.

Figure 56. Green Point network workshop

Following the final development of the application, the ITC team focused on promoting the service and seeking opportunities to have it tested or integrated by other food supply chains. This was a crucial step in further validating the concept and ensuring the service's broader applicability and effectiveness across different supply chain environments. The team aimed to demonstrate the value of the service in real-world scenarios, gather additional feedback, and refine the system based on diverse user experiences.

To achieve this, several demonstrations were organized, showcasing the service in various contexts. These demonstrations served as both promotional activities and practical tests, allowing potential users and stakeholders to see the application in action and understand how it could be adapted to their specific needs.

The remainder of this section will describe the main relevant demonstration activities. Sections from 12.4.1 to 12.5 describe regional workshops organized to improve the solution and receive feedback on the use case "Green Point". Sections 12.4.6 to 12.4.8 describe demonstrations and workshops done with partners of the CITIES2030 project. Finally, Section 12.4.9 provide results in terms of impact evaluation.

12.4.1 August 2023, Supply chain for Vanilla from Madagascar

Meeting with company D&P Solution from Slovenia, who is trying to establish the traceability of the Vanilla from Madagascar in the worldwide supply chain. The figure below illustrates the first online meeting to present the concept and idea of the blockchain-based marketplace:

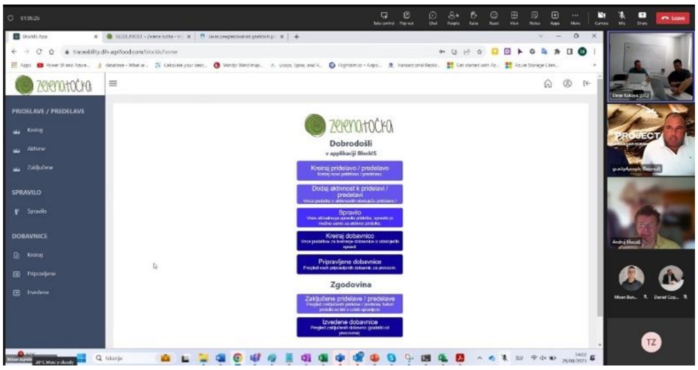


Figure 57. Stakeholder's meeting (august 2023)

Below, we show work meetings to model the processes of the Vanilla supply chain in the blockchain-based marketplace solution.

Figure 58. Modeling the processes of the Vanilla supply chain

The company has agreed to refine its processes and establish a cooperative involving all suppliers of Madagascar vanilla. Once these initial steps are completed, the ITC team will assist in integrating the traceability system. Various collaboration options are being explored, including EU projects, public-private partnerships, and other potential avenues.

12.4.2 February 2024, Meeting and demonstration for Slovenian company Vila Natura d.o.o.

Vila Natura d.o.o. is a local producer of eco-friendly products. The company is working to establish traceability within their supply chain to demonstrate that they use only locally sourced ingredients, avoiding imported products. During a recent meeting, it was agreed that Vila Natura would document the processes within their supply chain. Additionally, further collaboration will be explored, with a focus on securing national or EU funding to support the integration of blockchain-based traceability.

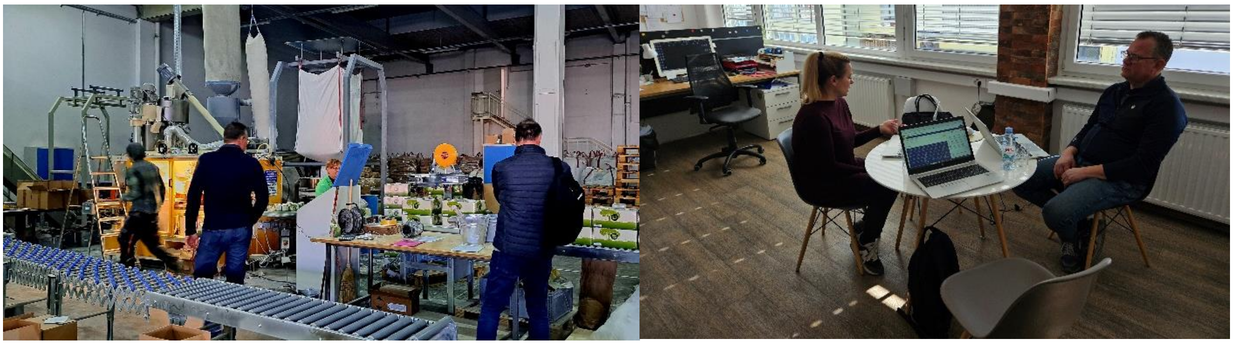


Figure 59. Showcasing the S2CP component for Vila Natura d.o.o.

12.4.3 April 2024, visit from the Ulster University from UK

Researchers from the University of Ulster are actively engaged in blockchain technology. They are collaborating with the University of Maribor, which has been instrumental in supporting the integration of blockchain within the Green Point initiative. Eager to explore the feasibility of implementing this technology in a real-time environment, the Ulster team visited Green Point. During the visit, the ITC team demonstrated the functionality of the blockchain-based marketplace solution. It was agreed that the researchers from Ulster University would review the system and propose any potential enhancements to the blockchain integration.

Figure 60. Co-creation meeting with blockchain experts for improvement of the solution.

12.4.4 April 2024, Visit from Janja Viher

Janja is an expert in the field of supply chains and is actively supporting the regional development in the neighbouring Štajerska region in Slovenia. She is working with local suppliers and cooperatives, where she is eagerly investigating different options on how to technologically and economically advance the supply chains in the region. During the visit, the ITC team has been elaborating on the options of transferring the solution from Green Point to another regional supply chain. It was decided at the end, that the next call for national funds will be an opportunity to advance activities.

Figure 61. Demo to build towards integration to neighbouring Štajerska region in Slovenia

12.4.5 May 2024, Visit by CUK – Centar za cjeloživotno učenje i kulturo Bjelovar

Visit by CUK – Centre for lifelong learning and culture Bjelovar from Croatia has been organized to inform local producers from Croatia how they can establish a short food supply chain in their region and how they can advance their network by introducing the blockchain based traceability.

Figure 62. Showcase of the working solution for CUK – Centre for lifelong learning and culture Bjelovar

12.4.6 Demonstration of the solution to Quart de Poblet living lab in Spain

On May 30, 2023, a workshop was held in Quart de Poblet, Valencia, Spain, where, in addition to the City Council of Quart de Poblet, experts in production and distribution of local products were invited. In this workshop, UPM (P20), with virtual support and materials from ITC (P30), presented the blockchain-based Marketplace component and the Green Point use case.

After presenting the Blockchain solution, comments were collected and classified according to their positiveness level. 87% of the comments were positive and only 13% were considered negative. The comments highlighted the ability to generate and read QR codes, the possibility of including the geographical location of the product or the shipment, the possibility of including photos of the products and the place where they are produced, and the ability of blockchain to certify the validity of the information. The negative comment discussed was the difficulty of aligning the processes that are constantly changing due to pressures from large distributors and also dynamic regulations.

Figure 63. Blockchain workshop in Quart de Poblet (30 of May 2023)

12.4.7 Demonstration and workshop with Velika Gorica living lab from Croatia and Vidzeme living lab from Latvia

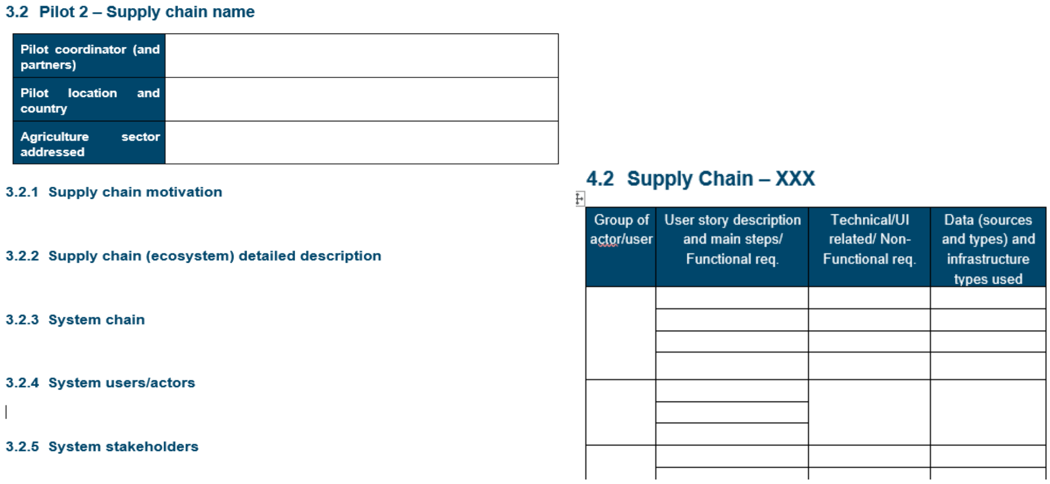
On the 9th of February 2024, the ITC team conducted an online workshop in collaboration with the Velika Gorica living lab in Croatia and the Vidzeme living lab in Latvia. The workshop had two primary objectives: first, to demonstrate the functionality of the traceability application developed by ITC, and second, to explore the feasibility of integrating this solution into the supply chains managed by the living labs in Croatia and Latvia.

The workshop began with a detailed presentation on the capabilities of the traceability application. The ITC team explained how the application benefits supply chain operators and their actors by enhancing transparency, efficiency, and trust within the supply chain. The presentation outlined the role of each actor, from farmers to logistics providers, processors, and retailers, and highlighted the advantages of integrating the application into existing supply chain operations. This was supplemented by a live demonstration of the application, where the ITC team showcased how various events within the supply chain are managed in real-time. Participants observed how different actors perform their respective roles within the application, providing a clear understanding of its practical implementation.

In the second part of the workshop, the focus shifted to a collaborative exploration with the living labs to identify opportunities for integrating the traceability solution into their regional supply chains. The Velika Gorica living lab expressed interest in applying the solution to their regional supply chain for apples and other fruits, aiming to enhance traceability and ensure the authenticity of locally produced goods. Meanwhile, the Vidzeme living lab considered the possibility of implementing the solution within their potato supply chain, seeking to improve the monitoring and management of this critical agricultural product.

To facilitate the integration process, the ITC team provided both living labs with a detailed template. This template was designed to help the living labs map out their supply chains by identifying the main stakeholders involved, their roles, and the services they provide. The template encouraged participants to thoroughly document the process flow of their respective supply chains, from production to distribution, to enable ITC to tailor the traceability application to their specific needs.

Below is the template provided to the Velika Gorica and Vidzeme living labs:



3.2 Pilot 2 – Supply chain name

Pilot coordinator (and partners)	
Pilot location and country	
Agriculture sector addressed	

3.2.1 Supply chain motivation

3.2.2 Supply chain (ecosystem) detailed description

3.2.3 System chain

3.2.4 System users/actors

3.2.5 System stakeholders

4.2 Supply Chain – XXX

Group of actor/user	User story description and main steps/ Functional req.	Technical/UI related/ Non-Functional req.	Data (sources and types) and infrastructure types used

Figure 64. Template for adapting traceability solution to other Cities2030 labs

By filling out this template, both the Velika Gorica and Vidzeme living labs provide ITC with the necessary insights to adapt and refine the traceability solution to suit their unique supply chain dynamics. This collaborative approach ensures that the solution is not only technically sound but also practically applicable, ultimately contributing to the sustainability and transparency of local food systems in Croatia and Latvia.

Unfortunately, the entire process of discussions and negotiations regarding the integration of the traceability application into the regional supply chains proved to be resource-intensive for both involved living labs. As a result, it was decided to pause the integration process for now.

Despite this setback, all parties acknowledged the importance of continuing their efforts to develop the supply chain and to identify the key actors and their roles within it. The focus will now shift toward building a solid foundation for future collaborations, ensuring that stakeholders are well-informed and prepared for any upcoming projects or initiatives in both the Velika Gorica and Vidzeme region.

This decision allows the partners to concentrate on enhancing their relationships and understanding the dynamics of their respective supply chains without the immediate pressure of integration. By investing time in stakeholder engagement and establishing clear roles, they hope to create a more collaborative environment that will facilitate smoother integration of innovative solutions, such as the traceability application, in future initiatives. The goal remains to enhance local food systems, improve transparency, and ultimately strengthen the regional economy in both regions as they explore new opportunities together.

12.4.8 Demonstration in Cities2030 GA in Marseille:

At the CITIES2030 final event held in Marseille, France, ITC showcased the successful implementation of a blockchain-based solution in Slovenia, specifically at Green Point. This innovative solution was presented as an example model in enhancing transparency and efficiency within food supply chains.

During the event, a workshop was conducted that sparked a dynamic discussion around the potential challenges and opportunities of transferring and adapting this blockchain solution to other interested parties and regions. Participants engaged in a thought-provoking question and answer session, exploring key issues such as the scalability of the technology, the regulatory frameworks required for implementation, and the potential for collaboration across different sectors. This exchange of ideas highlighted the significance of such innovations in the broader context of sustainable urban development and the future of food systems in cities.

Figure 65. Presentation of blockchain solution at GA in Marseille

12.4.9 KPI's of Blockchain-based marketplace solution for Slovenian living lab

Finally, the ITC team began measuring the impact of the integration of the traceability solution within the regional supply chain. Since the application was completed at the end of 2023, it was too late to capture meaningful data for that year, as the vegetable and fruit production season was already winding down. As a result, the key performance indicators (KPIs) being tracked are from the ongoing 2024 season, covering the period from March 2024 to July 2024.

The following KPIs have been monitored to assess the impact of the solution:

- Number of events that have been happening within the supply chain and are stored on the blockchain
- Number of farmers that are using the traceability application
- Number of customers scanning the QR code in the retail store
- Number of products

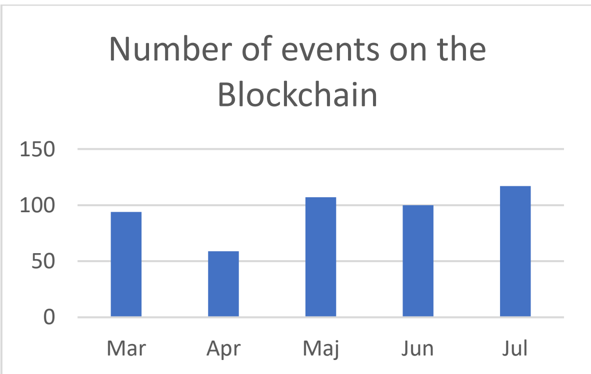


Figure 66. Result of KPI "Number of events on the blockchain"

Events on the blockchain are directly linked to the production cycle of the product, capturing every significant action or transaction within the supply chain. These events are recorded by various actors, including farmers, logistics personnel, and supply chain operators, and are securely stored on the blockchain. The blockchain's immutable ledger ensures that each recorded event is transparent, traceable, and tamper-proof, providing a reliable record of the product's journey through the supply chain.

On average, approximately 100 events are recorded on the blockchain each month. These events may include activities such as planting, harvesting, transportation, processing, and distribution. Each actor in the supply chain contributes to this record by logging their specific actions, ensuring that the entire production process is comprehensively documented. This robust event tracking not only enhances transparency but also allows for real-time monitoring and verification of the product's origin and handling, building greater trust among consumers and stakeholders alike.

