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Processing of use cases for the development of an open platform to support the smart urban development

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Abstract. The topic of smart cities is assuming an increasing relevance, both locally and nationally. The key challenge for smart cities and communities is to significantly increase the overall quality of life in urban areas, for the benefit of their inhabitants and economic activities. This process occurs both through the improvement of traditional utility-grids and services, and through the implementation of digital sensor- and communication technologies in the urban ecosystem. In this scenario, the adoption of enabling tools to support the smart urban development, appears crucial to manage processes and data information flows, as well as to permit better communication and collaboration among the involved stakeholders.

This paper describes the development methodology of an open digital platform for smart cities. This platform will be an enabling tool for the smart urban development of a city i.e. will be able to support and encourage the growth of new services for - and with - citizens, companies, tourists, and public administrations. The concept derives from the ongoing research project OPENIoT4SmartCities, funded by the Operational Programme European Regional Development Fund ERDF 2014-2020 (CUP: B11B17000720008) Südtirol/Alto Adige. The main objective is to realise a product-prototype software, for the management of smart services in cities, using IoT.

The platform has been designed based on the specific service needs of Merano, a city in South Tyrol, Italy. The activities regard the identification of concrete use cases in the field of public illumination and water management. In particular, this paper will present the results of previous analysis, consultation meetings and workshops that have been conducted by the research team together with the public administration and local service providers of the city of Merano.

1. Introduction

The smart city concept finds itself in the center of an intense debate already for several years and is giving life to many initiatives. In fact, cities represent the greatest scenarios of industrial and economic activity, moreover, the growth of urban centers is constantly increasing, bringing out the urgent need of complex management tools. The smart use of information and communication technologies, enabling the connection of buildings, devices and people with each other, is the essential starting point for systems of urban innovation within all areas of urban life [1]. Considering this, the question about the most effective way to lead the urban transformation towards a smart city has not been answered yet. To give an answer to this problem, the fundamental idea of the OPENIoT project is to develop an open platform for smart cities to support the smart urban development. This platform should be a flexible and scalable



operating tool, able to offer and handle different smart services based on well-defined use cases as described in the methodology section. The adoption of the platform should boost the development of new services for and with citizens, businesses, tourists and public administrations.

The aim of this paper is to present the methodology adopted for the processing of use cases for the development of the IoT platform. Since the definition of a methodology cannot be realized without the analysis of the specific reality in which it will be applied, a real city has been considered. Therefore, this work gives a look at Merano, a city located in the mountainous region of South Tyrol, Italy, which presents unique challenges and opportunities. Section 2 presents case studies of framework for the definition of a clear roadmap to the smart city, especially in the field of public illumination and water management. In Section 3, the methodology used for the development of the use cases is described. Section 4 presents the first two steps of the methodology applied to public illumination and water management in Merano and the two final implementation steps are described in Section 5. Results are presented in section 6. Section 7 concludes the paper with the main recommendations and the future avenues of the work.

2. Related works/Case studies

Although the concept of a “smart city”, which generally foresees the vision of cities going through a technology-driven evolution, has been researched thoroughly in the past decade, its term remains vaguely defined causing confusion for all stakeholders. In particular, the buzzword “smart” is used not only on the urban scale, but also interchangeably for elements that are part of the city or connected to it (i.e. smart buildings, smart meters, etc.), thus creating possibilities of misinterpretation [2]. Moreover, technology may address multiple urban challenges and customers, in the spatial, social, and economic dimension, increasing the number of solutions that can be included in this field. Therefore, it is not always evident in which way solutions contribute to make the city “smarter” and concretely improve the citizens’ quality of life [2]. For these reasons, research has been done to develop bottom-up frameworks to guide the digital evolution in a city. These frameworks usually start from the actual needs derived from stakeholders’ requirements, which are based on the assessment of the city as-is. The latter is the starting point of several methodologies whose final aim is the creation of a smart city roadmap. One of the most notable examples is the “City Lab” model, part of Fraunhofer’s project Morgenstadt [3], which builds on the evaluation of the current state of the city on several sectors with different kinds of interdependencies and interrelations. The evaluation is elaborated with the help of relevant stakeholders, as the basis to prioritize the fields which are more urgent or relevant to intervene [4]. The assessment of the city as-is may vary in the level of detail. An interesting example is offered in [5], which not only defines city sectors, but also city layers, from the physical infrastructure to the digital interface oriented to the end users. Finally, other frameworks include the creation of future visions, made in collaboration with stakeholders, from the beginning, in order to consider not only the present, but also the future, in the early stages of the roadmap [6].

