Framework for Assessing the Smartness Maturity Level of Villages

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Abstract. In this work, we have developed the first version of a smartness assessment framework that allows the representatives from a village to make a self-evaluation of its current status based on smartness criteria identified by an international group of experts. The framework allows a detailed evaluation of six different aspects including Mobility, Governance, Economy, Environment, Living, People, with weightings of the criteria using the multi-criteria analysis Electre Tri. In addition, the results enable further data analysis and offers an input for different functionality like identification of best practices and collaboration and matchmaking among potential stakeholders. In addition, we show the effectiveness of the proposed framework by means of a case study on a test area around the European Alpine space.

Keywords: Rural Development, Smart Villages, User-Centered Data Analytics

1 Introduction

The digital revolution and the possibilities offered by the new technologies have radically transformed the way we live in the last decades. As a result, for the first time in many years there is a hope to overcoming very negative trends such as the rural depopulation. In fact, there is an increasing amount of young people that prefer to leave the comfort of large conurbations and exploit their knowledge in the villages by creating innovative development models. In this way, the new generations are increasingly turning places that seemed doomed to be abandoned into nodes of attraction of great dynamism and employment. This

could put an end to the high rates of unemployment, the aging of the population, talent drain, and the loss of public services.

Contrary to popular opinion, digital advances are not only reserved for large megalopolis and conurbations; there are also small villages that bet on disruptive technologies to improve the lives of their inhabitants, boost the local economy and promote themselves as a tourist destination [12]. One of the ways to implement these technologies is through the concept of Smart Villages that, although with specific nuances of each place, is widely spread in the five continents. In fact, areas which do not have many inhabitants have now the opportunity to embrace intelligent modernization and information technology based on Artificial Intelligence, Big Data, Blockchain, Internet-of-Things, Energy Informatics, Digital Health, Collaborative online tools, Open Source, Civic Tech, and so on, with the goal of turning the old village into a smart village [4].

In addition, the smart villages paradigm aims to transform traditionally rural sectors such as agriculture, livestock, fishing, mining, etc. by applying novel methods for intelligent data management and robotics. In this way, new concepts linked to sustainability and competitiveness gain a lot of importance and give rise to new forms of development such as agriculture 4.0, agribusiness, or other kinds of business models.

In this work, we present our framework for the automatic assessment of the smartness maturity level in villages. This framework mainly consists of a software system that assists to analyze the smart functionality that a given village implements at a given time. The framework aims at providing a smartness score, a.k.a. maturity level score, based on the users perceptions of how this smartness fulfills their expectations. At the same time, new opportunities for improvement or development of new concepts can be found by looking for gaps with the help of the smartness reports provided within the system. As a side effect, the tool can be used for the identification and sharing of best practices as well as for stakeholder collaboration and matchmaking. The implemented framework is offered to the general public as a part of the Digital Platform developed within the SmartVillages project [11].

The rest of this work is structured in the following way. Sec. 2 describes the State-of-the-Art in relation to smartness assessment frameworks. Sec. 3 describes the design, implementation, and exploitation of our framework. In Sec. 4, we show preliminary results obtained from the exploitation of the framework in the context of an Italian municipality belonging to the European Alpine space. Finally, we present the major conclusions and future lines of research.

2 State-of-the-art

New trends on technologies and smart infrastructure such as connectivity can transform the old notion of village whereby the unequal property distribution and lack of opportunities were assumed. In this context, the development of novel initiatives that address territorial development and innovation is of vital importance. For example, in recent years, much has been done towards the goal

of creating smart spaces for living [9]. However, there are still regions where proper infrastructure and services are lacking, not so much the basic Internet, but other necessary aspects such as broadband and 4G and 5G connectivity are still very deficient [8]; so it is clear that there are still blank areas that need further development.

Moreover, this a common problem in all the continents of the world, although perhaps it is aggravated in low-income countries where the lack of monetary resources for infrastructures does not facilitate the reduction of the gap between cities and villages. However, not everything is dependent on the available budget since the situation is not very different in places with larger public investments such as the European Union. In fact, according to figures provided by the European Commission, there are large differences in smart facilities between urban and rural areas across all the continent. Therefore, developing the concept of smart villages by providing new business models and supporting infrastructures to the rural world are some of the challenges that public and private organizations have on the table to make this notion a reality.