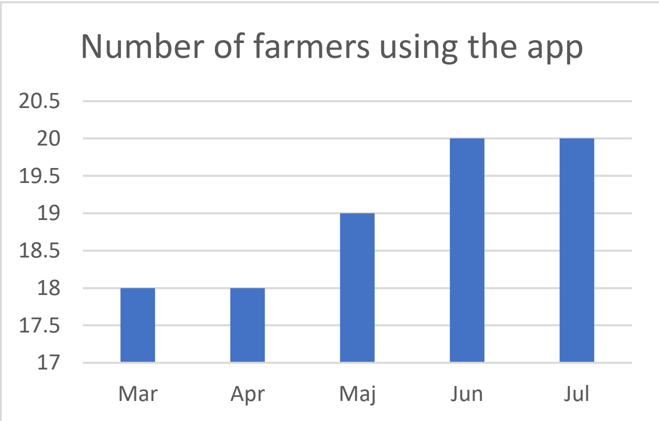


Figure 67. Result of KPI "Number of farmers using the app"

ITC actively involved farmers from the very beginning of the application development phase, recognizing the critical role they play in the local food supply chain. Given that the application was specifically designed to support and enhance the regional short food supply chain, it was essential to incorporate farmers' input and feedback throughout the process.

Initially, in March, the project included 18 farmers. By the end of July, the number of participating farmers had grown to 20, representing a significant portion of the regional short food supply chain vegetable and fruit growers.

Given that Pomurje is a relatively small region, this increase meant that the majority of farmers involved in the regional short food supply chain were now engaged with the application. This widespread involvement was crucial for the application's success, as it not only ensured that the tool was effectively meeting the needs of the local agricultural community but also facilitated a broader adoption of the technology within the region. The collaboration with farmers throughout the development process ensured that the application was practical, user-friendly, and capable of delivering tangible benefits to the farmers and the overall supply chain.

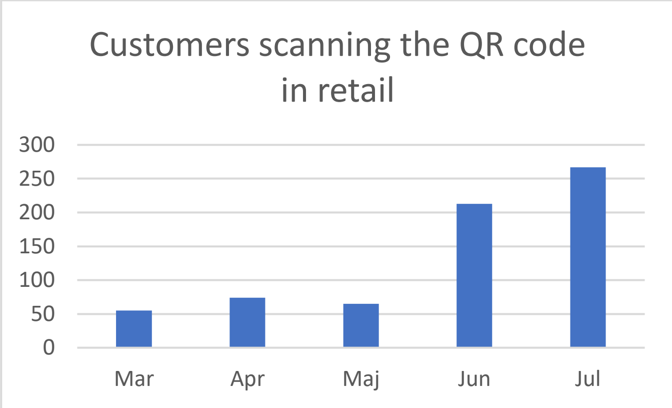


Figure 68. Result of KPI "Customers scanning the QR code in retail"

The chart above illustrates the number of customers scanning the QR code in the retail store, providing insight into consumer engagement with locally sourced products. The data reflects the seasonal nature of local food production, which begins in earnest around March or April. However, since the first batches of home-grown vegetables and fruits were not delivered to retail stores until June, the chart shows a corresponding increase in QR code scans starting from that month.

In the initial months, March through May, the number of scans remained relatively low. This was due to the limited availability of products with a local origin in the stores, as the growing season had only just begun. As a result, customers had fewer opportunities to engage with the traceability feature provided by the QR codes.

However, in June and July, there was a noticeable increase in the number of scans. This spike directly correlates with the arrival of the first locally grown produce in the stores. With the availability of fresh, home-grown fruits and vegetables, more customers were able to scan the QR codes, reflecting a growing interest in the traceability of their food and the benefits of supporting local agriculture.

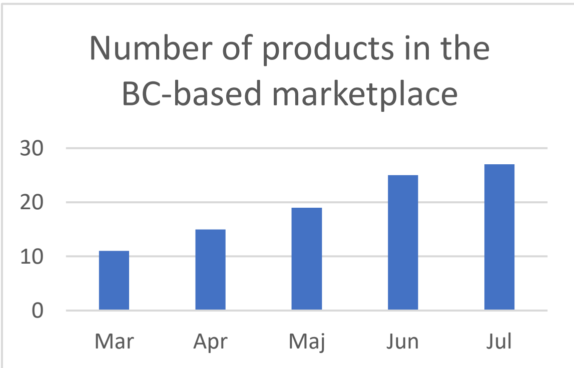


Figure 69. Result of KPI "Number of products in the BC-based marketplace"

On average, each farmer within the regional short food supply chain is responsible for supplying a single product. This is primarily because most farmers focus on the production or delivery of one specific type of product, whether it be a particular vegetable, fruit, or other agricultural item. As the growing season progresses, the variety and number of available products within the supply chain naturally increase, reflecting the seasonal nature of farming.

In March, the early stage of the season, there were approximately 10 different products available for consumers to track through the traceability system. As the season advanced, with more crops maturing and becoming ready for harvest, the number of available products grew significantly. By July, consumers had access to nearly 30 different products within the supply chain network, all of which could be tracked for their origin and journey through the supply chain.

12.5 Conclusions and future work

The S2CP component "Blockchain-enabled marketplace for SFSC" has been developed and integrated within the regional short food supply chain. From the outset, farmers were actively engaged in the development process, ensuring the solution was tailored to their needs. This early collaboration led to the inclusion of a majority of the region's farmers by mid-2023, reflecting strong community buy-in.

Workshops with various stakeholders, including regional living labs, facilitated valuable discussions on integrating the solution into broader supply chains, though some integration efforts were halted due to resource challenges. Despite this, the solution's impact became evident during the 2024 season. Key performance indicators showed a steady increase in the number of tracked products, robust farmer participation, and heightened consumer engagement through QR code scans, particularly as the season progressed. These metrics underscore the solution's effectiveness in enhancing transparency and efficiency within the supply chain.

While the project has seen significant success, several challenges have surfaced throughout the process, offering valuable lessons for future initiatives. One of the primary challenges was ensuring widespread farmer participation. Although early involvement of farmers was crucial, securing their continued engagement required consistent communication and adapting the solution to meet their specific needs. Initially, farmers expressed concerns about the additional workload that the application introduced, highlighting the importance of balancing technological innovation with practical usability. This feedback led to crucial adjustments, such as the introduction of features that reduced administrative burdens, ultimately increasing farmer buy-in. Another significant challenge was the resource-intensive nature of integration discussions with regional supply chains, particularly in the Velika Gorica and Vidzeme living labs. These negotiations demanded substantial time and effort from all parties involved, which eventually led to a halt in the integration process. This highlighted the importance of managing resources effectively and setting realistic timelines when working with diverse stakeholders.

While the late 2023 finalization limited initial data collection, the 2024 season provided critical insights. The project's success in demonstrating the solution's benefits highlights its potential for broader adoption in other regions. The groundwork laid by this initiative not only strengthens the local food system but also sets the stage for future projects, fostering trust among consumers and supporting the regional economy's growth.

13 Geospatial services: Cities2030 labs and follower cities

The Geospatial Services component shows the geographical distribution of the different agents throughout the different CRFS on a map system and serves as the basis for geospatial representation in the S2CP dashboard. This section will describe the development of the component and how data from the cities where the CRFS labs are located and also the follower cities were incorporated.

13.1 Development of solution

13.1.1 Introduction and methodology

The geospatial services component collects information on points of interest in the regions where innovation activities are taking place within the framework of Cities2030. It uses maps and information download services in standard formats. The component offers the following functionalities:

- Support for point elements and geometries, according to the spatial datasets of T6.2 (Geospatial information component).
- Filtering by geographic locations, administrative boundaries and municipalities under study.
- Provision of information in standardized APIs, using OGC's standards Web Map Service and the Web Feature Service.
- Personalized visualizations, thanks to the integration into the S2CP dashboard (T6.5). Possibility of performing spatial operations or complex analysis in the S2CP dashboard.

Below, we describe the methodology used to generate the full version of this application:

First, a set of scripts is defined for the semi-automatic capture of geospatial information, classifying each dataset with labels associated with its geographic location. This information is then published in a geospatial database and a server is deployed to offer this information through standardized OGC APIs.

Next, we integrate these services with other components of the platform. For this, we select the single-sign on functionality, through the Communities component, with the procedure described in Section 3.4 "Shared mechanisms: Single Sign-On". We also establish links with the S2CP dashboard application.

Finally, we validate this service by applying the process of capturing, storing and publishing geographic information for the municipalities where the labs are established, and for the follower cities. In the rest of this section, we detail each of these phases of the methodology.

13.1.2 Data collection

In the data collection process, data from *OpenStreetMaps* has been downloaded through a set of scripts designed for this purpose. The following figure shows an extract of a script (in Python language) to obtain points of interest in the field of food systems, for follower cities. The libraries *overpass*, *geojson*, *requests* and *osmtogeojson* were used.

```
for key,value in alias2osm_name.items():
    query = """
        area['name'='{0}']->.city;
        (
          node["shop"="bakery"](area.city);
          node["shop"="butcher"](area.city);
          node["shop"="beverage"](area.city);
          node["shop"="alcohol"](area.city);
          node["shop"="convenience"](area.city);
          node["shop"="supermarket"](area.city);
          node["shop"="greengrocer"](area.city);
          node["amenity"="bar"](area.city);
          node["amenity"="pub"](area.city);
          node["amenity"="bbq"](area.city);
          node["amenity"="biergarten"](area.city);
          node["amenity"="cafe"](area.city);
          node["amenity"="restaurant"](area.city);
          node["amenity"="drinking water"](area.city);
          node["amenity"="fast food"](area.city);
          node["amenity"="food court"](area.city);
          node["amenity"="ice cream"](area.city);
        );
        out geom;
        """.format(value)
    nodes = api.get(query, verbosity='geom')
```

Figure 70. Collecting CRFS points of interest in follower cities

When selecting the required data, the labels amenity[24] and shop[25] were used.

Amenity represents useful and important facilities for visitors and residents, such as toilets, telephones, banks, pharmacies, prisons and schools. For this component, sustenance-based amenities were identified: bar, pub, café, restaurant, food court, etc. The label shop was also considered, as a location selling goods and services related to food and beverages, such as bakery, butcher, supermarket, greengrocer, etc.

There have been some important points to consider in the design of the data collection. Some features (amenities and shops) can be identified with a single geographic point, defined in OSM language as a "node", or as an area, defined by the concept of a way. They also exist, and have been maintained in the capture process, as a node on an area outline, for example in a shopping center, where the area makes up the entire extension of that center, and the nodes identify the entrance to the building.

Considering shops, there have also been decisions to be made. Some shops do not clearly fit into one category, particularly if they sell disparate items. For example, there are shops selling drinks and electronics. In these cases, we have taken any shop that contains the label we are interested in, even if it incorporates some additional category.

The process of storing in the database and eliminating duplicates is described in the user manual in Annex II.

13.1.3 Deployment of information server

As indicated in the user manual, we use the Open Source Geoserver[26] software, and the standard Web Feature Service (WFS)[27], to obtain geographic features according to the information stored in the database. The designed connection model can be seen in the following figure:

[24] https://wiki.openstreetmap.org/wiki/Key:amenity

[25] https://wiki.openstreetmap.org/wiki/Key:shop

[26] https://geoserver.org/

[27] OGC Web Feature Service (WFS) Implementation Specification: https://www.ogc.org/standards/wfs

```
owsrootUrl := <DOMAIN>:<PORT>/geoserver/cities2030/ows?<defaultParameters>

<defaultParameters> := {
      service: 'WFS'
      version: '1.0.0'
      request: 'GetFeature'
      typeName: <typeNameNodes> | <typeNameWays> | <typeNameLimits>
      outputFormat: 'text/javascript'
      SrsName: 'EPSG:4326'
}
                          <typeNameNodes> :='cities2030:<City>_nodes'
                          <typeNameWays> :='cities2030:<City>_ways'
                          <typeNameLimits> :='cities2030:<City>_limit'

<City>:= Quart de Poblet | Bremerhaven | Brugge | Velica Gorica
| Troodos | Seinäjoki | Vidzeme | Iasi | Murska Sobota | Vicenza | Haarlem
...
```

Figure 71. Data model syntax for Geospatial queries

As can be seen, a set of addresses are encoded in an API type space, with different variability parameters, indicated in the figure with a text highlight color. We highlight the three types of information that can be obtained:

<typeNameNodes>: *Point-type* set (OSM nodes), which represents the point-based elements of the establishments according to the categories present in D6.2. Section 7.3.2 Geospatial information.

<typeNameWays>: *Linestring type* set (OSM Ways), which are presented in open or closed polygons, generally demarcating an area of an establishment, such as a supermarket.

<typeNameLimits>: *Polygon type* set, which represents the administrative limits of the municipality involved in the Cities2030 Lab. This is being used alto to filter other *TypeNames* to ensure they belong to the experimentation area.

13.2 Validation: Integration with S2CP platform and provision of Cities2030 data

In this section we discuss the work carried out mainly in the third phase of the Combined Development Methodology, which, in relation to the Geospatial Services component, has been the integration with the rest of the components of the S2CP platform (Communities and S2CP dashboard) and the provision of geographic information on the municipalities where the labs and follower cities are established.

13.2.1 Integration with S2CP platform

For the geospatial services component, as this is not an independent component (it requires others to offer the functionality to the end user), it is critical to get connected to any other WP6 components generating spatial visualization, supporting decisions, or providing security services. In this section we discuss the main current and future interconnections.

13.2.1.1 Integration with SSO (Communities)

Like other components already mentioned, such as the S2CP dashboard, this component also incorporates the Single Sign-On functionality, as a way to integrate security and management of permissions and credentials following a single configuration for the S2CP platform. Following the S2CP SSO integration guide of Annex I, the Geospatial services has integrated SSO functionalities.

Below is a screenshot where the component can be seen with a session started by an administrator user:

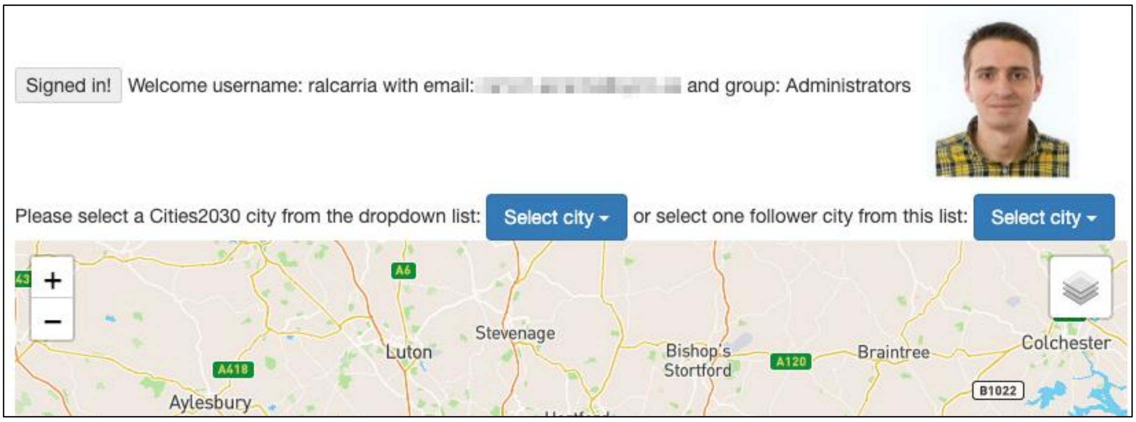


Figure 72. Data model syntax for Geospatial queries

13.2.1.2 Integration with S2CP Dashboard

The interconnection with the S2CP dashboard is done through the deployed services mentioned in section 13.1.3. The following figure shows a list of layers stored on the deployment server, which can be downloaded in various formats, such as GML, KML or GeoJSON.

