Certification of IPavement Applications for Smart Cities
A Case Study

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Abstract: The installation of Intelligent Pavement (IPavement) in cities highlights the obvious need for the development of software services that can be offered by this technology. These services should be developed in conformance with international quality standards such as ISO/IEC 25000, which make it possible to give assurance that the services must established quality requirements. This paper therefore presents the environment for the quality certification of the services developed for the IPavement, created by the authors. This environment is formed by an assessment process, a quality model, and set of assessment tools. The results of a case study carried out to evaluate the quality of a service developed for IPavement are also set out; this study has tested the practical application of the environment created and has proven the need to develop tools to assist in the evaluation of the quality IPavement services.

1 INTRODUCTION

We are witnessing the rise of a new paradigm—the "cyber-digital-intelligent-smart" city-- which has emerged as a solution to the challenges of the twenty-first century: globalization, urbanization and climate change (Komninos, 2015).

It is precisely the meaning of digital city as an intelligent environment that fits in with the concept of the intelligent street; this is ,indeed, the basis of intelligent cities. As Professor William Mitchell of MIT points out: "intelligent cities take advantage of the 'third wave of technological innovation', which means sensors and digital labels, and which will substitute the two previous waves as regards the incorporation of computers and the era of connectivity that the introduction of the Internet supposed" (Mitchell, 2007).

This same idea could include the concept of a city as a special case of the Internet of Things (Telefónica, 2011), in which a smart city is defined as "an urban space with intelligent infrastructures, networks and platforms, with millions of sensors and actuators, within which it is also necessary to include the people themselves and their mobile phones. A space that is capable of listening to and understanding what is happening in the city, which will help it to make better decisions and provide its inhabitants with the appropriate information and services.

All of these considerations highlight the need for the development of new services from a different perspective, one that focuses on developing service-oriented software that would allow citizens to make the most of the advantages offered by intelligent cities (López-Sanz, et al., 2014). If city-dwellers are to appreciate more fully the benefits afforded by intelligent cities, it is very important for the services offered by them to comply with quality standards that are based on international norms such as ISO/IEC 25000 (ISO/IEC, 2014).

This being so, the remaining part of the paper is organised as follows: in section 2 there is a description of Intelligent Pavement (IPavement) technology, which turns the conventional city into an intelligent urban place that offers a set of services. Section 3 presents the environment that has been built to assess the quality of the services developed for the IPavement, while in section 4 the case study of the assessment of an IPavement service is described. Finally, section 5 sets out the conclusions obtained and provides work lines future.

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2 INTELLIGENT PAVEMENT

The term 'IPavement' is currently applied to all paving that permits the propagation of radio frequency 'within the street's skin', and is provided with 'hotspots' (service propagation points) which, over predetermined distances (normally a distance of 20 metres), are able to provide services according to the range of the repeater (Navarro and Piattini, 2013).

The IPavement is unusual in that it contains within it elements that are not typical of conventional paving (electrical, electronic, radio frequency, etc.) (see Figure 1), which means that in addition to carrying out its conventional function it fulfils a second function, which is to support the intelligent city's service infrastructures.

Figure 1: Component of the Intelligent Pavement (before installation of connections and covering) Model 2010.

3 CERTIFICATION ENVIRONMENT

As pointed out above, it is of the utmost importance that the services developed for the IPavement should meet quality standards. It is to that end that the AQC laboratory (AQC Lab, lab to which the authors belong) an establishment that has accreditation for assessment of software product quality based on conformance with the ISO/IEC 25000 family (Verdugo et al., 2014), has been working. The laboratory has adapted a quality assessment environment (Rodríguez and Piattini, 2014) so as to be able to tackle assessment of the services developed by IPavement and assure that quality standards, such as those of the ISO/IEC 2500 family, are met.

3.1 IPavement Assessment Process

In order to take on the task of assessing the quality of IPavement services, it has been necessary to adapt the quality assessment environment of AQC Lab (Rodríguez and Piattini, 2014), that is based on ISO/IEC 25040 (ISO, 2011a).

In carrying out this adaptation, a remodelling of the Assessment Methodology has been undertaken. This has led to the IPavement Methodology being composed of three processes, rather than of one single process, as in the Methodology of AQC Lab. This may be observed in Figure 2.

