POLITECNICO DI MILANO

Department of Management Engineering

Doctoral Program in Management Engineering

Ph.D. Cycle: **XXVII**

INFOMOBILITY AND OPEN DATA: ARE THEY EASY PARTNERS?

Doctoral Dissertation of:

Silvia MALPEZZI

Supervisor:

Prof. Giovanni AZZONE

2014

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ABSTRACT

Infomobility refers to the use of ICTs in the field of transportation for increasing the efficiency and effectiveness of transport systems. It is a subject increasingly debated both in the academics and professionals' worlds as its capabilities for improving traffic operations and services through the collection, elaboration and distribution of information about transport systems to mobility managers and travelers. The effectiveness of Infomobility systems is still questioned. Some empirical studies have highlighted the inadequacy of such systems in supporting the improvement of transport systems. In order to overcome the actual deficiencies hampering the exploitation of Infomobility, our study investigates the potential benefits of adopting the Open Data approach in the Infomobility sector.

The thesis is structured as a collection of 3 papers focusing on 3 main issues of the Infomobility field. First, we clarify what Infomobility means and what it consists in, since we found the literature on this theme to be very fragmented and heterogeneous. Second, we identify the dimensions to be considered in order to assess the Infomobility systems. Indeed, even if it is often emphasized the dissatisfaction for the present exploitation of Infomobility, the capability of these Systems to provide mobility managers and travelers with the information that they need is a matter still unexplored. Finally, once understood the Infomobility meaning and identified how to assess its effectiveness, we investigate the real potentials of Open Data in supporting the achievement of the Infomobility goals.

EXECUTIVE SUMMARY

1 Area of investigation

The term Information Age refers to the historical period that goes from the introduction of the personal computer to today, which has been witnessing a technological revolution led by the development of Information and Communication Technologies (ICT), changing the way people communicate, work, travel, live (Wydro, 2011; Pellicer et al., 2013). In the Information Age, information quality and management have assumed greater and greater importance, above all in areas that are characterized by high complexity and uncertainty. Particularly, during the last decade the idea of leveraging on information systems in order to make infrastructure networks and public services more efficient and effective (Rocheleau, 2000; Pellicer et al., 2013) has spread out all over the world (Batty et al., 2012). The domains of applications of ICT has encompasses many different fields, including urban planning, sustainable mobility, transportation engineering, public health, and economic forecasting (Batty et al., 2012). ICT has started to be perceived as a possible solution to face exacerbated problems connected to social and environmental issues such as the overcrowdings of urban areas, and the economic and natural resources scarcity for answering the citizens' needs (Pellicer et al., 2013).

In this context, this work focuses more specifically on the theme of Infomobility - i.e. the use of ICTs in the field of transport systems with the aim of a better exploitation of existing transport infrastructure by improving traffic operations and providing new travel information services (e.g. Paganelli and Giuli, 2009; Stathopoulos and Tsekeris, 2009; Li et al., 2009). In general, the Infomobility goal is twofold. On one hand, it supports the transport network planning and control activities (Vlahos et al., 1994; Horan, 2003; Giannopoulos, 2004; Lee et al., 2010; Peng et al., 2011; Giannoutakis and Li, 2012). On the other hand, it assists travelers to plan the trip and to decide on the route to take during the trip (Giannopoulos, 2004; Lee et al., 2010; Giannoutakis, 2012). These two mechanism are much related because information services not only turn into better meeting the higher information requirements (in terms of amount and quality) of mobility systems users (Wydro, 2011), but also aim to influence their behavior for a more efficient use of the transport system (Chorus et al., 2007; Natvig and Vennesland, 2009; Chatterjee, 1999). Consequently, this information can be considered both a resource for support the mobility system management, and an integrative part of the mobility service itself (Zuylen and Weber, 2002; Sterle, 2009; Perra et al., 2009; Bazzi et al., 2011). Infomobility is a theme increasingly debated as a mean for facing the increasing challenges related on one hand to the growth of the levels of mobility required for the economic development (Wootton and Garcià-Ortiz, 1995; Xu, 2000; Piccolo and Galdi, 2006; Bazzi et al., 2008). On the other hand to the negative effects of road congestion[1] (Giuli et al., 2011), which are serious levels of pollution, accidents and mobility inefficiency with consequent growth of economic, social and environmental costs (Jin, 2003;

[1] EU Commission (2009). "The potential of Intelligent Transport Systems for reducing road transport related greenhouse gas emissions", Special Study, No. 02.

Stopher, 2004; Li et al., 2008; Paganelli and Giuli, 2009). Several countries has been claiming for innovative solutions to deal with these issues. The use of advanced communication, information and electronics technologies for increasing the mobility systems quality in terms of efficiency, safety and reliability, and for making it more environmentally friendly is a global phenomenon, that has attracted the attentions of political decision makers and operators from different sectors (transportation, automotive, etc.) (Jin et al., 2003; Smith and Venkatanarayana, 2005; Bin et al., 2013). The amount of reports published by governmental and nongovernmental organizations that define standards and guidelines for the implementation of such systems, especially at the urban level, has also increased (Giannopoulos, 2004). The higher number of both public and private companies, in different industries (automotive, telephony, transport, etc.), developing Infomobility projects (Li et al., 2008; Leviakangas, 2011), documents the relevance of the Intelligent Transport Systems (ITS), the ICTs at the basis of Infomobility, for mitigating traffic related problems (e.g. reducing travel time, increasing the transport network capacity and reducing the number of transport accidents, and finally the overall mobility cost) (Isola et al., 2007[2]; Perra et al. 2009; European Commission, 2013). The relevance of this theme has been recognized also by the academic world (e.g. Li et al., 2008; Wang, 2010; Kolosz et al., 2013). Researchers have argued that a greater information to users and managers of mobility systems has an important role in reducing the traffic congestion levels and travel times, and in improving travel safety (Xu, 2000; Nakanishi, 2004; Black, 2010). Nevertheless, at present, the capability of these systems of satisfying the mobility managers and travelers requirements and, in turn, their usefulness in solving the aforementioned problems of mobility, is still questioned (e.g. Logie, 1993; Chatterjee, 1999). Despite the rapid technological innovations and its significant potential benefits, the ITS world has so far failed to take off (Giannoutakis and Li, 2012).

In order to tackle the Infomobility problems, we investigate the potentials of the Open Data (OD) approach in achieving the Infomobility objectives. OD is an information management approach that entailing the free circulation of data for the use, re-use and re-distribution of them by the public (e.g. Borzacchiello and Craglia, 2012; Kassen, 2013). It has been receiving a great attention in the public sector because of the high value ascribed by citizens and various public and private organizations to public data such as those related to public transport, environment, safety and security, and other public services (Desouza, 2012). Lampathaki et al. (2010) define OD as a "philosophy" of freely data distribution not requiring copyright certifications, patents or other control mechanism and restrictions in the data delivery. Zuiderwijk, Marijn and Sunil (2012) define it as a "process" requiring that citizens, businesses, researchers, civil servants and other types of users be freely allowed accessing public data. Again, Janssen, Charalabidis and Zuiderwijk (2012) refer to OD as those "non-privacy-restricted and non-confidential data", about domains of public interest, and produced with public money. Therefore, it refers not necessarily to government related public data, and it is not about the provision of information services. It is related to the 'openness' of data that are made available equipped

[2] Williams L.V. (2002). "Industry efforts to standardize the car bus", Proc. of ICCE International Conference on Consumer Electronics, pp. 32 – 33.
Shalaby A., Lyon C., Sayed T. (2001). "Transferability of travel time models and provision of real-time arrival time information". IEEE Intelligent transportation Systems Conference Proceedings – Oakland (CA) USA

with a distribution and reuse license (Borzacchiello and Craglia, 2012). The OD paradigm has taken place in an era in which the classical information management approach of making datasets accessible only within the organizations borders started turning in a new liberal trend. Institutions such as public organizations and governments at all levels, which historically restricted access to their data, have been realizing that the new huge amount of available data enabled by ICTs, can be leveraged not only for supporting study, design, and managing infrastructure and services they are in charge of. They can also be used for making these systems more accessible and helping the public's decisions and activities (e.g. Curtin, 2010; Davies and Edwards, 2012; Kloeckl et al., 2012). A number of sovra-national, national and local governments have been developing initiatives in opening up public data, changing the public data access regulation, promoting transparency and openness and developing an increasing number of OD initiatives (Batty et al.. 2012; Cerrillo-i-Martínez, 2012; Davies and Edwards, 2012).

The OD approach seems to be much suitable for the Infomobility sector in terms of objective coherency. Indeed, where Infomobility aims at supporting the transport network planning and control activities and at assisting travelers to plan the trip and to decide on the route to take during the trip, OD aims at enabling a more transparent evaluation of the operators' activity, at increasing the quality of data for supporting decision making of all the information users, and at subsidizing the development of new information services.

2 Research objectives

With the aim of investigating the impact of the OD approach in exploiting the Infomobility potentials, we first deepened the study on the theme of Infomobility. Actually, the same term "Infomobility" is not much common in the academic literature, which generally refer to the use of the Intelligent Transport Systems, consequently shedding light just on the technological component (e.g. Hall, 1996; Kenyon and Lyons 2003; Rudin-Brown, 2009). Also in the practitioners' world, it has acquired different meanings depending on the specific area of investigation that has been addressed (e.g. social issues, technical studies). Then, studies related to the implementations of ICTs solutions for improving the mobility systems are characterized by a high degree of fragmentation and heterogeneity since they are characterize by a great variety depending on the specific areas of interest - e.g. Infomobility systems for specific applications like road accidents management (Vaa et al., 2008; Celidonio et al., 2012), and have analyzed them using different perspectives – e.g. specific technologies vs. wide projects. Therefore, the first aim is to provide a clear framework clarifying the meaning and constituents of what we call Infomobility. Then, we aim to identify the critical elements that determine the achievement of the Infomobility goals. Even though it is often emphasized the dissatisfaction for the present Infomobility exploitation and the need for improving their effectiveness, the theme of the assessment of the Infomobility Systems capability to fulfill the target of providing mobility managers and travelers with the information that they need, that we name Infomobility System Quality, is still unexplored. Consequently, a draft of the main dimension for assessing them has to be provided. Finally, considering these Infomobility Quality dimensions and the Infomobility goals, we investigate the potentials of the OD approach for Infomobility, which has not been deeply investigated yet. Indeed, up until now OD studies have

analyzed projects not specifically related to this sector (e.g. Kloeckl et al., 2012; Kassen, 2013). Some authors just mention transportation as one of the possible application fields of OD (e.g. Borzacchiello and Craglia, 2012; Desouza and Bhagwatwar, 2012; De Saulles, 2013). Moreover, it is still not clear how the potentials of OD can be realized at local level and through specific projects in the Infomobility sector.

This work is developed as a 'collection of papers', each of them answering to the following research questions:

1) What does Infomobility mean and consist in?
2) How can we assess the Infomobility effectiveness?
3) Can the OD paradigm facilitate the achievement of the Infomobility Goals?

3 Methodology

This section outlines the methodology that was adopted in order to achieve the research objectives (then specific details about the research method embraced in each step are reported in the three papers that constitute this thesis).

Two research instruments have been employed in order to support different parts of this research: literature review and explanatory case study. In particular, in the **Figure 1** we provide an overview of the methods used for the research development:

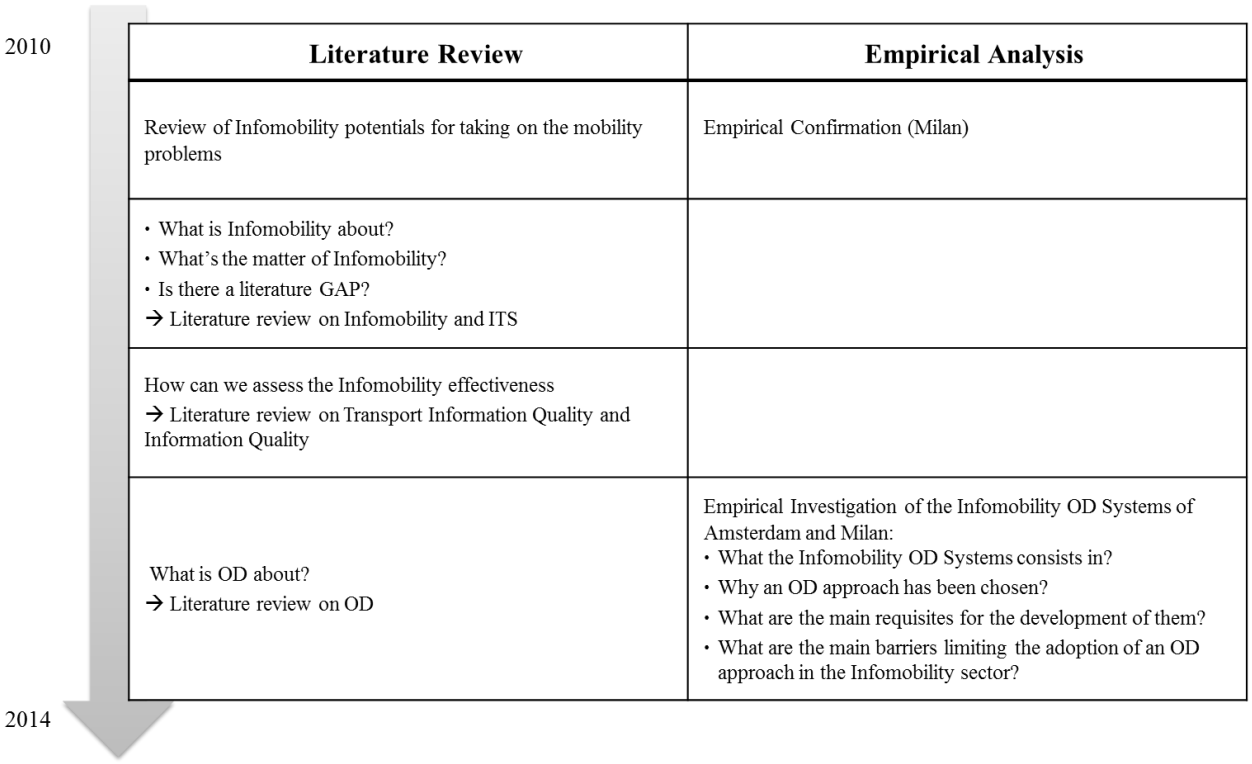

Figure 1 - Research Development

The first phase of the research was mainly explorative, with the aim of providing a broad picture the Infomobility value as possible answer to mobility problems. In this phase, we analyzed previous researches and we conducted some explorative interviews in order to verify empirically the outcomes of the literature analysis. This research confirmed the increasing relevance of this theme among academics and practitioners,

but it also showed the existence of a great confusion related to the meaning of the term 'Infomobility'. Then it emphasized a high level of heterogeneity and fragmentation not only in the theoretical studies but also in the empirical projects already developed (e.g. ARTIST in Italy, ACTIF in France, ASK-IT and SuperHUB in Europe, NITSA in USA, Melbourne City Link Project in Australia). The interviews, performed to the actors of the Infomobility system of Milan have confirmed these results, highlighting the coexistence of a great variety of objectives, technical solutions and services provided. Furthermore, the interviews emphasized tangible fights related to the roles that different actors should assume within this sector (e.g. the role of the public administration) and a certain dissatisfaction about the effectiveness of actual Infomobility initiatives. The **Table 1** reports the list of explorative interviews made and the organizations involved in the most relevant Infomobility projects of Milan.

Table 1 - Interviewees of the Infomobility systems of Milan

ACTOR	INTERVIEWEE ROLE	INTERVIEW DURATION
National Citizens Association for Mobility	ITS and Road Safety Project Manager	2h 22m
Technical Mobility Agency	Director of Management and Information Systems	1h 2m
Public Transport Operator	ICT Director	1h 33m
National Highway Operator	Responsible for Info-Traffic	50m
Center of Excellence For Research	Senior Manager	47m
National Public Infomobility Authority	Operators	1h 51m
Municipality Authority	Director of Planning Mobility Transport Environment Sector	1h 34m
Event Organization Boby	Transport and Mobility Engineering	28m
Exhibitions Center	Digital Services Factory & Delivery Manager	19m
Institution for the Innovation Development	General Director	18m
National Highway Infomobility Broadcaster	Responsible for Business Development and Management	56m
Regional Rail Operator	Transport and Mobility Engineering	1h 28m
Infomobility Private Operator	President and CEO	2h 3m
Telematic Technologies Supplier	Mobility Marketing Manager	51m
Private Broadcaster Research Center	Senior Research Engineer	1h 2m
Infomobility Broadcaster	Public Relations Manager, Redactor	1h 47m
Region Authority	General Manager of Infrastructure and Mobility	1h 3m
Orbital Road Operator	Technical Director Assistance	1h 10min
Orbital Road Operator	President Assistance	17m
Private Telephone Research Center	Innovation Area Manager	3h 2m

The second phase of the research aimed at clarifying the meaning of the term 'Infomobility' and at providing a response to the high level of fragmentation characterizing the Infomobility research field. In order to get an overarching Infomobility definition and to identify the key elements outlining Infomobility systems, we carried on an investigation of the main academic contributions on Infomobility and Intelligent Transport Systems (ITS) – i.e. the technology on which Infomobility is based. Many papers, in fact, do not mention the term "Infomobility" explicitly, but do refer to the Intelligent Transport Systems, hence providing relevant pieces of the knowledge about different functionalities, actors and processes enabling the development of Infomobility systems. This research was conducted on both printed materials (books or printed reports) and electronic source, through internet search engines and academic database. We chose papers dealing with the

concept of Infomobility and the related technologies from a holistic perspective and technical papers focusing on specific elements of the framework. We identified 63 articles whose relevance was determined based not only on the contents, but also on the language (English and Italian) and the year of publication (from 1994, the year of foundation of ITS America, hence it can be considered a good proxy for the origins of ITS). They constitute the basis on which we articulated the definition and developed the framework of Infomobility. For more details, see page 5, 6 and 7 of Article 1.

The third phase of the research aims to study and define the concept of Infomobility Quality and to identify some parameters for assessing it. To achieve this aim, this work is based on a review of academic contributions on Transport Information Quality and Information Quality literature. We chose papers that provided taxonomy of Information Quality attributes or reported on Information Quality features, while we excluded papers that focused on particular types of information (e.g. marketing, management control systems, supply chain management), or were tailored to sectors other than transportation. This research embraced a structured process, that resulted in the selection of 34 articles, with 25 papers whose relevance was determined based not only on the contents, but also on the language (English) and the year of publication (papers published before 1990 were excluded, being too far removed from current information requirements and technological capability). For more details, see page 4 and 5 of Article 2.

Finally, the fourth phase of the research focuses on the potentials of adopting an Open Data (OD) approach in the Infomobility field. To this goal, we first conducted a research of the main literature contributions on OD with a twofold objective: achieving a deeper understanding of the OD phenomena and identifying the key elements of OD initiatives as base for the following empirical investigations.
The empirical investigation was based on a multi-country case study (Yin, 1994). The case study methodology was chosen because it is considered the most appropriate approach for an exploratory investigation of complex systems (Yin, 1993). The empirical investigation was performed in two case settings, Milan and Amsterdam, where Infomobility OD initiatives have been implemented. Both the cases are embedded in the European institutional context where more and more countries are emphasizing transparency and openness of Governments' activities by making public information more easily accessible and available for re-use. Data were collected in the two settings combining multiple data sources: interviews, websites, internal documents, official presentations, as well as laws and regulations in place in the two regions, in order to efficiently gather rich empirical data and avoid possible bias (Eisenhardt and Graebner, 2007). We interviewed the main actors of the two OD Systems, which resulted in 15 face-to-face semi-structured interviews (**Table 2**) that were performed in 2013 and 2014. Each interview was digitally recorded and transcribed to better support the subsequent analysis, and further follow-up interviews and questions by email were made after the first results had been achieved in order to cover new lines of thinking emerged during the research (Eisenhardt and Graebner, 2007). The aim was to have a well-defined focus on the specific constructs of interest, but keeping them flexible to reflect ideas that emerged spontaneously (e.g. Pan and Scarbrough, 1999; Lockstrom et al., 2011).

Table 2 – Interviewees of the Infomobility OD Systems of Amsterdam and of Milan

CITY	ACTOR	INTERVIEWEE ROLE	INTEVIEW DURATION
Amasterdam	City Region of Amsterdam	Policy Advisor	2h 35m
	Connection	Concession Manager	2h
	GOVI	Partner Operations Management Director	2h 20m
	GVB	Project Manager	1h 16m
	Province of North Holland	Traffic management and public transport Project Leader	46m
	openOV	Chairman	2h 6m
	REISinformatiegroep BV	General Manager	39m
Milan	AMAT	ICT Director	2h 56m
	ATM Spa	ICT Director	2h 6m
	Municipality of Milan	Mobility Department Counselor	39m
	CEFRIEL	Deputy Project Manager E015	1h 48m
	Region of Lombardy	Infrastructure and Mobility Direction	1h 20m

After a within-case analysis for drawing a picture of the systems analysed, individuating emergent themes related to the OD approach, and finally reconstructing the OD approach used in the specific settings, we conducted a cross-case analysis. We compared evidence across different cases, in order to identify divergences and convergences concerning the elements of the OD framework. We searched for distinct patterns and for plausible explanations of the observed differences, trying to discriminate between contingencies and general regularities (Eisenhardt, 1989).

