Private connected vehicles data to support the implementation of urban PMS: the case study of the City of Palermo

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Abstract

This work aims to explore the potential of leveraging big data—particularly that generated by private connected vehicles—for extensive monitoring of road infrastructure in urban areas. Central to this exploration is the following research question: are data collected from connected vehicles (CVs) reliable and cost-effective source for road condition monitoring within urban Pavement Management Systems? In order to give an answer, at first characteristics of the few encountered urban PMS in literature were identified. On this basis, a prototype of urban PMS, leveraging connected vehicles as source of pavement condition monitoring was designed and applied to a case study within the city of Palermo (Italy). The application was validated by comparing these results with an additional visual monitoring operated by using the PASER method. Overall, the comparison supports the potential of using CVs data as a viable and scalable alternative for pavement monitoring in urban contexts; in fact, measurement accuracy is considered adequate to the level of precision realistically possible to obtain a cost-effective solution in such a dynamic and complex environment such as urban road pavements.

Keywords

Private connected vehicles, urban PMS, proactive maintenance

1 Introduction

Road infrastructures are strategic assets that require periodic monitoring and maintenance. This highlights the need to shift from reactive management methods, often ineffective and costly, to proactive and predictive approaches[1]. A key tool in this direction is the Pavement Management System(PMS).

Documented experiences of PMS in urban contexts[2][3][4] show the intention to move beyond traditional approaches toward progressive digitalization and rationalization of processes. Among the evaluation tools, the International Roughness Index (IRI) is one of the most widely used indicators to assess surface regularity[5]. Depending on the perceived ride comfort [6] or the vehicle's operating speed[7], threshold values can be defined as targets for planning maintenance interventions. Different technologies are employed to determine these indicators: profilers, highly accurate but expensive and less practical in urban context[8]; smartphones, which are more cost-effective and reliable[9]; and sensors installed on connected vehicles (CVs), which represent an innovative, frequent, and trustworthy source. Several studies have demonstrated a strong correlation between CVs data and traditional methods, making this option particularly promising for urban pavement monitoring[10]. The study proposes a proactive maintenance approach based on IRI data from connected vehicles, aimed at assessing their reliability and economic sustainability for monitoring urban pavement conditions.

2 Methodology

The system is structured into four main components, defined on the basis of studies on Urban PMS, with an additional final phase dedicated to validation. These are:

- Preliminary phase: case study identification.
- Monitoring and data collection: CV data (geo-referenced IRI values) were provided by NIRA dynamics, segmented into 25 m road sections and classified into five functional categories. (Only class 3 and class 5 roads are included in the case study)
- Data analysis: datasets collected weekly over two years were filtered and cleaned by eliminating outliers. The network was then divided into homogeneous sections, considered the minimum management units for maintenance.
- Decision-making process: classification thresholds were established using the percentile method, generating five surface condition categories (excellent–critical). Each section was assigned a

condition level based on the monthly average IRI (**Tab.1**), leading to the creation of a digital quality map (**Fig.1a**).

- Validation: CV-based results were compared with PASER assessments, which are based on visual inspections and a 1–10 rating scale.

Road segment	Length(m)	Percentiles
AB	82.77	0.35
BC	32.69	0.6
CD	61.63	0.35
DE	60.55	0.35
EF	117.63	0.35
FG	33.99	0.35
GH	61.73	0.35
HI	108.42	0.6
IJ	93.63	0.6
JK	120.3	0.6
KL	97.75	0.85
MG	79.93	0.85
MI	96.42	0.6

PERCENTILES	IRI	SURFACE CONDITION
10°	0<IRI≤4.19	EXCELLENT
35°	4.19<IRI≤5.61	GOOD
60°	5.61<IRI≤6.69	FAIR
85°	6.69<IRI≤8.16	POOR
100°	8.16<IRI	CRITICAL

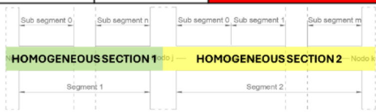

Table 1. Surface condition classes based on the IRI thresholds obtained

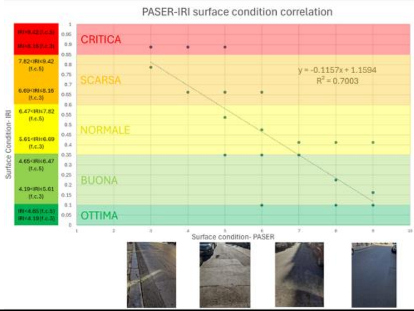

Figure 1a. CV-based Digital quality map of the case study

Figure 1b. PASER-IRI comparison

3 Findings/Expected outcomes/Potential applications

The output of the study consists in the creation of digital maps of pavement quality (**Fig.1a**). The comparison with PASER inspections revealed a positive correlation ($R^2 \approx 0.7$) between the two approaches, with about 70% of the variability explained by IRI data (**Fig.1b**). In particular, a correlation of 78% was found for class 3 roads and 61% for class 5 roads, which is consistent with the fact that class 3 roads, being more heavily trafficked, allow for greater accuracy. Only a few cases showed significant discrepancies, thus confirming the validity of using CVs data for urban pavement monitoring. Moreover, the pay-per-kilometer purchase of CVs data proves to be much more convenient than the use of specialized vehicles.

4 Conclusions

The study explores the potential of data generated by CVs for monitoring urban road infrastructure. One of the first prototypes of an Urban CV-PMS was developed and applied in Palermo, validated through comparison with PASER method. The results show that CV data represent a suitable solution for the urban context, where road monitoring information is often limited, offering a scalable and economically sustainable approach capable of ensuring continuous network coverage and fair assessments between primary and secondary roads. The approach proves adaptable to the needs of individual cities and provides a promising foundation for future developments, particularly toward the integration of predictive methods.

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