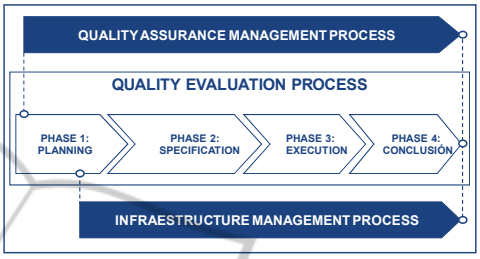

Figure 2: Processes of the IPavement Methodology.

It has also been deemed necessary to perform another adaptation, which consisted in making an addition to the **Quality Assessment Process.** The Vía Inteligente business entity was added as sponsor of the service, rather than as developer, Figure 3 show the steps needed to carry out the quality assessment of a service.

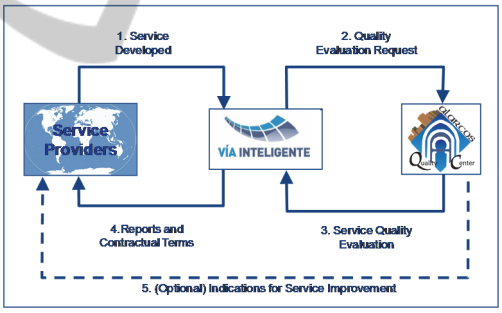

Figure 3: Implementation of the process of assessment of the quality of the services developed for IPavement.

3.2 IPavement Quality Model

The IPavement Model developed by AQC Lab (Montealegre et al., 2015), is based on the ISO/IEC 25010 (ISO/IEC, 2011b) norm. That being the case, the following characteristics defined in the ISO/IEC 25010 have been taken into account when assessing the different quality aspects of the services developed for the IPavement. In addition, the IPavement Model should make it possible to assess whether the services developed for the IPavement meet the requirements established by ASEPI (Agrupación Empresarial Innovadora Pavimento Inteligente The 'Intelligent Pavement' Innovative

Cluster) in the EPI standard (ASEPI, 2011), specifically in the EPI.C standard. It is to that end that a new characteristic was added to the IPavement model, one that is not defined in the ISO/IEC 25010 model. Its object is to assess the level of compliance with the requirements of the EPI.C standard.

In order to align this characteristic with those established in the ISO/IEC 25010 norm, a set of subcharacteristics have been defined for the characteristic of Conformity to the EPI. C standard: Intellectual Property, Data Protection, RFID Security and Safety, Security and Privacy of Geolocation and Multi-language support, that measures different aspects covered by the EPI.C standard (Navarro and Piattini, 2013).

Now it should be indicated how the assessment of these should be carried out. Nevertheless, the family of ISO/IEC 25000 norms does not as yet have a set of metrics or measurement functions at its disposal that would enable a quality value to be obtained for these characteristics and subcharacteristics. The scheme employed by AQC Lab in its quality models has therefore been followed (Rodríguez and Piattini, 2014). To carry this out, a set of quality properties and metrics that allow this model to be operative has been established. That means first of all obtaining the metrics values from the work-products and then going up the results until the value of the quality characteristics assessment is reached.
For the sake of space, it is not possible to describe the complete IPavement model.

3.3 Technological Environment

The last element in tackling quality assessments for IPavement services is the technological environment of AQC Lab. The following tasks have been undertaken in carrying out the adaptation of the technological environment.

- **Measurement Tools:** New tools have been developed; these enable and facilitate measurement of the work products generated during the development of the IPavemnet services.
- **Evaluation System:** The quality assessment criteria and the IPavement quality model have been implemented, making it possible to carry out quality assessments automatically.
- **Visualization Environment:** A new visualization environment has been produced, so that the results obtained after the assessment of the IPavement services can be presented.

4 CASE STUDY

The case study describe the quality assessment of a service developed for IPavement using assessment enviorement described in the paper. The assessment was performed on the Viateca service. It is an e-commerce web platform for the buying and selling of e-books in ePub format; this carries within it a complete admin.

