INTERREG MED Programme

2014-2020

ESMARTCITY

Enabling Smarter City in the MED Area through Networking

(3MED17_1.1_M2_022)

Priority Axis 1. Promoting Mediterranean innovation capacities to develop smart and sustainable growth

Specific Objective 1.1 To increase transnational activity of innovative clusters and networks of key sectors of the MED area

WP3 – Testing

Activity 3.2 – Testing preparatory activities

Deliverable 3.2.2 – Methodology for testing

Contractual Delivery Date: **31.05.2018**

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Dissemination Level		
PU	Public	X
PP	Restricted to Programme Partners and MED Programme	
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CO	Confidential, only for members of the partnership and MED Programme	

Project co-financed by the European Regional Development Fund

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1 Introduction

Activity 3.2 is expected to provide three different deliverables: a Feasibility Study (D.3.2.1), a Methodology for Testing (D.3.2.2) and Pilot Deployment Operational Plan Framework (D.3.2.3).

The current deliverable 3.2.2 is about specifying the methodologies that will be exploited to evaluate the different pilot deployment results. This validation phase is necessary to draw conclusions about the efficiency of the solutions which will be proposed by the different pilot deployment use cases. It is necessary to define a unique and straight-forward method to assess these conclusions in a clear, transparent and comprehensive fashion.

Considering the heterogeneity of the pilot deployments proposed in the previous deliverable 3.2.1, this homogenization phase is necessary to enhance an inclusive vision of the complete project. Even if all the use cases can be grouped into two main themes – “Building Energy Efficiency” and “Smart Public Lighting” – different focuses were posed by the different pilot deployments in order to include the widest range of topics and issue characterizing these themes. This evaluation will mostly rely on numerical indicators, in order to provide an objective comparison between a baseline case and the obtained results. Chapter 3 presents such indicators, which will be exploited to evaluate the pilot results. These indicators will be divided in categories to ease their representation. Chapter 4 draws some concluding remarks.

2 Indicators

In the previous deliverable 3.2.1, various pilot deployments have been presented. The current deliverable aims at proposing a unified evaluation criterion to establish the efficiency of each pilot deployment. This approach will highlight the strengths and weaknesses of each deployment. By analyzing these performances, it will be possible to integrate efficiently the different solution proposed in the deployments in order to exploit synergies among the transnational approaches. The best way to compare objectively these use cases envisages the use of numerical indicators, which are presented in this chapter.

These indicators must provide a correct trade-off between a unified vision on the results and the necessary elasticity to have them applied on pilot deployments with different natures. The former is needed to have an objective vision on the different results provided by the testing use cases, while the latter is needed to guarantee a meaningful applicability of these indicators.

These indicators are divided into four categories:

1. **Cost indicators**
   evaluating the economical costs and benefits of the proposed solutions.

2. **Performance indicators**
   quantifying benefits different from the purely economical ones.

3. **Technical indicators**
   describing the technical sophistication of the solutions, considering well-known qualities such as replicability and scalability.

4. **Social indicators**:
   to assess the perceived improvements from the user point of view.

Each category is presented in the following sections.

2.1 Cost indicators

The cost factor is the first tackled to evaluate the validity of a pilot deployment. These cost indicators are meant to provide an insight on two different meaning levels:

- The deployment costs – i.e. the expenses
- The cost reduction introduced by the provided solutions – i.e. the economic saving

In this way, it is possible to draw a purely economic conclusion on the proposed solutions. The indicators are presented in the list below:

- Solution deployment cost:
  It is of vital importance to determine the cost of the investment-solution proposed, in order to correctly evaluate the time required by the investment benefits to compensate the initial costs.

- Energy consumption variation:
  The purpose of this indicator is to quantify the economic benefits following the introduction of each proposed solution. Some solutions could provide benefits different from this purely economic one: other indicators will analyze these factors.

- Maintenance costs:
  Besides the initial deployment cost, it is necessary to estimate the maintenance cost deriving from the installation of the proposed solution. These costs will enrich the vision on the overall economic balance.

- Pilot deployment cost:
  This indicator expresses the overall cost sustained to deploy each specific pilot. With this information, it is possible to evaluate the economic impact of a third party willing to replicate the experiment to undergo further/different analyses.

2.2 Performance indicators

The advantages deriving from the installation of a proposed solution can diverge from the purely economic ones. Some of these non-economical improvements are represented by the performance enhancing. Some indicators are applicable when the solution concerns some sort of actuation and control over the system while other indicators will be exploited for solutions based on a monitoring approach.