By the empirical analysis, we obtained a complete picture not only of the functioning of the Infomobility OD systems in Amsterdam and Milan. It also yielded some general considerations about objectives and socio-technical requisites for adopting an OD approach in the Infomobility sector, and possible factors limiting its implementation and effectiveness, which confirmed some results emerged by our two previous research on Infomobility.

4 Thesis structure

Hereafter we provide a brief summary of the work and of the main contributions offered by the papers.

Article 1[3] contributes to the debate concerning the use of information technology for improving mobility, addressing the issue of Infomobility and its potential impact to increase the level of sustainability of mobility systems. It provides a review of the existing literature on Infomobility. It first provides a holistic definition of Infomobility that clarifies and formalizes its meaning. Then, it proposes a holistic framework as key to read the previous academic contributions. This framework encompasses four strongly interrelated elements that constitute Infomobility Systems and that have attracted the attention of most the researchers working in the Infomobility field. This paper, on one hand it aims to overcome the high level of fragmentation and heterogeneity that characterizes research in this field and to be at the base of future studies on this theme. On

[3] Forthcoming article: Arena, M., Azzone, G., Franchi, F., Malpezzi, S. (2013). Infomobility: a holistic framework for a literature review. International Journal of Critical Infrastructures - http://www.inderscience.com/info/ingeneral/forthcoming.php?jcode=ijcis

the other hand, providing an overarching picture of Infomobility Systems in terms of meaning and main elements to be considered, it could be a useful support for the implementation of future Infomobility initiatives.

Article 2[4] addresses the concept of Infomobility Quality and identifies some parameters for assessing the "Quality" of an Infomobility System. This paper first identifies different types of information managed through these systems, and then it proposes a framework of the main Infomobility Quality dimensions. This framework is thought not only as a contribution filling an important gap in the academic research on Infomobility. It could also an operational instrument for practitioners, aiming to design and evaluate the quality and potential effectiveness of the Infomobility System that they manage; therefore, it could be a useful support for the Infomobility systems improvement.

Article 3[5] finally accomplishes the final objective of this thesis, analyzing the strengths and weaknesses of the OD approach for achieving the Infomobility objectives. To this aim, we first analyse the impact of OD on the Infomobility Quality dimensions, by revising the key elements considered by previous work on OD. Then, based on these elements, we carry out a cross-case analysis of two different Infomobility systems adopting an Open Data approach in Amsterdam and Milan, and we draft some considerations on the OD potentials in supporting the transport network planning and control and in providing travelers with transport information services. Finally, after having identified pre-conditions and limits of an OD approach in the Infomobility sector, we compare it with another information management approach adopted in Milan with the same proposition of the Open Data one.

In order to fully get this last part of the thesis it worth to keep in mind the clear distinction between data and information. Starting from the Zins (2007)'s study, and particularly referring to the definition provided by Buckland (1991), Stonier (1997), we refer to data as disconnected records represented by basic, generally numeric, items resulting from a measurement or observation activity, which need to be processed for use; they are typically considered the "raw material" for information. This data can be grouped and structured in datasets, and turned into information by contextualizing, interpreting and representing them (Davies and Edwards, 2012). This paper analysing the potentials and the critical factors of adopting an OD approach in the Infomobility sector provides a very original contribution to both the Infomobility and OD streams of research. Then, it provides practitioners such as Governments and Public Transport Operators with practical knowledge about the possible opportunities and challenges of the Open Data Approach in the Infomobility field.

In conclusion, from an academic point of view, first this work fills literature gaps in the Infomobility field, addressing the Infomobility concept in terms of meaning, fundamental elements and quality requirements. Second, it contributes to the debate concerning the Open Data, investigating this approach in the specific field of Infomobility. In terms of managerial contribution, the three papers could be an instrument for

[4] Under review: Arena, M., Azzone, G., Malpezzi, S. (2014). Infomobility System Quality.
[5] Under review: Arena, M., Azzone, G., Malpezzi, S. (2014). The use of Open Data in the Infomobility sector – A case study.

Transport Systems decision and policy makers to support the development and the quality assessment of Infomobility Systems since on one hand it suggest the basic elements and the quality dimensions to consider when Infomobility Systems are implemented and managed. On the other hand, it provides practitioners with managerial recommendations useful for the implementation of Infomobility Systems, particularly but not only those based on the OD.

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ARTICLE 1

Infomobility: an holistic framework for a literature review

Marika Arena, Giovanni Azzone, Federica Franchi, Silvia Malpezzi*
Department of Management, Economics and Industrial Engineering
Politecnico di Milano,
Via Lambruschini, 4/B
20156 Milan, Italy

* **Corresponding author email:** silvia.malpezzi@polimi.it

Abstract

In recent years, Infomobility started to be considered a key instrument in relation to sustainable mobility. Infomobility has a potential to decrease environmental, social and economic transportation costs, gathering a wide range of information about mobility dynamics that can increase users' awareness and improve the mobility management. However from an academic point of view there is a high confusion about this term due to the high fragmentation and heterogeneity of the literature. To provide a possible answer to this problem, this article aims to perform a literature review of the concept of Infomobility, proposing a reference framework to go through existing contributions. The framework encompasses the four main dimensions of Infomobility: value chain, application areas, technologies and actors. Based on this review, the authors highlight the existence of overlapping areas among the elements of the framework and discuss criticalities and potentialities of Infomobility.

Keywords. Infomobility, Intelligent Transport Systems, System integration, Socio-technical system, holistic framework

1 Introduction

Infomobility is a theme increasingly debated due to its potentiality of making the mobility system more efficient and effective in meeting users' needs. It can support the mobility systems in facing the increasing challenges related to the growth of need for mobility (Wootton and Garcià-Ortiz, 1995; Xu, 2000; Piccolo and Galdi, 2006; Bazzi et al., 2008) and efficiency of transport systems (Zuylen and Weber, 2002; Wang, 2008; Sterle, 2009; Perra et al. 2009; Bazzi et al., 2011). In particular, Infomobility has been recognized as a potentially very important instrument in relation to the issue of sustainable mobility (Isola et al., 2007; da Silva et al., 2008; Paganelli and Giuli, 2009; Perra et al. 2009) defined as the "Transportation that does not endanger public health or ecosystems and meets mobility needs" (OECD, 2002). This is confirmed by studies and reports published by the European Commission documenting the contribution of the Intelligent Transport Systems (ITS), the technology at the basis of Infomobility, for reducing the negative effects of

road congestion such as environmental pollution and accidents rates (EU Commission, 2009; Giuli et al., 2011; Hidalgo and Huizenga, 2013; Nelson and Mulley, 2013), and by the increasing number of projects that have been financed over the world to support the spreading of Infomobility systems (Isola et al., 2007; Perra et al. 2009). Despite their high potential, at present, the effective implementation of these systems is still questioned (Nelson and Mulley, 2013). Today's mobile information systems do not respond adequately to operators and users information needs and they are often insufficient in solving the aforementioned problems of mobility (Paganelli and Giuli, 2009; Spanoudakis and Panou, 2009; Giuli at al., 2011). Some authors such as Paganelli and Giuli (2009) state the inability of Infomobility systems to fully satisfy the requirements in terms of real-time knowledge, multi-modality supports and customized and reliable information (Hine and Scott, 2000, Nelson and Mulley, 2013). The reason behind are ascribable not to technical problems but due to organizational and political issues (Kaparias and Bell, 2012). In particular it lies in three main factors: the high confusion among different types of available information and technologies, the large possible uses of this information, and the great number of different actors involved in the production processes of different Infomobility services (e.g. information services) (Grotenhuis et al. 2007; Tuominen and Ahlqvist, 2010; El Faouzi et al., 2011).

In academic literature the Infomobility theme has been highly debated. Nevertheless it is not properly formalized yet. The term "Infomobility" has acquired different meanings depending on the specific area of analysis (e.g. social issues, technical studies) that has been addressed. The literature on Infomobility is characterized by a high degree of fragmentation. Indeed, several studies have usually focused on specific topics in relation to certain areas of interest, such as the way in which users choose the path according to the type of information being given (Kenyon and Lyons, 2003; Yin et al. 2004; Ridwan, 2004); Infomobility services for specific user categories (e.g. elderly and disabled travellers) (Panou et al., 2007; Pastor et al., 2007; Bekiaris et al., 2007); Infomobility systems for specific applications like road accidents management (Vaa et al., 2008; Celidonio et al., 2012). Furthermore, various authors have studied Infomobility starting from different point of view and using different levels of analysis, consequently determining a high level of heterogeneity. For instance, looking at empirical studies, some researchers have analysed projects in an overall way: e.g. CityLog project (Zuccotti et al. 2011), ASK-IT European project (Pastor et al., 2007; Bekiaris et al. 2007), ARTIST (Isola et al., 2007; Piccolo and Galdi, 2006). Others have focused on specific technologies used for the implementation of Infomobility projects: e.g. Geographic Information Systems (Kotsakis et al., 2001), Internet (Lyons, 2002), Systems Security (Kulmala, 2010), Wireless Sensor Networks (Magrini et al., 2011), Vehicular Ad-Hoc Networks (Caviglione et al., 2011).

Moving from these considerations, this work purpose is providing a basis in order to solve Infomobility problems from both an academic and a managerial point of view. Indeed, we make a survey, with a twofold goal: integrates different literature contributions to the aim of solving the high level of fragmentation characterizing them; supporting Infomobility managers in better satisfying the aforementioned Infomobility requirements.

Consequently, we first formulate a holistic definition of Infomobility for clarifying and formalizing its meaning; afterwards, we propose a framework for guiding a literature review of Infomobility that facilitate

the understanding and the analysis of it. The framework relies on the idea of socio-technical systems, encompassing the key elements constituting Infomobility. From this perspective, our work doesn't deepen a particular application, but provides an overarching view on the theme of Infomobility in the field of land transportation.

The proposed framework, other than provide an overarching view of Infomobility filling a literature gap, could also support the identification of possible improvements from a systemic perspective, revealing the existence of overlapping areas in terms of objectives of different actors, activities and technologies. The model in this way could provide a useful support to policy makers in designing more effective strategies and interventions on the mobility system.

The paper is structured as follow. In Section 2, after having defined the "Infomobility" concept, we design the framework integrating the existing literary contribution on this topic, and we highlight the close relationships that characterize the technical and organizational dimensions. In Section 3, the methodology for the literature analysis is presented. In Section 4, we integrate the results of the literature review according to the framework. Finally, Sections 5 provides a discussion of the results and some reflections about possible implications for the future research.

2 Infomobility: Definition and framework

In this section, we provide a definition of Infomobility based on the state of the art of literature, and we propose a reference framework to guide the literature review.

As mentioned in the introduction, there is great confusion about the term Infomobility. The main reason of this situation could be trace back to the way in which telematics have spread over various mobility areas. The concept of "Infomobility", in fact, is the result of the application of technologies created to meet the needs of sectors other than transport (e.g. telecommunication technologies), which were subsequently used to tackle mobility problems (Moraïtis et al., 2003). Consequently, those who deal with transport and information technology use this term with different meanings by referring to specific technologies or to certain applications, depending on their specific area of interest. Different definitions of Infomobility proposed in the literature emphasize different aspects of the concept, such as the idea of services for users (Moraïtis et al., 2003; Paganelli and Giuli, 2009; Giakoumis et al., 2009; Giuli et al., 2011) or the technological component (Kotsakis et al., 2001; Sterle, 2009; De Cantis and Antoniola, 2006) (see Annex 1). Starting from the literature, we formulate an overarching definition of Infomobility, whereby it is defined as "*the set of information management systems that aim at improving the mobility systems, providing the required information to managers and users*."

Furthermore, to provide guidance to the analysis and the interpretation of different contributions, we propose a holistic framework for Infomobility that is grounded on the concept of socio-technical systems recognizing the relevance of the interplay of human actors and technology. It encompasses four elements (**Figure 2**):

- *Application fields*, that refers to the macro-areas of action that can benefit from increased information on the mobility system.

- *Actors*, that includes the different players covering different roles and involved in different relationships according to their necessities or capability to get information.
- *Value chain*, that consists in the stream of processes/activities that permit to make the information available for the final goal.
- *Technologies*, that refers to the technical systems that enable and support the functioning of the Infomobility systems, in the different application fields.

In other words, the "application fields" define WHAT Infomobility aims at improving, "actors" include WHO is involved in a specific Infomobility system, "value chain" and "technologies" describe HOW Infomobility works.

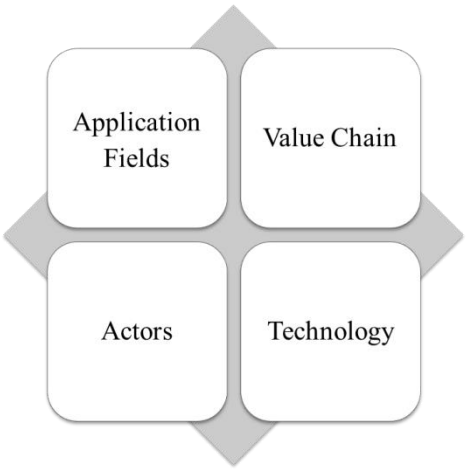

Figure 2 - A framework for Infomobility

3 Methodology

The survey was performed through an analysis of the four dimensions of the proposed framework.

To this aim we relied on the process model proposed by Mayring (2003) and we structured the analysis into three phases:

1. Material collection, that consists in the definition of the criteria used for papers search and selection;
2. Descriptive analysis, that reports the results of the review process in terms of papers found, and provides a synthesis of the coverage of the framework dimensions through the identified papers;
3. Material evaluation, that consists in an in-depth analysis performed according to the framework dimensions (see section 4).

3.1 Material Collection

The paper search was conducted on both printed materials (books or printed reports) and electronic source, through internet search engines and academic database. First we searched:

- SciVerse Scopus, a large abstract and citation database of peer reviewed that collects articles concerning scientific, technical, medical, social sciences and arts and humanities fields.
- ISI Web of Knowledge, a research platform that collects a wide variety of content on the sciences, social sciences, arts, and humanities.

Then we selected a set of journals that particularly focused on Infomobility and related topics, such as transport/mobility systems and technology:

- Journal of Transportation Systems Engineering and Information Technology
- Journal of Transport Geography
- Research in Transportation Economics
- Transportation Research: Part A
- Transportation research: Part C
- Transportation Research: Part F
- Transport Policy
- Accident Analysis and Prevention
- Technological Forecasting and Social Change
- GeoInformatica
- Mathematical and Computer Modelling
- Lecture Notes in Computer Science
- Information Fusion

The analysis of the databases and journals was carried out searching title, abstract and "keywords" for terms related to Infomobility or to the technology enabling its implementation (ITS). The terms we used are the following:

- (Infomobility) OR (info-mobility)
- ("intelligent transport systems") OR ("intelligent transportation systems")
- (sustainable mobility) OR (sustainable transport)
- (travel information) OR (traveller information)

In addition, when searching specific journals, the keywords were slightly modified depending on the field covered: within journals focused on technology we used keywords such as "transport" and "mobility"; within journals focused on transportation we used terms such as "information technology".

The relevance of a paper for the analysis was determined based on the following inclusion criteria:

- Year of publication: papers from 1994 to date we included. The 1994 is the year of foundation of ITS America, hence it can be considered a good proxy for the origins of ITS (the technology supporting Infomobility).
- Language: papers written in English and in Italian were considered; in fact, the term "Infomobility" is very common in the Italian practitioner literature.
- Topic: the review included papers that deal with the concept of Infomobility and the related technologies from a holistic perspective and technical papers focusing on specific elements of the framework. Instead, papers dealing with a particular technology or pure technical issues were excluded.

3.2 Descriptive analysis

The selection process resulted in the identification of 63 articles. In the **Table 3**, we report the list of the analyzed papers that constitute the basis on which we articulated the definition and developed the framework, and we provide a synthetic representation of the covered issues.

Table 3 - The contributions to the framework

Papers	Definition	Application Fields	Value Chain	Actors	Technology
Wootton and Garcià-Ortiz, 1995		x			x
Hall, 1996				x	
Kenninen, 1996		x			
Janelle, 1997		x			
Xu, 2000				x	x
Kotsakis et al., 2001	x	x			x
Lampignano and Tesi, 2002					x
Moraïtis et al., 2003	x				
Kauber, 2004			x	x	
Nakanishi, 2004		x			x
Naniopoulos et al., 2004			x	x	
Panou and Bekiaris, 2004			x		x
Montanari et al. 2005		x			x
Canali and Lancellotti, 2006	x				
De Cantis and Antoniola, 2006	x				
Piccolo and Galdi (2006)				x	
Brugnoli, 2007					x
Isola et al., 2007		x		x	
Panou et al., 2007		x		x	
Pastor et al., 2007		x			x
Fuchs, 2008		x			
Nykvist and Whitmatshal, 2008		x			
CEFRIEL, 2009				x	x
Giakoumis et al., 2009	x	x			
Paganelli and Giuli, 2009	x	x			
Perra et al., 2009					x
Sterle, 2009	x		x		
Spanoudakis and Panou, 2009				x	
Black, 2010		x			
Toppan et al., 2010		x			
Bazzi et al., 2011					x
Caviglione et al., 2011			x		x
Giuli et al., 2011				x	
El Faouzi et al., 2011		x			x
Magrini et al., 2011			x		x
Zuccotti et al,. 2011		x	x		
Celidonio et al., 2012		x			
Nelson and Mulley, 2013		x		x	

It is worthy of noticing that none of these study provides a comprehensive description of Infomobility (Canali and Lancellotti, 2006; Paganelli and Giuli, 2009), generally focusing on more specific aspects. In particular, many papers concern the Intelligent Transport Systems and operation areas where they are

applied. Though these studies do not mention the term "Infomobility" explicitly, they provide a relevant piece of the knowledge about different functionalities, actors and processes enabling the development of Infomobility systems.

4 Infomobility: reconstructing a comprehensive concept

As follows, we report the results of the literature analysis that is articulated based on the four elements of the proposed framework.

4.1 Application fields

The first dimension of analysis refers to the application fields that are the macro-areas of action that can benefit from increased information on the mobility system.

Several authors have dealt with Infomobility application fields, presenting the results of empirical projects and analysing strengths and weaknesses of different applications (e.g. Toppan et al., 2010; Zuccotti et al., 2011; Celidonio et al., 2012) or even proposing taxonomies (e.g. Isola et al., 2007). Nevertheless a shared classification of Infomobility application fields is still missing and various models present gaps and overlapping areas (see Annex 2). Depending on the specific area of interest, researchers use different points of view, terminologies and levels of detail. For example, dealing with the "information services" Kotsakis, Caignault, Woehler and Ketselidis (2001) refer to the generic application field of "information for the mobility assistance", whereas Paganelli and Giuli (2009) define more specifically the application fields of "navigation", "route planning", "extraordinary events alert", etc. Different authors have described even the same case studies in different terms (e.g. ASK-IT project) using different labels and covering different application fields (e.g. Pastor et al., 2007; Panou et al., 2007; Giakoumis et a., 2009).

A further element of complexity is determined by the various roles of telecommunications in relationship to the dynamics of traffic flows, whereby researchers have ascribed to the term "Infomobility" also application fields very far from the definition embraced in this work. For instance, some scholars have included the potential to change physical travel characteristics (e.g. frequency or length) through activities such as teleworking under Infomobility application fields (Janelle, 1997; Nykvist and Whitmarsh, 2008; Fuchs, 2008).

In this context, an attempt to provide a taxonomy of different application fields can be found in the ITS literature. Researchers in this field often rely on the IVHS America model, that classifies different technologies according their areas of use (Wootton and Garcià-Ortiz, 1995; Black, 2010), or adopt some modified versions. For instance, Kenninen (1996), and El Faouzi, Leung and Kurian (2011) move from the IVHS model and change the level of analysis, identifying and including some application areas that include or are included in different systems of the former.

In the same stream of reference, Montanari, Zara and Gragnani (2005) outline a functional classification of ITS based on a model proposed by the European Commission; Nakanishi (2004) reports the framework proposed by the Federal Highway Administration, that includes 15 program areas of ITS; Nelson and Mulley (2013) report the current National Intelligent Transport Systems (ITS) Strategy for Australia (ITS Australia, 2010) that proposed a framework consisting of 8 priority intelligent transport solutions, and the EC-ITS

Roadmap (EC-ITS, 2007) that identifies 5 core ITS applications. Still these works present a high level of fragmentation and heterogeneity, covering some areas and overlooking other areas.

Based on these considerations, we integrate different schemes found in literature and we propose a classification of Infomobility application fields, centred on their purpose – i.e. WHAT Infomobility aims at improving (see also Brugnoli, 2007). As shown in **Table 4**, we schematize the "application fields" into five main areas, and, for each application field, we provide a list of the specific areas to which Infomobility can be applied.