It is necessary to remark that there are many worldwide initiatives in this context. For example, the IEEE Smart Village program has been calling for new technologies based on smart village thinking to bridge the urban-rural breach [2]. With a view to reducing the digital divide between rural and urban areas and promoting the rural economy, the aforementioned European Commission has also given priority to the development of Smart Villages within its community agricultural policies, as well as in other plans related to research programs including: the European Rural Parliament, the SIMRA project and the ERUDITE project or some specific calls from the Horizon 2020 program. Moreover, Policy on Digital India has envisaged national level focus in rendering services to citizens in India. This focus plans for convergence of all possible services through a digital backbone [5]. Also, the South African government is constantly developing new ICT projects which are initiated by individuals, government and private organizations within the context of the ongoing SEIDET Digital Village [7].

In the literature, there are some works on smart cities, for example [1] and [10]. However, there is a lack of field-oriented systematic tools to guide and monitor the evolutionary process of the villages to higher smartness maturity levels. In fact, at present, this process is so unstructured that most local authorities do not have a starting point and guidelines that support them in making adequate progress in terms of smartness maturity. our work aims to overcome that limitation.

3 Framework for Smartness Maturity Level

A maturity model is defined as a set of practices which is considered as a development path or an improvement tool for public or private organizations. The maturity level indicates in which exact part of that path we are at a given moment. However, it is important to note that the question of how smart a village is, does not only have to do with the degree of advanced facilities that have been

deployed but also on how people perceive it. In order to develop this notion, we have created a framework to audit the current village status and guide local authorities to higher levels of smartness.

3.1 Introduction to the framework

To shed light on this context, we have developed a framework for the assessment of the smartness maturity level. What we present here is an intermediate version, while in the future, new functionality will be added. This framework works around an advanced questionnaire that allows obtaining information directly from the people involved in the village, together with other complementary information that can be compiled from open sources available on the web. The general architecture of the smartness assessment framework is presented in Figure 1.

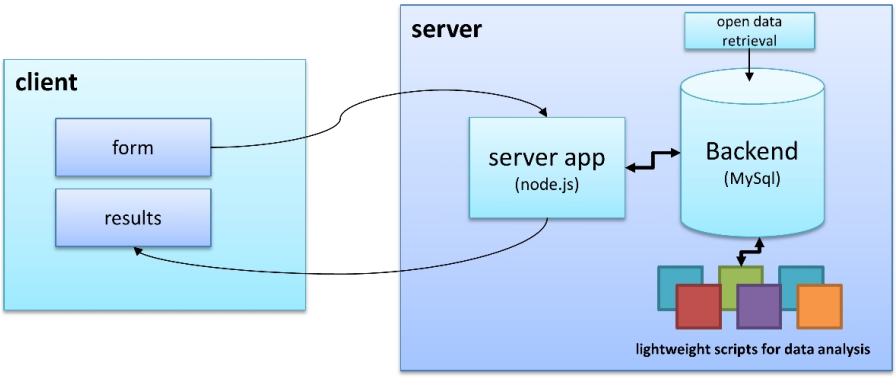

Fig. 1: General architecture of the smartness assessment framework

The framework is integrated into the Digital Platform developed within the SmartVillages project from where it can be accessed through a regular web browser. An online questionnaire allows users to fill in all the information concerning the smartness indicators. The questionnaire consists of 24 questions with multiple choice answers grouped into six sets representing six smartness domains: Smart People, Smart Governance, Smart Living, Smart Environment, Smart Economy, and Smart Mobility. In addition, text fields are provided to allow users providing comments inputted in natural language that it deems appropriate. When the online questionnaire is complete, the data, e.g. the village name, the answers to the questions, and the comments provided are sent to the server and analyzed according to the developed methodology. The results are then calculated and plotted on the screen so that the user can view and analyze them. All the data generated during the process are stored in the server in order

to proceed with further analysis. In addition, every entry is appropriately timestamped in order to enable functionality that allow monitoring the evolution of the test areas along the time.

Fig. 2: Screenshot from the online questionnaire which is used to collect data from stakeholders

Figure 2 shows us the questionnaire which is used to collect data from stakeholders. Please note that, as requested by the stakeholders involved in the design phase, each question admits a double answer. On the one hand, a short and concise answer that our system transforms into a numerical value for later automatic analysis, and an answer based on natural language, which will be analyzed by expert personnel. It is also worth mentioning that no personal data is stored and that all information complies with current EU regulations for the processing of data provided by users.