The responsible use of natural resources seems to be one of the most relevant challenges of smart cities. This is especially true for limited resources, such as water. Therefore, several smart city projects focus on water management, with the aim of evaluating consumption, demand, and of monitoring possible leakages. The diffusion of IoT-enabled technology, such as smart meters, made it possible to drastically change the water management market, enabling a real time collection of data, thus granting a finer granularity of information. Moreover, wireless technologies facilitate a unified open data architecture, overcoming the logic, diffused in today’s market, of point solutions to point problems, offered by different actors (such as management of water pressure, leakages, etc.) [6]. New installation of smart meters requires a long-term, holistic strategy, as real-time monitoring generates a huge amount of data. For these reasons, smart metering is often associated with the use of advanced data processing techniques, such as machine learning and data mining, to disaggregate data and provide them to customers [9]. Most importantly, data must be meaningfully delivered to end-users in a readable way; this is usually done through platforms, which may be dedicated to selected users (f. i. Autoflow© [9]) or linked to a city and open to the general public (f. i. Bristol is Open [10]). However, the latter

alternative can be only used in solutions concerning information that does not carry any sensitive data and is interesting for a broad public, such as the monitoring of the water quality rather than personal use [10].

For the same reasons as water management, public illumination is a similarly recurring theme in smart city projects. Urban lighting poles offer a very convenient infrastructure which is both homogeneously scattered across the city and connected to electricity. Therefore, they are ideal carriers of IoT sensors to both monitor their surrounding streets and environment. Given this, an interesting research trend concerns the reduction of energy consumption by reacting to the collected data. This has been enabled by the advancements in LED technology, which not only remarkably reduces consumes, but also permits faster switching and better intensity control [11]. Depending on the system architecture, communication protocol, and usage scenario, an intelligent lighting system based on motion sensors can help reduce power consumption up to 33,33 % [12]. Apart from energy savings, thanks to the characteristic listed above, public lighting has been, and can be, exploited in many ways to create a smart city environment. To this end, experiments involving citizens and stakeholders from the city administrations in a co-creation smart city project have been conducted, to promote a participated vision of possible technologies and services [13]. Collected ideas ranged from light-based information for drivers to neighbourhood bonding and communication.

3. Methodology

Given the issue of ambiguity of the concept of a smart city [2] presented in the previous section, which forces to consider various aspects of a city holistically, it is clear that the successful transformation of an urban area needs the operational support of a systematic, flexible and complex tool. For the development of this tool it is necessary to define a specific methodology.

After the evaluation of successful examples from the state of the art in methodologies for smart city development, both service- [4][6] and technology-driven [5][7], it has been chosen to follow a bottom-up approach. This approach follows a specific process:

- starting from consideration of the end customer;
- definition of the service characteristics,
- specification of the data workflow management;
- choice and configuration of the required technology and infrastructure.

The next sections describe the elaboration and implementation of the first two use cases for the city of Merano, which are public street lighting and water management. In this context, use case means the precise and unambiguous specification of an urban service such as public illumination or water management, through the identification of different smart sub-services. Each use case constitutes a service development scenario and his elementary utilization by users provides the explicit requirements for the development of the platform.

4. Processing of use cases

Two workshops were conducted based on the results obtained by Fraunhofer Italia from an analysis of the city's digitization needs in the project MeranoSmart [14]. These workshops were the first of a series, which will provide, at the end of the ongoing project, a broad overview of use cases for the entire city.

4.1. Workshops

The stakeholders that took part in both working groups were mainly representatives of the public administration or belonged to the service provider companies of the city of Merano. They were selected for their knowledge of the specific features of the territory in order to realistically identify priorities of interventions. Regardless of the subject, the workshops lasted three hours, and had a unique structure, as described below. About 7-8 people were involved to each round. A first introductory phase addressed the theme of the workshop, the mutual presentation of the participants and the general description of the methodology. The results already obtained in the project 'MeranoSmart', in relation to the subject matter, were deliberately omitted to avoid influencing the participants with content information.