Table 4 - Application Fields

Application Fields	**Specific areas of improvement**
Fleet Management	- Transport management people • Personalized services • Intermediate services (e.g. Car sharing) • Community services - Freight management
Traffic Management	- Individual urban mobility management • Smart traffic light • Ltz (limited traffic zone) management • Parking lots managment - Road infrastructure management - Modal transport integration - Park&ride services - Economic sanctions management - Incidents data statistic management
Mobility Payments	- Parking payment - Road pricing - Payment service (rail, public and individual transport) - Integrated fares
Safety and Security	- Advanced vehicle control - Emergency management • Vehicle tracking and telemonitoring • Integrated solution for vehicle security
Information service	- Geographical location and navigation - Traffic report and forecasting - Routing and travel time for public and private transport - Weather information - Point of interest and other tourist information - Route fare information - Public transport information - Transport connection information - Extraordinary events information - Expected event information - Parking information

Obviously, the same type of information can be used for different purposes, in various application fields. For instance, data on public transport used for the "fleet management" could also be provided to travellers in order to facilitate private mobility – "information services" (De Cantis and Antoniola, 2006). Moreover, the overall goals of different application fields could be related to one another, as shown by **Figure 3**. The arrow indicates that thanks to Infomobility improvement in one application field may determine improvement in

another application field. For instance, information service can contribute to the improvement of Safety and Security, Fleet management and Traffic management; in turn Fleet management can contribute to Traffic management and Safety and security, and Traffic management can contribute to the improvement of Safety and security.

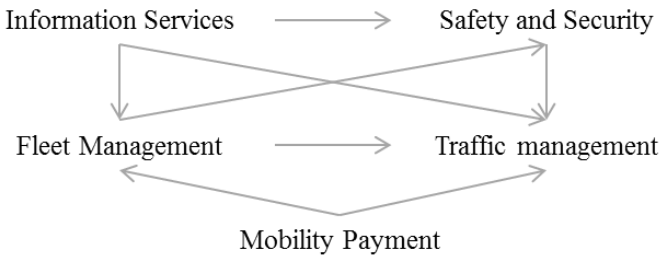

Figure 3 - Application fields mutual effects

The application fields guide the implementation of a specific Infomobility system; therefore they are central in relationship to how the other three elements of the framework could be configured.

4.2 Value chain

The second dimension of analysis is the value chain that consists in the stream of activities and processes that permit to make the information available for the final goal.

Compared to the other elements of the framework, relatively few contributions have addressed the issue of the value chain, and always in a fragmented way. In particular, few papers outline the set of activities that ensure the flow of information for transport systems management and for the information delivery (Naniopoulos et al., 2004; Sterle, 2009). Other authors address activities and process related to the implementation and operation of specific technologies (Magrini et al., 2011; Caviglione et al., 2011; Zuccotti et al., 2011).

More holistic framework are proposed by Kauber (2004) and the ISO. In particular, Kauber (2004) addresses the problem of the value chain in a more holistic way, defining the Infomobility flow of activities by referring to the actors involved in the process of implementing a service for the user (**Figure 4**).

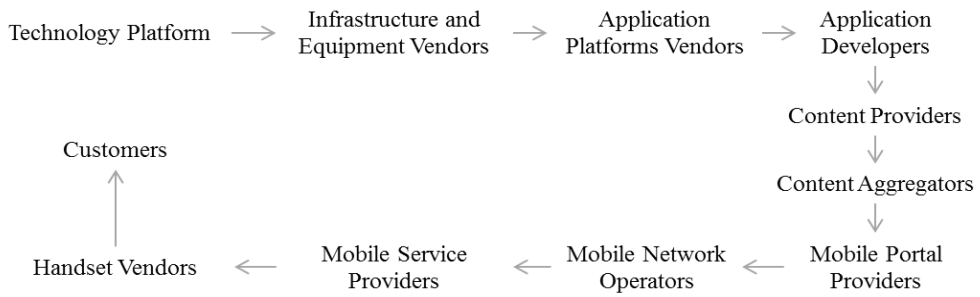

Figure 4 - The mCommerce Value Chain. Source: (Kauber, 2004)

Finally, the Organization of Standardization (ISO) refers to a five-step process, that includes data acquisition, data processing, data communication, information distribution and information utilization (Panou and Bekiaris, 2004).

Since the aim of our work is to integrate the existing contributions in order to provide an overarching description of the processes required for the functioning of an Infomobility system, we represent the value chain articulated into four macro-phases, as shown in the **Figure 5**. First, data are collected through different systems and technologies; since sources of information are diverse, data are often very heterogeneous and need to be further elaborated to make the information available for its final use. Hence data are elaborated to render them homogenous and integrated in dedicated Data base and information platforms. Afterwards, the information can be provided to operators for being used in relationship to different application fields.

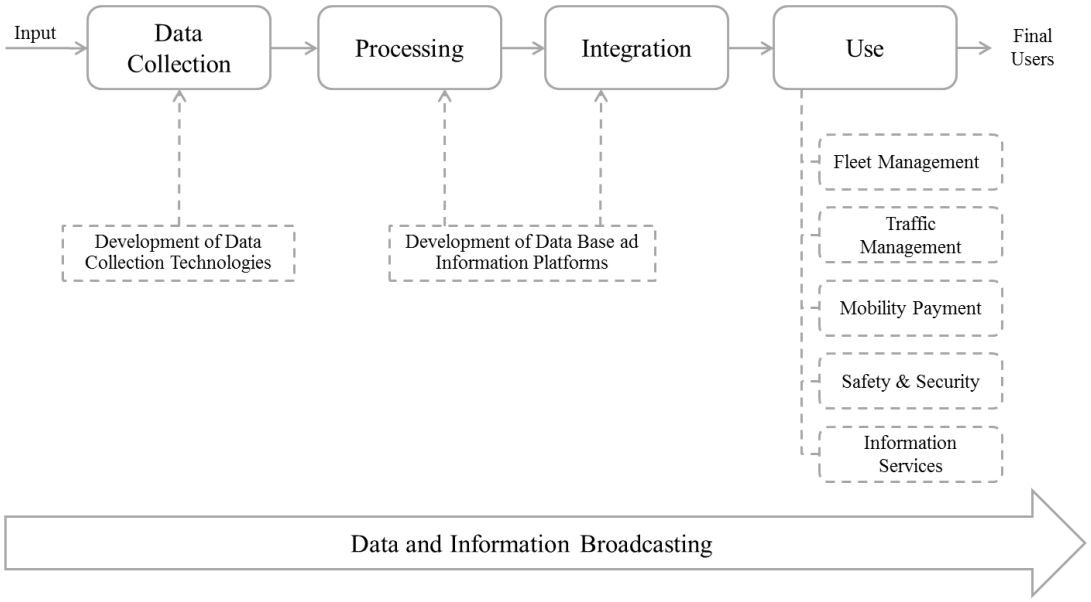

Figure 5 - Value chain

4.3 Actors

The third element of the framework refers to the actors, which include the broad range of stakeholders that play a role (active or passive) in relationship to the Infomobility system. Once again, this element has been addressed in a very heterogeneous way by different authors, depending on their specific focus.

Some authors analyse the providers' side, offering a schema identifying some main type of actors who enable the implementation of a Infomobility system such as operators, content providers, billing agencies, service providers, vehicle and component manufacturers, etc. (Kauber, 2004; Isola et al, 2007; Nelson and Mulley, 2013). Other authors analyse the user's side, referring to those subjects that exploit Infomobility for different purposes (Naniopoulos et al., 2004). Works in this stream of references generally focus on specific categories of users, such as drivers (Hall, 1996; Spanoudakis and Panou, 2009), mobility impaired people (Panou et al., 2007) or institutional organization (Xu, 2000). Even at this level of analysis, some differences emerge. For instance Hall (1996) clusters drivers based on the specific information needs (static, dynamic, etc. information); Spanoudakis and Panou (2009) group based on their profiles (tourists, commuters, businessmen abroad, pleasure travellers at their own city and emergency transport), in order to identify the actual requirements to develop useful services in an efficient way. Finally, authors such as Piccolo and Galdi (2006) analyse actors on the basis of their role in the value chain and develop broader categories (providers, operators, users, etc.).

Based on the prior works, we propose an overall taxonomy of Infomobility actors, in order to provide an overarching view of the groups of stakeholders to be considered in the development of an Infomobility system (**Table 5**). At a first level of analysis, we distinguish three macro-categories: Consumer, Business and Public actors. At a second level of analysis, different typologies of actors are further detailed (Giuli et al. 2001).

Table 5 - Actors

Consumer	Private vehicle user
	Public transport user
Business	Data collection/elaboration technologies supplyer
	Mobile device (e.g. smartphone) supplyer
	Private company managing public transport systems
	Vehicle rental company
	Taxi society
	Infrastructure management society
	Exhibition organizers / extraordinary events society
	Radio, TV, internet administrator
	Telephone operators
	Weather stations
	Insurance companies
	Freight companies
Public	Public Administration
	Public body
	Public-private company

The customer category includes the final users of an Infomobility system. Business actors include firms operating in transport, communication, IT and other correlated sectors. They can contribute to fuel the informative system related to road and rail networks or simply exploit it in order to improve their own activities (CEFRIEL et al., 2009). Public actors include the Public Administration, public bodies (e.g. Police) and public-private companies. They have a key role in the management of the mobility system. They can appoint different private companies to manage various mobility areas (roads, parking lots, public transport, etc.) or directly act on the system collaborating with them, in order to provide people with effective services. The involvement of public actors derives from the public utilities features of Infomobility and from the consequential need to integrate payment services with frees ones (Xu, 2000; Naniopoulos et al. 2004).

According to the specific application field, the actors can carry out different activities along the value chain and can be linked to others through different relationships depending on the need of gathering resources, skills and technologies. For instance, consumers are usually considered both “users and source of information”, since, for instance they can pinpoint emergencies and service malfunctioning (Nelson and Mulley, 2013).

4.4 Technologies

The last element of the framework refers to technologies supporting Infomobility. The literature dealing with this issue is rich of papers that can be broadly categorized into three typologies.

First, there are holistic papers that discuss, at a general level, ITS functions (e.g. Wootton and Garcià-Ortiz, 1995; Panou and Bekiaris, 2004; Montanari et al., 2005) and processes (Panou and Bekiaris, 2004); we have already introduced these papers in the beginning of Section 4. Second, there are papers that provide a technical overview of clusters of technologies supporting Infomobility. They tackle, for instance, devices (e.g. smart phone), operating systems (e.g. Windows Mobile OS), programming systems (e.g. Java development) and networking technologies (e.g. GPRS/UMTS), or the underlying technologies (satellites, one-way and two-way communication systems, data collection systems, terminal devices, etc.) (Xu, 2000; Pastor et al., 2007). Third, there are technical papers that describe in details specific technologies (e.g. Perra et al., 2009; Magrini et al, 2011; Caviglione et al., 2011; Bazzi et al., 2011). These works go beyond the objective of this paper, because they address in detail technical issues.

Based on the literature analysis, we provide an operational view of technologies supporting Infomobility. To this aim, different technologies are grouped in four macro-categories corresponding to various steps of the information process (from the data collection to the service supply) (Panou and Bekiaris, 2004). As shown in the **Figure 6**, such categorization allows mapping the available technologies for each stage of the process and identifying those that are most coherent with the goals of the system and the environment where it is being developed (Kotsakis et al., 2001).

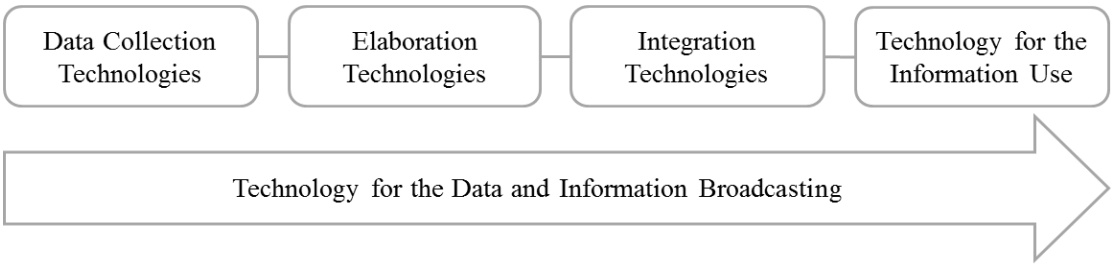

Figure 6 - Technologies

Data collection technologies are at the bottom of information chain. The choice of these technologies which constitute the monitoring systems can be performed by taking in account intended uses of users. As underlined by the Ministero dei Lavori Pubblici (2001) measurement technologies can be classified based on the characteristics of the specific area of analysis, which include:

- Spatial extension of the area under observation (urban and extra-urban area, etc.) and of the road network (intersection and groups of intersection, etc.);
- Temporal extension (reference period, investigation timing, measure frequency, etc.);
- Monitoring goals;
- Type of requested data;
- Pros and cons of technologies;
- Budget and available instrumentation.

Technologies for both data elaborating and data integrating mainly include data translation and homogenization software and dedicated database to archive them. Data deriving from different sources have to be integrated, filtered and processed to be used by an Infomobility system (Lampignano and Tesi, 2002;

Brugnoli, 2007). Technologies for data and information transmission comprise network infrastructures, transfer supports and communication protocols which allow data and information transmission between different technologies belonging to different operators. It is worthy of noticing that the technology choice related to the data transmission toward processing centres depends on the type of sensors used in the previous step and on their position. For instance, if infrastructural sensors are uses, the connection will be set up through a physical link (wire-line), while in the case of non-infrastructural sensors, the choice depends on the coverage area, the bandwidth and on the required transmission frequency (Lampignano and Tesi, 2002).

The way a user accesses the information depends on the type of these information and on the characteristic of the offered service. Most of the Infomobility usage technologies are portable devices which use standards and systems like GSM, WAP, GPS, etc. Among them the most commonly used are notebook and netbook, palms, smartphones, and mobile phones. Other technologies, which are installed on vehicles, on infrastructures or which are personal devices that provide information about mobility to the final users, are cycling messaging panels, television (also digital) and radio, teletext, audiotext, etc. (CEFRIEL, 2009).

To the aim of covering all the possible technologies useful in Infomobility systems, beyond the technologies we have just listed, there are some others, located in different steps of the value chain, which can improve the mobility level because they permit a more efficient management of activities and services linked with it. This work doesn't pretend to provide an exhaustive list of them, but among the most common devices we report:

- Weather sensors and facilities for measuring pollution levels (data collection technologies);
- Electronic payment systems for the road and area pricing and for the parking lots managing (data collection and usage technologies)
- Systems for vehicles control and assistance (data collection and usage technologies).

5 Discussion and conclusion

This paper contributes to the debate concerning the use of information technology for improving mobility, addressing the issue of Infomobility and its potential contribution to increase the level of sustainability of mobility systems.

From an academic perspective, this article provides a review of the existing literature on Infomobility in the attempt to overcome the high level of fragmentation and heterogeneity that characterizes research in this field. To this scope, it proposes an overarching definition of Infomobility, and a key to read the current literature going beyond its high level of fragmentation. The paper proposes a holistic framework encompassing four constituting elements of Infomobility that are strongly interrelated, and articulates the literature review based on these elements: application fields, value chain, actors and technologies.

Based on the literature analysis is possible to drawn some general managerial conclusion on Infomobility. First of all, it emerges the necessity to align the characteristics of Infomobility systems to the specific features of the context where they are developed (Spanoudakis and Panou, 2009). In order to develop a good Infomobility system, given the ample potential offered by technical innovation, it's necessary to study the technologies available for each stage of the development and identify the most coherent with the system goal

and the development context. The importance of such consistency is confirmed by some authors such as Kotsakis, Caignault, Woehler and Ketselidis (2001) who underline the importance of knowing what technical solutions are available in order to find the best one for the specific implementing purpose. Furthermore, the reciprocal influences and the blurred boundaries that characterize different goals and application fields are reflected in operational difficulties in the management of Infomobility systems. In particular, application fields, which are at the basis of how the other elements can be configured, are characterized by relevant overlapping and mutual relationships with each other, which is reflected in different Infomobility configurations. These circumstances make this topic complex and articulated, and they highlight the importance of properly defining the linking between different services and integrating data that are often provided by different actors with different purposes (Paganelli and Giuli, 2009).

This challenge and the potential benefits deriving from the development of a more holistic approach to the problem emerge as key issues in the literature. On one hand this idea is coherent with the notion of 'integrated transport'. It is a term widely used in transport research papers and government publications (e.g. in the UK the Department for Transport published a consultation document in1998, entitled *The government's consultation on developing an integrated transport policy: a report*) and typically refers to the necessity of integrating the different modes of transport (public and private), and land-use policy with transport policies, for increasing the level of sustainability from an economic, social and environmental point of view (O'Sullivan et al. 2004; Santos et al., 2010). On the other hand authors such as Hine and Scott (2000) and Kauber (2004) strongly emphasizes the necessity of cooperation among those who have access to data, and those who offers information or mobility management services, in order to provide users with a service consistent with their requirements. Integration of transport is crucial for successful sustainable transport policy, and to this aim information must be comprehensive, real-time and fully integrated, and different institutions have to cooperate effectively (Santos et al., 2010).

The relevance given to the issue of integration suggests the opportunity to develop System Integration Activities also not strictly connected to the treatment and usage of information, but that aim to make easier and more effective the coordination of different operators. For instance, the coexistence of public and private subjects creates a remarkable complexity due to the necessity of integrating two different worlds in terms of sets of values, management approaches and decision making criteria (Kenninen, 1996; Kauber, 2004). System Integrators could facilitate the interaction among different actors by defining overarching solutions, promoting the sector activity (Xu, 2000), and aligning diversified data coming from heterogeneous sources and technologies (Lampignano and Tesi, 2002).

Finally we address possible paths for future research. Future works could exploit the practical utility of the proposed framework in assessing and improving the effectiveness of Infomobility systems for sustainable mobility, that has been often questioned (Paganelli and Giuli, 2009). To the aim to go along this direction, first of all it could be interesting finding out and investigating the existing Infomobility archetypes, and positioning them within the framework. The research could analyse the implementation of Infomobility systems through case studies, deeply investigating from an empirical point of view the declination of the different elements of the framework in relation to the specific context in which the Infomobility systems are

implemented. Then, it could highlight the real criticalities and potentialities of them, also verifying the real need for an information and services integration, and also for System Integrators coordinating the amount of Infomobility actors.

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Annex 1

Service	Paganelli and Giuli, 2009	"Information delivery for user mobility support. At present most commercially available Infomobility services are conceived as static information delivery targeted to drivers or focused on a single transportation mode"
	Moraïtis et al., 2003	"The new term "Infomobility" services refers to services that allow the mobile citizen to have seamless access to, and interaction with, personalised - location dependent - rich content multimedia information"
	Giakoumis, 2009	"Info-mobility services are usually consumed by systems that offer users on the move (and not only) information regarding Points of Interest, how to reach them etc."
	Giuli et al, 2011	"With the term "Infomobility" we refer to the broad range of information services which provide users with information and transactions required for supporting mobility of persons and goods - in private as well as public transport - in Intelligent Transport Systems (ITS)."
Technological Component	Kotsakis et al., 2001	"Infomobility is a term used to describe the set of technologies and the applications that allow the "user on the move" to access positioning and geographic information anytime, anywhere"
	Sterle, 2009	"Infomobility indicates the set of technologies and procedures which provide the required information to managers and customers in order to obtain an efficient mobility of private and public transport"
	De Cantis and Antoniola, 2006	The term 'Infomobility' stands for the set of systems (hw / sw platforms and services) constituted by mobile devices, elements distributed throughout the territory and CPUs, aiming at improving efficiency, quality, safety and the mobility impact.

Annex 2

Articles	**Application fields**
Kotsakis et al., 2001	- Security operation management - Rescue activity supervision - Managing crisis situations - Travel assistance - Tourist guide - Traffic assistance - Personalized tracking
Paganelli and Giuli, 2009	- Navigation - Route planning and re-planning - Geo-referenced content delivery (e.g. Pois) - Alerts about critical events (es. Incidents) - Payment services and facilities booking (e.g. Parking and seat reservation).
Moraïtis et al., 2003	- Suggest optimal transportation solutions, tourist events and nearby attractions - Monitor the users route and automatically provide relevant information about events during the journey (i.e. Info on traffic jams)
Spanoudakis and Panou, 2009	- Location-based, intermodal transport information (static and dynamic) - Mapping - Routing - Navigation - Plan the journey from origin, i.e. Home (pre-trip and en-trip). - Bookmark a planned journey. - Push events that may change the details of the active journey.
Sterle, 2009	- Planning the routing of the vehicles and their scheduling; - Localization of the vehicles; - Automation of the guide and of the handling; - Tracking of the freights; - Exchange of the information among the different urban logistic actors; - Management of the logistic flows deriving from the on-line market; - Traffic light and electronic regulation; - Support to the economic measures, as road and park pricing; - Optmization of the parking for loading/unloading operations.
Naniopoulos et al., 2004	- Traffic information management - Traffic management market - Multi-modal travel management and traveler information (travel-guide focus on it) - Commercial vehicles operations systems. - Advancedvehicle control and safety systems (called advanced driver assistance systems – adas in europe).
Giakoumis, 2009	- Search for points of interest - Multimodal route planning - Social events - E-learning - E-working - Domotics management - Health and emergency - Mapping

ARTICLE 2

Review on the Infomobility Quality - a new framework

Marika Arena, Giovanni Azzone, Silvia Malpezzi*
Department of Management, Economics and Industrial Engineering
Politecnico di Milano,
Via Lambruschini, 4/B
20156 Milan, Italy

* **Corresponding author email:** silvia.malpezzi@polimi.it

Abstract

Infomobility systems are spreading across the world attracting the attention of policy-makers and practitioners from a variety of industries. However, several studies have asserted that they not always are effective in improving transport systems, since they do not convey the required information to mobility managers and customers. Based on existing academic contributions in the Transport Information Quality and Information Quality literature, this paper addresses the concept of Infomobility Quality, proposing a comprehensive framework that encompasses the main quality dimensions to be considered in the design and assessment of the quality and potential effectiveness of the Infomobility System. This paper aims to fill a literature gap and to provide transport system decision-makers with an instrument to develop and improve Infomobility Systems.