List of all layers configured in GeoServer and provides previews in various formats for each.

<< < 1 2 > >> Results 26 to 33 (out of 33 matches from 55 items) cities2030 Clear

Type	Title	Name	Common Formats	All Formats
	Velika_nodes	cities2030:Velika_nodes	OpenLayers GML KML	Select one
	Velika_ways	cities2030:Velika_ways	OpenLayers GML KML	Select one
	Vicenza_limit	cities2030:Vicenza_limit	OpenLayers GML KML	Select one
	Vicenza_nodes	cities2030:Vicenza_nodes	OpenLayers GML KML	Select one
	Vicenza_ways	cities2030:Vicenza_ways	OpenLayers GML KML	Select one
	follower_limit	cities2030:follower_limit	OpenLayers GML KML	Select one
	follower_nodes	cities2030:follower_nodes	OpenLayers GML KML	Select one
	follower_ways	cities2030:follower_ways	OpenLayers GML KML	Select one

<< < 1 2 > >> Results 26 to 33 (out of 33 matches from 55 items)

Figure 73. Layer preview of Geospatial data in deployed Geoserver

Finally, the geographic information appears in the S2CP dashboard, representing the three types of spatial elements, as can be seen in the following figure:

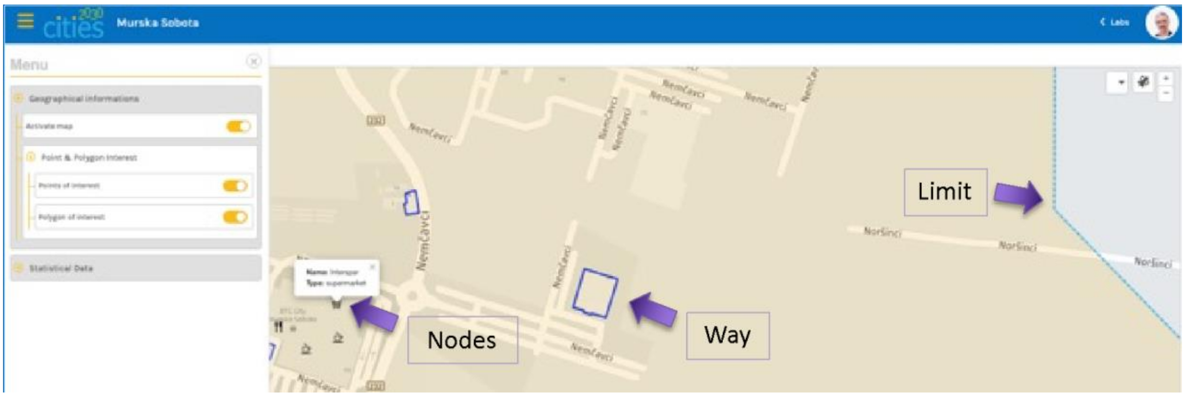


Figure 74. Geospatial information data types for Murska Sobota Lab in S2CP dashboard

13.2.2 Provision of S2CP data

On January 25th 2024, the "Data in Cities2030" workshop was held, where the WP6 managers described to the participating labs the functionalities of this component and the user manual attached in Annex II. As documentation for this workshop, information about the current CRFS Labs and also about the follower cities was introduced into the component. Below, we indicate a table where you can see the information available in the Geospatial Services component, classified by municipality and considering the number of Points of Interest (POIs) available.

Table 4. Information captured through the Geospatial Services component

Municipality (Country)	Lab/City	Geospatial Data (number of POIs)
Bremerhaven	Bremerhaven Lab	Point (298), Area (48), Administrative Limit
Brugge	Brugge Lab	Point (988), Area (316), Administrative Limit
Haarlem	Haarlem Lab	Point (362), Area (11), Administrative Limit
Iasi	Iasi Lab	Point (730), Area (126), Administrative Limit
Murska Sobota	Murska Sobota Lab	Point (96), Area (47), Administrative Limit
Quart de Poblet	Quart de Poblet Lab	Point (49), Area (6), Administrative Limit
Seinajoki	Seinajoki Lab	Point (115), Area (18), Administrative Limit
Troodos	Troodos Lab	Point (1), Area (9), Administrative Limit
Velika Gorica	Velika Gorica Lab	Point (104), Area (10), Administrative Limit
Vicenza	Vicenza Lab	Point (2409), Area (329), Administrative Limit
Venice (Italy)	Follower City	Point (7264), Area (742), Administrative Limit
Udine (Italy)	Follower City	Point (4762), Area (954), Administrative Limit
Colceresa (Italy)	Follower City	Point (40), Administrative Limit
Rethymnon (Greece)	Follower City	Point (926), Area (114), Administrative Limit
Tokyo (Japan)	Follower City	Point (74476), Area (3778), Administrative Limit

Okishima (Japan)	Follower City	Point (4), Administrative Limit
Kesennuma (Japan)	Follower City	Point (676), Area (88), Administrative Limit
Pollica (Italy)	Follower City	Point (42), Administrative Limit
Valmiera (Latvia)	Follower City	Point (106), Area (42), Administrative Limit
Cesis (Latvia)	Follower City	Point (80), Area (26), Administrative Limit
Sigulda (Latvia)	Follower City	Point (116), Area (14), Administrative Limit
Preili (Latvia)	Follower City	Point (4), Area (6), Administrative Limit
Quebec (Canada)	Follower City	Point (25388), Area (4060), Administrative Limit
Thessaloniki (Greece)	Follower City	Point (5418), Area (344), Administrative Limit
Quinto Vicentino (Italy)	Follower City	Point (24), Administrative Limit
Fara Vicentino (Italy)	Follower City	Point (26), Area (2), Administrative Limit
Monticello Conte Otto (Italy)	Follower City	Point (12), Area (6), Administrative Limit
Monteviale (Italy)	Follower City	Point (6), Area (2), Administrative Limit
Caldogno (Italy)	Follower City	Point (80), Administrative Limit
Sandrigo (Italy)	Follower City	Point (70), Area (8), Administrative Limit
Dueville (Italy)	Follower City	Point (62), Area (20), Administrative Limit
Bolzano Vicentino (Italy)	Follower City	Point (26), Area (6), Administrative Limit
Torri di Quartesolo (Italy)	Follower City	Point (62), Area (6), Administrative Limit
Thiene (Italy)	Follower City	Point (108), Area (16), Administrative Limit
Val Liona (Italy)	Follower City	Point (6), Administrative Limit
Sovizzo (Italy)	Follower City	Point (62), Area (4), Administrative Limit
San Vito di Leguzzano (Italy)	Follower City	Point (32), Area (2), Administrative Limit

13.3 Conclusions

The geospatial services component is a functional unit that supports other components within the S2CP such as the data repository and the S2CP dashboard. It uses standard interfaces, such as the OGC's Web Map Service and Web Feature Service for seamless integration with other web services.

Within the framework of the work methodology, a set of scripts has been enabled for the capture of points of interest in the study regions, all this information has been integrated into a geospatial database and the system for providing geospatial information has been validated with the integration of point, linear and polygonal information in 37 municipalities, according to Table 4.

14 Blockchain food supply chain digital twin

The S2CP component "Blockchain food supply chain digital twin" consists of a Platform powered by UNISOT technology, which enables to provide that products are sustainable, original, safety and ethically sourced. The architecture of the system enables data capturing and monitoring from all parts of the supply chain. In this section we highlight the key features of this component.

14.1 Introduction: UNISOT blockchain system overview

UNISOT is a Web3 Supply Chain Traceability & Sustainability platform that provides comprehensive visibility and interoperability throughout the entire global supply chain. The platform is designed to foster collaboration and data sharing among all actors in the value chain by incentivizing the exchange of information. Built on public blockchain technology, UNISOT employs a unique approach called "Smart Digital Twins," creating digital representations of physical assets in the supply chain, such as products or resources. These Smart Digital Twins enable detailed tracking and tracing of each product's lifecycle, from production to consumption, recording all relevant data such as location, temperature, and quality.

14.2 Key Features of the UNISOT technology

Supply Chain Transparency: UNISOT enables businesses to track food products from farm to fork. Each step in the supply chain is recorded, verified, and shared with all parties in the network. This transparency ensures product authenticity and helps prevent fraud and counterfeit products.

Traceability: The platform simplifies the process of tracing the origin and journey of fresh foods through the supply chain. In the event of a food safety issue or recall, this technology can quickly and accurately identify the source of the problem, minimizing the impact on consumers and reducing costs for businesses.

Improved Efficiency: UNISOT streamlines various processes within the supply chain, reducing the need for paperwork, administrative tasks, and manual data entry. The platform automates transactions, payment processing, and other aspects of the supply chain, resulting in faster and more cost-effective operations.

Enhanced Trust: By using a tamper-proof, decentralized public blockchain, UNISOT ensures data integrity and builds confidence among producers, importers, retailers, and consumers. This trust is further enhanced by the transparency and traceability features of the platform.

Reduction in Food Waste: Improved traceability and transparency enabled by UNISOT help identify inefficiencies and areas of food waste within the supply chain. Businesses can then implement targeted measures to reduce spoilage and optimize resource utilization.

Better Quality Assurance: The platform allows businesses to monitor and verify product quality at each stage of the supply chain, ensuring that only the highest-quality foods reach end consumers. This enhances the reputation of producers and increases consumer confidence in their products.

Consumer Engagement: The UNISOT Digital Product Passport provides consumers with access to detailed product information, empowering them to make informed choices about the fresh foods they purchase. This transparency leads to increased consumer loyalty as customers are more likely to choose brands that are open about their products and supply chains.

Regulatory Compliance: UNISOT facilitates compliance with food safety regulations, sustainability reporting, and import/export laws by providing a transparent, traceable, and immutable record of all transactions and product information. This simplifies audits and reduces the risk of fines or penalties due to non-compliance.

14.3 Implementation of Blockchain food supply chain digital twin

This component consists of the following functionalities:

Smart Digital Twins: Each physical asset in the supply chain, such as a piglet, is represented by a Smart Digital Twin on the blockchain. This digital twin records all relevant data about the asset's lifecycle, including origin, feed type, health treatments, and processing history.

Data Collection and Integration: The system encourages and facilitates data collection through a user-friendly, engaging mobile app that incorporates gamification elements. Field workers are incentivized to collect data, which is then validated by a machine learning algorithm before being added to the blockchain.

Real-Time Monitoring: IoT sensors integrated with the platform monitor various conditions such as temperature and humidity during transport and handling. This real-time data collection ensures optimal conditions are maintained throughout the supply chain.

Seamless Integration: The IoT Integration Engine, ERP plug-ins, APIs, and SDKs ensure smooth and efficient integration with existing IT systems throughout the supply chain. This allows businesses to quickly adopt the platform, minimizing downtime and disruption.

Pilot Testing and Continuous Improvement: The implementation process involves pilot testing to validate the system's functionality in a real-world environment. Continuous monitoring, evaluation, and improvement ensure the platform remains agile and effective in meeting the evolving needs of the supply chain.

In summary, the blockchain system offers a robust solution for enhancing traceability, transparency, and efficiency in the food supply chain. By leveraging Smart Digital Twins, real-time monitoring, and seamless integration, the platform ensures high-quality standards, regulatory compliance, and increased consumer trust.

14.4 Experiments

In this section, two experiments are described: (i) the demonstration on Ecofarming6 (Slovakia) and (ii) the definition of "Orange certification" use case within the Quart de Poblet lab context.

14.4.1 Blockchain Demonstration in Piglets Scenario Traceability (22nd March 2023)

This section aims to demonstrate the use of blockchain technology to enhance traceability in the piglet supply chain, specifically focusing on the scenario of Ecofarming 6 in Slovakia. The goal is to showcase how blockchain can provide transparency, sustainability, and ethical sourcing from birth to consumer purchase. For this, a purpose and scope were defined:

- **Purpose**: Demonstrate the use of blockchain technology for enhancing traceability in the piglet supply chain.
- **Scope**: Covers the lifecycle of piglets from birth to consumer purchase, emphasizing transparency, sustainability, and ethical sourcing.

14.4.1.1 Demonstration scenario

Ecofarming 6[28] is a farm that specializes in raising, leasing pigs and selling pork products to consumers. To ensure the originality of their food, they decide to use blockchain technology to track the entire process of raising the pigs and producing the pork, from the quality of the fodder to the transportation to the customer.

[28] Ecofarming6 Instagram website: https://www.instagram.com/ecofarming6jankowitch/

First, the farm would need to establish a blockchain network. They could do this by selecting a blockchain platform, such as Ethereum or Hyperledger Fabric, and creating a network of nodes that would be responsible for verifying and recording transactions on the blockchain.

Next, they would need to gather data on the quality of the fodder used to feed the pigs. This could include information such as the pH of the soil where the feed was grown, the types of fertilizers used, and the conditions during transportation. They could use sensors and other IoT devices to collect this data and store it on the blockchain.

As the pigs are raised, the farm would continue to collect data on their health, growth, and other important metrics. They could also record the dates and types of veterinary treatments, vaccinations, and other interventions.

Once the pigs are ready for slaughter, the farm could use blockchain to record the entire process, from the time the pigs are brought to the processing facility to the packaging and shipping of the pork products. This would allow consumers to trace the origins of their food and ensure that it was produced according to high quality standards.

Finally, the farm could use blockchain to track the transportation of the pork products to the customer. They could record information such as the temperature and humidity during shipping, the route taken, and the time of delivery. This would help ensure that the pork arrived in good condition and was safe to eat.

Overall, using blockchain to track the entire process of raising pigs and producing pork products would help the farm assure the originality of their food and maintain high quality standards. It would also provide consumers with greater transparency and trust in the food they are buying.

Figure 75. Diagram of Ecofarming 6 Blockchain vision

Initial steps:

1. The pig farm registers on a blockchain platform that provides food traceability services.
2. Each pig is assigned a unique identifier, which is recorded on the blockchain. This identifier could be in the form of an RFID tag or a QR code.
3. Whenever a pig is sold or transferred to a new owner, the transaction is recorded on the blockchain. This creates an immutable record of the pig's ownership history.
4. When the pigs are slaughtered, the meat is processed and packaged with the unique identifier of the pig that it came from. This information is also recorded on the blockchain.
5. The packaged meat is then transported to retailers or restaurants. Each time the meat changes hands, the transaction is recorded on the blockchain. This allows consumers to trace the journey of the meat from the farm to their plate.
6. Consumers can scan the QR code on the meat packaging using their smartphone to access the blockchain record. They can see the pig's ownership history, the date of slaughter, the processing and packaging details, and the transportation history.

7. By using blockchain technology, the pig farm can assure consumers that the meat they are buying is original and has come from a specific farm. This enhances the trust between the farm and consumers and can potentially increase sales and revenue.