4.1.1. Workshop Part A: definition of use cases. Participants were asked to brainstorm about new smart services connected to the subject matter, i.e. illumination for the first and water for the second workshop. The brainstorming was driven by filling canvases (Figure 1) that suggest the identification of different end customers. The main objective was to collect a high quantity of use cases on a theoretical and strategic level. For the workshop, it was fundamental to focus on the city of Merano, without taking into account the feasibility of the idea, that could also have been visionary.

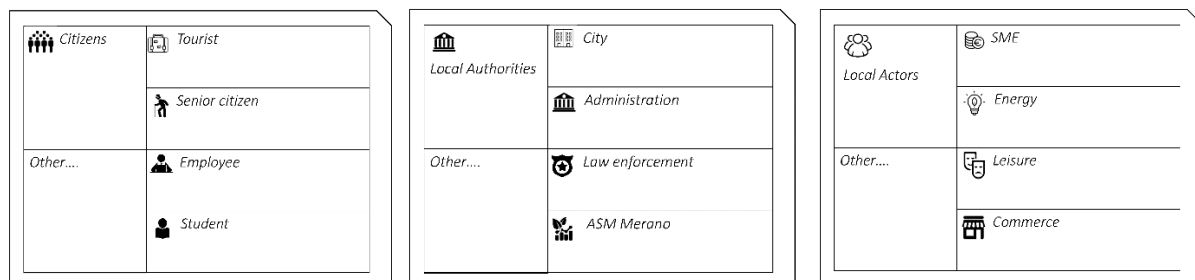


Figure 1. Workshop Part A. Canvas

4.1.2. Workshop Part B: use cases mapping. After a brief reorganization of the first results, the multiple contributions were grouped in a defined number of services. In order to classify them, participants were asked to express an evaluation and assign an indicative value of “impact” and “effort”, which have been rounded to a number from 0 (none) to 4 (extreme). Another canvas was used to direct the discussion to the consideration of different aspects such as the impact on citizens, on the local economy, on city authorities, as well as on the technical, financial and maintenance effort.

4.2. Outputs of the workshops

The final output consists in two cost/benefit analysis, which classifies the 13 use cases for the public street lighting (Figure 2) and 9 use cases for the water management (Figure 3), divided in four different categories.

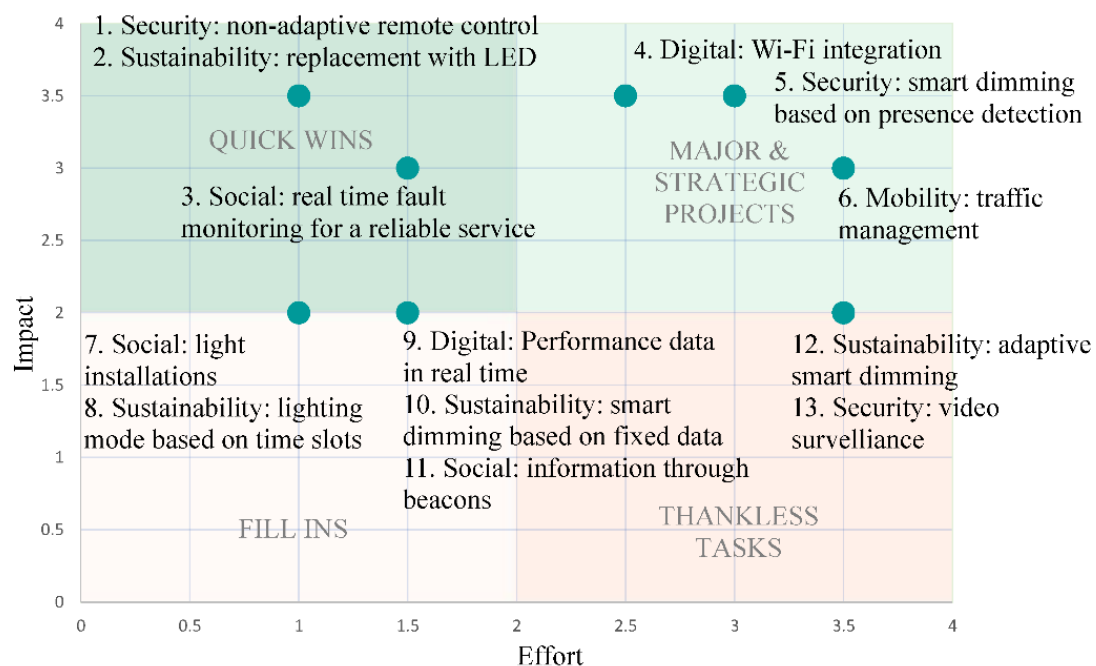


Figure 2. Workshop about public street lighting, 13 outputs.