3.2 Smartness dimensions

The smartness dimensions identified by an international group of experts are those related to Mobility, Governance, Economy, Environment, Living, and People. Below, we can see them in more detail.

Smart Mobility. Smart People is related to the quantity and quality of sustainable transport and mobility systems in the village. Examples of indicators include the number of non-conventional-fuel cars being owned or used, the presence of limited-traffic zones, the level and sustainability of public transport, etc.

Smart Governance. Smart Governance is related to the level of smartness of the governance systems, the penetration of green public procurement, e-governance, facilities to networking. Some examples of indicators include the

number of electric cars used, the convenience of recycling policies, energy policies, etc.

Smart Economy. Smart Economy is measured in terms of the presence of creative and innovative enterprises and business models in the area, level of employment and unemployment, level of economic attractiveness, penetration of ICT in the local economic system. Examples of indicators include the number and density of certified enterprises, number of young and women-led enterprises, the rate of business creation, the number of patents, etc.

Smart Environment. Smart Environment involves measuring the quality of the environment in terms of air, water, and soil. Examples of indicators include the air quality, level of recycling, percentage of natural spaces in the overall area, etc.

Smart Living. Smart People is related to the quantity and quality of services to the population in the area, and the degree of satisfaction in them. Examples of indicators include the level of criminality, the level of general services such as banks, post offices, and so on, the quality health care and social care services, as well as the quality and quantity of services to the elderly, etc.

Smart People. Smart People measures the participation of local citizens to the job market, the decision-making and the involvement in associations, and the education level of people. Examples of indicators include the number of associations, policies for promoting equal opportunities, level of schooling, overall employment, degree of political engagement, etc.

3.3 Score calculation

The calculation of scores represents the first step in the multi-criteria analysis Electre Tri (Elimination and Choice Expressing Reality) methodology that has been implemented to assess and rate the level of smartness. 24 core indicators of smartness, 4 for each of the 6 smart dimensions (Mobility, Governance, Economy, Environment, Living, and People) have been selected and presented in the form of questions in a dedicated survey. For each of the questions, 4 answers are possible, from the most negative one (scored 1) to the most positive one (scored 4). A further round of scoring allows to determine the degree of certainty with which each of the answers are given, on a scale from 1 (not very certain) to 3 (very certain): this second round of scoring allows for integrating the subjective assessment of smartness for a given compiler which is fundamental in the Electre Tri self-assessment process.

A further step to be integrated enables the creation of a system of weights capturing the perceived importance of each smart dimensions with respect to

all others. This is done by creating a comparison matrix between the 6 dimensions (it can also be done at indicator level, although this would be more time and machine-consuming) in which the compiler indicates how important one dimension is with respect to all others. This creates a 6x6 matrix, the eigenvalues of which result in the assignment of multiplying factors (weights) for the previously-calculated scores.

The weighting factors are useful for the compilers to ascertain which dimensions are more critical for their own assessment and for their present and future smart transformation. The final step of the Electre Tri assessment and rating methodology entails the creation of profiles and categories: it was decided that a categorization along four categories (maturity levels) and three profiles were reasonable, in order to capture the variability between low scoring areas and very high-scoring areas; the profiles have been created with the Electre-Tri outclassing rationale, with the concept of -cutting levels, outclassing, winning combinations and vetoes. The four maturity levels are described in the following.

3.4 Maturity levels

From the score calculation, we can establish four maturity levels:

Level A: high level of smartness or new goals level. It is the level whereby the majority of the dimensions registers the highest level of smartness considered reachable in this model. In other words, most indicators score between 10 and 12. It is important to highlight that these are the targets used in this survey and so, placing in this category is only a milestone in a possibly more complex process

Level B: good level of smartness or satisfactory level. It is the level that indicates that there are numerous activities and initiatives that focus on innovation, the services are adequate and innovative approaches are used in a lot of sectors. However, not the majority of facilities score the highest level of smartness in their services.

Level C: medium level of smartness or work in progress level. This level means that there are some smart services planned and people are aware of the importance of smart transformation.

Level D: low level of smartness or traditional concept level. This level indicates that there are very few initiatives that focus on innovation and very little is planned to improve this situation.