Considering the diversity of each pilot deployment use case, it is necessary to distinguish the indicators depending on the specific theme tacked – i.e. "Building Energy Efficiency" or "Smart Public Lighting". To recall how these themes are tackled transnationally, the following table from deliverable 3.2.1 is re-proposed.

Country	Region	Locality	Theme	
			Building Energy Efficiency	Smart Public Lighting
BiH	Republic of Srpska	East Ilidza		X
EL	Western Greece	RWG	X	
		Patras	X	
ES	Andalusia	Huetor Tajar		X
		Agron		X
FR	Auvergne-Rhône-Alpes	Lyon		X
IT	Abruzzo	Pescara		X
	Lombardy	Milan city	X	
		Milan PoliMi	X	
PT	Lisbon	ENA	X	

To evaluate the improvements resulting from the deployment of IoT technologies, a common performance indicator is defined:

- Network and system architecture relevance:
  Mainly, the pilots rely on IoT technologies with networked sensors and actuators and an information system to control and monitor the pilot. This indicator is meant to evaluate the relevance of the chosen network and system architecture in fulfilling the relative user requirements. Different features and improvements are captured by this indicator, such as:

    - The capability of the system to support any peak activity and its subsequent evolution.

- The capability of the system to localize different devices and adapt to their eventual relocation.
- The stability of the deployed network

Other performance indicators are presented in the two following sub-sections.

2.2.1 Building Energy Efficiency performance indicators

- Thermo-hygrometric comfort:
  This indicator is the most commonly used to quantify the user comfort in a thermally controlled building. The overall comfort is represented through the combination of two controlled factors, namely the controlled building temperature and its humidity. Extensive studies have been carried out to establish how the perceived user comfort behaves by varying the combination of these two controlled quantities.

- Set-point tracking:
  To manage the comfort in a building usually it is necessary to manipulate some controlled variables – such as the aforementioned temperature and humidity. If the proposed investment-solution envisages the introduction of new control devices or control algorithms, it is recommended to evaluate the resulting performances in terms of set-point tracking. This evaluation assesses the ability of our control-based solution to reach and maintain a desired state of the controlled building. This indicator provides the requested flexibility to fit to different pilot deployment use cases, since it can be applied to any relevant controlled variable of our system. It is possible to quantify the set-point tracking of each controlled variable by computing the Root Mean Square Error RMSE. This quantity is defined – for N time samples of a controlled variable y with set-point value y_{ref} – as:

  $$RMSE = \sqrt{\frac{\sum_{t=1}^{N}(y(t) - y_{ref}(t))^2}{N}}$$

  It is then possible to compute the difference between the RMSE of a baseline case with respect to the RMSE obtained through the installation of each proposed solution. The differences between the baseline RMSE and the improved RMSE for each variable will be averaged together to produce a unique performance index for each pilot deployment, assessing any set-point tracking capability improvements.

- Insight increase:
  this performance index describes the eventual improvements obtained on the level of insight acquired. In this sense, each kind of additional information or measurement

obtained on the system which is not used for a direct control purpose has to be highlighted by this indicator. This information will eventually be exploited to draw further conclusions on the behavior of the monitored system, thus allowing future studies to develop more sophisticated solutions.

2.2.2 Smart Public Lighting performance indicators

- Lux level:
  By exploiting different lighting technologies, it is possible that a proposed solutions presents an increased value in the perceived light intensity. To assess this measure, this lux indicator is exploited. The “lux” is a derived unit of measure of the illuminance, which measures the luminous flux per unit surface. It is used in photometry to describe the perceived luminosity of a light source.
  If compliant with the specific pilot deployment use case, the difference between the lux of the previous technology and the lux provided by the new solution will be described with this indicator.

- Illuminated area:
  Beside an eventual increase in the perceived lighting provided by the public lighting system, another improvement can be represented by an increase of the illuminated area. If such improvement is obtained, this numerical indicator can express it. The increase of the illuminated area can have different benefits, from the social perception of urban good management to safety issues.

- Illumination waste reduction:
  By exploiting smart technologies, it is possible to reduce the time in which the illumination system is working without purpose, i.e. when no user benefits from it. Depending on the specific solution proposed by each pilot deployment, this waste can be tackled and reduced. Any reduction of this specific waste will be presented in this indicator. Moreover, such reduction should be indirectly represented in the economic cost indicators as a cost reduction. However, since the overall consumption reduction can be caused by different factors, this indicator is exploited to focus the attention on the efficiency obtained by this kind of solution.