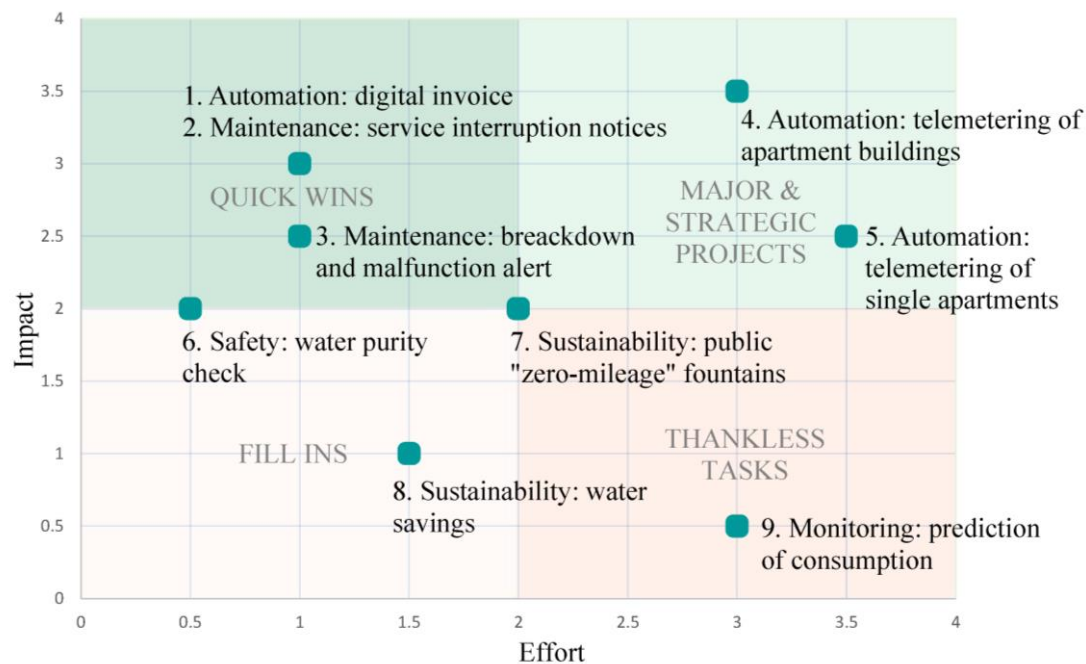


Figure 3. Workshop about water management, 9 outputs

The categories “quick wins”, “major and strategic projects”, “fill ins”, and “thankless tasks” identify the feasibility of the various solutions. The outputs that correspond to “quick wins” are the most suitable for the platform implementation and will be considered first.

5. Implementation

After evaluating the outcome of the workshops, the following actions were implemented.

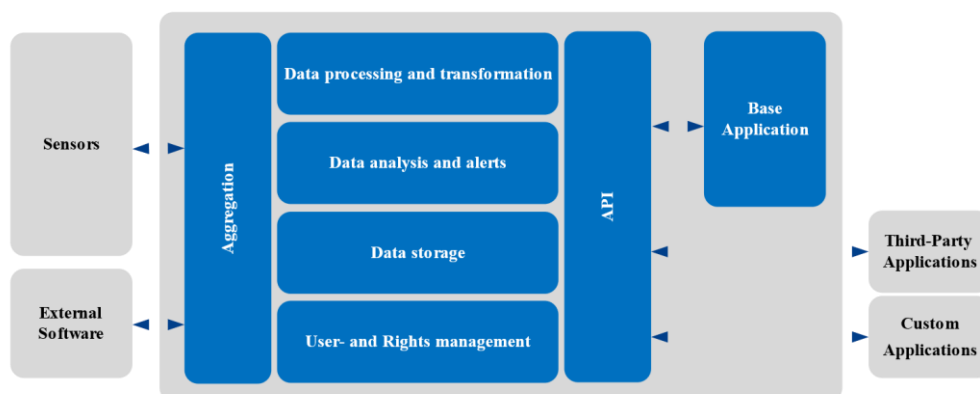


Figure 4. The OpenIoT4SmartCities conceptual platform design.