4 Data Analysis

One of the key modules of our framework is devoted to data analysis. The goal is to discover useful hidden information, that can derive conclusions for supporting the decision-making of the stakeholders who make use of our framework, e.g. for identification of similarities among villages, clustering of villages, allowing analysis even when data was not entered completely or by providing forecasts of smartness maturity level development.

4.1 Similarity between villages

Since we have several sources of information, we can have a very rich set of features that unequivocally identify a village. The appropriate processing of these features allows us to establish similarities between villages according to different criteria, based on the application of various statistical measures of similarity, distance, and correlation.

4.2 Clustering of villages

The purpose of village clustering is to group set of villages in such a way that villages in the same cluster are more similar (according to some predefined criteria) to each other than to those in other clusters. This functionality is really useful in order to provide informed facts specifically targeted on clusters that meet some requirements.

4.3 Working with missing data

Many questions are difficult to answer, either because they are not easy to understand, or because the user filling the questionnaire does not have that information, or maybe they are not applicable in that context. For cases such as these, our data analysis module is able to dive into the historical record, combine these data with data retrieved by online sources such as DBpedia[1] or Wikidata[2], e.g. number of inhabitants, geographical coordinates, etc., and identify similar situations in order to predict the most likely response to a given question.

4.4 Development forecast

In addition, the prediction functionality is also able to guess how the smartness maturity level of a given village will evolve along the time. To do that, we will use the historical record of village evolution that will help in the task of automatic learning.

[1] http://dbpedia.org
[2] http://www.wikidata.org

4.5 Visualization

The results of statistical processes are often difficult to understand. For this reason, our framework implements a module for the adequate visualization of most outputs and reports. The idea is to offer the capability to the visual inspection of results by means of charts, plots, maps or any other means that may facilitate its understanding and/or dissemination.

4.6 Querying

In addition, the platform offers the capability to formulate complex queries. Traditional systems are based on the manual compilation of information coming from different sources. In our case, the semi-automatic integration of open data sources such as DBpedia or Wikidata along with the information entered by users through self-evaluation allows us to answer very complex questions that could not be handled otherwise.

4.7 Best practices

Best practices [6] are a set of actions that have performed very well in a given village and that are expected to perform similarly in similar villages. Users are encouraged to document their best practices through using a predefined template to gather the information, that are going to be available for other users that score high on the similarity index. Our framework is able also to support the identification and sharing of best practices with other platforms with similar interest such as CESBA[3].

4.8 Matchmaking

The matchmaking process aims to identify stakeholders who, due to a similar degree of smartness, might be willing to collaborate or exchange experiences [3]. In addition, this process is not limited only to villages, but may also be able to bring together companies, or even regional organizations.

The first version of the matchmaking functionality is using different algorithms to match queries with companies descriptions. The idea is to use open datasets of European Companies such as the ones provided by the European Business Register[4], etc.

4.9 Multi-language support

Since the framework is developed in a multinational context around the European Alpine region (Austria, France, Germany, Italy, Slovenia, Switzerland), it is necessary to have a multilingual version of the framework. Therefore, we have worked to offer the framework in several languages and will continue to add languages as more stakeholders join the community.

[3] http://wiki.cesba.eu/wiki/Greta_Best_practices
[4] https://www.ebr.org/

5 Results

As an example of a completed self-assessment procedure, we include an use case on the Test Area of Tolmezzo (in the Friuli-Venezia Giulia region, North-Eastern Italy). This municipality has self-assessed itself as Level B good level of smartness or satisfactory level. The overall rating of Tolmezzo is included in Figure 3.