4.1 Devices Used in the Assessment

The assessment of Viateca was carried out on two different types of devices, their characteristics are displayed in Table 1, since one of the main characteristics of IPavement is the independence of the device for the use of its services. The service quality can, however, be affected by the type of device (screen size, processing ability, etc.) employed during the use of the service.

Table 1: Characteristics of Device 1 and Device 2.

Device	PC	Smartphone
Operating System	Windows 7 Enterprise Service Pack 1	Android 4.1.2
RAM Memory	8 GB	1 GB
Processor	AMD Phenom 64x4 945 3.00 GHz	Quad-core 1.2 GHz Cortex-A7

4.2 Assessment of Viateca

The quality results obtained are shown in Table 2, where the quality value reached for each characteristic in each of the devices employed in the assessment is indicated.

Table 2: Results of the characteristics in the assessment of Viateca.

Characteristic	Device 1	Device 2	Final Value
EPI. C	2	2	2
Usability	2	2	2
Reliability	4	4	4
Security	4	4	4
Functional Suitability	4	4	4
Portability	3	3	3
Compatibility	4	4	4
Performance Efficiency	5	5	5

The quality values obtained in both of the

assessments of Viateca are identical, due to the fact that Viateca was developed to be an IPavement service. These results have been obtained from the subcharacteristics of each characteristic, whose results are presented in the following sub-sections. It is true that the results of the assessments carried out on device 1 and 2 are identical, but in the following sections only the final results of the assessment.

4.2.1 The EPI. C Standard

In the assessment of the EPI. C standard, the subcharacteristics of Security and RFID Privacy and the Privacy of Geolocation were not taken into account. This was because Viateca does not offer functionalities related to RFID and Geolocation technologies.

In the assessment of the EPI.C Standard it has been demonstrated that Viateca has reached quality level 2 for this characteristic. This value was obtained from the quality results that its subcharacteristics have reached in the assessments conducted, the results of which are displayed in Table 3. On examining the results, it may be seen that the lack of support for enabling other languages to be chosen, and the non-availability of regional configurations other than those of Spain have led to the result obtained by Viateca for the characteristic of Compliance with the EPI.C Standard.

Table 3: Results of the Subcharacteristics of the EPI.C Standard.

Subcharacteristic	Result
Intellectual Property	100
Data Protection	100
RFID Security and Safety	-
Security and Privacy of Geolocation	-
Multi-language Support	0

4.2.2 Usability

To assess Usability, it has been shown that Viateca has reached quality level 2 for this characteristic. This value was attained on the basis of the quality results reached by its subcharacteristics in the assessments performed, the results of which may be seen in Table 4.

Table 4: Results of the Subcharacteristics of Usability.

Subcharacteristic	Result
Appropriateness recognisability	72,62
Learnability	72,62
Operability	50,00
User Error Protection	100
User Interface Aesthetics	46,37
Accessibility	0,00

An examination of the results shows that the non-compliance with the accessibility standards, for example: (W3C, 2011) and (W3C, 2013), and along with the impossibility of customising the user interface, lie behind the results Viateca obtained for Usability.

4.2.3 Reliability

In the assessment of Reliability, Viateca was shown to have reached quality level 4 for this characteristic. This value was obtained on the basis of the quality results that its subcharacteristics reached in the assessments carried out, the results of which appear in Table 5.

On examining Table 5, it may be seen that the good results obtained by its subcharacteristics are the reason for the good result reached for the Reliability characteristic. Nonetheless, the Reliability level could increase, thereby improving the availability of the service. That is why mechanisms should be put in place to make it possible for the service to be used whenever the user wishes under the conditions established.

Table 5: Results of the Reliability Subcharacteristics.

Subcharacteristic	Result
Maturity	95,87
Fault Tolerance	100
Recoverability	100
Availability	87,79

4.2.4 Security

In the assessment of Security it has been established that Viateca has reached quality level 4 for this characteristic. This value was obtained on the basis of the quality results reached by its subcharacteristics in the assessments performed, the results of which are shown in Table 6.

On observing the information in Table 6, it may be seen that the good results achieved by the subcharacteristics lie behind the good result reached for the Security characteristic. Nevertheless, the Security level could increase and bring with it an

Table 6: Results of the Subcharacteristics of Security.