Keywords: Infomobility, Transport Information Quality, Intelligent Transport Systems

1 Introduction

In recent years, information and how it is managed have become critical issues for most organizations operating in both the public and private sectors, including transport services (e.g. Andersen et al.,1994; Lillrank, 2003; Paganelli and Giuli, 2009). Information is critical for managers in the transport system to make decisions about how to configure and run the network, plan and control operating activities, and monitor the system's performance (e.g. Vlahos et al., 1994; Horan, 2003; Peng et al., 2011). Information is also valuable for travelers when planning their trip (e.g. Giannopoulos, 2004; Lee et al., 2010; Giannoutakis and Li, 2012) and, at the same time, it can play a significant role in influencing their behavior and habits. In this way, it contributes to a more efficient use of the transport systems (e.g. Chorus et al., 2006; Natvig and Vennesland, 2010; Chatterjee, 1999). In this perspective, information can be considered as both a resource for supporting mobility system management and an integrative part of the mobility service itself (e.g. Zuylen and Weber, 2002; Sterle, 2009; Bazzi et al., 2011).

The term Infomobility encompasses the set of information management systems that aim at improving mobility systems by providing required information to transportation managers and travelers (Arena et al., 2013). Infomobility is based upon the use of Intelligent Transport Systems (ITS), technologies that enable the collection, processing, storing and distribution of information on mobility systems and its criticalities (e.g. Montanari et al., 2005; Bisdikian et al., 2009; Bin et al., 2013). Infomobility has the potential to improve the mobility system, in terms of its effectiveness, efficiency and sustainability (e.g. Li et al., 2008; Wang, 1998; Kolosz et al., 2013) contributing towards reducing traffic congestion levels and travel times, and increasing travel safety (Nakanishi, 2004; Black, 2010; Chatterjee, 1999). These systems have attracted the attention of policy-makers and practitioners from a variety of industries (automotive, telephony, transport, etc.) (Jin, 2003; Smith and Venkatanarayana, 2005; Bin et al., 2013), as demonstrated by many projects in this area (Li et al., 2008; Leviäkangas, 2011). Alongside this, the number of reports published by governmental and non-governmental organizations defining standards and guidelines to implement such systems, especially within an urban context, has also increased (Giannopoulos, 2004; European Commission, 2013). However, the status of several existing projects also emphasizes a certain criticism in connection with Infomobility systems and the need to improve their effectiveness (e.g. Chatterjee, 1999; Popovic and Habjan, 2012; Kulmala et al., 2013). Despite the rapid technological innovation and the increased efforts to develop Infomobility services, several empirical studies have highlighted that these systems are inadequate in enabling a sustainable transport development (Paganelli and Giuli, 2009; Giuli et al., 2011; Bin et al., 2013). Nevertheless, the theme of the assessment of the Infomobility Systems in achieving their goals, is still unexplored. Given that directly measuring the effects of an Infomobility system is hardly feasible due to the existence of a time lag between the conception, implementation and results of an Infomobility initiative, and the complexity of the transportation sector where a multiplicity of factors can influence these results (e.g. Du and Nicholson, 1997; Golob, 2011; Wang, 2010), this paper focuses on the so called Infomobility Quality. Similarly to Zahedi, Ngai, Gelenbe, Mylaraswamy and Srivastava (2008), we define it as the capability of an Infomobility system to provide mobility managers and travelers with information that they require for their activities and we consider it as a proxy of their effectiveness in solving the actual mobility problems. Previous research have already highlighted how the lack of proper information management and regulations, and of a narrow focus on the type and quality of information supplied can hamper the improvement of transportation managers and travelers' activities (e.g. Logie, 1993; Wydro, 2011a; Stvilia et al., 2007). However, up until now a deep and structured investigation of the capability of these systems to provide managers and customers with "right" and high quality information is still missing. The objective of this paper is to address the theme of Infomobility Quality by providing a comprehensive framework that can be used to analyze it. This work, based on a review of academic contributions on Transport Information Quality and Information Quality literature aims to identify the characteristics of information determining the capability of Infomobility systems to achieve their objective of providing transportation managers and users with the information that they need (Popovic and Habjan, 2012).

The paper is structured as follows: Section 2 presents the methodology adopted to develop the framework; Section 3 presents the results of the literature review; Section 4 describe the Infomobility Quality framework; Section 5 draws some considerations on the new framework and highlights the contribution of this work to the practitioner and academic world, and possible future development of research in this field.

2 Methodology

In order to get a broad overview of the previous studies dealing with the theme of the Infomobility Quality and to propose a structured framework of the main quality dimensions to consider for assessing the capability of an Infomobility System in providing transportation managers and travellers with the information that they require, according the recommendations of Webster and Watson (2002), we accomplished a literature review following five main steps:

1. Keyword search using Google Scholar and Scopus and (ISI) Web of Knowledge databases
2. Review of relevant journals
3. Review of relevant conferences
4. Review of references for publications identified in steps 1, 2 and 3 (going backwards)
5. Identification of publications citing the key publications (going forwards)

This process started by focusing specifically on contributions dealing with the Transport Information Quality theme that were published in journals and at conferences in the field of Transport and Intelligent Transport Systems (e.g. Transport Policy, IET - Intelligent Transport Systems, World Congress on Intelligent Transport Systems). To reach our scope, we used "keywords" connected to this area of investigation: 'Information Quality AND Transport*', 'Intelligent Transport* System* AND Information management', 'Intelligent Transport* System* AND Information Quality' and 'information requirement* AND Transport*'.

The review was then extended beyond the specific field of Transport in order to gain a deeper understanding of the more general concept of Information Quality. To this extent, we selected papers from journals and conferences in the field of Management and Computer Science (e.g. Academy of Management Review, Journal of Information Science, Communications of the ACM), based upon the following keywords: 'Information Quality Dimension*', 'Info* AND Manage* AND Quality*' and 'Information management AND quality'.

The purpose of this process was to identify theories and concepts applicable to the research field of Infomobility Quality. We considered the year of publication as a criterion for a paper's inclusion or exclusion. In the field of Transportation, papers published before 1990 were excluded, being too far removed from current information requirements and technological capability. Secondly, language was a further criterion of inclusion, and only papers from international journals and conferences written in English were included. Thirdly, we selected papers from specific research area that are Transportation, Urban, Information, Communication, Computer, Engineering, Social, Public Administration and Governmental Science. Due to the extent of the subject matter and its complementarity with a wide body of research streams, rather than conducting an exhaustive literature review, which would have been impractical and of little additional value, we specifically focused the research on the identification of dimensions of analysis

and attributes for assessing this kind of information systems (Bititci et al, 2012; Stadler et al, 2014). Indeed, first based on papers titles or abstract, we selected papers close with the theme under investigation (Gubán and Kása, 2013) and excluded papers that focused on particular types of information (e.g. marketing, management control systems), or were tailored to sectors other than passenger transportation (e.g. supply chain studies). 64 papers, whose 35 related to the Transportation field, have been found and read in depth. Our publication search reached saturation when it was sufficiently extensive to identify the main quality dimensions and attributes required to assess the aspect of Infomobility Quality and new publications did not seem to add any new theory or concept (Webster and Watson, 2002). We selected 33 articles that provide taxonomy of quality dimensions and attributes, with 20 papers focusing on Information Quality dimensions and only 13 papers dealing specifically with Transport Information Quality. In conclusion, the outcome was a relatively low number of papers in relevant journals and conferences proceedings dealing with the Transport Information Quality theme, and in most cases they show few information quality attributes. Indeed, even though the potentials of Infomobility and their questioned effectiveness of achieving their goals, few works mentioned or studied the quality attributes and dimensions that determine the capability of Infomobility systems to fulfil the transport information users' requirements. However, the literature analysis seem to reveal that there is a growing attention towards this topic.

3 Literature review on Information Quality

This section provides an overview of the concepts related to the Infomobility Quality that we found in the existing academic works on Information Quality within and beyond the Transportation field. To this aim, we first define the types of information implicated in connection with Infomobility Systems, since this information is eventually the object of the assessment.

The types of information emerging from studies about Infomobility can vary in concept. Some studies deal specifically with information for mobility system operators (public administration, public transport operators, policy-makers, etc.) (e.g. Smith and Venkatanarayana, 2005; Bin et al., 2013), other studies focus on information for mobility system users (e.g. Logie, 1993; Grotenhuis et al., 2007). However, most authors take an overarching look at information, where information is considered as a mean to exploit the existing transport infrastructure better, by using its potential to optimize traffic operations and provide new and improved travel information services (e.g. Paganelli and Giuli, 2009; Stathopoulos and Tsekeris, 2009; Li et al., 2008). Information is typically about time (departure, arrival, trip duration etc.), space (starting point, destination, stopover, direction, etc.) and transport systems (fare rates, operators, etc.) (Beul-Leusmann et al., 2013). Chorus, Molin and Van Wee (2006) make a distinction between "core" information on transport systems (such as travel times and cost of alternatives) and "soft" information, which involves other aspects relating to the quality of mobility systems (e.g. convenience and comfort). Some other authors also include information on weather conditions or other services (hotels, museum, etc.) that can have an influence on transport system use (e.g. Yamamoto et al., 2000; Smith and Venkatanarayana, 2005). The aspects most widely used to categorize this information are: the information upgrade mode (statistical/historical or real time information - e.g. Grotenhuis et al., 2007; Wydro, 2011a), the time validity (static, dynamic - e.g.

Paganelli and Giuli, 2009; Natvig and Vennesland, 2010), the customization level (mass or personal information – e.g. Chorus et al., 2006; Stathopoulos and Tsekeris, 2009), the trip phase that it supports (pre-trip, wayside and on-board information – e.g. Grotenhuis et al., 2007; Beul-Leusmann et al., 2013), the transport means which it is about (ferry, train, bus, road, parking – e.g. Paganelli and Giuli, 2009; Natvig and Vennesland, 2010), the coverage level (single-mode or multi-modal transport information – e.g. Chorus et al., 2006; Stathopoulos and Tsekeris, 2009), and the uncertainty level of the event that it is about (perfect information and imperfect information – e.g. Stathopoulos and Tsekeris, 2009).

The high quality of this information is essential for both managers and users to avoid taking wrong or late decisions (e.g. Popovic and Habjan, 2012; Beul-Leusmann et al., 2013). Nevertheless, the concept of Transport Information Quality is hardly ever defined by the authors in the transportation area (e.g. Caulfield and O'Mahony, 2007; De Borger et al., 2012). Transport Information literature often connects this concept to that of information of value for users (e.g. Stathopoulos and Tsekeris, 2009; Leviäkangas, 2011), but it provides neither a unique and shared definition of the concept, nor a common set of attributes and dimensions for deploying and evaluating the quality of information (Herrala, 2007). Indeed, only few works mention different information quality attributes, often without specifying the precise meaning they are using. **Table 6** outlines information quality attributes that are taken into account most frequently in literature.

Table 6- Transport Information Quality Attributes

	Timeliness	Accuracy	Accessibility	Reliability	Completeness	Correctness	Usefulness
Logie, 1993 [36]	x	x	x				x
Yamamoto et al., 2000 [46]	x	x		x			x
Chorus, 2006 [10]	x		x	x			
Herrela, 2007 [49]	x	x	x	x	x		x
Zhang and Zhang, 2008 [50]	x	x				x	
Li et al., 2008 [20]	x	x					
Paganelli and Giuli, 2009 [3]	x		x	x	x	x	
Leviäkangas, 2011 [27]	x	x	x	x	x		
Wydro, 2011 [37]			x	x	x	x	x
De Borger and Fosgerau, 2012 [48]		x	x				
Du et al., 2012 [51]	x	x					
Popovic and Habjan, 2012 [29]	x	x	x			x	
Bin et al., 2013 [19]	x	x					

Several other attributes appear in these studies, such as precision, redundancy and currency, but their meanings can be blurred, or they can partially overlap with those in **Table 6**. Interesting is the Leviäkangas's (2011) work that not only gives a connotation to the attributes, but also specifies the relationships among them all. For instance, he describes timeliness as how up-to-date information is, and links it to relevance of information, since information given too late becomes worthless, or even harmful. Academic works pay a particular attention to the topic of accessibility, in terms of effective presentation of information and channels used to pass it on to users (e.g. Smith and Venkatanarayana, 2005; Chorus et al., 2006; Wydro, 2011a). However, the literature on Transport Information and, in particular, Transport Information Quality, still does not provide an overarching and structured framework of the dimensions and attributes to assess information provided by Infomobility systems. Consequently, we extended the research across the literature on Information Quality. Over the past two decades, research into Information Quality has attracted much

attention from scholars working in Computer Science and Management (e.g. Beul-Leusmann et al., 2013; Lillrank, 2003). In this field, multiple definitions of Information Quality have been proposed (e.g. Reeves and Bednar, 1994; Strong et al, 1997). They derive from different perspectives used to deal with this concept. For instance, the "internal" and "external" perspectives respectively emphasize the information attributes that are not application specific (such as the information accuracy), and the quality concepts that are strictly related with the specific use of information (Reeves and Bednar, 1994). Four different definitions has been frequently taken up by other authors, such as Reeves and Bednar (1994) and Kahn, Strong, and Wang (2002), which are:

- Excellence, which implies that quality is "both absolute and universally recognizable, a mark of uncompromising standards and high achievement" (Garvin, 1984).
- Value, which implies both internal conformity to specifications and fitness for customer requirements.
- Conformity to specifications, emphasizing that the customers' perspective is "the driving force" behind the information provided.
- Meeting or exceeding consumer expectations, which includes elements defined by managers and researchers (such as courtesy and helpfulness) that are considered important for customers.

These works highlight that Information Quality can either be "intrinsic", independent on the context in which data and information are produced and used – the Reeves and Bednar' s (Reeves and Bednar, 1994) Excellence, or "extrinsic", with no possibility of data and information being assessed independently by the consumers of them (e.g. Strong et al., 1997; Madnick et al., 2009). This second concept, highlighted by several authors (e.g. Markus and Robey, 1983; Tayi and Ballou, 1998; Helfert and Ge, 2006), is based upon a consumer perspective, and has been broadly described in terms of fitness for use (e.g. Tayi and Ballou, 1998; Strong et al., 1997; Shanks and Darke,1998; Helfert and Ge, 2006). The consumer perspective approach is a major breakthrough in the wider literature on quality and embodies a broader meaning other than that of the conventional intrinsic view. Indeed, it implies that the importance of every "intrinsic" Information Quality attribute depends upon the potential use of this information (Wydro, 2011b). For instance, Wand and Wang (Wand and Wang, 1996) highlight that the importance of information timeliness, interpreted as "the delay between a change of the real-world state and the resulting modification of the information system state", depends on the use of this information, because what can be considered good information for a specific user may not be good enough for another. We can deal with Information Quality as a multi-attributes concept (e.g. Wand and Wang, 1996; Helfert and Ge, 2006). Depending on the specific perspective of Information Quality stressed, different attributes has been taken into account in order to assess it. **Table 7** contains the Information Quality attributes that reoccur the most in literature.

Table 7 - Information Quality Attributes

	Accuracy	Completeness	Timeliness	Consistency	Accessibility	Relevance	Concise representation
O'Reilly, 1982 [63]	x		x				
Ballou and Pazer, 1985 [64]	x	x	x	x			
Fox et al., 1994 [65]	x	x	x	x			
Levitin and Redman, 1995 [66]	x			x			
Wang et al., 1996 [67]	x				x	x	
Wand and Wang, 1996 [62]	x	x	x	x			
Miller, 1996 [68]	x	x	x		x	x	
Redman, 1998 [69]	x	x	x	x		x	
Shanks and Darke (1998) [60]	x	x	x	x	x		x
Giannoccaro et al. (1999) [70]	x	x	x	x	x	x	x
Ehikioya, 1999 [71]		x	x				x
Hwang et al., 1999 [72]	x	x		x	x	x	x
Eppler and Wittig, 2000 [73]	x	x	x		x		x
Fisher and Kingma, 2001 [74]	x	x		x		x	
Kahn et al., 2002 [54]	x	x	x		x	x	x
Bovee et al., 2003 [75]	x	x	x	x	x	x	
Francalanci et al., 2004 [76]	x	x	x	x	x		
Stvilia et al., 2007 [38]	x	x		x			
Zahedi et al. (2008) [35]	x		x				
Sachidananda et al. (2010) [77]	x	x	x				

The attributes that are mentioned most frequently in literature are accuracy, completeness, consistency and timeliness, although there is no general agreement concerning them (Wand and Wang, 1996). Other attributes make an appearance in these studies, and include reliability, conciseness, objectivity, believability, age, volatility, understandability, integrity, precisions, ambiguity and redundancy. Differently to the literature on Transport Information, all these attributes are often explained, but their meanings vary from work to work and they partially overlap or, at least, are strongly related to each other (Giannoccaro et al., 1999). For instance, accuracy can imply solely the concept of correctness or being error-free (e.g. Bovee et al, 2003; Sachidananda et al., 2010), or it can include other meanings, such as precision (e.g. Fox et al, 1994), or ambiguity (e.g. Wand and Wang, 1996). In general, there are a great confusion as terms, such as accuracy and reliability, can have very close meanings. For instance, reliability can also be interpreted as information correctness (e.g. Eppler and Wittig, 2000). The concepts of timeliness and accessibility are particularly interesting, both because most authors consider them to be important, and because of the wide range of connotations that they can assume. Timeliness can include the concepts of volatility, age and currency (e.g. Wand and Wang, 1996; Francalanci and Pernici, 2004). They are respectively defined as information instability, i.e. the frequency of change of the data for an entity attribute of interest (Bovee et al, 2003), the delay between generating and delivering the information (Fox et al, 1994), the level of information updating (Wand and Wang, 1996). Consequently, timeliness can refer to features relating to context (volatility), system (age) and information (currency). Data and information accessibility, on the other hand, concerns ease of access and ease of understanding them. It, therefore, includes both channel accessibility in terms of technical concerns (i.e. terminal connectivity, access permission and methods), and representation and handling issues (e.g. understanding and interpreting information) (O'Reilly, 1982; Strong et al., 1997). O'Reilly (1982) affirms that accessibility is the most critical determinant of information use.

However, different attributes have assumed different importance, depending on the specific fields of analysis, the definition assigned to Information Quality and the "aspects" of information that authors considered as relevant, such as contents, form and time (Wang et al, 1996; Eppler and Wittig, 2000). For instance, Wang, Strong and Guarascio (1996) stressed that many Data Quality studies include accuracy, accessibility and interpretability as either the only or one of several key dimensions; Accounting and Auditing literature mostly considers reliability as a key attribute; and Information Systems literature looks at a broader set of attributes, such as accuracy, timeliness, precision, reliability, currency, completeness and relevance.

Attributes have been often systematize according to different dimensions constituting more structured frameworks (Eppler and Wittig, 2000). Typically, the latters are specific to certain application contexts, rather than generic and widely applicable. We will focus our attention on those that appear particularly interesting for our purposes. In order to identify the Information Quality attributes, some of these frameworks (e.g. Fox et al, 1994; Levitin and Redman, 1995) start from information dimensions (such as contents, level of detail, scope, etc.) or even from different information conceptualizations. The framework proposed by Kahn, Strong, and Wang (2002) is based on a product and service performance model (PSP/IQ), where attributes are identified as product features (accuracy, completeness and freedom from errors) or as characteristics of the service delivery (ease of manipulation, security and information benefits to consumers). Other frameworks are based on quality perspectives and they include dimensions such as Intrinsic, Contextual, Representational and Reputational data quality (Wang et al, 1996; Bovee et al, 2003; Stvilia et al., 2007).

However, even in the literature on Data and Information Quality, there is no rigorous and shared definition of the set of quality attributes and dimensions (Giannoccaro et al., 1999) and it is widely accepted that the choice of specific dimensions and attributes is highly context-dependent (Bisdikian et al., 2009; Leviäkangas, 2011). In the next chapter, we formulate a framework of the main dimensions and attributes to be considered in Infomobility systems, and that summarizes the Infomobility Quality meaning. The framework consists of a taxonomy of Information Quality attributes, organized into several dimensions in a systematic way.