5.1. Data collection and processing

As core of the project, an open data processing platform has been designed. This platform integrates different sensor systems, wireless protocols and networks and external data providers. The aggregated data can then be stored, processed, analysed, and the results again provided using an open API to other applications, including third-party ones. (cp. Figure 4). The platform was implemented using C# and python for the backend, running on the Azure cloud, which offers a rich environment for IoT applications. The LoRaWAN network is integrated by the use of the Loriot Network Server, the leading enterprise capable tool integrated with the Azure IoT Hub.

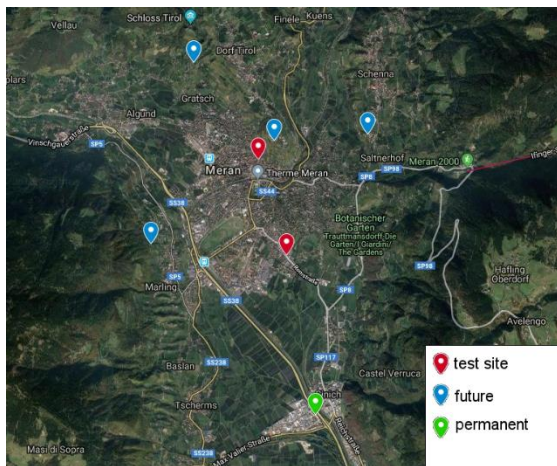


Figure 5. LoRaWAN gateway sites. Green denotes a permanent gateway, red current test sites, and blue future permanent gateways.

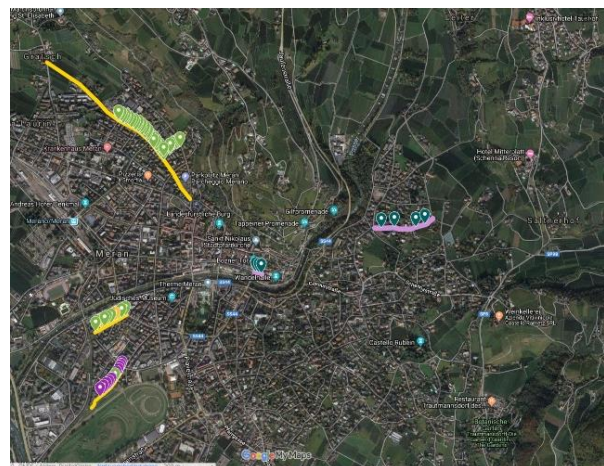


Figure 6. Smart light installation sites. This figure shows where the LED light points were upgraded with a connected controller.

5.2. Communication Infrastructure

Based on the requirements elaborated in the workshops and the experience provided by the stakeholders, it was chosen to implement a LoRaWAN-based communication system. This allows each sensor to be wireless and low-power. For testing purposes, three gateways connecting the LoRa-network to an IP based network were installed on premises belonging to the municipality of Merano (cp. Figure 5). These gateways cover the current test sites. Nevertheless, due to the mountainous landscape in the city, they will not cover 100% of the city's territory. For a more permanent installation, two of these temporary gateways will be replaced by four permanently installed ones, in- and outside of Merano, providing complete coverage.

5.3. Public street lighting

The public lighting provider in the city of Merano is currently replacing over 6000 light points with modern LED lighting systems. Having already replaced about 40% of the installed lights, the work is expected to be completed in 2023 [4]. The public lighting provider decided to install sensor-ready light fixtures, which include Zhaga Book 18 Luminaire Extension connectors [16], allowing external sensor / controller modules to access a 24V power supply and the luminaires Digital Addressable Lighting Interface (DALI).

For the test site, 100 luminaires in the city (cp. Figure 6) were fitted with a controller interfacing the lamps driver with the LoRaWAN network, allowing monitoring (defect detection, power monitoring, etc.) and control (dimming) of the attached light.

5.4. Water management

For the monitoring of water consumption, residential multi-jet water meters, fitted with static pulsers and a LoRaWAN-based wireless communication module, were installed at five selected test-sites. The installed communication module is external to the meter itself. This allows for a) installation of the communication module up to a 10m distance from the meter, thereby allowing flexible positioning of the antenna and b) independence of the installed meter, as the installed meter can be replaced by a different make/model without replacing the communication module. The downsides of the chosen approach are: a) increased complexity, due to one additional component and wiring effort and b) susceptibility of wires to be damaged by rodents.