These steps are modeled in basic workflow diagrams such as the one below:

```
+------------------+   +------------------+   +------------------+   +------------------+
|   Pig Farm with  |   | Unique Identifier|   | Immutable Record |   | Slaughter & Meat |
|Blockchain System |   | for Each Pig     |   | of Ownership     |   | Processing       |
| (Registration)   |   | (RFID/QR Code)   |   | (Blockchain Entry)|  | (Packaging with  |
+--------|---------+   +--------|---------+   +--------|---------+   | Unique ID)       |
         |                      |                      |             +--------|---------+
         |                      |                      |                      |
         |                      |                      |                      |
         |                      |                      |                      |
         |                      |                      |                      |
         |                      |                      |                      |
         |                      |                      |                      |
         |                      |                      |                      |
         |                      |                      |                      |
         |                      |                      |                      |
+--------V---------+   +--------V----------+ +-------V------------+ +-------V----------+
| Transaction of   |   | Transaction of    | | Meat Transportation| | Consumer Access  |
|Pig(Sale/Transfer)|   | Meat (Change of   | | to Retailers/      | | to Blockchain    |
| Recorded on      |   | Hands) Recorded   | | Restaurants        | | Record via QR    |
| Blockchain       |   | on Blockchain     | | (Blockchain Entry) | | Code on Packaging|
+------------------+   +------------------+   +------------------+   +------------------+
```

Figure 76. Simplifying demonstration initial steps via workflow diagram

14.4.1.2 Demonstration execution

After the preparation of the scenario followed up by a three-day personal meeting (22.03.2023 – 24.03.2023) in Slovakia to collect all data together with the farmer and fulfill the blockchain system using the pre-production system of UNISOT.

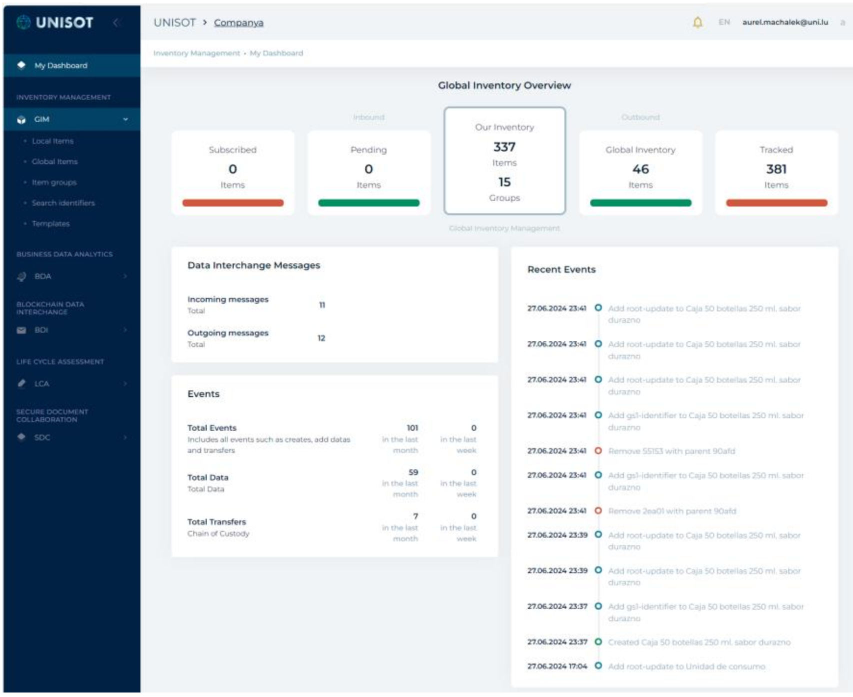


Figure 77. UNISOT pre-production dashboard

UNISOT blockchain system has a unique feature of how to optimize workflow with new articles by creating a one-time template with all relevant data and after just collecting new and updated data.

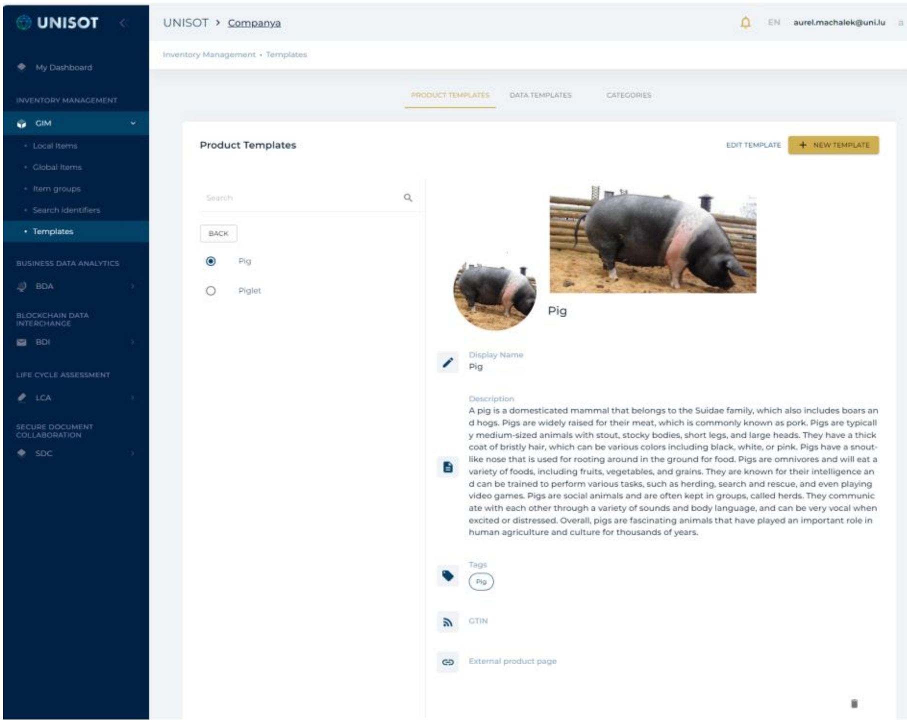


Figure 78. UNISOT pre-production template for Ecofarming6 pig leasing

After the creation of the template followed the preparation of the dataset. In the case of Ecofarming and demonstration purpose dataset was created as follows:

<table>
<tr><td>+--------------------+</td><td>+--------------------+</td><td>|</td></tr>
<tr><td>| Pig |</td><td>| Farm |</td><td>|</td></tr>
<tr><td>+--------------------+</td><td>+--------------------+</td><td>| 1</td></tr>
<tr><td>| - ID |</td><td>| - Food Farm Number |</td><td>|</td></tr>
<tr><td>| - Type |</td><td>| - Food Farmer |</td><td>v</td></tr>
<tr><td>| - Breed |</td><td>+--------------------+</td><td>+--------------------+</td></tr>
<tr><td>| - Date of Birth |</td><td>|</td><td>| Transport |</td></tr>
<tr><td>| - GPS Coordinates |</td><td>|</td><td>+--------------------+</td></tr>
<tr><td>| - Sex |</td><td>| 1</td><td>| - Date and Time |</td></tr>
<tr><td>| - Weight Monthly |</td><td>|</td><td>| - Destination |</td></tr>
<tr><td>| - Medical Notice |</td><td>v</td><td>| - Temperature During Transport |</td></tr>
<tr><td>| - Date of Illness |</td><td>+--------------------+</td><td>| - Transport Breaks with GPS Coordinates |</td></tr>
<tr><td>| - Other Illness |</td><td>| Customer |</td><td>+--------------------+</td></tr>
<tr><td>| - Temperature |</td><td>+--------------------+</td><td></td></tr>
<tr><td>| - Other Breeding Condition |</td><td>| - Name |</td><td></td></tr>
<tr><td>| - Weight Before Slaughter |</td><td>| - Distance to Farm |</td><td></td></tr>
<tr><td>| - Weight After Slaughter |</td><td>+--------------------+</td><td></td></tr>
<tr><td>| - Temperature of Storage |</td><td>|</td><td></td></tr>
<tr><td>| - Health Examination Date |</td><td>|</td><td></td></tr>
<tr><td>| - Transport Permit |</td><td>| 1</td><td></td></tr>
<tr><td>| - Health Examination |</td><td>|</td><td></td></tr>
<tr><td>| - Form of Taking |</td><td>v</td><td></td></tr>
<tr><td>| - Nonstandard Demands |</td><td>+--------------------+</td><td></td></tr>
<tr><td>+--------------------+</td><td>| Slaughterhouse |</td><td></td></tr>
<tr><td>|</td><td>+--------------------+</td><td></td></tr>
<tr><td>|</td><td>| - Slaughterhouse Number |</td><td></td></tr>
<tr><td>| 1</td><td>| - Date of Incoming |</td><td></td></tr>
<tr><td>|</td><td>| - Date of Exiting |</td><td></td></tr>
<tr><td>v</td><td>+--------------------+</td><td></td></tr>
</table>

Figure 79. Demonstration dataset for Ecofarming6 pig leasing

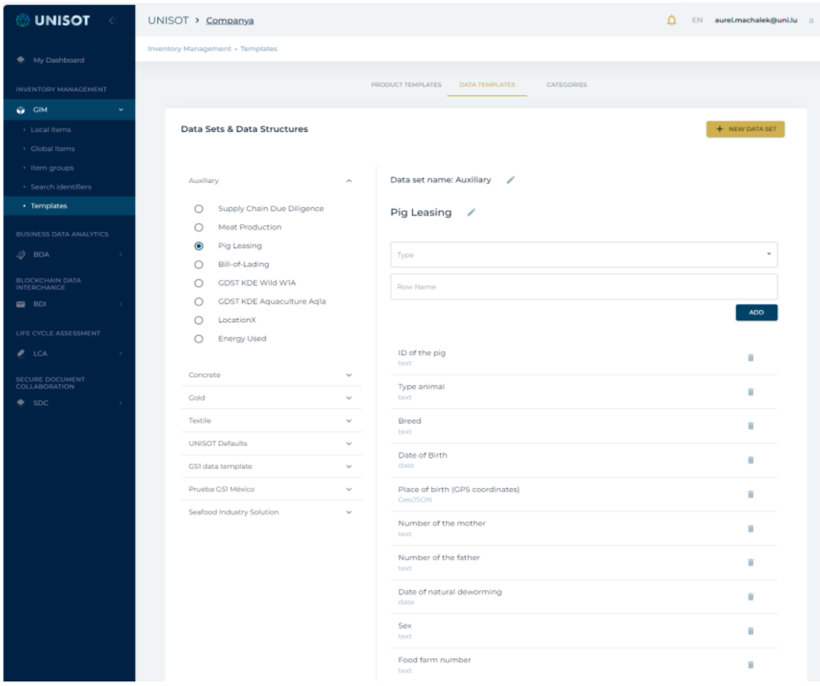


Figure 80. UNISOT pre-production template with datasets

Now it was all set up to create a new item, in our case a new piglet was born.

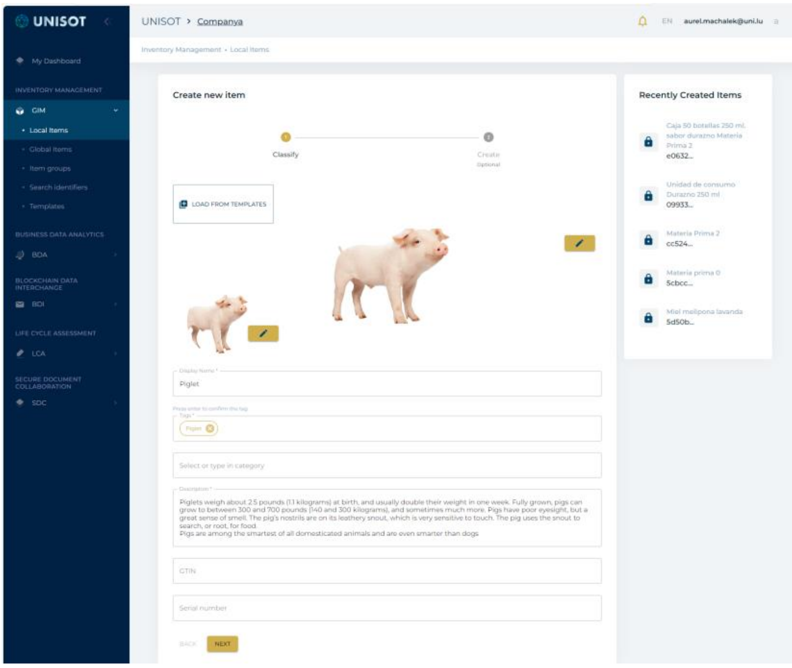


Figure 81. UNISOT pre-production new item creation

All the data can be provided manually with each newborn piglet, or the system can be linked with its own farmer database or connected with the farmers accounting system.

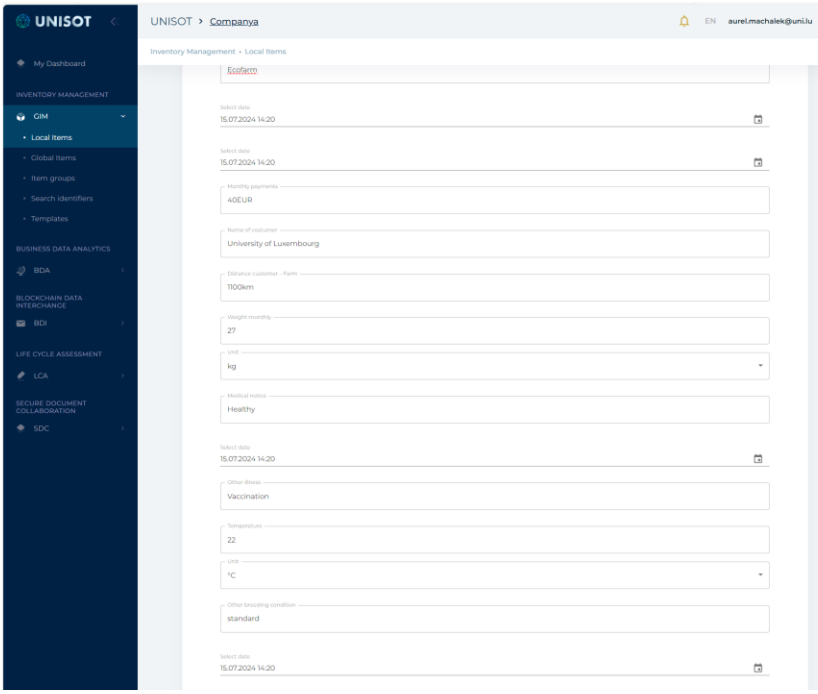


Figure 82. UNISOT pre-production data entering using the template

Customers can see data based on farmers' decisions; what kind of data is useful for customers. Customers afterward can give feedback or do micro payments to support farmers.