4 Infomobility Quality Framework

This work adopts what Wang, Strong and Guarascio (1996) call an "intuitive approach". Starting from the Information Quality literature review, we selected some characteristics that, based on previous studies (Arena et al., 2013) and intuitive understanding on Infomobility, are supposed to be necessary for an effective implementation of Infomobility (Sachidananda et al., 2010). The aim is to provide a holistic and structured framework of the Infomobility Quality. Particularly, we organized attributes, that are the characteristics of data and information (e.g. accuracy), according to the three main perspectives of Information Quality that come to light in the past studies, which we call "dimensions". The framework make use of dimensions adopted by Bisdikian, Kaplan, Srivastava, Thornley, Verma, and Young (Bisdikian et al., 2009), but the meaning we confer to any of them is quite different. They are:

- Quality of Information (QoI).
- Value of Information (VoI)
- Quality of Service (QoS)

The first dimension represent the intrinsic characteristics of information, i.e. attributes such as those identified in **Table 6** and **Table 7**. The other two perspectives shed light on the fact that Information Quality depends not only on its feature, but also on how it answers to the customers' requirements and it is delivered to them (Miller, 1996). They influence the users' capability and willingness of using the information provided. In particular, the Value of Information is about the fitness of information characteristics and contents to the consumer needs. The Quality of Service is about the fitness of the service delivery characteristics with consumers' requirements for acquiring information. **Figure 7** shows the three dimensions of the Infomobility Quality framework.

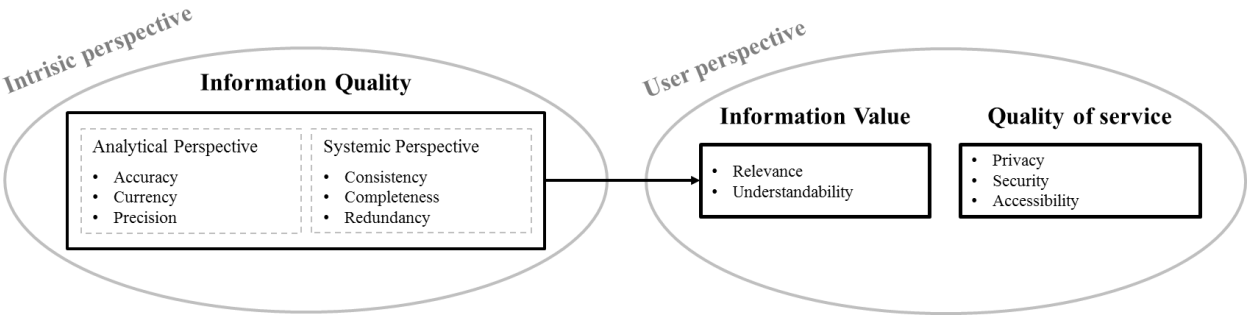

Figure 7 - The Infomobility Quality framework

Since there is not a thoroughly shared set of "intrinsic" Information Quality attributes and the same attribute can assume different meanings, among those mentioned we have chosen those that better fit with the particular area of investigation, specifying the particular connotation we adopt in this work. We consider:

- Accuracy, which means that the recorded data reflect the real words status, hence data lack of errors (Wand and Wang, 1996).
- Currency, which implies that data are updated when user requires them (Fox et al, 1994).
- Precision, which include the level of detail in specifying every transport system characteristics (Fox et al, 1994).
- Completeness, which is having all required parts of an entity's information present (Bovee et al, 2003).
- Consistency, which implies that data in a database are required to agree (Fox et al, 1994).
- Redundancy, which is about the repetition of the same content (Stvilia et al., 2007).

The choice of every attribute is based on the analysis of different definitions in the Information Quality literature and it aims to avoid confusion rising from the closeness of various concepts. For instance, the choice of the term accuracy rather than reliability is because the second one could refer to the entire Infomobility system: Fox, Levitin and Redman (1994) cites the definition proposed by Parnas (1975) and Brodie (1980) according to which reliability is "a measure of robustness (e.g. the absence of system failures)". In the same way, we have chosen the term currency rather than timeliness because the latter can

encompass not only the concepts of age, referring to the entire system, but also the concept of volatility, denoting the entire context (Bovee et al, 2003). Then, we distinguish attributes characterizing a single information to those about the mutual relations among them all. The latters emphasize the necessity of considering how information and services, provided in the same context by different operators, can be combined. It is very required in the Infomobility field, where several researchers support the need for adopting a systemic perspective (e.g. Paganelli and Giuli, 2009; Natvig and Vennesland, 2010; Wydro, 2011a).

Then, we analyse how the intrinsic characteristics of information fit with the users requirements (Value of Information). It depends first on its relevance in relation to the problem being addressed (O'Reilly, 1982). Indeed, what is found important in some situations and contexts, it can be found useless in others because its value depends almost entirely on its uses (Tayi and Ballou, 1998). Then, information has a different value according to the user's capability of understanding and interpreting it (Tayi and Ballou, 1998). Consequently, both the concepts of relevance and the understandability of information implies that the Value of Information is related to the information "fitness for use", which has been one of the most cited by the past academic works.

Both Quality of Information and the Value of Information are information specific. However, we point out that the Infomobility Quality depends not only by the intrinsic attributes of information and by their fitness with the user requirements, but also on the user's capability or willingness to gain it. The latters are much related to the level of privacy and security guaranteed in gathering information, and to the level of accessibility to it, in terms of channel technical characteristic used for providing it (i.e. terminal connectivity, access permission and methods) (Logie, 1993; Wydro, 2011a). The potentials of accessibility in influencing the decision to acquire information, such as for understandability, comes from the effort - economic, temporal, physical, cognitive and affective (Grotenhuis et al., 2007) - required for acquiring and using information (Chorus et al., 2006). In particular, we point out that, in order to capture this effort, we include in the accessibility the concept of information openness, according the Wydro's (Wydro, 2011a) acceptation (free or paid/limited access). These "channel characteristics", which often have been mentioned both in studies on Information Quality (e.g. Wang et al, 1996; Redman, 1998; Hwang and Lin, 1999) and in studies on Transport Information Quality (e.g. Zahedi et al., 2008; Paganelli and Giuli, 2009; Wydro, 2011a) are considered in the Quality of Service dimension. This one, as the VoI, is much user dependent, because the conditions for retrieving information are different among users (Smith and Venkatanarayana, 2005; Chorus et al., 2006; Bin et al., 2013).

5 Discussion and Conclusion

The high dependency of the Infomobility Quality to the specific users' characteristics and needs make particularly hard the assessment of the Information Quality. Indeed, in such uncertain and complex contexts, some factors hamper the understanding of information users' requirements. First, the great variety in transport information users. Also within the same "category" of users (transport systems decision makers or customers), it does exist a huge amount of heterogeneity, and customers' personal needs are influenced by

individual characteristics (e.g. age, education level, disability, etc.), journey purpose, familiarity of travelling, etc. (Grotenhuis et al., 2007). Then, the modern technology is increasing the scope and options both for the type of information that is supplied, and the means by which it is delivered and accessed by the user (Logie, 1993; Wydro, 2011a). Even the same information may be needed for multiple tasks or users that require different quality characteristics that can change over time (Strong et al., 1997). Moreover, the use of information may not even be fully known (Tayi and Ballou, 1998; Lillrank, 2003) and information consumers can be not very capable of recognizing the level of information quality (Helfert and Ge, 2006). This introduces another criticality that has to be considered. It is the difference between the Information Quality and the perceived Information Quality, which varies according to user' personal characteristics, expectations experience and goals (Herrala, 2007; Stathopoulos and Tsekeris, 2009). Then, it can be influenced by the opinion about the source of information (O'Reilly, 1982), even leading users not to examine the information itself but to use it based on source credibility or reputation (Bovee et al, 2003). Finally, the deep understanding of the user's requirements is very critical also because of an issue that rarely has been considered in literature, with some exceptions such as Levitin and Redman (1995), Redman (1998), Helfert and Ge (2006). It is the existence of dependencies and trade-offs between Information Quality attributes such as between currency and accuracy (Eppler and Wittig, 2000), which ask for a great attention to the actual Information Quality attributes that can make an Infomobility System effective.

This work, after having presented different characterizations of the information types that researchers have considered in the Transport Systems field, it proposes a framework for Infomobility Quality aiming at supporting the future developments and assessments of Infomobility Systems. The framework consists of three perspectives synthetizing the Information Quality characteristics to be taken into account for managing information in the transport field. Combining these perspectives, we consider the intrinsic features of information (QoI), and the fitness of the information itself (VoI) and of the information delivery characteristics (QoS) to the specific users' needs.

Providing a review of different characterizations of the information types and a framework for the Infomobility Quality, this paper on one hand it fills an academic literature gap. Indeed, previous academic works do not provide an overarching and structured framework of the dimensions or the attributes to assess the capability of these systems to provide managers and customers with "right" and high quality information. On the other hand, the new framework of Infomobility Quality could be an instrument for transportation managers to assess the Infomobility Quality and to support the development of future Infomobility Systems, in turn contributing to the mobility systems improvement.

It could be criticized because it still lacks in proposing a comprehensive taxonomy of users and of their specific information requirements. Nevertheless, we support the idea that, they should be univocally defined when the specific application is developed, just because of the "fitness for use" principle so much widely accepted.

Future steps could consist first in a case study for understanding the adoption of the three perspectives and of attributes by the Infomobility practitioners. Then, researchers could conduct a study of present Infomobility Systems through the analysis of the Infomobility Quality dimensions and, starting from this analysis, an

investigation of possible solutions that mobility mangers can adopt for dealing with Infomobility Quality problems could actually contribute to future improvements in this field.

Acknowledgements

The authors would like to thank Prof. Irvine Lapsley who contributed to improve this work.

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ARTICLE 3

An Open Data approach for Infomobility Systems

Marika Arena
Department of Management, Economics and Industrial Engineering
Politecnico di Milano, Via Lambruschini, 4/B, 20156 Milan, Italy

Giovanni Azzone
Department of Management, Economics and Industrial Engineering
Politecnico di Milano, Via Lambruschini, 4/B, 20156 Milan, Italy

Silvia Malpezzi*
Department of Management, Economics and Industrial Engineering
Politecnico di Milano, Via Lambruschini, 4/B, 20156 Milan, Italy

Wijnand Veeneman
Department of Multi-actor Systems Section of Policy, Organization, Law and Gaming (POLG)
Faculty of Technology, Policy and Management - TU Delft, Jaffalaan 5, 2628 BX Delft, The Netherla

*** Corresponding author email:** silvia.malpezzi@polimi.it

Abstract

This paper reports the results of a double case study aimed to analyze the potential of Open Data (OD) for increasing the quality of Infomobility systems and, therefore, for contributing to the achievement of the Infomobility goals. Based on the state of the art literature, the paper identifies the key elements of an OD system, and the basic dimensions of quality of an Infomobility system. Then, the paper presents the OD systems implemented in the Infomobility sector in two European cities. The key findings of this paper shed light on the potentials of OD in the field of Infomobility and on the main pre-requisites and barriers that should be considered when adopting this emerging approach.

Keywords: Infomobility, Open Data, Transport Information Quality, Intelligent Transport System, Information Management.

1 Introduction

In the last years, Infomobility has attracted the attention of policy makers and transport operators as being a potential solution for reducing the traffic congestion levels and related problems such as pollution, delays and incidents (e.g. Xu, 2000; Nakanishi, 2004; Black, 2010; Kolosz et al., 2013).

Infomobility can be defined as the bundle of information management systems aimed at increasing the quality of transport systems in terms of efficiency, safety and reliability, by providing proper information to managers and users (Arena et al., 2013). Hence, it has two broad objectives: supporting the transport network planning and control (e.g. Vlahos et al., 1994; Horan, 2003; Peng et al., 2011) and assisting travelers to plan and run their trips (e.g. Giannopoulos, 2004; Lee et al., 2010; Giannoutakis, 2012). However, the

achievement of these objectives largely depends on the quality of an Infomobility system, i.e. on the capability of these systems to provide managers and customers with the "right" information (e.g. Bisdikian ate al., 2009; Wydro, 2011; Popovic and Habjan, 2012).

An emerging trend that appears to be particularly relevant in connection to the quality of an Infomobility system consists in the increasing diffusion of Open Data (OD), that are conceived as an approach to enable easier access to a great amount of information for users and decision makers (e.g. Borzacchiello and Craglia, 2012; Lampathaki et al., 2013).

OD have been receiving a growing attention in different sectors due to the high value ascribed by citizens and various public and private organizations to the idea of making available to everybody data such as those related to public transport, environment, safety and security, and other public services (Desouza and Bhagwatwar, 2012). However, OD studies have rarely focused on the Infomobility sector (e.g. Kloeckl et al., 2012; Kassen, 2013). Some authors just mention transportation as one of the possible application fields of OD, highlighting potential benefits associated to their use for public transport planning and service delivery, public resource management (efficiency), and accountability (e.g. Curtin, 2010; De Saulles, 2013).

Moving from these considerations, this paper investigates the potentials of Open Data (OD) of increasing the quality of an Infomobility system and, therefore, contributing to the achievement of the Infomobility objectives. To this aim, we revise the key elements considered by previous work on OD and the basic dimensions of quality of an Infomobility system and we use them as a framework to analyze two different cases of use of OD for Infomobility, settled in the Netherlands and in Italy. Based on the empirical analysis, we highlight the main pre-requisites and barriers that should be considered when adopting this emerging approach and we discuss possible alternative solutions.

2 Methodology

In order to study OD in the field of Infomobility, we adopted a multi-country case study (Yin, 1994). We chose the case study methodology because it is considered the most appropriate approach for an exploratory investigation of complex systems (Yin, 1994). It allows understanding the institutional context that characterizes a single setting (Eisenhardt, 1989) and individuating and analysing the existence of different phenomena that influence the object under investigation across different settings (Eisenhardt and Graebner, 2007).

The empirical investigation was performed in two case settings: Amsterdam and Milan. Both the cases are embedded in the European system where more and more countries are emphasizing transparency and openness of Governments' activities by making public information more easily accessible and available for re-use. In the last years, in fact, the Europe Commission has spent growing efforts for overcoming existing obstacles connected to the actual legal, licencing and privacy issues (Borzacchiello and Craglia, 2012; Cerrillo-i-Martínez, 2012; European website). The European Directives on OD, issued on the 26th of June 2013, requires that Governmental data must be available to anyone requiring them with a general reuse license, and it encourages the availability of data in open formats.

The data collection was articulated into two steps. First, we studied the normative framework of the countries in order to understand the main differences in how the mobility system is structure and ruled in the two cases. Then, we collected data on OD and Infomobility systems in place in the two settings combining multiple data sources: interviews, internal documents, websites and official presentations. In both the cases, we had the possibility to interview all the main actors of the two OD Systems, which resulted in 15 face-to-face semi-structured interviews, performed between 2013 and 2014 (see **Table 8**).

Table 8- Interviewees

Amsterdam	
City Region of Amsterdam	Policy Advisor
Connexxion	Concession Manager
GOVI	Partner Operations Management Director
GVB	Project Manager
Province of North Holland	Traffic management and public transport Project Leader
openOV	Chairman
REISinformatiegroep BV	General Manager
Milan	
AMAT	ICT Director
ATM SpA	ICT Director
Municipality of Milan	Mobility Department Counselor
CEFRIEL	Deputy Project Manager E015
Region of Lombardy	Infrastructure and Mobility Direction

The interviews were performed according to the following protocol. Prior to interviews, information on the various entities was collected from public sources. Then, all interviews were carried out on the premises of the studied organisations. Each interview was digitally recorded and transcribed to better support the subsequent analysis. The transcripts were shared with the interviewees, and preliminary findings were further investigated through follow-up interviews and questions by email in order to cover new lines of thinking emerged during the research (Eisenhardt and Graebner, 2007). The aim was to have a well-defined focus on the specific constructs of interest, but keeping them flexible to reflect ideas that emerged spontaneously (e.g. Pan and Scarbrough, 1999; Lockstrom et al., 2010)

For the data analysis, we used within-case and cross-case analyses (Eisenhardt and Graebner, 2007). The first step was to analyse each individual entity. Based on the interviews and archival material, we drew a picture of the systems analysed based on the key elements of the OD identified in previous academic works, their impact on the Infomobility Quality and their capability in achieving the respective goals.

Once we had completed the within-case analysis, we conducted a cross-case analysis. We compared evidence across different cases, in order to identify divergences and convergences among them all. We searched for distinct patterns and for plausible explanations of the observed differences, trying to discriminate between contingencies and general regularities (Eisenhardt, 1989).

3 The research Framework

The research framework is constituted by two set of elements: (1) the building blocks of OD systems, (2) the Infomobility Quality dimensions.

3.1 OD systems

Figure 8 outlines the building blocks of OD systems. They comprise five interrelated elements: the institutional context, in which the OD initiative is developed, and the OD's objectives, technology, process and governance, which represent the key characteristics of the specific OD initiative.

The *institutional context* is defined as "the set of fundamental political, social and legal ground rules that establishes the basis for the information production, exchange and distribution" (Davis and North, 1970). Prior studies dealing with OD identify it as a crucial factor to both enable and constrain the adoption of OD systems (Janssen et al., 2012), since it regulates the disclosure and reuse of governmental data and information (e.g. about intellectual property and digital rights issues) (Curtin, 2010; Kassen, 2013).

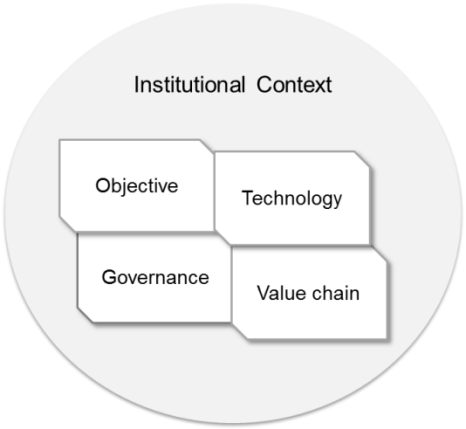

Figure 8 - The building blocks of OD systems

The second element of the framework is represented by OD *objectives*. Prior literature highlights that the main objectives of an OD system can be related to:

- Ensuring transparency: OD systems allow citizens to easily read and use data owned by the public authorities (e.g. Cerrillo-i-Martínez, 2012; Desouza and Bhagwatwar, 2012; Kassen, 2013).
- Improving decision-making: OD systems make available a great amount of data, that can facilitate decision-making processes for the information users (e.g. Citroen, 2011; Borzacchiello and Craglia, 2012; Kloeckl et al., 2012).
- Fostering Socio-Economic growth and innovation: OD systems have also a potential in terms of service innovation, job creation and, eventually, economic growth (e.g. Janssen et al., 2012; De Saulles, 2013; Curtin, 2010; Lampathaki et al., 2013). For instance, OD enable the development of the new mobile application services (Apps), which represent an emerging field for the development of new business and it may lead to efficient and citizen-centric services (Desouza and Bhagwatwar, 2012; Kassen, 2013).
- Improving efficiency: OD can lead to a potential reduction of the workload for public agencies employees for satisfying citizens' information requirements, hence bringing to easier and more efficient job practises (Desouza and Bhagwatwar, 2012).

The third element of the framework is the *governance* of the OD initiative that refers to the network of actors characterized by certain roles and relationships within the OD systems (e.g. Melin and Axelsson, 2010; Davies and Edwards, 2012), as well as the control mechanisms they implement on the data value chain (Desouza and Bhagwatwar, 2012; Janssen et al., 2012). Some authors have specifically focused on the new

roles that different actors are assuming because of the growing diffusion of OD. For instance, governments are taken the role of "data platform" from which third parties can gathered data for the new services development (e.g. Desouza and Bhagwatwar, 2012; Kassen, 2013). Organizations other than Apps developers work as intermediaries aggregating the different types of publicly accessible data from multiple OD sources and making information available to other developers that do not want to spent effort or do not have the resources for integrating data (Desouza and Bhagwatwar, 2012).

The fourth element of the framework is the OD *technology*, which refers to the technical aspects of the OD initiative. The data format and the technological system to access and re-use the data determine the system suitability for achieving the specific objective of the OD initiative (De Saulles, 2013). Indeed, different technologies and data format determine different levels of data usability for the users (e.g. citizens, Apps developers, other public agencies) and, in turn, the amount of users interested in valorizing these data and the relationships among them all (Curtin, 2010; Davies and Edwards, 2012; Kloeckl et al., 2012). A potential data user requires them to be presented in a format understandable by computers, and to be easily manipulated (De Saulles, 2013). In this connection, several authors highlight the necessity of adopting shared standards in order to promote OD practices and to increase the diffusion of applications based on these data (Curtin, 2010; Desouza and Bhagwatwar, 2012; Kassen, 2013).

Finally, the last element is the data *value chain*, that consists in the process from the data collection to the data delivery to the final users. Zuiderwijk et al. (2012) provide a preliminary analysis of the steps of the the OD value chain, even if a shared framework is still missing.