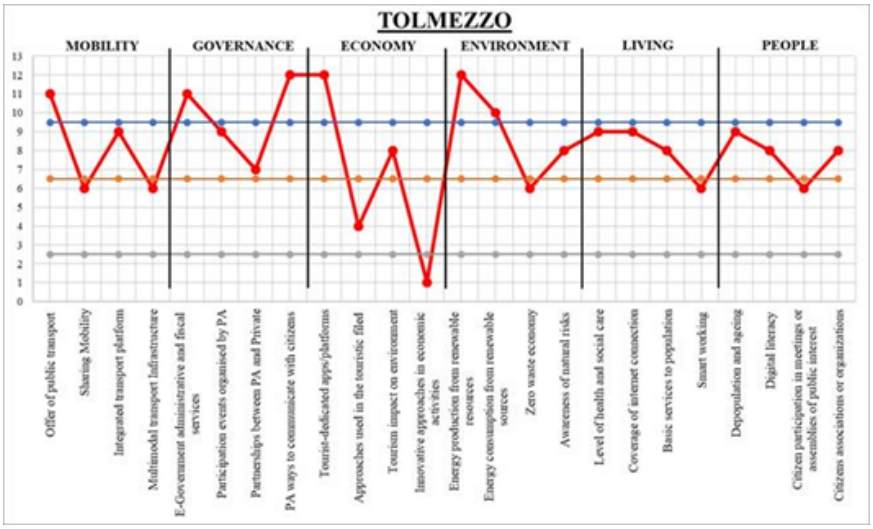

Fig. 3: Tolmezzo scores following the first two steps of the Electre tri procedure. The three horizontal profiles divide Level A (at the top, above 9.5), Level B (between 6.5 and 9.5), Level C (2.5 to 6.5), and Level D (below 2.5)

The Level B rating has been mostly due to the winning combination of having high scores in the dimensions of smart governance, smart living and smart people (see Figure 3, and categories in each dimension in Table 1).

Table 1: Tolmezzo comparison matrix, step three of the Electre Tri procedure. Dimensions scored on a 1 to 6 scale, with 1 = equally important to 6 (or 1/6), 6 times more (or 6 times less) important.

Tolmezzo	Mobility	Governance	Economy	Environment	Living	People
Mobility	1	1/4	1/5	1/4	1/5	1/2
Governance	4	1	1	2	2	5
Economy	5	1	1	2	3	4
Environment	4	1/2	1/2	1	1	2
Living	5	1/2	1	1/3	1	3
People	2	1/5	1/4	1/2	1/3	1

It has however to be noted that, according to the Tolmezzo comparison matrix, the most crucially-assessed dimension has been that of smart economy (see Figure 4): the area can therefore be inspired to further smart transition in the smart dimension locally defined as more crucial.

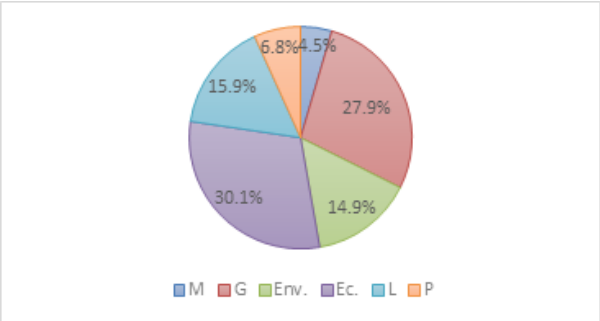

Fig. 4: Tolmezzo weights, or percentage values of the priority vector. M= Mobility, G= Governance, Env. = Environment, Ec. = Economy, L = Living, P =People

6 Conclusions and Future Work

We have presented our research towards a framework for assessing the smartness maturity level of a particular village at a given time. With this regard, many villages aim to raise their level of smartness by considering a number of aspects belonging to a wide range of thematic areas: Mobility, Governance, Economy, Environment, Living, and People. However, there is a lack of field-oriented systematic tools to help them to pilot the transition into a smart village.

In the context of this work, we have shown the design, implementation and exploitation phases of our smartness maturity assessment framework, which is intended to serve as a useful tool and decision support system for planners, administrative staff, political decision-makers, builders, and other users. Although this framework has arisen around a community belonging to the European Alpine space, the lessons learned can be easily transferred to other scenarios in which determining the degree of smartness maturity of the rural communities is a key challenge which can facilitate undertaking public or private investments.

In this context, we have been able to assess the smartness maturity level of an Italian municipality from the European Alpine space. The incremental development of our tool will even allow adding new functionality in the future, according to the feedback we receive from the stakeholders involved. But for the moment it seems clear that we need to design mechanisms to facilitate the aggregation of data from data entered by a number of people belonging to the same village, so that the data entered can reflect much better the collegiate opinion of the stakeholders from the same village.

Disclaimer

The Tolmezzo data and self-assessment has been published in a Master Dissertation Thesis in Civil Engineering entitled Smartness Assessment of rural areas: multicriteria rating with Alpine stakeholders, defended in April 2019 by Francesca Polettini at the Politecnico di Milano. Data are to be considered preliminary and functional only to the testing of the procedure for research purposes.

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