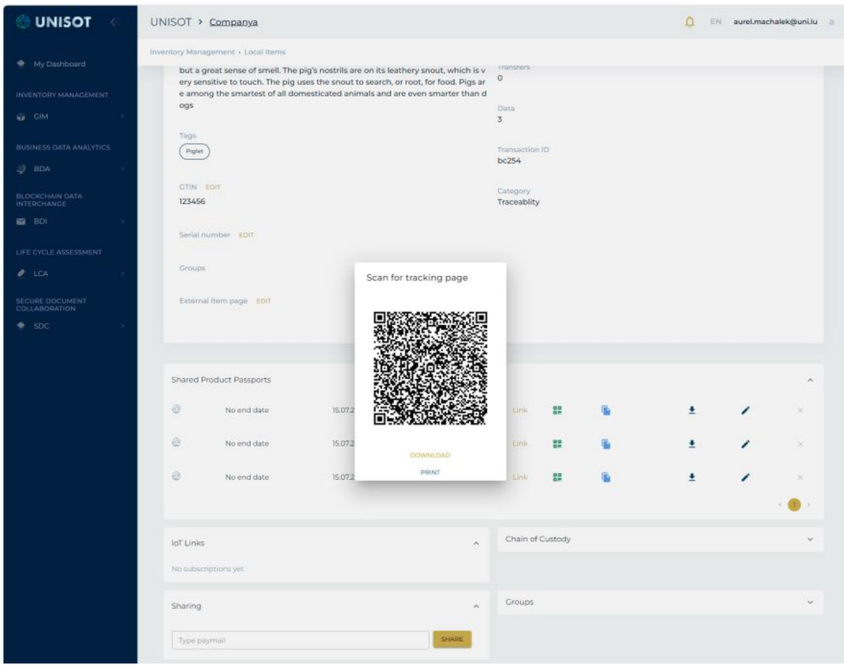


Figure 83. UNISOT sharing data with public

14.4.1.3 Conclusion and dissemination

The demonstration of blockchain technology in the piglet supply chain at Ecofarming6 in Slovakia has showcased the remarkable potential and readiness of this technology to revolutionize the food supply chain industry. Through this pilot project, several key benefits and positive outcomes were observed, affirming the viability and advantages of implementing blockchain in food traceability.

The implementation of blockchain provided unparalleled traceability, allowing every step of the piglet's journey—from birth to consumer purchase—to be securely recorded and verified. This comprehensive traceability ensures that all stakeholders can access detailed information about the origin, handling, and processing of the products.

Figure 84. Demonstration days in Slovakia

Figure 85. Guinea pig transportation with temperature monitoring

Dissemination with Latvian Rural Forum

The blockchain solution for pig leasing was first presented at a workshop in October 2023 for the Latvian Rural Forum, from Vidzeme lab. Stakeholders attempted to understand how blockchain could address their specific issue with tracing the origin of potato supplies to school canteens in Latvia. During the workshop, we identified problems, demonstrated how the process was executed in Slovakia, and showcased the live pre-production UNISOT system. Based on this information, the potato scenario was prepared.

A second workshop with the Latvian Rural Forum was held in January 2024, involving key stakeholders. We presented the principles of blockchain and the potato scenarios. Using the UNISOT solution, we clearly demonstrated the technology's advantages in tracing the journey of potatoes from farmers to school canteens.

Figure 86. Potatoes scenario with data structure for blockchain

United Nation Food System Coordination Hub

Cities2030 blockchain demonstration submitted by University of Luxembourg in 2023 to the Database of Practices in Food System Transformation, in the form of stories, practices, and reports towards the UNFSS+2 was accepted and published. FAO OSG - Practices for Food System Transformation.

https://foodsystems-goodpractices.review.fao.org/practices/322

Dissemination in GA in Marseille. Expert discussion

On the occasion of the GA in Marseille, the workshop "Demonstration of blockchain marketplace and digital twin" took place. 20th June 2024, planned in the WP6 schedule for the validation of the S2CP components. In this workshop, the Blockchain food supply chain digital twin was presented through the use case of the piglet supply chain at Ecofarming6. A discussion took place on the impact and effort of modelling a similar solution for other labs, such as the one in Velika Gorica.

Figure 87. Discussion with Mario Konic, from Velika Gorica lab, about component integration possibilities

14.4.2 Demonstration with Oranges certification in Quart de Poblet

This section aims to demonstrate the use of blockchain technology to provide trust to the distribution chain of locally produced oranges. In the same way as in the previous experiment, a purpose and scope were defined:

- **Purpose:** Demonstrate the use of blockchain technology for enhancing traceability in the piglet supply chain.
- **Scope:** Cover information about orange provenance, quality attributes, certification processes and adaptive visualization interfaces.

14.4.2.1 Demonstration scenario

On May 30, 2023, a workshop was held in Quart de Poblet, Valencia, Spain, where, in addition to the City Council of Quart de Poblet, experts in production and distribution of local products were invited. In this workshop, UPM (P20), with virtual support and materials from Uni.Lu (P35), presented the blockchain food supply chain digital twin.

The phases of this scenario are presented below and will be developed in the following subsection:

1. Modeling of data on the life cycle of the Javelina variety orange
2. Establishment of local twin, as instances of the general model
3. Introduction of the information of each shipment through the UNISOT interface
4. Generation of visualization and interaction by events

14.4.2.2 Demonstration execution

Below we review the phases of the scenario and discuss how they have been executed in this experiment:

1. Data modeling on the life cycle of the Navelina orange variety

With the information obtained by the experts invited to the workshop, a template is created with the most important elements: Date, Energy consumption, File attachments, Image attachments, Location, Number, Temperature, Text, Volume, Weight, Certification, Production Date, Harvest Date, Best-Before Data and url.

2. Establishment of local twins, as instances of the general model

Once the product template that we are going to trace is established, we generate instances of that product, through the concept of local twin. This local twin is similar to the concept of shipment, that is, it is a physical quantity of that element that has a set of dynamic properties such as "location", "production date", "weight", etc.

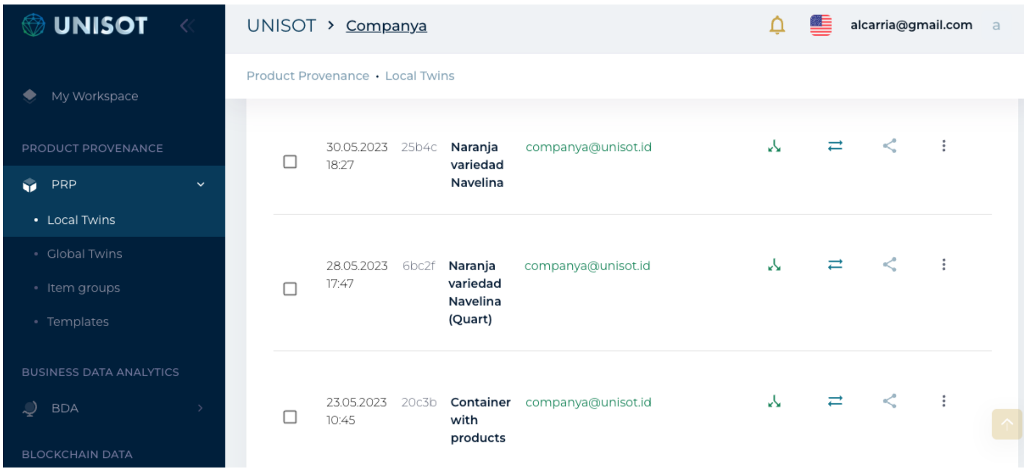


Figure 88. Establishment of local twins, as instances of the general model

Once each twin location has been established, the general information (twin detail) can be consulted according to the following figure:

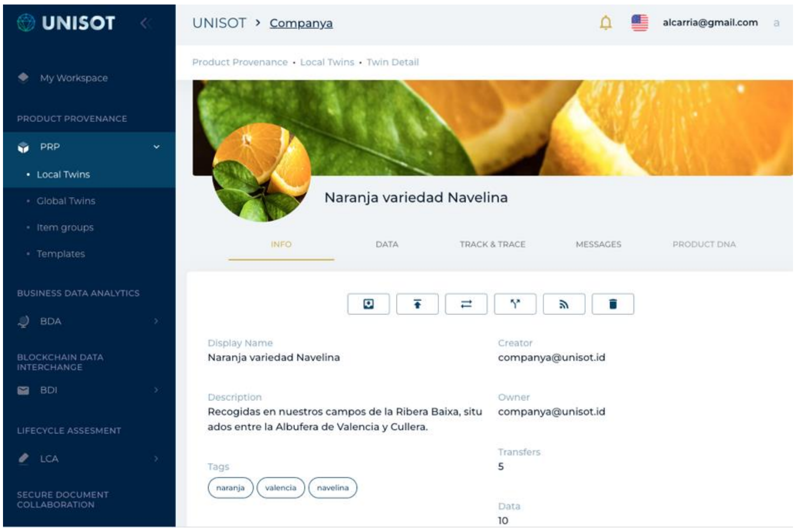
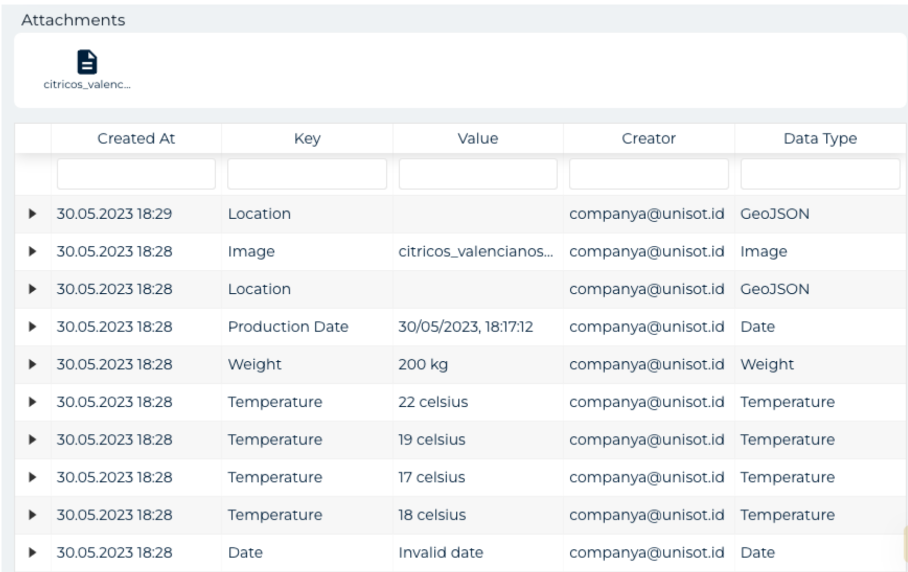


Figure 89. Twin detail in UNISOT platform

3. Introduction of the information of each shipment through the UNISOT interface

This platform allows the introduction of information about each shipment in multiple ways. For the demonstration, and for convenience, we enter the information through the UNISOT web interface, but we could perfectly have temperature sensors sending the shipment information in real time, which would be recorded in the blockchain.

In the following figure we see the information provided as an example for a shipment of oranges:



Attachments

citricos_valenc...

Created At	Key	Value	Creator	Data Type
30.05.2023 18:29	Location		companya@unisot.id	GeoJSON
30.05.2023 18:28	Image	citricos_valencianos...	companya@unisot.id	Image
30.05.2023 18:28	Location		companya@unisot.id	GeoJSON
30.05.2023 18:28	Production Date	30/05/2023, 18:17:12	companya@unisot.id	Date
30.05.2023 18:28	Weight	200 kg	companya@unisot.id	Weight
30.05.2023 18:28	Temperature	22 celsius	companya@unisot.id	Temperature
30.05.2023 18:28	Temperature	19 celsius	companya@unisot.id	Temperature
30.05.2023 18:28	Temperature	17 celsius	companya@unisot.id	Temperature
30.05.2023 18:28	Temperature	18 celsius	companya@unisot.id	Temperature
30.05.2023 18:28	Date	Invalid date	companya@unisot.id	Date

Figure 90. Introduction of information of each shipment in UNISOT platform

4. Generation of visualization and interaction by events

Each shipment has an associated QR code that can be generated with different visibility permissions (public or private) and that also allows you to consult all or a subset of the information associated with the product. In the following figure (left) you can see the generation of the QR code and (right) the consultation of it with a smartphone. As you can see, the information on the screen is correctly distributed when we have small interfaces such as those on a mobile phone.

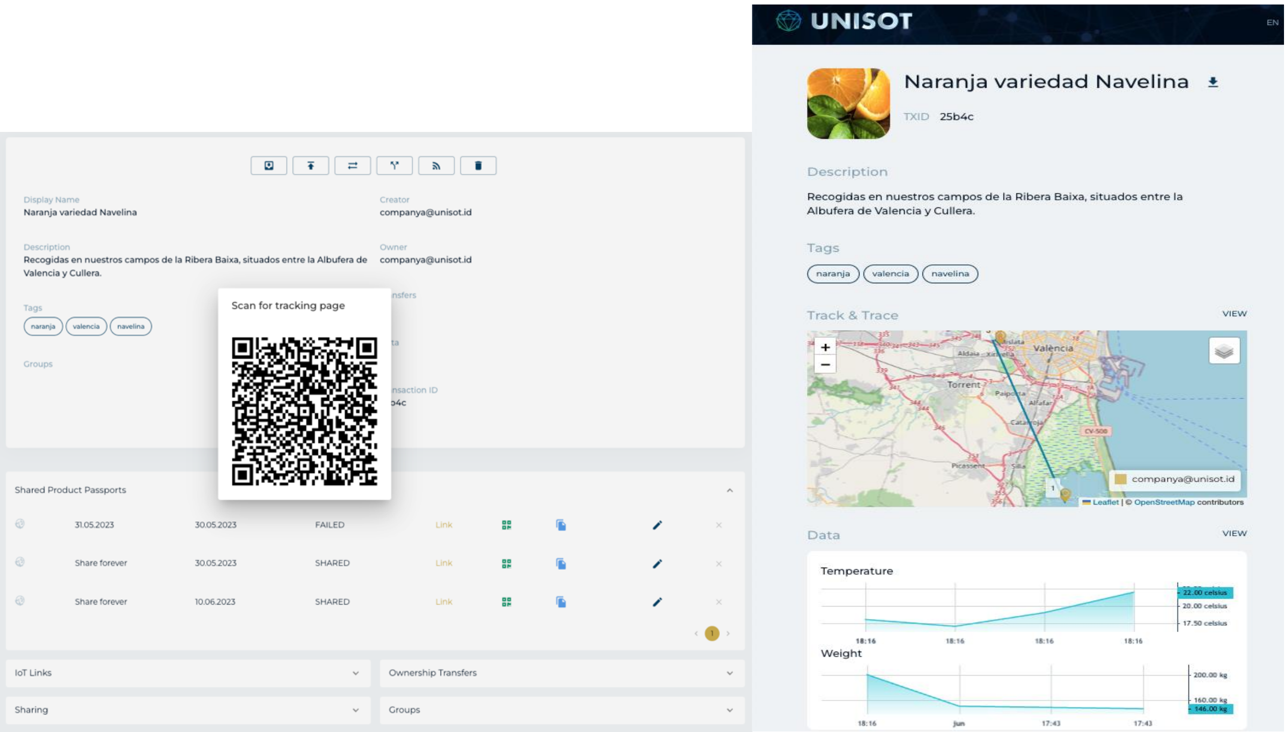


Figure 91. Generation of visualization

Finally, every user registered on the platform and able to read the QR code can send relevant information about the process. This notification function is necessary to determine whether a shipment leaves a warehouse, or has already been received by a logistics company, or distributed to a local market. The following figure shows the interface where all these events have been saved and are available for consultation by all interested stakeholders.