3.2 Infomobility Quality

The quality of an Infomobility system refers to its capability to provide managers and customers with the "right" information. Prior literature in the fields of Transport Information Quality and Information Quality highlights three main dimensions that are at the basis of this concept: Quality of Information (QoI), Value of Information (VoI) and Quality of Service (QoS).

The Quality of Information refers to the intrinsic characteristics of the information provided. It comprises not only attributes characterizing a single piece of information, but also attributes concerning the mutual relationship among them all, emphasizing the necessity of considering how information provided in the same context by different operators can be combined[6]. The attributes are:

- Accuracy, i.e. recorded data reflect the actual status of a system, hence data lack of errors (Wand and Wang, 1996;
- Currency, i.e. data are up to date, consistently with users' requirements (Fox et al., 1994).
- Precision, i.e. the level of detail in specifying every transport system characteristics (Fox et al., 1994).
- Completeness, i.e. data cover all the needed pieces of information (Bovee et al., 2003).

[6] This is a key requirement in the Infomobility and Transport systems fields, where several researchers support the need for considering information with a systemic perspective (e.g. Paganelli and Giuli, 2009; Natvig and Vennesland, 2010; Wydro, 2011).

- Consistency, i.e. data in a database / different databases are coherent (Fox et al., 1994).
- Redundancy, i.e. there is no repetition of the same contents (Stvilia et al., 2007).

The Value of Information refers to the fitness of information format, contents and intrinsic quality with the users' requirements. It depends on how the intrinsic characteristics of the information fit with the users' requirements in terms of its relevance in relation to the problem being addressed (O'Reilly, 1982).

Finally, the Quality of Service is about the fitness of the characteristics of the channel used for delivering transport information with the users' requirements. It takes account of the level of privacy and security guaranteed in gathering information, and the level of accessibility to it (Logie, 1993; Wydro, 2011). More specifically, the concept of accessibility refers to the effort - economic, temporal, physical, cognitive and affective (Grotenhuis et al., 2007) - required for accessing and using information (Chorus et al., 2006) and it is connected to the information 'openness', according the Wydro's (2010) acceptation: free or paid/limited access.

It is worthy of noticing that the QoS, as the VoI, is user dependent, because the conditions for retrieving the information change among the users (Smith and Venkatanarayana, 2005; Chorus et al., 2006; Bin et al., 2013). Consequently, Infomobility Quality depends not only on the intrinsic features of information (QoI), but also on how it answers to the contents and quality requirements (VoI) and to the accessibility and security requirements (QoS) of information users.

4 The Infomobility OD Systems in Amsterdam

4.1 Institutional context

The Dutch transport system is under the governance of both National and local Public Administration. Since 2000, Provinces and Regions (groups of Municipalities working together in the sphere of spatial development, traffic and transport, economic affairs, housing and youth welfare) have assumed a greater relevance because of a decentralization process that has transferred them the responsibility for public transport. The national government is now responsible for the tax policy related to mobility, for financing the transport sector, the largest infrastructure investments, the management of the national motorway network, and the national rail network and services concessions. Provinces and Regions, instead, are responsible for metropolitan and provincial public transportation operated by different public transport operators (PTOs). They are in charge of developing the terms for the PTOs biddings and they can choose the bid that best answer to their requirements. Public tender mechanisms have given a strong power to the local authorities for developing their own transport policies and have produced a high competitive environment for PTOs. In the specific setting analyzed, the City Region of Amsterdam, part of the Province of North Holland and including 16 municipalities, is the public transport authority (PTA) in charge of four concession areas assigned to three different PTOs. Most Dutch PTAs are more and more dictating OD policies (differently from the National Public Authorities governing the rail and road networks), firmly believing that having all the public transport information available in a government database is a great opportunity for exploiting public information.

4.2 The OD system

The system studied in the Dutch case embeds two OD initiatives, both of them covering not only the city analyzed but also the overall region around it and the most Dutch territory. The former is governed by the Public Transport Authorities (PTAs) and the latter is directly managed by the Public Transport Operators (PTOs).

The first OD initiative studied has the main *goal* of promoting the emergence of mobile information services (Apps) developed by third private parties in order to stimulate innovation and improvements of public transport and Infomobility services, with positive impacts on the citizens' satisfaction. As we have already mentioned, local PTAs are in charge of the overall *governance* of this OD initiative. In particular, the City Region of Amsterdam is responsible for the public transport service in the urban area of interest. A fundamental actor within the PTAs' OD initiative is GOVI, an organization founded and hosted by the Province of North Holland and funded by most PTA's in The Netherlands. It is the organization integrating all automatic vehicle location data, announcements and interruptions coming from the three PTOs concessionaire in charge of gathering data from the transport systems. It is also in charge of delivering information to both the OD platform and the displays systems (Dynamic Travel Information Systems - DTIS) and of providing the City Region of Amsterdam with reports about the public transport services operated by the three PTOs (e.g. timetables, punctuality). Indeed, this information is recognized to be very important as "management information" because it allows monitoring the PTOs' activity[7]. Furthermore, thanks to its ICTs and transport systems knowledge, GOVI provides City Regions and Provinces with technical competencies to write terms of concessions contracts about information. Then, after having been integrated within the GOVI database, information are sent to openOV. It is a no-profit organization that receives the integrated transport information from GOVI and opens them to third parties for the development of mobile applications. Finally, connected services providers make the information cross-section in order to provide different data views corresponding to different aggregation levels that can be stops, routes, trips (e.g. "the bus is arriving at the stop" or "when are the buses arriving and departing?"). The *technical* heart of this initiative is the database owned and managed by the GOVI, which controls, elaborates and integrates raw data gathered through GPS installed on the transport means owned by different PTOs. This central database collects data via interfaces (koppelvlak) making use of national standards. Public transport concessionaires have learned that they have to include these standards for facilitating the information exchange within the public transport sector. Hereafter, **Figure 9** shows the main components of the GOVI OD *value chain* and the data interfaces between them.

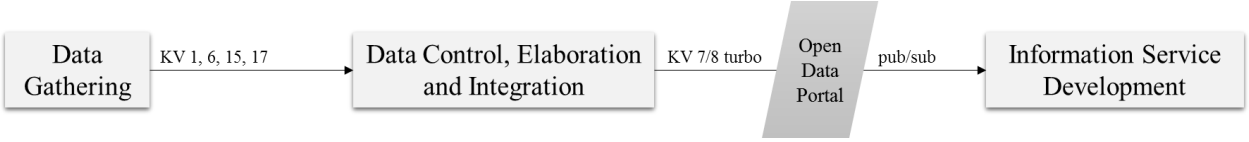

Figure 9 – GOVI OD value chain

[7] Actually, several PTAs are still using data directly provided by the PTOs.

The public transport data delivered to the central database are static data related to planned timetables, routes and stops (interface 1), and real time data related to vehicles position and possible delays (interface 6), service variations to the planned timetable such as cancelled ride (interface 17), and messages announcing weather conditions, strikes, roadwork (interface 15). Once processed by this central system, planned timetables (interface 7) and live departure times per stop (interface 8) are sent to the DTIS, and live departure times per stop for mobile applications (interface 7/8 turbo) are supplied to openOV, the OD portal that afterwards makes them available for the mobile applications development using an enterprise publish-subscribe. Data are then distributed with the "no rights reserved" license called Creative Common 0 (CC0) that guarantees a complete renunciation to whatever copyright and database rights, therefore allowing a completely free re-use of data.

The second initiative is operated by the REISinformatiegroep BV. It is a shared service center funded in 1992 with the *goal* of answering to the legislation and market requirements for a greater openness of public transport. In the first decade, the *governance* of this initiative was under the responsibility of several PTOs (including Connexxion) and the National Government. Since the 2001, it is governed by the PTOs. The REISinformatiegroep BV is both the data integrator and the OD portal. Then it is the main national provider of travel planning services. The *technical* heart of this initiative is the REISinformatiegroep BV database collecting static and real time data from all Dutch PTOs (including the national rail transport company). Hereafter, the **Figure 10** shows the main components of the REISinformatiegroep BV OD *value chain* and the data interfaces between them.

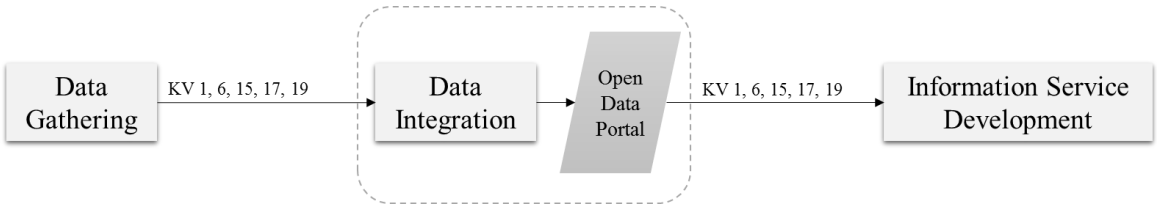

Figure 10 - REISinformatiegroep BV's OD value chain

The REISinformatiegroep BV OD portal provides static data (interface 1) on all the three PTOs operating in Amsterdam, and real time information (interface 6, 15, 17 and 19[8]) just on Connexxion (and other PTOs not working in the area of interest), adopting its own license reviewed and validated by the National Government. Particularly, this license, in order to protect the public transport sector, states that data are not suitable to provide management information (i.e. information about the performances of public transport operators), according to the belief that the set of data provided is not completed enough for assessing the PTOs performance. Moreover, every person or organization that wants to use the REISinformatiegroep BV's data can accede them upon previous registration at the website. **Figure 11** illustrates the overall OD system of Amsterdam.

[8] It is the actual time of arrival of a mean at a bus stop.

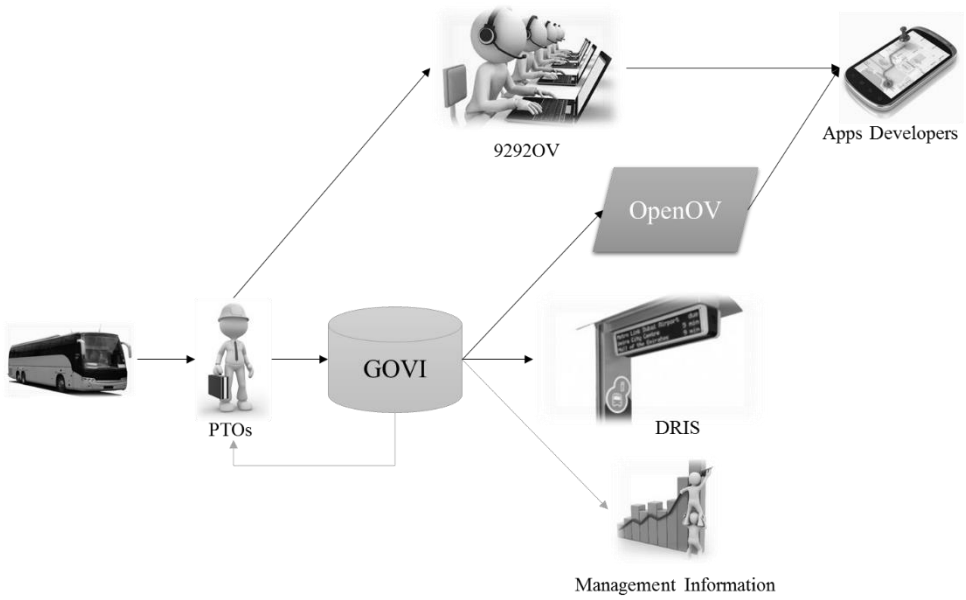

Figure 11 - The Infomobility OD System of Amsterdam

A National project under the Ministry of Transport, Public Works and Water Management is now embracing both these OD initiatives. It undertakes the role of collector involving all the PTAs and PTOs, including even the national rail operator. The aim is comparable but not the same of the GOVI one. Indeed, it does not want management information but just traffic information in order to promote integrated platforms for supporting the new market of Apps. However, up until now it does not aggregate the data. It selected two contents aggregators providing data and information through their OD portal: REISinformatiegroep BV and OpenOV.

5 The Milan Infomobility OD systems

5.1 Institutional context

In Italy, the repartition of responsibilities for the local public transport system (LPT)[9] is defined by the D.lgs 422. According to it, the National Government is in charge of issuing guidelines and polices, and realizing large infrastructure networks, whilst the local authorities (Regions, Provinces and Municipalities) are jointly responsible for all the other activities, such as transport and mobility planning, investment planning, financial resource management and transport system monitoring. The Regions, which are comparable to the Dutch Provinces, are responsible for the rail service planning and administration and for the regional public transport planning and management. They provide funding to the Municipalities for the minimum service level to meet the citizens' mobility demand. The Provinces, which have jurisdiction over a group of Municipalities, define the public transport operators in relation to the suburban services network, and identify and finance any additional (to the minimum) services. Currently, the territory served by suburban public transport is divided in 6 lots that have been assigned to 7 public transport companies as a result of tendering (ex. LR 11/09). Finally, the Municipalities define a shared rational system of objectives and strategies for the improvement of mobility in the urban area, and they develop appropriate projects and the related services management.

[9] D.lgs. n. 422, 18th November 1997 (Decreto Burlando)

In the specific setting analysed, the Municipality of Milan owns 100% of the share capital of ATM, the PTO that carries out activities in the field of public transport within the city area. It is worth to underline that, whereas in the Dutch case the City Region of Amsterdam is in charge of both the city area and the region surroundings governs the public transport system, the situation in the Italian case is more fragmented. The Municipality of Milan is responsible only for ATM operating in the city analysed and in a few other surrounding areas, and other different public authorities (such as the Region of Lombardy) are responsible for the various PTOs operating in the areas nearby the city. The Municipality of Milan has increasingly promoted the OD approach because of three main reasons. Intensifying the participation level by increasing the citizens' awareness about the opportunities offered by the city, and supporting them in easily satisfying their own needs. Making data freely accessible to research entities, with the aim of incentivizing and improving their activities and results, without further burdening its own workload. Encouraging entrepreneurship enabling the emergence of new companies developing innovative information services and systems.

5.2 The OD System

The Municipality of Milan adopts an OD approach with the main *goal* of increasing the public information value through the diffusion of data. The City Council approved an OD project endorsing the principle for the free distribution and re-use of data in 2012. The *governance* of the system is under the responsibility of the Municipality of Milan itself, but the OD platform and all the related datasets have been created, updated and managed by the AMAT. This is an in-house Agency of the Municipality of Milan providing services and technical activities related to the analysis, planning and monitoring of participated entities' activities in the fields of general mobility, public transport, environment, energy and climate. As concerns the *technology* and *process*, it is worth to underline that not all the data are directly collected by the AMAT (hence by the Municipality of Milan itself). Indeed, whereas data on road traffic flows are gathered directly by the AMAT, data on the public transport service are provided by the PTO. Because of the contract, the Municipality of Milan has free access to these PTO's data for controlling and assessing its activity (i.e. management information). The data provided are non-real time data. They are about public transport timetables, cartography mapping of the public transport lines (tramway, bus and metro) of the urban area, numbers and location of parking lots and areas dedicated to car sharing and bike sharing services, bicycle paths, pedestrian areas and LTZ (with specified types of vehicles allowed to circulate) for the entire urban area. These data are made available through a Municipality's OD platform according to a Creative Commons 3 license, allowing the free distribution and reproduction of data, even for commercial purposes, but providing the source acknowledgment.

Other than this OD initiative, since 2012 another project has been carried on with the main purpose of supporting the emergence of services for the diffusion of integrated and real-time information. This initiative consists in the creation of E015. The E015 *goal* is facilitating the information sharing among all the

Infomobility actors[10], overcoming the difficulties in defining bilateral agreements that usually yield great inefficiencies in terms of time, efforts and technological components duplication. The initiators of this project are public and private entities in charge of the local economic development, including in particular different industrial associations. These entities are also in charge of the strategic *governance* of the system. Then, the CEFRIEL, a research center with specific focus on new technologies developments is the technical-scientific coordinator of this initiative and is responsible for defining the communication protocol and for developing and evolving standards and rules. The system value is at the peripheral level, where information providers handle information maintaining the total control and ownership on it. In fact, even if their goals are much close, the *technical characteristics* of the E015 are substantially different from OD projects. Indeed, it is not an open database. It is a digital environment based on interoperability standards between some contractors, which enables communication among information systems. It is worth to underline that it enables the supply and use of information services through the web, not the access to datasets. The technological standards are chosen from the market due to their wide adoption. The mandatory interoperability protocol for sharing information services is contents independent, but some data formats that are context specific are just suggested to be those defined at European level (e.g. DATEX/TMC for describing traffic events). The *information value chain* calls for two main figures: the service provider and the application provider. The former supply the information service, the latter ask for the use of it. However once an operator join the system, he can cover both these roles. The information exchange is fast carried out under appropriate information sharing rules and policies defined through an overall contractual agreement that actors have to subscribe when they join the system. Once the connection between the provider and the user of information has been established and the contract has been signed, there are not continuous contacts between the parties, but the user can directly accede to the information service whenever he needs it. The users, after having gathered information from the holder's platform, are in charge of the information rendering on their own Apps or webpages. The E015 represents just "the thread of the tube" for the information exchange (interoperability standards), but the decision about which information is provided and used is up to the contractors (there is not a minimum level). Everyone decides which service to distribute and who can use it to create benefit through this information. The provider of it, after the user has specified its objective, is in charge of authorizing the access to the information service. On the platform website it is possible to see the system participants, what they have offered and under what conditions (e.g. restricted or open access). Indeed, all the services has to be described in terms of eventual rules and policies to use them (other than to those already defined by the platform).

6 Cross-case analysis

A comparison of the OD systems developed in the Netherlands and in Italy highlights how they exploit OD potential in a different way and with different impacts on the quality of the Infomobility systems. In this section, we first analyze how the OD approaches adopted contribute (or not) to improve the three dimensions

[10] Actually, this system includes several services related to the territory, not only transport information services (e.g. tourist and cultural services.

of the Infomobility Quality, and we formulate some considerations about the capabilities of the OD systems of achieving the Infomobility objectives (i.e. providing travelers with transport information services and supporting the transport network planning and control). Then, we discuss the critical factors that emerged from the case analysis for the adoption of an OD approach in the Infomobility sector.

6.1 OD and Infomobility: what impacts?

First, we analyze the impact of OD on the Quality of Information (QoI). In general, the adoption of an OD approach fosters the improvement of the QoI in both the cases analyzed. Indeed, the broad diffusion of information enables the establishment of "information control mechanisms" that are implemented by the public (citizens, Apps developers and other operators and authorities) or by dedicated actors of the information value chain. Then, the more the quality improves, the higher are the quality requirements for the users. Indeed, the PTOs shaded light on the increased effort they are spending for answering the travelers' complaints related to the information quality due to the higher diffusion of this transport information. In the Dutch case, the PTA's initiative enables a further QoI control by the GOVI, which pushes PTOs to improve continuously by monitoring the quality of the information they provide based on a dashboard of indicators that don't have to be lower than pre-determined and increasing standards (e.g. precision not lower than 98%). The same considerations are also applicable to the OD system and the E015 implemented in the Italian case.

Second, we consider the Value of Information (VoI) – i.e. the fitness of information to users' requirements - for whom we found different impacts in the two cases. The OD system implemented in the Dutch case is much oriented to make available information and services to travelers. Other than fostering ITS (Intelligent Transport Systems) solutions through some campaigns called "Better Benutten" (Better use of infrastructure) that challenge experts to solve mobility problems, it provides real time information to enable a flourishing Apps market. It is seen as an opportunity for increasing the availability of information services to users and stimulating the economic development of the region of Amsterdam. At present, there are around 100 Apps based on the GOVI's database that provide real-time information about bus departure time, location and timeliness, and real time and scheduled journey plans. In addition, since this OD system permits the access to information hold by all the PTOs operating in the city, it potentially allows both PTAs and PTOs acquiring a greater awareness on the overall public transport system. Nevertheless, the Dutch PTOs still do not use reciprocal information available through OD and there is not an integrated transport service planning operated by PTOs. The monitoring of the overall system is run just by the PTAs through integrated information provided by the GOVI. Finally, we have to consider that, even if some PTOs show information related to the rail system on their displays, the OD system of Amsterdam is just about public transport. This makes difficult the creation of Apps based on the integrated multi-modal travel information desired by travelers (e.g. Kenion and Lyons, 2003; Grotenhuis et al., 2007).

Moving to the Italian case, the OD system provides non-real time information, which is in contrast with travelers' expectations (Grothenhuis et al., 2007). Therefore, it does not appear suitable to support real time information services, even if this system has been proposed for favoring the Apps development. In addition, this system allows free access just to the information owned by the Municipality of Milan, and it does not

provide information and data hold by actors other than the AMAT and the PTO. Hence, its impact in terms of improvement of the PTA's transport management activity mainly consists in a potential reduction of the workload for public agencies employees when facing specific information requirements. The E015 instead provides an easier access to static and real time information services, potentially facilitating both the development of new services and greater awareness about the overall mobility system by the mobility managers. Even if not forcing transport operators to open their own data to the public, this initiative fosters the circulation of real time information and the consequent development of integrated real time transport information services. Different Infomobility operators that are both information providers and users have developed 13 integrated Infomobility applications for the travelers based on the E015. However, even if nowadays there are many Apps that are being developed based on the E015 by third parties, they are still not about transportation.