Subcharacteristic	Result
Confidentiality	100
Integrity	100
Non-Repudiation	100
Authenticity	50
Accountability	100

improvement in the authenticity of the service. To that end, mechanisms that enable there to be a strengthening of the measures to control access should be implemented. These mechanisms should also cover all the functionalities of the service that need to be protected by access control mechanisms.

4.2.5 Functional Suitability

In the assessment of Functional Suitability, Viateca has demonstrated that it has reached quality level 4 for this characteristic. This value was obtained from the quality results achieved by its subcharacteristics in the assessments performed, the results of which are shown in Table 7.

An examination of Table 7 demonstrates that the good results achieved by the subcharacteristics led to the good result obtained for the characteristic of Functional Suitability. However, the Functional Suitability level could rise, with a consequent improvement in the Functional Appropriateness of the service. This means that the functionalities of the service which have not been described in the requirements, and which are therefore neither necessary nor appropriate for the user, should be eliminated.

Table 7: Results of Subcharacteristics of Functional Suitability.

Subcharacteristic	Result
Functional Completeness	95,87
Functional Correctness	98,23
Functional Appropriateness	93,81

4.2.6 Portability

The assessment of the Portability showed that Viateca has reached quality level 3 for this characteristic. This value was obtained on the basis of the quality results that its subcharacteristics reached in the assessments performed, the results of which are set out in Table 8.

On examining the results in Table 8, it may be seen that the low result obtained in Adaptability due to lack of customization of the service, has led to the result obtained by Viateca for the Portability characteristic.

Table 8: Results of the Subcharacteristics of Portability.

Subcharacteristic	Result
Adaptability	38,13
Instalability	100
Replaceability	100

4.2.7 Compatibility

Viateca was found to have reached quality level 4 for this characteristic in the assessment of Compatibility. This value was obtained from the quality results which its subcharacteristics reached in the assessments undertaken, the results of which may be seen in Table 9.

An examination of Table 9 leads us to affirm that the good results achieved by the subcharacteristics have led to the good result reached for the subcharacteristic of Compatibility. However, the Functional Suitability level could increase, thereby solving the problems detected in the exchange of service data with other services, such as e-mail.

Table 9: Results of the Subcharacteristics of Compatibility.

Subcharacteristic	Result
Co-existence	100
Interoperability	66,67

4.2.8 Performance Efficiency

Viateca was shown to have reached quality level 5 for this characteristic. This value was obtained from the quality results achieved by its subcharacteristics in the assessments carried out, the results of which are set out in Table 10.

Table 10: Results of the Subcharacteristics of Performance.

Subcharacteristic	Result
Time-behaviour	100
Resource utilisation	97,71
Capacity	100

Table 10 shows, on examination, that the excellent results obtained by its subcharacteristics have caused the good result for the Performance characteristic. Thus, because level 5 has been reached, no other improvement in the service needs to be made to raise the quality level for that characteristic. However, if new assessments are undertaken for this service, this characteristic ought to be assessed along with the rest; it should be checked that the changes introduced into the service have not had negative consequences for this characteristic.

5 CONCLUSIONS

IPavement is innovative technology which places in the hands of citizens a set of services that make it

easier for them to be more integrated in the city. If these services are to be of any benefit they must meet some quality requirements. This paper has presented an environment for the quality assessment of services developed for IPavement. In addition, details on a case study carried out have been provided, to show the practical application of the quality assessment of a service.

During the development of the environment for the quality assessment of the services of IPavement, it was shown that the type of device employed to use the IPavement services could affect the different aspects related to quality of service. It was thus determined that a quality assessment for an IPavement service should consist of various assessments (one by type of device). After this, during the case study, it was observed:

- Quality assessment of the IPavement services is independent of the technology and language.
- IPavment services shoud have techincal documentation.
- Evaluation is largel manual because there aren't tools to automate the assessment.
- Easy to introduces errors by the evaluator.

Bearing all these considerations in mind, we are working on the following lines:

- Increasing the set of devices on which to carry out the simulation and assessment of the services.
- Automatising the assessment tasks as far as possible, aiming to reduce the time frames and improve the reliability of the results.

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