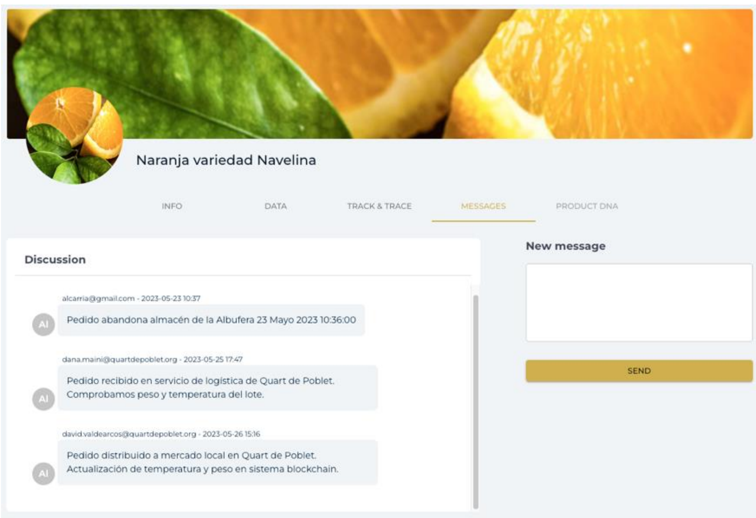


Figure 92. Interaction by events

14.4.2.3 Conclusion and dissemination

As a conclusion of this experiment, feedback from local trade experts has been very relevant and aligned with the theories of the workshop organizers. Blockchain technology is very interesting and offers many advantages in terms of reliability, identification and data security. In recent years, its use has become easier, with user-friendly web interfaces and connection to mobile phones and tablets through QR codes. The negative comment discussed was the difficulty of aligning the processes that are constantly changing due to pressures from large distributors and also dynamic regulations.

Figure 93. Showcasing Blockchain food supply chain digital twin in Quart de Poblet's workshop (30 of May 2023)

14.5 Conclusions

In contrast to the Blockchain-enabled Marketplace for SFSC solution (described in section 12), which is a solution programmed by WP6 participants, in this case we have chosen to base ourselves on UNISOT technology, an industrial solution supported by the company of the same name that has provided its infrastructure for the execution of experiments.

The labs of Quart de Poblet, Velika Gorica, and Vidzeme have participated in the validation of this tool, providing use cases and knowledge of the operation of the supply chain of local products. In addition, other companies associated with Cities2030 such as UNISOT and Ecofarming6 have participated in the validations with technological support (in the case of UNISOT) and use case modeling and implementation (in the case of Ecofarming6). The ease with which this solution is able to adapt to the use cases that have been analyzed (Piglets Scenario Traceability and Oranges certification) makes it ideal for implementation in environments that do not require high technological assistance, and that can be operated by CRFS experts and not necessarily computer systems experts.

15 S2CP dashboard

S2CP dashboard is a platform designed to aid decision-making by providing easy to use web interfaces, adapted to various screen sizes, and with options to customize the visualization of statistical and spatial data.

This section summarizes the evolution of this S2CP component since the presentation of Deliverable D6.5 (M30) and the experiments carried out with it.

15.1 Introduction

S2CP dashboard is a platform designed to aid decision-making, relies heavily on data visualization to unlock its true potential. By transforming raw data into clear, concise charts, graphs, and maps, S2CP empowers users to grasp trends, identify patterns, and gain insights they might miss in spreadsheets. This visual representation of information makes complex data accessible to a wider audience, from farmers to policymakers, ensuring everyone can leverage the platform's power.

15.2 Architectural design

The S2CP platform empowers stakeholders across the food system with data-driven decision-making. A critical component of this platform is the S2CP dashboard, a user-centric interface that translates complex data into actionable insights. The platform has been developed according to the structure described in the following Figure.

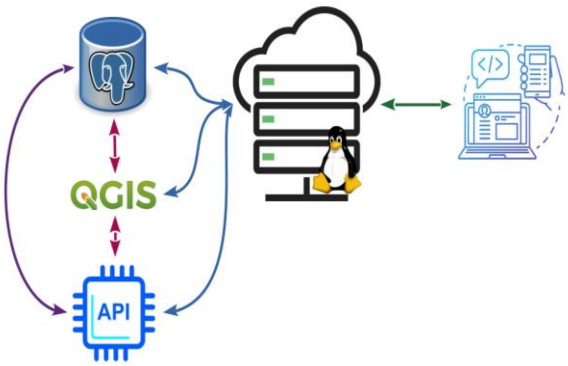


Figure 94. S2CP dashboard architectural design

The S2CP dashboard's front-end needs to be not only visually appealing but also intuitive and user-friendly. Frameworks like ReactJS, Angular, and Vue.js have been used for a reliable foundation and to build dynamic and interactive interfaces. These frameworks enable component-based architectures, promoting code reusability and maintainability for a future-proof platform. Effective data visualization has been achieved by means of *Chart.js* library, which provides a vast array of options for creating clear and informative charts, graphs, and maps. These libraries allow developers to tailor visualizations to specific data sets and user needs. The dashboard should empower users to explore data. For that, interactive features like filters, drill-downs, and custom dashboards allow users to tailor their experience. For instance, filters enable users to focus on specific regions, crop types, or timeframes. Dynamic dashboards allow users to create personalized views with the most relevant data points and visualizations.

The S2CP dashboard's back-end has been designed and implemented on a cloud-based Linux server with high accessibility and robust performance in mind. The architecture employs a microservices approach, allowing for modular development and scalability. High availability is achieved through the use of load balancers instances distributed over CPU cores and across different geographical regions implemented by the server supplier, being agnostic to the user. This not only enhances the dashboard's reliability but also minimizes latency for users regardless of system crashes and system uptime. The server utilizes automated scaling mechanisms to accommodate varying load conditions, ensuring optimal performance during peak usage times.

In addition to accessibility and performance, security is a paramount consideration in the S2CP dashboard's back-end design. Data at rest and in transit safeguards sensitive information with secure protocols (ssh, https, among others), while role-based access control ensures that users can interact only with the data and functionalities according to their roles. Regular security audits and compliance checks are conducted to adhere to industry standards and best practices. comprehensive monitoring and logging systems are in place to track performance metrics and troubleshoot potential issues promptly. This ensures a smooth user experience, as the development team can identify and rectify problems before they impact users.

The back-end integrates with various APIs and third-party services, allowing for seamless data exchanges and real-time updates as the Copernicus land monitoring service layers. Data security is mandatory even for the current governance rules of the European Commision. Implementing robust role-based access control (RBAC) has been carried out using the Single-Click Login which ensures that users can only access data relevant to their roles. This integration capability enhances the dashboard's functionality, enabling users to gain insights from multiple data sources easily.

The S2CP dashboard relies on a well-structured and secure database to store available data that provides the relevant insights. A relational database has been selected due to the structure of the data and querying capabilities, based on postgreSQL. The Quantum GIS Geographic Information System engine has been implemented to visualize, analyze geospatial data and manage various vector and raster data formats.

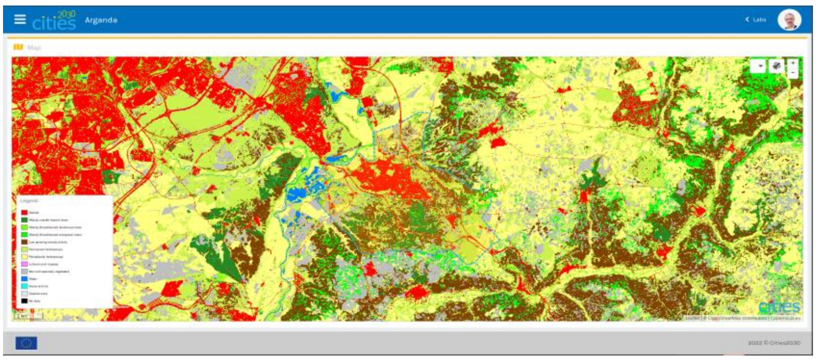
The success of S2CP hinges not just on data clarity but also on user experience (UX). A well-designed platform with an intuitive interface is crucial. Users should be able to navigate easily, filter data based on their needs and find the information they seek quickly. A smooth and efficient UX keeps users engaged and fosters trust in the data presented, ultimately promoting informed decision-making across the entire food system.

The S2CP platform empowers stakeholders across the food system with data-driven decision-making. A critical component of this platform is the S2CP dashboard, a user-centric interface that translates complex data into actionable insights. The S2CP dashboard relies on a well-structured and secure database to store available data that provides the relevant insights. A Relational database has been selected due to the structure of the data and querying capabilities.

15.3 Development of solution (M30 to M48)

Two major add-ons have been included over the last life-cycle interactions. One is the use of Copernicus Land cover layer. The second one is the adaptive display for non-pc architectures.

The S2CP dashboard is constantly evolving to provide users with even more powerful tools for food system decision-making. It has integrated the Copernicus Land cover layers powered by QGIS. This new functionality unlocks a wealth of geospatial information, enriching the insights users can glean from the platform. The Copernicus Land Cover program provides high-resolution, pan-European land cover maps. These maps categorize land into various classes, such as forests, cropland, grasslands, and urban areas. By integrating these layers into the S2CP dashboard, users gain access to valuable spatial context for their data analysis: (1) spatial analysis in which it can overlay user data (e.g., crop yield data) on top of the land cover maps and identify correlations between land cover types and specific agricultural outcomes; (2) targeted interventions for the identification of areas most suitable for specific agricultural practices or in need of conservation efforts, allowing stakeholders to make data-driven decisions about resource allocation and policy development; (3) monitoring change through historical and current Copernicus Land cover data which is crucial for the understanding the impact of climate change, agricultural practices, and other factors on land cover.



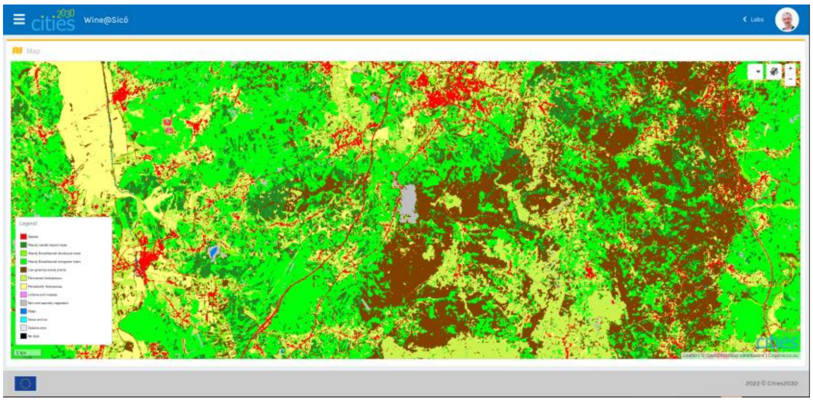


Figure 95. Land cover of from Copernicus Land Monitoring: (up) Arganda (down) wine@Sicó lab (Condeixa-a-Nova region)

The second feature is the reactivity of the front-end for non-desktop versions. This adaptation requires a responsive design approach. Responsive design ensures the dashboard layout automatically adjusts to fit the screen size and capabilities of the device being used. This involves utilizing flexible grids, fluid images, and optimized navigation elements. Users should be able to access all dashboard functionalities, including data visualizations, filters, and drill-down options, regardless of their chosen device. Additionally, prioritizing touch-friendly interactions and simplified menus further enhances usability on mobile devices. By adopting a responsive design approach, the S2CP dashboard remains accessible and user-friendly across desktops, tablets, and smartphones, empowering informed decision-making anywhere, anytime.

During the last period of development, it has implemented the outcomes of the user experience and usability making the software more user-friendly. It has considered the front-end design of the product experience and has already developed similar products deployed by Primelayer (P37). The test reported previously has been carried out in using 23 participants, fulfilling the forms and questionnaires. The Labs had the opportunity to navigate along the menus, showing that within its current state it is an easy to navigate platform, with an acceptable number of clicks prior to reaching the information, having relevant information for the Labs in charts and maps. The metrics of the labs of the access dashboards has shown a total of 954 single clicks navigation for a 10 min activity. Some users explored the platform thoroughly, with typical 60 pages accessed, and not only one living/policy lab, but tried to correlate with different labs. It is also seen that the UX multiplatform approach and libraries used resulted in a good access independently of the operating system and browser.

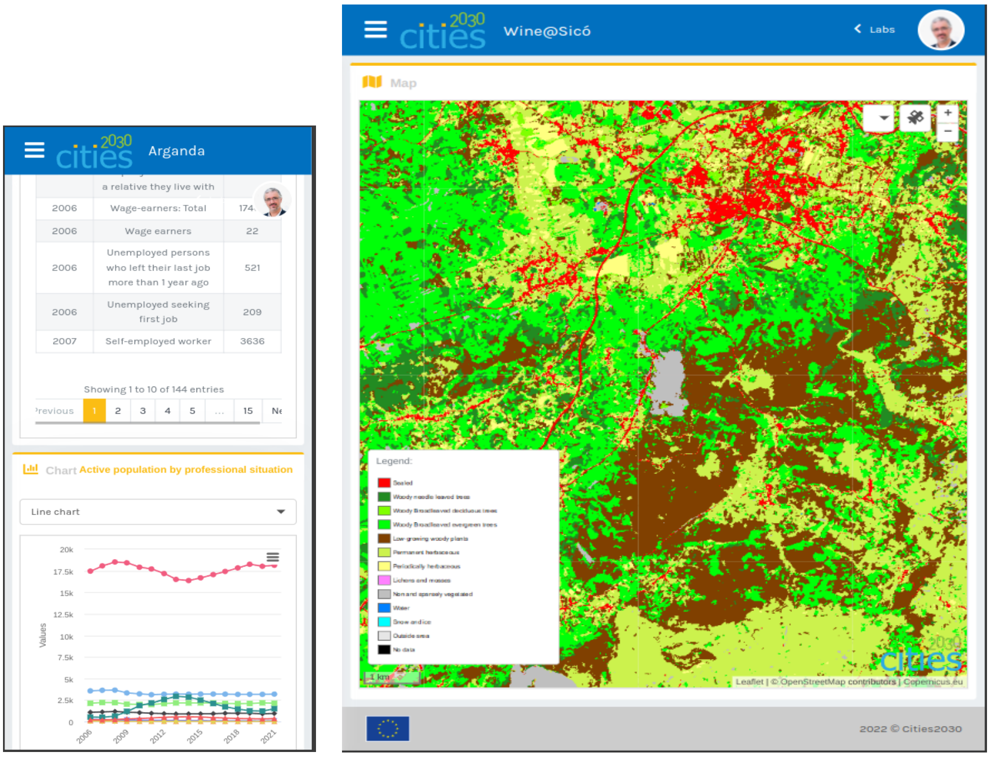


Figure 96. (up) Smartphone view (Google Pixel 7) and (down) tablet view of the S2CP dashboard

15.4 Experiments

Beside the two technical features and bug corrections, the core of the last period has been prioritizing User Experience and designing for informed decisions. Beyond the technical aspects, the S2CP dashboard's success hinges on a user-centered design approach. The workshops carried out with Labs and allowed the consolidation of defining the User Personas, i.e, developing user personas that represent different stakeholder groups (farmers, policymakers, consumers). Understanding their needs, data literacy levels, and preferred interaction styles helps tailor the dashboard functionalities and interface to their specific use cases.

The main workshop carried out to test S2CP dashboard was provided on 23rd February 2023, on occasion of GA in Haarlem. During the workshops, the interface design was tested, focusing on the clean, uncluttered, and easy to navigate design. Clear menus, labels, and consistent visual design patterns ensure users can find the information they need quickly and efficiently. Accessibility considerations are also crucial, ensuring users with disabilities can interact with the dashboard seamlessly. The data visualization should go beyond just presenting information, with the dashboard helping users tell stories with the data. Highlighting trends, anomalies, and correlations empowers users to draw insights and make informed decisions.