Finally, we consider the Quality of Service (QoS) – i.e. the fitness of the channel used for delivering the information to the user requirements. First, data and information provided by the OD systems studied are not critical in terms of privacy and safety issues because they are about the public transport means position, not the travelers' mobility flows. Second, both the OD systems analyzed are based on open licenses guaranteeing free access and re-use of public transport data by citizens and all the private and public entities that aim at creating value on them. Then, since the transport information on the public transport systems in the Dutch case are delivered through a high number of Apps, it increases the information accessibility also during the trip.

6.2 OD and Infomobility: criticisms and barrier

We now discuss the elements that the analyzed cases have revealed to be important determinants of the results of an OD initiative in the field of Infomobility. They are barriers and requirements for the adoption of an OD approach and for its effectiveness in increasing the quality of the Infomobility systems analyzed, and in facilitating the achievement of the Infomobility objectives.

First, the cases show that the main criticisms to the exploitation of the OD potentials are related to *governance* issues. Infomobility systems are participated by actors with objectives, priorities and managerial approaches that sometimes much hinder the process of sharing information. In the Italian case, PTOs' real-time data are not open for two main reasons. First, PTOs, as being the public transport managers, consider themselves to be the most qualified entities for taking responsibility of information services and related Apps. Second, they perceive data as being their own property, which could be misinterpreted and misused by third parties. This issue can be noticed also in the Dutch case where there is still a certain opposition by PTOs. As mentioned above, PTOs work in a high competitive environment and see OD as a potential threat to "level playing field". According to PTOs, OD could favor new third parties aiming to enter the market, and could allow competitors to imitate their operational practices and get information about their performance. This problem is also sharpened by the existence of possible differences in the service contracts (even with the same PTA) in terms of information required.

In the Dutch case, this opposition is overcome thanks to the law on OD and concession contracts that bestow a high control power by PTAs over PTOs. Nevertheless, it is worthwhile noting that the OD system of Amsterdam that we have analyzed is now dedicated to public transportation (one-modal). Whereas the most PTAs are local governments that agree on mandatory OD policies, rail and road networks are governed by national public authorities that do not dictate neither OD nor 'management information'. For instance, an organization promoted by the Ministry of Transport, Public Works and Water Management, integrates real time data on the motorways and secondary roads network (such as traffic, road work and tariff information) managed by 15 national, provincial, regional and municipal authorities, but it distributes them only to road managers for traffic management and to traffic information providers for information services. Consequently, the commitment and the power of PTAs in the public transport sector and their information management policies are determining factor of the OD system configuration and, in turn, of their capability to fulfill the information users' requirements. These findings shed lights on the first pre-requisites, which is the establishment of an *institutional context* giving a high power to the PTAs willing to adopt the OD.

Then, we have individuated other two important pre-requisites for the use of OD system in the field of Infomobility, which are related respectively to *technology* and *value chain*. First, the OD systems implemented in both the cases demand for the definition of data formats and communication standards in order to enable an easy access, understanding and reuse of transport information (above all in presence of an upstream integration phase). Standards are required for any solution that implies information sharing and inter-operability of applications, hence it is even more essential for the adoption of an OD approach and for enabling the development of applications leveraging on OD (Desouza and Bhagwatwar, 2012; De Saulles, 2013).

Second, a critical aspect characterizing the OD approach comes from the users' feedback about the transport and information services. In order to exploit these contributions, an OD system has to integrate a feedback management phase in the data value chain, and to consider the additional effort for responding to the information users' needs and complaints. Indeed, as most both Italians and Dutch practitioners stated, having a bad transport information is worse than being without information at all.

A final consideration, that is somehow more "behavioral", comes from the analysis of the E015 initiative. In this case, data holders, who are increasingly aware of the advantages of providing the public with a great amount of information in terms travellers satisfaction, resulted to be more inclined to share real time information services when they maintain decision power on both information contents, users, and usability conditions. Indeed, even if PTAs are not dictating the participation to this system, in one year 181 among private and public organization providing many services related to the urban territory have already joined the E015. Moreover, the E015 has triggered an auto-induction mechanism such that, starting from a small group of subjects inclined to share some information, a domino effect is leading several other actors to join the system, both for reasons of marketing and for having the easier access to other operators' information services.

7 Conclusion

This research highlights the potentials of OD in the Infomobility sector for improving both the transport system management and the information services for travellers. OD can in fact contribute to ensure a better quality of Infomobility systems, thanks to the larger diffusion of transport information enabled by this approach. On the one hand, OD enables control mechanisms by transport managers, travellers, Apps developers and other interested entities (e.g. academic researchers) not only over the transport systems, but also over the transport information itself, hence guaranteeing a higher Quality of Information. On the other hand, it contributes to increase the value of information and its accessibility for travellers.

The cases analysed in this work contribute to highlight the technical and managerial pre-requisites and barriers for the implementation of OD initiatives. First, in order to achieve the OD objective it is necessary the definition of shared standards that allow distributing and accessing data, and that enable Apps developers to create information services easily usable by travelers (Curtin, 2010; De Saulles, 2013; Kassen, 2013). Then, a feedback phase is required in order to deal with the increasing expectation about the Infomobility Quality by the users. Finally, a suitable institutional context dictating the norms and policies about intellectual property and digital rights issues, and clear roles, responsibilities and decision power of transport authorities and operators has to be established (Curtin, 2010). This last requisite is related to the main criticality that we found in the adoption of the OD approach in the Infomobility field, i.e. the reluctance of actors collecting the most portions of transport data in opening them to the public, because considered very sensitive and strategic assets. Once PTAs turn out to be interested in OD, if the transport information holders are annoyed or refuse the OD, they would need such an institutional power allowing them dictating it, for instance by resorting to instruments such as public tenders. However, when PTAs overcomes this criticality through control mechanisms, forcing operators to distribute data freely, PTOs are usually annoyed and hold out basing their opposition on level 'playing field issues'. Interoperability initiatives, such as the E015, could be a very interesting solution in those cities where OD is not feasible because of missing public administration's power dictating the adoption of an OD approach.

Even though the relevance of the PTAs commitment toward the adoption of an OD approach, this research has so far neglected the analysis of the key factors and the decision-making processes leading PTAs to choose OD in the Infomobility sector. Furthermore, it has not deepened the aspects of the possible instruments (other than public tenders) in the hands of PTAs for leading transport information holders to make data freely available for re-use. Future research could investigate both these aspects, even widening the analysis beyond the specific OD approach. Third, researches could deepen the potential of other interoperability solutions in increasing the Infomobility Quality, for instance monitoring both the E015 initiative effectiveness in supporting the development of an Apps market.

Future studies could also investigate the potentials of a higher level of complexity of the Infomobility governance for supporting improvements and innovations in this sector. Indeed, considering the two OD initiatives in the Dutch case, the structure of the GOVI OD system appears much more complex than the REISinformatiegroep BV system. It is due to the principle that has led the GOVI OD system development is the belief of the market as the main incentive mechanism for improvements. Participants now perceive the

very GOVI as an incentive for other OD initiatives (even for the REISinformatiegroep BV's one) development and improvement. Consequently, future research could aim at verifying if a greater number of actors participating the Infomobility OD value chain, also assuming the same role within it, is supposed to stimulate progresses.

Then, focusing on the data and information aspects, the real need for a higher information sharing among PTOs operating in the same area and the importance of leveraging on real-time data for providing services that really fit the travellers' needs, could also be investigated. A better understanding of the relevance of integrating data before than distributing them in OD to the Apps developers, could much contribute to the actual discussions on Infomobility among academics and practitioners. This objective could be achieve, for instance, by analysing the actual use of the two OD initiatives in the Dutch case: the GOVI one providing already elaborated and integrated information, the REISinformatiegroep BV one providing raw data.

Finally, the impact of promotion and incentive mechanisms for the creation of an Apps market could also be deepen. Indeed, previous OD studies have highlighted that only with a wide public awareness about these initiatives and apt incentives (such as the Better Benutten in Holland), it is possible to encourage the Apps development (Borzacchiello and Craglia, 2012; Desouza and Bhagwatwar, 2012; Kassen, 2013).

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CONCLUSIONS

1. Summary

With the aim of investigating the impact of the Open Data (OD) approach in exploiting the Infomobility potentials, this thesis contributed to fill three main literature gaps in the field of Infomobility. First, it provides a clear definition of Infomobility and a holistic framework of its constituents. Second, it identifies the main dimensions of Infomobility Quality that constitute a basis for its assessment. Third, it explores how the OD approach affect Infomobility goals and Infomobility Quality dimensions.

1.1 Article 1

The first paper moves from the premises that those who deal with the use of information technology in the transportation field usually focus on specific elements of this complex theme depending on their area of interest. As mentioned in the introduction, the term Infomobility is not much common in the academic literature and its meaning is blurred. Different definitions of Infomobility emphasize different aspects of the concept, such as the idea of services for users (e.g. Moraïtis et al., 2003; Giakoumis et al., 2009), the technological component (e.g. Kotsakis et al., 2001; Canali and Lancellotti, 2006), or the potential outcomes on the mobility system (e.g. Sterle, 2009; De Cantis and Antoniola, 2006). The reason of this heterogeneity can be trace back to the multi-disciplinary of this theme and to the multi-applicability of ICTs within the transportation sector.

In order to lay out ideas and concepts related to Infomobility and to provide a guidance for the analysis and management of its practical implementations, Article 1 performs a literature review aimed to propose an overarching definition of Infomobility and a holistic framework of its components. Based on the review of prior literature, Infomobility is defined as "*the set of information management systems that aim at improving the mobility systems, providing the required information to managers and users*." This definition deals with Infomobility Systems as Information Management Systems, going beyond its technical aspects and objectives of single initiatives. It conceives Infomobility as a set of complex socio-technical systems characterized by an interplay of technological and human factors. Through the analysis of different literature contributions, the paper proposes a holistic framework for Infomobility that encompasses four dimensions defining WHAT Infomobility aims at improving *(Application fields)*; WHO is involved in a specific Infomobility system (*Actors)* and HOW Infomobility works (*Value Chain* and *Technologies*). Hereafter we briefly define every dimension.

- Application fields, refers to the main macro-areas of action that can benefit from an increased information on the mobility system. We identify five application fields: Fleet Management, Traffic Management, Mobility Payment, Safety and Security, Information Service. For each of them, we provide a list of the specific functions to which Infomobility can be applied (e.g. in the area of Traffic management some of them are the road infrastructure management, park and ride management, LTZ management). The various application fields are characterized by overlaps in terms of information

required and overall objectives. In effect, the double general goal of supporting the activities of transport managers (behind the first four application fields) and of assisting the travelers' mobility (through transport information services) are strictly related and influence each other.

- Actors, includes the different players taking part to the Infomobility sector. We propose an overall taxonomy of stakeholders that can participate to an Infomobility system, dividing them in three macro-categories: Consumer, Business and Public actors. The Customer category includes the travelers. Business actors include firms operating in transport, communication, IT and other correlated sectors. Public actors include the Public Administration, public bodies (e.g. Police) and public-private companies involved in the mobility system management. Usually, Customer are considered to be the user of transport information, for making more efficient their mobility experience (Nelson and Mulley, 2013); Business actors can contribute to develop and feed the information systems related to transportation networks (CEFRIEL et al., 2009); Public actors participate due to the public utilities features of Infomobility (Xu, 2000; Naniopoulos et al. 2004). However, all of them can be both "users" and "source" of information. Travelers can be information providers when they pinpoint emergencies and service malfunctioning; business actors can simply exploit transport information in order to improve their own activities; public authorities can be users of information for improving the services that they provide (Nelson and Mulley, 2013). According to the specific application field, the actors can carry out different activities and can be linked to each other through different relationships depending on the need of gathering resources, skills and technologies. For instance, public authorities can be policy makers or operators, since they can either directly take actions or appoint different private companies to deal with of various application fields of the Infomobility system (roads, parking lots, public transport management, etc.), in order to provide people with effective services.
- Value chain, consists in the stream of processes/activities that permit to make the information available to achieve the final goal. Through the literature review, we identify the following main macro-phases: first, data are gathered from the field; then, they are processed in order to be transformed in information useful to the final user; afterwards, the information is ready for being used in relationship to different application fields. Particularly, the processing phase, other than the information elaboration, can include an integration step. The latter is not obvious but it has been often taken for granted or observed in empirical Infomobility implementations (e.g. Kauber, 2004; Panou et al., 2007). However, it has been not deeply motivated and investigated in terms of what it requires, implies and produces from both a technical and managerial point of view.
- Technologies, refers to the technical systems that enable the functioning of the Infomobility systems. This dimension includes Intelligent Transport Systems (ITS) at the base of collection, processing and use of information on mobility systems (Montanari et al., 2006; Bin et al., 2013). We provide a categorization that makes easier the mapping of different available technologies for providing information about the mobility systems and its criticalities. It consists in macro-categories supporting various phases of the information value chain (from the data collection to the information use) (Panou et al., 2004). Data collection technologies, at the bottom of information chain, are those for the transport

systems monitoring. Technologies for data processing mainly include data translation and homogenization software, and dedicated database to archive them (Lampignano and Tesi, 2002; Brugnoli, 2007). Technologies for the data and information use comprise both network infrastructures, usage technologies and communication protocols enabling their flows along the value chain (e.g. most of Infomobility systems require portable devices which use standards and systems such as GSM, WAP, GPS, etc.). The ITSs have to be chosen depending on the specific goal of the system, the environment where it is being developed and the overall system itself (Kotsakis et al., 2001).

1.2 Article 2

The second paper identifies some dimensions of analysis for assessing the effectiveness of Infomobility systems. Some studies have highlighted the inadequacy of Infomobility systems to satisfy fully the requirements of information users (e.g. Hine and Scott, 2000, Nelson and Mulley, 2013) and to support a sustainable transport development (e.g. Paganelli and Giuli, 2009; Giuli et al., 2011; Bin et al., 2013). Nevertheless, this theme is largely unexplored, despite the growing interest in the potentials of Infomobility and the persisting dissatisfaction for many implementations (e.g. Giuli et al., 2011; Bin et al., 2013). The paper grounds on the premises that directly measuring the effects of an Infomobility system is hardly feasible due to the existence of a time lag between the conception, implementation and results of an Infomobility initiative, and the complexity of the transportation sector where a multiplicity of factors can influence these results (e.g. Du and Nicholson, 1997; Golob, 2003; Wang, 2010). Therefore, it focuses on the capability of an Infomobility system to provide mobility managers and travelers with information that they require for their activities, which it is called Infomobility Quality, as a proxy of their usefulness in solving the actual mobility problems.

This paper first defines the types of information that can be managed through these systems, since this information is eventually the object of the assessment. It embraces an overarching perspective to define what transport information is, including information that aids in optimizing the transport operations, and information at the base of information services for travellers (e.g. Li et al., 2008; Stathopoulos and Tsekeris, 2009). This information is typically about timing (e.g. trip duration etc.), space (travel route, etc.) and other transport services related information (fare rates, operator etc.) (Beul-Leusmann, 2013). Sometimes it is made a distinction between the "core" information, such as travel times and costs of alternatives, and the "soft" information encompassing some qualitative characteristics of mobility systems - e.g. convenience and comfort (Chorus et al., 2007), or other information that can have an influence on the use of transport systems – e.g. weather conditions (e.g. Yamamoto et al., 2000; Smith and Venkatanarayana, 2005).

Then, the paper identifies the set of quality dimensions to consider in the Infomobility field. By dealing with Infomobility Systems as "transport information management system', this work starts with a literature review on Transport Information Quality, and then extends beyond the specific field of Transport in order to gain a deeper understanding of the more general concept of Information Quality. The dimensions identified through this review shed light on three different perspectives that represent respectively the *intrinsic*

characteristics of information, the information *fitness* for the use, and the technical characteristics of channels for the information *delivery*. In particular:

- Quality of Information (QoI): it includes the intrinsic characteristics of the information. We distinguish attributes characterizing a single information to those about the mutual relations among them all. The latter emphasize the necessity of considering how information and services provided in the same context by different operators can be combined (e.g. Paganelli and Giuli, 2009; Natvig and Vennesland, 2010; Wydro, 2011).
- Value of Information (VoI): it is about the fitness of information characteristics to the users' needs, hence its *relevance* in relation to the problem being addressed (O'Reilly, 1982), and to the *understandability* of this information by the user (Tayi and Ballau, 1998). Indeed, on one hand what is important in some situations and contexts, it can be useless in others. Then, information has a different value according to the user's capability of understanding and interpreting it.
- Quality of Service (QoS) is about the "channel characteristics" for the information delivery and depends on their consistency with the users' requirements. It is related to the level of accessibility of information and to the level of privacy and security guaranteed by the channel for providing it (Logie, 1993; Wydro, 2011). The potentials of the accessibility in influencing the decision to acquire information, such as for understandability, comes from the effort - economic, temporal, physical, cognitive and affective, required for acquiring and using information (Chorus et al., 2006; Grotenhuis et al., 2007). In particular, in order to capture this effort, we embed in the accessibility the concept of information 'openness', according the Wydro's (2011) acceptation: free or paid/limited access.

The last two dimensions depends not only on the information features, but also on how it answers to the customers' requirements and they very determine the users' capability and willingness to use it. The definition of the Infomobility System objective and of the specific information users is fundamental above all if we consider dependencies and trade-offs between Information Quality attributes such as between currency and accuracy (Eppler and Wittig, 2000).

1.3 Article 3

The last paper aims to explore how OD approaches can be used in connection to Infomobility, and its impact in improving the Infomobility Quality and achieving the Infomobility objectives. We revise the OD literature in order to identify the key elements that characterize OD initiatives. The OD five interrelated elements are the institutional context, in which the OD initiative is developed, and the OD's objectives, governance, value chain and technology. The *institutional context* is defined as the set of fundamental political, social and legal ground rules that establishes the basis for the information production, exchange and distribution (Davis and North, 1971). About the *objectives*, prior literature highlights that the adoption of an OD approach can be related to reasons of transparency and efficiency growth, decision-making improvement, and socio-economic and innovation gains. Particularly, providing free access to public data, OD incentivizes new combinations of different data contents and the development of new information services (e.g. mobile application services - Apps), which in turn represent a new economic opportunity and have the potential to better respond to the

citizen requirements. When we talk about the *governance* of the OD initiative, we refer to the roles and relationships assumed by the network of actors involved in the OD systems (e.g. Melin and Axelsson, 2010; Borzachiello and Craglia, 2012; Davies and Edwards, 2012), as well as to the control mechanisms they implement in the data *value chain* (Desouza and Bhagwatwar, 2012; Jansen et al., 2012). The latter is the fourth element of the framework; it is the process enabling the collection, processing and delivery of data for their final uses. Finally, *technology* represent the technical aspects of the OD initiative, i.e. the data and information format and the technological system to access and re-use them (De Saulles, 2013). These elements are at the base of the analysis of two different cases where an OD approach is adopted in connection to Infomobility: Amsterdam and Milan. This double case study highlights the strengths and opportunities of the OD approach for Infomobility, but also its possible limitations and alternative solutions.

The Infomobility OD systems analyzed has been implemented in two European cities characterized by quite different institutional contexts. In the Dutch system, Provinces and Regions, in charge of adjudging concessions to public transport operators (PTOs) through public tender mechanisms, have a strong power in developing their own transport policies. Whereas in the city of Amsterdam the supra-municipality public authority (the City Region of Amsterdam) governs the public transport system operated by three different PTOs (GVB, Connexxion and EBS), the public transport situation of Milan is more fragmented. Indeed, the Municipality of Milan governs just the urban transport system operated by ATM - i.e. a PTO owned 100% by the Municipality itself. Following the European Community directives emphasizing transparency and openness of Governments' data, both the City Region of Amsterdam and the Municipality of Milan promote OD policies. However, the Infomobility OD initiatives analyzed are very different in terms of capability of achieving the Infomobility objectives of supporting the transport network planning and control, and of providing travelers with transport information services. We analyzed this capability referring to the three dimensions of the Infomobility Quality identified in the Article 2: the Quality of Information (QoI), the Value of Information (VoI) and the Quality of Service (QoS). Then, we draft some considerations about the systems capabilities of achieving the Infomobility goals.

The first dimension that we analyze is the Quality of Information (QoI). In general, the OD approach entails a higher information diffusion, which fosters a general improvement of the QoI. Indeed, it leads to higher quality requirements by the information users, and enables "control mechanisms" by the public (citizens, Apps developers and other operators and authorities) on the information and transport services. Furthermore, the PTA's initiative implemented in Amsterdam enables a further QoI control by GOVI that pushes PTOs to improve continuously.