6. Results

As shown in Figure 7, a dashboard application was implemented in Microsoft Power BI on top of the OpenIoT4SmartCities platform stack. This dashboard application allowed in real-time monitoring of all connected sensors during the testing phase. The graphical user interface runs in a state-of-the-art web browser and is thereby accessible independently from the used operating system or hardware platform, enabling user access from every kind of computer or smartphone.

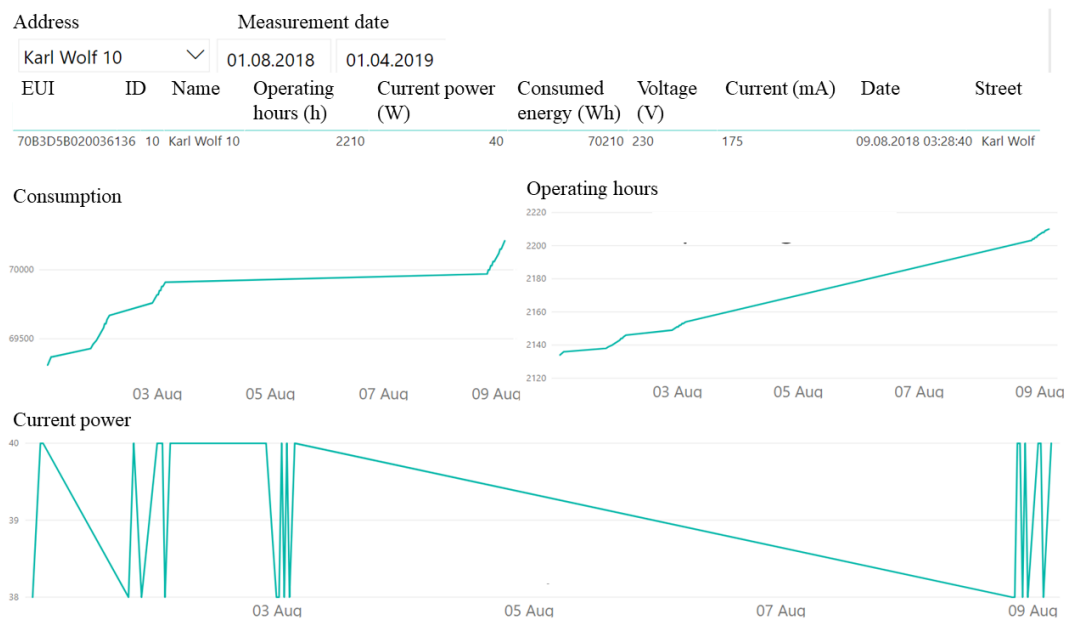


Figure 7. Detail of a specific light point, showing accumulated energy usage, power profile, and hours of operation.

The current version of the application allows the monitoring of operating hours, current power consumption, total energy use, voltage and dimming level of the installed lights, as well as current and total water use for the water meters.

At the moment, the implemented application is merely a showcase of the possibilities offered by the platform. As the implemented system is open by design, the collected data, analysis results and alerts are also available for future third party applications and services.

7. Conclusion and future work

In this research paper, a methodology for the implementation of use cases for a smart city was discussed. The methodology is scalable, meaning that it can be used for all urban areas (e.g. water, lighting, waste, etc.) and for the definition of a wide range of smart services, which allow the development of the OPENIoT platform. What turned out to be the most promising aspect is the bottom-up approach, which allows to collect possible solutions from citizens for the short, medium or long term. The limitation of this approach is its comparability between the different service areas, i.e. the interconnection of services that may have elements in common. Moreover, a future testing phase should include a greater number of elements in order to simulate realistic data analysis and management.

The discussed use cases will be implemented again with more alerts (i.e. for unusual consumption spikes or signalling of faults), and the current dashboard will be replaced by a fully custom-written application in the near future, allowing for even more flexibility and customizability. The city of Merano has the objective of becoming one of the best regional examples of smart city technology. Once a certain degree of robustness is achieved, the public administration of Merano has expressed interest in adopting a pilot version of the platform for validation.

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