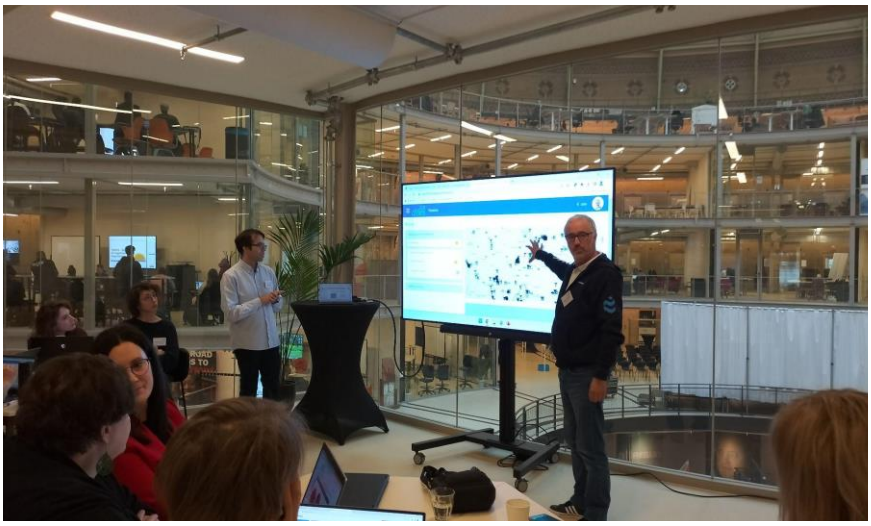


Figure 97. S2CP dashboard workshop carried out on 23rd February 2023 (Haarlem-Amsterdam)

Some additional experiments have been carried out using the wine@sicó lab. For example: *can land monitoring using a combination of remote sensing techniques can significantly improve grape crop optimization by providing comprehensive data on key environmental factors that influence grape growth and quality across a wider geographical area?*

The activity tries to create vineyard management tools through the power of remote sensing. This technology would gather detailed data on vineyards, enabling comprehensive monitoring of grapevine health throughout the growing season. By tracking various aspects like vine stress, nutrient deficiencies, and disease outbreaks, the system provides real-time insights for targeted interventions. This data-driven approach has the potential to optimize grape quality and yield, potentially leading to increased profits for vineyard owners. It has been found that the initial investment in setting up the remote sensing infrastructure is significant, and expertise might be needed to interpret the data effectively. We have used the S2CP dashboard to somehow reduce the cost of the initial learning curve. Additional layers are required and are being implemented as environmental data for the local based on open data api.

Figure 98. Experimenting in the scope of wine@sicó lab

15.5 Conclusions

As the impact of the S2CP dashboard to the CITIES2030 project and for future developments of the CFRS we may highlight:

- Enhanced Transparency and Traceability: A dashboard based on UX outcomes allows transparency by providing a centralized view of critical data points across the food system. This could include information on crop yields, food prices, supply chain movements, and even environmental factors. This transparency allows consumers to make informed choices about the food they purchase, while producers and distributors gain insights into potential disruptions and bottlenecks.
- Data-Driven Decision Making: By translating complex data sets into clear visualizations, the dashboard empowers decision-makers at all levels. Farmers can optimize planting strategies based

on real-time weather data and market trends. Policymakers can design evidence-based interventions to address food insecurity and promote sustainable agricultural practices. Retailers can leverage data to predict demand and optimize inventory management, reducing food waste.

- Improved Collaboration and Coordination: The food system is a network of interconnected actors. A shared dashboard fosters collaboration by providing a common platform for information exchange. Stakeholders can identify areas for collaboration, such as optimizing food distribution networks or developing joint sustainability initiatives.
- Risk Management and Proactive Action: Real-time data visualization allows for early identification of potential threats to food security, such as extreme weather events, pest outbreaks, or price fluctuations. By proactively monitoring these risks, stakeholders can take preventive measures to mitigate their impact and ensure food system stability.
- Promoting Innovation and Efficiency: Data-driven insights from the dashboard can spark innovation across the food system. Identifying trends in consumer preferences can guide the development of new food products. Insights into resource use can encourage the adoption of more efficient and sustainable practices. The ripple effect of decision-making paves the way for a more innovative and efficient food system overall.

16 Conclusions and future works

This deliverable presents the final version of the S2CP platform to M48. This milestone is considered the main outcome of WP6 and contains the work carried out by all participating partners. Although there is no specific task in WP6 that produces this deliverable, it has a direct relationship with task T6.1 "Requirements and reference architecture" which will provide the CITIES2030 technical architecture, based on the experiences of participants from previous project platforms and compatible with other already established ecosystems. In this document we can find, finally, the technical report with all the implementations matching the original design and architecture described in T6.1. This document, moreover, can be understood as a closure report for documents D6.2, D6.3, D6.4 and D6.5.

The document begins with a reconsolidation of the methodology created in T6.1, the Combined Development Methodology, which was adapted in turn to the methodologies used by the Labs in WP4 and WP5, to align it with the experimentation stages of the same. In particular, the last two phases (component development and experimentation) of the CDM are detailed and it is demonstrated that the main outcomes of each of them have been achieved.

A component-based architecture is designed for S2CP where each component has a member of the WP as responsible. This deliverable proposes a final version, with the complete list of implemented components and other cohesion and security mechanisms in the platform, such as the single-sign-on system as a way to integrate security and management of permissions and credentials following a single configuration. Five of the components have managed to integrate these unified security mechanisms, using the *Communities* component as the central core, given the good reception and continued use by partners.

The actions of continuous monitoring of the indicators foreseen in deliverable D3.8, and whose fulfillment was entrusted to WP6, are also reviewed. It has been possible to reach expected values except in just three indicators. On the other hand, for some indicators, the expected value has been greatly exceeded (e.g. percentage of open standards, or number of registered cities).

After a review of the previous released components, whose development was concluded within the period M1-M24, the deliverable goes on to describe in detail the design and implementation decisions of each of the S2CP components and emphasizes the validation activities of these components. Below, we highlight the main conclusions of each of them:

In relation to the *Data Mining component*, a complete and functional system for sentiment analysis of reviews of food-related places has been developed. Some novel technologies studied in the scope of Task 6.2 were employed, such as natural language processing (NLP) and web scraping. Despite its effectiveness, the identified limitations provide a clear roadmap for future improvements, including continuous adaptation to changes in the web structure, understanding of scrapping policies, and expanding the linguistic capabilities of the model.

The *S2CP data repository* was launched with the aim of offering a configurable place for publishing information related to labs and experiments, in the form of datasets. Built-in features such as spatial extension and secure cloud provision have allowed the component to be used to host the introduction of 64 datasets associated with Labs and Cities2030 organizations.

In relation to *Real-time data monitoring*, this service equipped with sensor terminals (using temperature, humidity and air quality sensors) has been implemented within the framework of the Arganda Lab, and the results have been showcased to the rest of the Labs for discussion.

The *Cities2030 community* component has served as a communication environment between project participants, and also as a dissemination platform, grouping in a very visual way the actions carried out by the partners, structured through the labs and the follower cities. The high number of registered members (129 at the time of finalizing D6.7) and the number of labs created (12 Pilots, 9 multipliers, and 3 flagships) demonstrate the interest aroused by this component and the benefit to the project.

The *Good Practices* component has been improved compared to the version presented in D6.3, including new data sources (up to 84 good practices in total), improvements in security and the implementation of a usability test, with surveys of users who have valued the creation of this tool.

The development and implementation of the *Multi-Actor Approach Tool* have demonstrated the tool's capability to enhance collaboration and efficiency across multiple actors by employing the multi-actor approach methodology. The MAATool has successfully aggregated diverse information streams and provided a robust framework for monitoring and tracking KPIs. The demonstration of the Tool in workshops (Marseille, Cuenca) has validated its practical utility and impact.

The S2CP component *Blockchain-enabled marketplace for SFSC* has been developed and integrated within the regional short food supply chain of Murska Sobota Lab. From the start, farmers were actively involved in the process, allowing the solution to be tailored to their needs. By mid-2023, most farmers in the region were already included, reflecting strong community buy-in, and the 2024 season evidenced the impact of the solution, with an increase in tracked products, greater farmer participation, and more engaged consumers. However, difficulties also arose, such as maintaining consistent farmer participation and the intensive resources required for negotiations with regional life labs. The success of the project, despite the challenges, demonstrates its potential to be adopted in other regions and strengthen the local economy.

The *Geospatial service* component has a supporting component nature, since it is responsible for enabling the geospatial component of the data repository and the dashboard. The work methodology involved the capture of points of interest (point, linear and polygonal) in the study regions, integrating all this information (in 37 municipalities) into a geospatial database.

The *Blockchain food supply chain digital twin* makes use of the recognized UNISOT solution for the execution of experiments. Three Cities2030 labs have participated in the validation of this tool, providing use cases and knowledge of the operation of the supply chain of local products. In addition, other companies associated with Cities2030 have participated in the validations with technological support and use case modeling and implementation.

The *S2CP dashboard* is intended to aid decision-making by data analysis and visualization. The main work in the last period has been prioritizing User Experience and decision-making functionality. The workshops carried out with Labs and allowed the consolidation of different stakeholder groups (farmers, policymakers, consumers). Understanding their needs, data literacy levels, and preferred interaction styles helped tailor the dashboard functionalities and interface to their specific use cases.

In summary, the 13 components developed and integrated in the S2CP platform make it a space for interaction between stakeholders, and acts as a support tool for decisions and experiments in the field of CRFS. The modular nature of this implementation facilitates its evolution after Cities2030, incorporating new tools to support particular experiments, or improving existing components with more data and new functionalities.

Annex I: SSO integration manual

The aim of this document is to serve as a technical handbook to the successful implementation of the Single Sign-On functionality. The Single Sign-On functionality is provided by the Cities2030 Community platform[29]. This platform is based on the Invision Community Software, which provides a REST API authenticated by OAuth access tokens[30].

SSO, or Single Sign On, is a technique where-by one (or more) applications can automatically recognize a user as logged in when that user has logged in elsewhere. You can implement single sign on with Cities2030 Community platform by letting a remote application recognize a user who has already logged in to the Community platform as being logged in within the remote application.

OAuth clients can be one of the following:

1) Custom Public OAuth Client

A browser-based app written in JavaScript or a mobile/native app which will be installed on a device an end-user does have access to. No client secret will be issued

In order to setup a public oauth client the client must provide the following information:

Redirection URIs: This will be the authorized URLs from the Client's domain that will be used for redirection once the user has been authenticated.

The end-user will be shown a login screen and redirected back to a specified Redirection URI with an Access Token in the fragment.

2) ***Custom Confidential OAuth Client (Preferred option)***

A server-side app such as a website where the code will be written in a server-side language and stored on a server that no end-user has access to. A client secret will be issued.

These two grant types are available:

- Authorization Code: The end-user will be shown a login screen and redirected back to a specified Redirection URI with an Authorization Code in the query string which you will then exchange for an Access Token.
- Implicit: The end-user will be shown a login screen and redirected back to a specified Redirection URI with an Access Token in the fragment.

In order to setup a public OAuth client the client must provide the following information:

Redirection URIs: This will be the authorized URLs from the Client's domain that will be used for redirection once the user has been authenticated.

The end-user will be shown a login screen and redirected back to a specified Redirection URI with an Access Token in the fragment.

In the following sections we detail each one of these OAuth client types.

1. Custom Public OAuth Client

This client is intended for static web pages without server support. Due to the lack of client-secret token, their use if less secure, and the only protection relies in the Redirect URI that must be provided, for example:

[29] S2CP official website: https://cities2030project.eu/single-click-crfs-platform/

[30] REST API Documentation: https://invisioncommunity.com/developers/rest-api?endpoint=core/me/GETindex

https://cities2030.primelayer.pt/labs

To implement a simple javascript-based *oauth* client this tutorial can be followed[31]:

Important: The oauth authentication in Community is based on **scopes**. The available scope is: **'profile'.** You need to explicitly request the *profile* scope for the authentication. In order to also receive the email address of the user, you need to add the 'email' scope.

```
var params = {'client_id': YOUR_CLIENT_ID,
'redirect_uri': YOUR_REDIRECT_URI,
'scope': 'profile email', //we have defined these scopes in Cities2030 community
'include_granted_scopes': 'true',
'response_type': 'token'};
```

Also, a working example of the authentication is provided in the Geospatial information component, and is available in[32], section: Geospatial CRFS web services.

The login process is as follows. The client (1) request authentication to the authentication server. (2) A redirection to the login website (Communities platform) occurs, to validate the credentials. (3) A redirection to the 'redirect_uri' is provided with the *accessToken*.

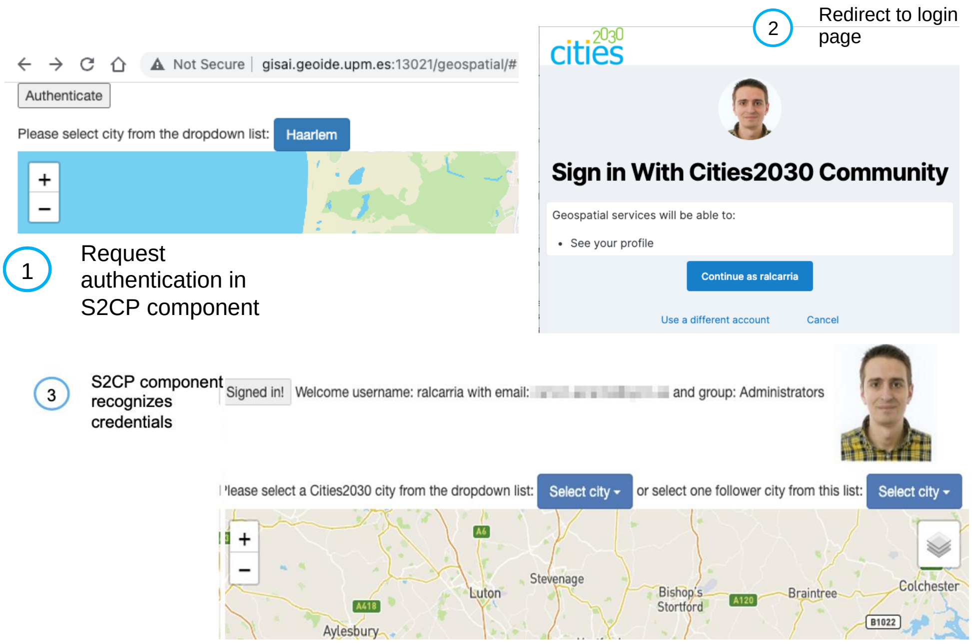


Figure 99. Example of SSO process for Custom Public OAuth Client

Once the *accessToken* is recovered, it is possible to use the Rest API to get all the information about the authenticated user.

The following URL:

https://cities2030-community.gisai.eu/api/core/me/?accessToken=<accessToken>

[31] OAuth 2.0 for Client-side Web Applications: https://developers.google.com/identity/protocols/oauth2/javascript-implicit-flow#oauth-2.0-endpoints_4

[32] https://cities2030project.eu/single-click-crfs-platform/

Provides all the information about the user's profile. Once the user profile is recovered, we can process the information to personalize the experience of the authentication user in the Web.

2. Custom Confidential OAuth Client (Preferred option)

This client is intended for web pages with back-end, or server support.