Then, we consider the Value of Information (VoI). The Infomobility OD system of Amsterdam embeds two OD initiatives covering not only the urban area of Amsterdam, but also the overall region around it and the most Holland territory. Both of them provide also real time transport information that are used for the development of Apps. Indeed, the Dutch system is witnessing the rising of a flourishing Apps market, seen as an opportunity for increasing the availability of information services for users, and stimulating the economic development and innovation. The Infomobility OD system of Amsterdam, enabling the open access to information hold by all the PTOs operating in Amsterdam, potentially allows both PTAs and PTOs

acquiring a greater awareness on the overall public transport system of Amsterdam. However, we have to consider that the OD system of Amsterdam is just about public transport. This makes difficult in Amsterdam the creation of Apps based on the integrated multi-modal travel information desired by travelers (e.g. Kenion and Lyons, 2003; Grotenhuis et al., 2007). The monitoring of the overall public transport system is run just by the PTAs through integrated information provided by GOVI (Public Transport Information Without Frontiers) – i.e. the organization collecting public transport data gathered by PTOs and delivering them through an OD platform and displays systems at the bus and metro stops (Dynamic Travel Information Systems - DTIS). Nevertheless, the Dutch PTOs still do not use reciprocal information available through OD and there is not a joined/integrated transport service planning operated by PTOs.

The Infomobility OD system of Milan provides non-real time information about public transport, car sharing and bike sharing services gathered by AMAT, the mobility technical agency of the Municipality of Milan, and ATM. Real-time data, as Grothenhuis et al. (2007) affirm in their work, are the most-desired type of information by travelers. Consequently, even if the Infomobility OD system of Milan has been proposed as favoring the Apps development, it seems not suitable for the traffic real time information services. Then, the OD initiative developed in Milan allows free access only to the information owned by the Municipality, so not leading to a higher awareness and knowledge on the overall urban system by the Municipality and to a consequent improvement of the PTA's transport management activity. It just leads to a potential reduction of the workload for public agencies employees for satisfying researchers' information requirements.

Finally, we consider the Quality of Service (QoS). First, data and information provided by all the OD system studied are not critical in terms of privacy and safety issues because they are about the public transport means position, not the travelers' mobility flows. Second, both the OD systems of Amsterdam and Milan are based on open licenses guaranteeing free access and re-use of public transport data by citizens and all the private and public entities aiming at creating value on them. Particularly, inspired by our findings related to the OD potentials, it is worth to highlight that OD systems, authorizing the dissemination of knowledge, not only facilitate the information access for public transport mangers, travelers and Apps developers. They also foster research works on mobility and Infomobility systems by Universities or Center of Excellence at the base of innovations and future development in this field.

In Milan, other than the OD initiative, this study presents another project implemented in Milan by some public and private entities in charge of the local economic development (Confindustria, Camera di Commercio di Milano, Confcommercio, Assolombarda e Unione del Commercio) along with Expo 2015 Spa. This initiative, called "E015 digital ecosystem", has been carried on with the purposes of supporting a greater diffusion of information about the territory (not only transport information) and the emergence of innovative and effective information services. It is not an open database. It consists in a digital environment based on interoperability standards between some contractors, which enables communication among information systems. As in the case of OD, the greater diffusion of information enabled by this interoperability solution has led to a higher control of information by the public that potentially guarantees a

higher QoI. Then, E015, allowing an easier access to both static and real time transport information[11], facilitates the circulation of real time information among all the transport and Infomobility operators, fostering integrated real time Infomobility services and leading to a greater awareness about the overall mobility system by the mobility managers. Different Infomobility operators have developed 13 integrated applications for travelers based on E015. However, even if nowadays there are many Apps that are being developed based on E015 also by third parties, they are still not about transportation.

2. Results and contributions

This research, throughout the three articles, answers three main key research questions and fulfills some relevant gaps of the Infomobility literature. Then, it provides also relevant contributions to practitioners operating in the Infomobility sector. Results and academic and managerial contributions of every paper are summarized hereafter.

Article 1 addresses the concept of Infomobility in terms of meaning and fundamental elements to be considered in the attempt of overcoming the high level of fragmentation and heterogeneity that characterize the research in this field. To this aim, after having defined Infomobility, we develop a holistic framework of Infomobility as key to the analysis and interpretation of different academic works and empirical projects. This research could also provide a useful support to policy makers in designing more effective strategies and interventions on the mobility system, since it not only clarifies and outlines the Infomobility theme, but it also identifies the most critical elements of an Infomobility system. Particularly, the proposed Infomobility framework underlies the relevance of not only technologies but also of the objectives, actors and processes characterizing an Infomobility system. Then, the analysis reveals the existence of overlapping areas, reciprocal influences and blurred boundaries characterizing different goals and application fields, which in turn can cause operational difficulties in the management of Infomobility systems. However, these circumstances highlight the potentials of properly defining the link between different services and of integrating data useful for different purposes in order to avoid possible redundancies. Then the Infomobility framework finds out the possible complementarity or compresence of different actors along the value chain, suggesting the convenience of making easier and more effective the coordination among them all. This could be very challenging since the coexistence of public and private subjects diverging in terms of sets of values, management approaches and decision-making criteria. Finally, it suggests the relevance of selecting the most suitable technologies at any value chain phase based not only on the Infomobility system goal, but also on the specific context requirements.

Article 2 addresses the unexplored theme of the Infomobility systems assessment in terms of capability of providing mobility managers and travelers with information that they require for their activities. Previous academic works have just mentioned Infomobility potentials or weaknesses, or evaluated performances of single system, without providing a structured and general instrument for the analysis of them. By reviewing the existing literature on Transport Information Quality and Information Quality, after having defined the

[11] Actually, this system includes not only transport information services, but also many services related to the territory of Milan (e.g. tourist and cultural services).

types of information managed through these systems, we identify three Infomobility Quality dimensions synthetizing the characteristics to be taken into account by decision makers for increasing the Infomobility effectiveness in improving the mobility systems. Whereas the first dimension (QoI) refers to the intrinsic information quality, the other two dimensions (VoI and QoS) suggest the need of tailoring the system on the characteristics of the users that are supposed to exploit the transport information provided. This framework aims at leading the future developments and assessments of Infomobility Systems by supporting practitioners in the Infomobility system design coherently with their specific objectives, and at evaluating their effectiveness in order to identify possible corrective actions to be implemented. It suggests that not only the intrinsic quality of the transport information, but also the fitness of the information contents with the users' requirements and the characteristics of accessibility, privacy and security to this information are potentially determinant elements of the effectiveness of Infomobility initiatives. Therefore, it is necessary to specify previously the context and the reasons why the Infomobility system is implemented, and to identify the users of the transport information provided. Nevertheless, the variety and uncertainty characterizing the users' world make the definition of Infomobility systems archetypes based on the information users' requirements a very complex task.

Article 3 accomplishes the thesis main goal. Through a double case study, based on OD key elements identified in the previous academic works on OD, we not only analyse the real potentials of this approach in supporting the achievement of the Infomobility objectives. We also identify criticisms and barriers for an effective exploitation of this approach in the Infomobility sector. It provides an innovative contribution to the academic literature since a research on the adoption of this information management approach in the Infomobility sector has been still missing. It is particularly interesting considering that the research of possible solution making more effective the exploitation of transport information for improving mobility system is a more and more debated issue. Finally, it shows the relevance of the Infomobility Quality dimensions proposed in the Article 2 for the assessment of Infomobility initiatives. We assess two OD initiatives based on differences in these dimensions and in the achievement of Infomobility objectives depending on different declinations of the OD system elements. OD, enabling a free circulation of data for the use, re-use and re-distribution of them, on one hand allows a higher control and improvement of the QoI. On the other hand, by definition, it entails a high level of information accessibility, which in turns potentially enables a more effective transport system management and the creation of new information services that better fit the travelers' needs.

This research also deepens some understanding of previous research in relation to the technical and managerial criticisms and barriers for the implementation of Infomobility initiatives. First, it confirms how also within OD initiatives, the main criticality to consider in the Infomobility sector is the coexistence of different types of actors with different objectives, priorities and managerial approaches. Indeed, even where there is a high commitment towards OD by PTAs, transport operators, which are usually the information holders, are very reluctant in opening their data to third parties. The reason for that is twofold: because they consider themselves as the most qualified entities for providing transport information services; because they consider data as their own assets that can also be misinterpreted and misuse (e.g. for business or spill over

goals) by third parties. Obviously, this problem is heightened when PTOs are private enterprises and when they work in a high competitive environment. In order to overcome this problem a possible solution is that one adopted by Amsterdam, where the Public Administration have the power of forcing operators to freely distribute data. However, PTOs are usually annoyed and hold out basing their opposition on 'level playing field issues'[12]. The level of decision power of transport authorities and operators has to be clearly defined since it much determines the level of accessibility to transport information and in turn different results in achieving the Infomobility goals. It brings to the light the first key element to be considered for the implementation of Infomobility OD systems. When the OD is adopted, a suitable institutional context calling for a high commitment and power of PTAs is required. These results validate the necessity of aligning the characteristics of an Infomobility system to the specific context where it is implemented (Spanoudakis and Panou, 2009).

Then, this study confirms the relevance of both the technical and process elements. First, Infomobility OD systems ask for the adoption of technological standards and the definition of shared data formats to enable the easy sharing of data and information among different systems and devices owned by various actors along the Infomobility value chain (Curtin, 2010; De Saulles, 2013; Kassen, 2013). Actually, standards are required for any form of solution that implies an information sharing and an inter-operability of applications (Desouza and Bhagwatwar, 2012; De Saulles, 2013). Second, OD system has to include a feedback management phase in the data value chain, in order to improve the systems through the exploitation of users' complaints due to the greater transparency of the services provided and the higher expectations of travelers. This research finally shows how Interoperability initiatives such as the E015 system could be a very interesting solution in those cities that wish a wide diffusion of transport information among both mobility managers and travellers, but where OD is not feasible because of missing institutional and governmental conditions in the Infomobility context. E015 allows information providers handling data and information services and maintaining the total control and ownership on them. Every data holder decides which service to distribute and who can use it to create benefits through this information. In this way, we found data holders, who are increasingly aware of the marketing and travellers satisfaction advantages of providing the public with a great amount of information, to be more inclined to share real time information services when they can maintain the control on their data and the monitoring on information services based on them.

Finally, the Article 3 deepens two ideas that have come to light in Article 1 and 2. The former is the need of clearly defining the specific goal of the Infomobility system. In the Article 1, we highlight that the definition of the Infomobility application filed is the starting point for the implementation of a system, since it determines how the other elements of it could be configured. However, we also shed light on the difficulties in closing off single application fields due to reciprocal influences and blurred boundaries characterizing their objectives. The Infomobility goal of supporting the transport management activities, and of assisting travelers previous and during the trip are much related because they influence each other. Then, for instance, a better 'Fleet Management' can contribute to 'Traffic Management' and 'Safety and Security', and 'Traffic

[12] It refers to the PTOs' possible loss of competitive advantage because of OD, due to both eventual new third parties that want to enter the market, and the actual competitors that could imitate their operational practices and spy on their performance.

management' can contribute to the improvement of 'Safety and security'. In the Article 2, we have emphasized the importance of not only defining the general goal, but also the transport information users that can get benefits from the implementation. Depending on the application fields, the final information user could be either a transport system managers or a traveler. Obviously, they have different information contents and delivery requirements (see Infomobility Quality dimensions) that can even change over time (Strong et al., 1997) and only by understanding them it is possible the development of an Infomobility system very effective in achieving its own objectives. The Article 3 confirms these results since it highlights how even adopting a same approach (in our study, the OD one) the different technical and managerial aspects of the system needs to be differently shaped depending on the specific Infomobility goal (e.g. travelers assistance) and users' requirements (e.g. PT real-time information) in order to be useful.

Another consideration is related to the theme of the transport information integration. Different previous studies on Infomobility affirm that integrating comprehensive and real-time data related to different transport means, even provided by different actors, is crucial for satisfying mobility managers and users' needs (Xu, 2000; Hine and Scott, 2000; Kauber, 2004; Santos et al., 2010). This statement is based on a more general idea of the need of a more holistic approach to both the transport and transport information management. Indeed, first it is close to the notion of 'integrated transport' that, applying the concepts of the System Theory, typically refers to the necessity of integrating the different modes of transport (public and private), and land-use policy with transport policies, for increasing the level of sustainability of mobility systems (O'Sullivan et al. 2004; Wang, 2008; Santos et al., 2010). Second, previous works show the travelers' desire for integrated multi-modal travel information (Grotenhuis et al., 2007) and affirm the potential benefits of Integrated Multimodal Transport Information Systems (Kenion and Lyons, 2003). The objective of these systems is to make transport information more accessible, reducing the effort of searching for information about the different travel modes, and to lead to a more rational and informed modal choice. To this aim, they are characterized by a unique point of access to the knowledge about the overarching mobility system (in forms of raw data as well as information services) and automatically provide users with information concerning different mode choice options in response to a particular journey. IMTI, presenting information on all the options, also can also minimize the issue of the ignorance about the transport and information services available, and even suggest modal alternative, so affecting travelers' behaviors (Kenion and Lyons, 2003; Grotenhuis et al., 2007). The integration element, after having been identified in the first Infomobility literature review (Article 1), has been found out critical also throughout our research on Infomobility Quality (Article 2) and the empirical study on the OD initiatives (Article 3). Article 1, considering the overlaps among application fields and mutual relationships with each other, highlights the importance of properly integrating data that can be exploited for different purposes (Paganelli and Giuli, 2009). Article 2 is coherent with several academic works supporting the need for considering information with a systemic perspective within a same context (e.g. Paganelli and Giuli, 2009; Natvig and Vennesland, 2010; Wydro, 2011). Indeed, first it sheds light on the mutual relations among information collected through different systems for a higher level of information completeness, accuracy and precision, hence for improving the QoI. Second, it considers the two dimensions of the information fitness for the use, and of information accessibility, which can be both

improved by the information integration. Information integration guarantees the suitability of the information provided with the multi-modal information requirements of mobility managers and travelers. Then, it enables a higher information accessibility to mobility managers, travelers, and other new Infomobility service developers. The last study shows that in Amsterdam, the PTOs' provision of a unique point of access to homogenous information about the overall public transport service has exactly the aim of increasing the accessibility level of information for users such as Apps developers, not willing to invest effort in integrating data from multiple organizations (Desouza and Bhagwatwar, 2012). However, despite the public transport information integration, information provided by the OD system of Amsterdam is not yielding a greater use of respective information and a greater interoperability among PTOs, hence it is not supporting the 'integrated transport'. After all, it is worth to highlight that the Dutch system is characterized by a high competitive environment where the data integration is operated by PTAs that dictate PTOs to share all the available data they gathered in a unique database, so yielding some resistances from PTOs annoyed and holding out basing their opposition on level 'playing field issues'. In the **Table 9**, we summarize the main result related to the Infomobility and OD themes.

Table 9 - Results

Art	Objectives	Results
1	It provides a clear definition of Infomobility and a holistic framework of its constituents	• Overlapping areas, reciprocal influences and blurred boundaries among application fields ➔ Potentials of properly defining the link between different services and of integrating data • Complementarity or compresence of different actors along the value chain ➔ Convenience of increasing the coordination among the Infomobility actors, but difficulties due to the coexistence of public and private subjects • Many options offered by the modern technologies both in terms of type of information and means by which it is delivered and accessed ➔ Relevance of selecting technologies at any value chain phase that are the most suitable in relation to the system goal and the context requirements
2	It identifies the main dimensions of Infomobility Quality that constitute a basis for its assessment	The elements determining the effectiveness of Infomobility initiatives are: • The intrinsic quality of the transport information, including also systemic attributes such as the overall information completeness • The fitness of the information contents with the users' requirements • The characteristics of accessibility, privacy and security to this information ➔ Need of specifying the context of implementation, and goals and users of the Infomobility system
3	It investigates the potentials of the Open Data approach in the Infomobility sector: analysis of the 3 quality dimensions in some OD initiatives, assessment of the capability of these OD systems in achieving the Infomobility objectives and identification of criticisms and barriers for an effective exploitation of this approach	The OD approach, enabling a free circulation of data for the use, re-use and re-distribution of them: • Allows a higher control and improvement of the QoI • Entails a high level of information accessibility (QoS) • Entails a higher fit of the available information with the users' requirements (VoI) Findings in the Infomobility field are related to: • The need of clearly defining the specific goal to achieve and the information users before the development of a specific Infomobility system • The necessity of aligning the characteristics of an Infomobility system to the specific context where it is implemented • Criticisms and barriers in achieving the Infomobility goals: o Institutional context: The decision power of transport authorities and operators o Governance: Actors involved, relative objectives and roles, and control mechanism o Technology: The adoption of technological standards and the definition of shared data formats o Value chain: The existence of feedback management and data integration phases • Interoperability as an interesting solution to achieving the Infomobility goals also overcoming managerial problems of the OD approach

3. Limitations and future research

This research, based on qualitative data, provides an explorative investigation of the adoption of an OD approach in the Infomobility field. On one hand, it is able to confirm and deepen some results of previous stream of literature on OD and Infomobility. On the other hand, it opens up several new research questions that could be further explored in order to provide a more concrete managerial contribution to both the academics and practitioners' worlds. These emergent concepts should be analysed in order to extract new knowledge and generalizable results. Future research could provide deeper insights on them with stronger internal validity and wider generalizability by quantitative data collections and by more focalized literature reviews (Eisenhardt, 1989). Hereafter we provide a summary of these open areas of investigations.

Our studies suggest the importance of identifying the socio-technical solution more coherent with specific goals of the Infomobility initiative and the users' requirements. However, we have not identified Infomobility systems archetypes tailored on the Infomobility goals and users. The overlaps among goals and the great variety of transport information users, along with the amount of options offered by the modern technologies in terms of data provision and information services could make this aim hardly achievable. A taxonomy of the characteristics of information and channels required by different macro-types of users (e.g. travelers, public transport managers) and more coherent with the Infomobility goal, could be the first step towards this direction. Particularly, starting from the critics moved on the Amsterdam and Milan OD systems, we could deepen the need of leveraging on real-time data and multi-modal integrated information for providing information services that really fit the travellers' needs, for instance through surveys to both citizens or focus groups with mobility managers and Apps developers in Amsterdam and Milan. Furthermore, the theme of the integration of information about different transport modalities owned by several and different types of actors could be investigated in terms of integration mechanisms and consequent results on the transport operations and services. For instance, when achieved through the collection of data in a unique database, integration could be critic, because it would implies the necessity of cooperation among these actors characterized by different objectives, priorities and managerial approaches (Kenninen, 1996; Kauber, 2004). Interoperability initiatives, since they do not require the creation of a unique co-managed datasets integrating homogenous sensitive data, could have the further advantage of overcoming the problem related to the number or variety of information holders to be involved in the Infomobility system. Providing a digital environment to potentially infinite numbers of datasets owned by different actors that keep the control on their data, they leverage on an increasing complexity for the creation of new knowledge on the mobility system and new information services for travelers (e.g. Lampathaki et al, 2010; Davies, and Edwards, 2012; Kloeckl et al., 2012). However, even the capability of interoperability solutions of satisfying the mobility managers and travellers' information needs should be further studied, for instance by monitoring the evolution of the E015 initiative.

The theme of data integration could be further analysed also focusing on the different impact of different types and levels of data integration on the Infomobility effectiveness, which we have neglected in this study. Researchers could collect data on the actual use by Apps developers of the two OD initiatives of Amsterdam - the GOVI one providing already elaborated and integrated information, the REISinformatiegroep BV one

providing raw data, in order to analyse the effect of either providing integrated information, or just making available raw data through a unique point of access.

Another interesting concept emerged from the empirical study is related to the impact of increasing the governance complexity on the quality, innovation, and economic development grade characterizing the Infomobility OD systems. Indeed, the fundamental idea in the City Region of Amsterdam is that a greater number of actors participating the OD value chain, also assuming the same role within it, stimulate progresses on the overall quality of the Infomobility system. For instance the role split between GOVI and openOV is thought to keep divided the OD portal in order to leave the much possible part of the data value chain in a competitive environment where everyone is encourage to participate to stimulate each other in making progress. In order to investigate this issue it is necessary extending the research to further case studies.

Finally, even though the relevance of the PTAs commitment toward the adoption of an OD approach, this research has so far neglected the analysis of the key factors and the decision-making processes leading PTAs to choose OD (or other information management approaches) in the Infomobility sector. These aspects, such as that one of the possible strategies and instruments (e.g. public tenders) that can be implemented by PTAs for leading to a more effective use of transport information could be investigated by future studies.

In conclusions, this is an explorative research that, first, contributes to fill important literature gaps, providing an overarching definition and framework of Infomobility, identifying some dimensions for its assessment, and analyzing possible solutions to increase the effectiveness of Infomobility systems. Second, it contributes to the debate concerning the Open Data, investigating this approach applied to Infomobility. Third, starting from the points of weakness of our investigation, it proposes causes of reflection for future researches in the Infomobility field. Finally, it can also be the base for forthcoming improvements and innovations in the Infomobility sector since it shows some evidences related to the topical OD approach as Infomobility solution, and provides general considerations related to key elements and criticisms determining the development and results of Infomobility systems.

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