- Environmental impact:
  some solutions could provide an increase in the overall environmental impact, such as the

light pollution issue. Any performance increase of this kind will be represented by this indicator.

2.3 Technical indicators

To complete the analysis of the solution proposed by the different pilot deployments, it is necessary to tackle the less numerical benefits. Despite being hard to quantify, these kind of benefits represent the feasibility of the proposed solution when facing real challenges in the implementation and maintenance of innovative technologies. Even if providing substantial economic and performance benefits, a solution could result unfeasible for technical reasons: these indicators are meant to measure this kind of feasibility. Any proposed solution should provide promising results through these indicators to guarantee its future applicability and overall techno-social impact.

The indicators are presented in the list below:

- Replicability:
  It is vital to propose a solution which is replicable under the assumptions proposed by the solution itself. If the excessive sophistication of a solution prevents it to be easily reproduced in a similar context, it would highlight the necessity to undergo further research before approaching the wide-range market.

- Scalability:
  The potential of a proposed solution can sky-rocket depending on its ability to be applied in contexts different from the original one. In particular, this indicator expresses the capability of any proposed solution to be applied in a context characterized by a different scale from the pilot deployment one. For example, this indicator would highlight if a solution developed for a single building could be scaled up to a network of building.

- Ease of deployment:
  It would be appreciable to provide a solution which does not need an excessive effort to be installed, both in terms of skills required by the installer and deployment time. A solution that cannot claim this quality is highly unlikely to be adopted by a customer, thus limiting its possible spread in the wide market. This indicator is meant to monitor this characteristic.

- Ease of management:
  Considering the potential spread of the proposed solutions, it is recommended to maintain

a low level of complexity from the user point of view. With this indicator, ease of usability will be rewarded in order to promote solutions exploitable by the largest amount of population.

- Ease of maintenance:
  After installing a particular solution, it is necessary to guarantee a relatively easy maintenance. This quality guarantees good probability that the deployed solution will not be abandoned when facing its first technical issues. Together with the maintenance costs presented in the cost indicators, this indicator expresses the effort required to maintain the proposed solution for a long time.

- Ease of integration:
  considering the advanced technology generally implied in these solutions, it is advised to envisage the possibility to integrate the presented solutions with other well-known architectures and structures. This quality would ensure advantages both in the initial installation phase and in the long-term renewing and affirmation of the solution in the wide market.

- Ease of upgrade:
  To guarantee that a solution is not going to be easily replaced in the next future, it is necessary for it to possess the potentiality to be further developed. In this way, the attention around this solution would not fade in a few years, so the performance and economic benefits can be further improved by future researches.

2.4 Social indicators

Finally, it is necessary to analyze the impact of the proposed solution on the users' community. It is vital for the solution to be perceived as a rich source of benefits and innovation from the final users, in order to guarantee a wide application and spread of the proposed solution itself.

It is notoriously hard to numerically quantify this user satisfaction. However, when compliant with the specific use case, a satisfaction questionnaire will be submitted to the users to evaluate this impact.

The questionnaire will be posed as a list of questions with a numerical answer, ranging from a minimum value to a maximum value. The user will then be required to express his opinion in a numerical fashion. In this way, it will be possible to draw numerical indicators on the social impact of each proposed solution, by averaging and analyzing the numerical answers provided by the users.

Considering the heterogeneity of the pilot deployment use cases, the questionnaire should be tailored around the specific solution proposed by the use case itself. For this reason, it is suggested to leave a high degree of freedom in the development of such questionnaire, in order to produce an evaluation instrument which can really fit each use case singularly. In this way, it will be possible to extrapolate the highest amount possible of information on the user point of view.

3 Conclusions

Deliverable D3.2.2 presents a detailed methodology developed for the testing phase of the project use cases. This methodology is mainly based on the use of numerical indicators. The presented indicators will allow an objective evaluation of each use case, which in turn will allow a deep and comprehensive analysis of the results obtained through this project.

Since the overall project deals with two main themes – namely “Building Energy Efficiency” and “Smart Public Lighting” – some indicators have been divided based on the theme tackled in the specific use case, while others have been defined as common to the two topics. Moreover, the indicators have been divided into four main categories depending on the field they have been designed for, namely: costs, performances, technical improvements and social impact.