Then following tokens and codes are generated by the oauth server:

- authorizationURL: '<auth server>/oauth/authorize/',
- tokenURL: '<auth server>/oauth/token/',
- clientID: Will be provided by upm by email,
- clientSecret: Will be provided by upm by email
- callbackURL: example: " https://good-practices.gisai.eu/ssocallback"

Callbackurl, or redirect_url is the redirect URI that must be provided, where authentication token will be received, for example: https://cities2030.primelayer.pt/labs

To implement this oauth client this tutorial can be followed[33]

Important: The oauth authentication in Community is based on **scopes**. The available scope is: **'profile'.** <u>You need to explicitly request the *profile* scope for the authentication</u>. In order to also receive the email address of the user, you need to add the **'email'** scope.

An extract of Nodejs (Express + passport) is provided as an example of how oauth authentication is provided in the good practices oauth client:

```
router.get('/ssocallback',
  passport.authenticate('oauth2', {
    scope: 'profile email',
    failureRedirect: '/login' }),
  function(req, res) {
    console.log("Successful authentication, redirect home.");
    res.redirect('/');
  });
```

Also, a working example of the authentication is provided in the "Good practices" component, available thought the S2CP official website[34]

In the login section, we can press "Login with Cities2030 S2CP" (1). After that a redirection to the community platform occurs (2). Once the accessToken is recovered, it is possible to use the Rest API to get all the information about the authenticated user, through the following url[35]. Once the user profile is recovered, in the redirect_url we can personalize (3) the experience of the authentication user in the Web.

[33] Using OAuth 2.0 for Web Server Applications: https://developers.google.com/identity/protocols/oauth2/web-server

[34] S2CP official website: https://cities2030project.eu/single-click-crfs-platform/

[35] https://cities2030-community.gisai.eu/api/core/me/?accessToken=<accessToken>

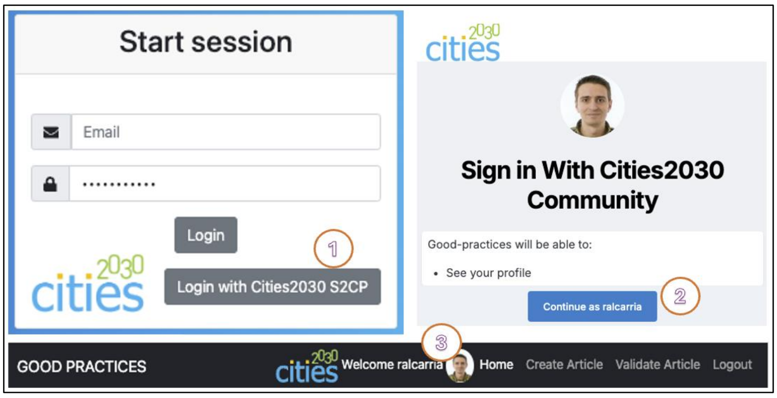


Figure 100. Example of SSO process for Custom Confidential OAuth Client

For example, if the user is admin in Cities2030 he will have admin privileges also in Goodpractices platform. If the user is a normal member in Communities platform, he will have just normal credentials in good practices web. But all this depends on the use case.

Annex II: Geospatial services: User manual for API integration

This section presents the user manual containing instructions for incorporating the information provided by the geospatial services into other interested components. Although this is the main objective, the first part of the manual indicates the procedure used to capture the geospatial information from the Open Street Maps services. The objective of incorporating this information in the user manual is to allow a reproduction of this capture stage, and a possible improvement or refinement by partners.

1. Data download

A Python script has been used to download POIs from OSM. It has been necessary to previously install the following libraries; overpass, geojson, requests and osmtogeojson from osmtogeojson. When selecting the required data, a series of labels are used, such as amenity and shop.

In the process of capturing information, a geojson file is generated for each municipality. In the case of follower cities, all these files are subsequently integrated into the database. To ensure that the geographic location of the points is preserved in the integration process, we include a new property "follower-city" in each of the geojson files with the name of the municipality, as shown in the code snippet in the following figure:

```
nodes = api.get(query, verbosity='geom')
for d in nodes.features:
    d["properties"]["follower-city"] = key
with open("./"+key+"_nodes.json",mode="w") as f:
    geojson.dump(nodes,f)
    print("{} features as nodes: {}".format(key, len(nodes.features)))
```

```
rethymnon features as nodes: 926
thessaloniki features as nodes: 5418
```

Figure 101. Data download code snippet for follower cities

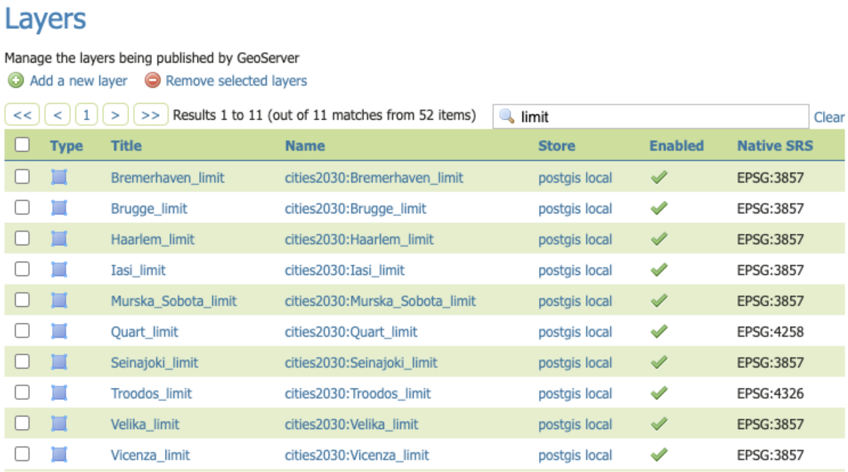
2. Integration into database

The QGIS software has been used to load data into a PostGIS database, from the geojson files generated in the previous step. The presence of duplicate geometries has been detected, which will interfere with the correct display of markers on a map, so they are removed. The following SQL query is used for this:

```
DELETE FROM schema_name.table_name a
  USING schema_name.table_name b
WHERE a.gid > b.gid AND st_equals(a.geom, b.geom);
```

3. Provision of Geoserver API

Once the information is stored in the database and duplicate geometries have been removed, the integration with the Geoserver server is carried out, which will be in charge of providing the information through a standard API. A set of layers have been created in Geoserver associated with the cities2030 workspace. The set of layers can be seen below:



Layers

Manage the layers being published by GeoServer

Add a new layer   Remove selected layers

<< < 1 > >> Results 1 to 11 (out of 11 matches from 52 items)   limit   Clear

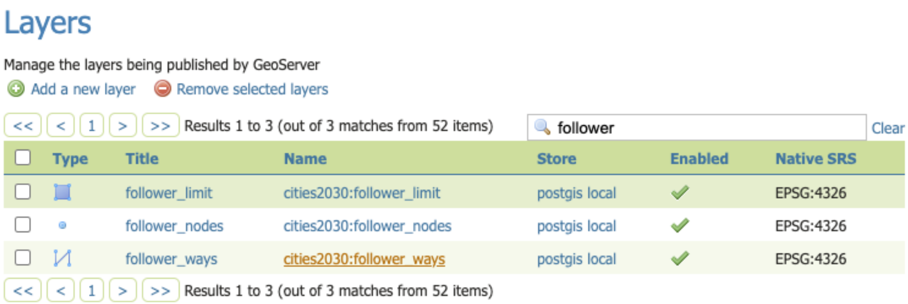
Type	Title	Name	Store	Enabled	Native SRS
	Bremerhaven_limit	cities2030:Bremerhaven_limit	postgis local	✓	EPSG:3857
	Brugge_limit	cities2030:Brugge_limit	postgis local	✓	EPSG:3857
	Haarlem_limit	cities2030:Haarlem_limit	postgis local	✓	EPSG:3857
	Iasi_limit	cities2030:Iasi_limit	postgis local	✓	EPSG:3857
	Murska_Sobota_limit	cities2030:Murska_Sobota_limit	postgis local	✓	EPSG:3857
	Quart_limit	cities2030:Quart_limit	postgis local	✓	EPSG:4258
	Seinajoki_limit	cities2030:Seinajoki_limit	postgis local	✓	EPSG:3857
	Troodos_limit	cities2030:Troodos_limit	postgis local	✓	EPSG:4326
	Velika_limit	cities2030:Velika_limit	postgis local	✓	EPSG:3857
	Vicenza_limit	cities2030:Vicenza_limit	postgis local	✓	EPSG:3857

Figure 102 Geoserver published layers for Lab cities

For each Lab is provided:

- Cities2030:<Labcity>_nodes (OSM nodes, type point)
- Cities2030:<Labcity>_ways (OSM ways, type linestring)
- Cities2030:<Labcity>_limit (administrative limit)

Except for follower cities, whose layers are named this way:



Layers

Manage the layers being published by GeoServer

Add a new layer   Remove selected layers

<< < 1 > >> Results 1 to 3 (out of 3 matches from 52 items)   follower   Clear

Type	Title	Name	Store	Enabled	Native SRS
	follower_limit	cities2030:follower_limit	postgis local	✓	EPSG:4326
	follower_nodes	cities2030:follower_nodes	postgis local	✓	EPSG:4326
	follower_ways	cities2030:follower_ways	postgis local	✓	EPSG:4326

<< < 1 > >> Results 1 to 3 (out of 3 matches from 52 items)

Figure 103 Geoserver published layers for follower cities

Links to get the geojson data for each layer are provided below. Example with Cities2030:Bremerhaven_nodes:

<Geospatial_base_URL>/geoserver/cities2030/ows?service=WFS&version=1.0.0&request=GetFeature&typeName=cities2030%3ABremerhaven_nodes&outputFormat=application%2Fjson

As can be seen, the typeName parameter of the WFS service is the one used to specify the information to query:

- typeName=cities2030:Bremerhaven_nodes
- typeName=cities2030:Troodos_limit
- etc.

It is possible to add "maxFeatures" property to limit the results:

<Geospatial_base_URL>/geoserver/cities2030/ows?service=WFS&version=1.0.0&request=GetFeature&typeName=cities2030%3ABremerhaven_nodes&maxFeatures=50&outputFormat=application%2Fjson

NOTE about SSL: The geoserver software is secured with HTTPS. Thus, SSL is required for consumer-side applications in order to avoid certificate-based communication problems.

4. Test web page and associated source code

For testing the API, an example website is provided, which is served by an Apache server. The Leaflet, jQuery and Bootstrap libraries are used. An example website is available upon request to UPM P20.

All the coding is on the client side, so the source code allows you to see how the $.ajax calls are made to obtain the geojson files, and how to use Leaflet to represent all the information, using custom icons depending on the type of establishment.

```
/* Include points */
var PointsOfInterest = null;
$.ajax({
    url: URL,
    dataType: 'jsonp',
    jsonpCallback: 'getJson1',
    success: function(response) {
        PointsOfInterest = L.geoJson(response, {
            onEachFeature: function(feature, layer) {
                popupOptions = { maxWidth: 200 };
                var popupText;

                for(var prop in feature.properties){
                   if(feature.properties[prop]){
                      popupText += prop + ": "+feature.properties[prop]+"<br>";
                   }
                }
                layer.bindPopup(popupText, popupOptions);
                //layer.bindPopup("amenity: " + feature.properties.amenity + " shop:
                switch (feature.properties.amenity || feature.properties.shop) {
```

Figure 104: Ajax call for API consumption in Example HTML

In relation to the web interface, there are a couple of city selectors at the top, one for Cities2030 cities and one for follower cities. When a city is selected, the map is centered on that area, and the layer selector in the upper right corner is activated, as in the following example with Preiļi municipality.

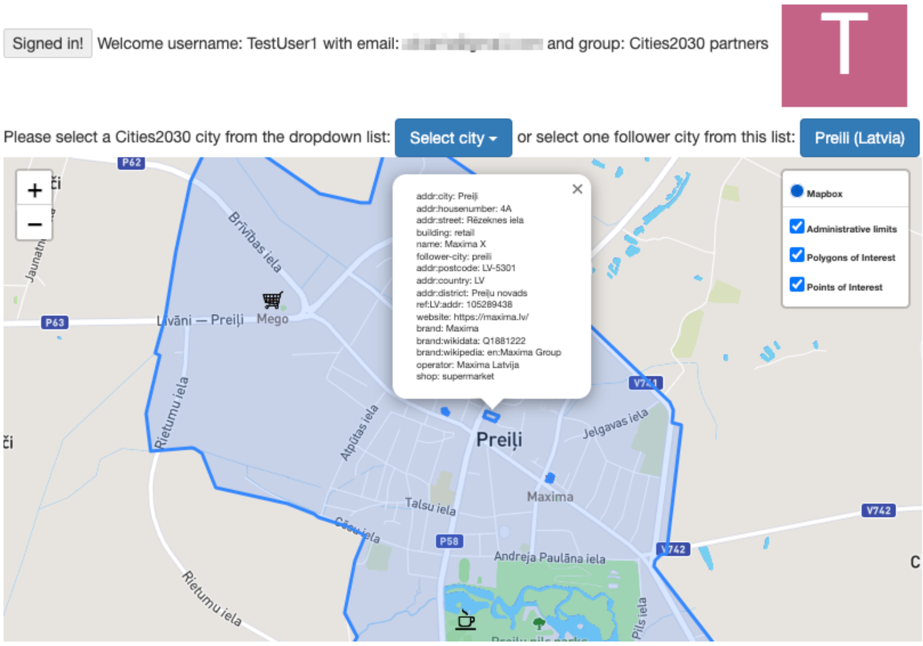


Figure 105: Ajax call for API consumption in Example HTML

The three layers that exist for each city appear, we can activate and deactivate them to our liking.

If a new city is selected from the dropdown above, the current layers will be cleared and the new layers for the selected city will appear.

Finally, a graphic categorization system has been established, according to the type of OSM establishment.

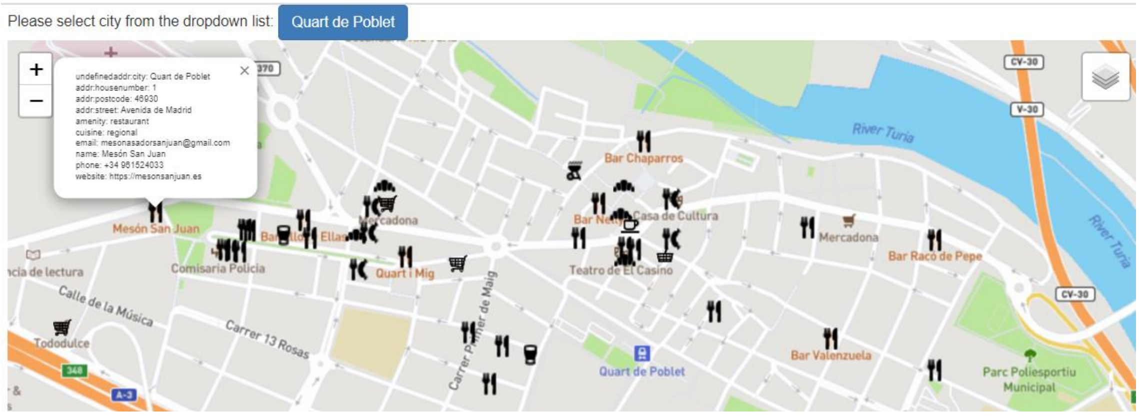


Figure 106: Quart de Poblet example categorized

As it is observed in the image, all the information available for each POI is also displayed through a popup.