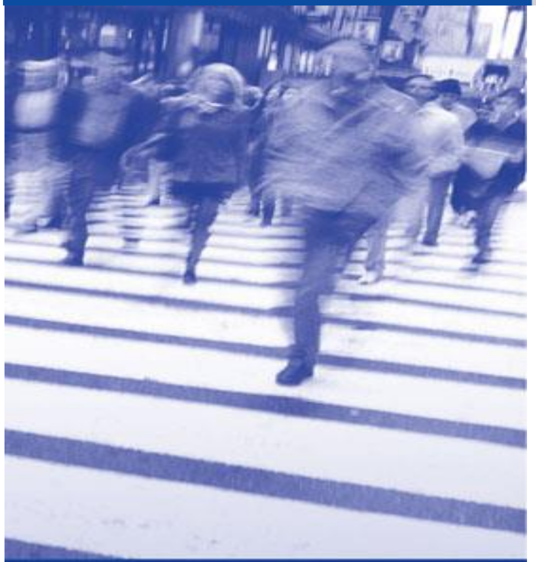
2020 CIVITAS
Cleaner and better transport in cities

SUITS



Work Package 3

D3.1 Research and Gap analysis on data collection and analysis methods

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2020 CIVITAS
Cleaner and better transport in cities

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Abstract

Mobility Plans establish short, medium and long-term planning in cities, where possible taking into account available data for passengers and freight movements. D3.1. aims to provide an introduction to the current strategies available and used by medium-sized European cities for data collection, including traditional and more technologically, automated methods. It will provide the project with information on where there are gaps and difficulties in data collection processes which SUITS can address in its capacity building.

A main section in this deliverable is the analysis of information regarding urban mobility data, which enables conclusions to be drawn and the identification of generic possible problems of the cities. D3.1. presents current methods and solutions that have been developed around Europe.

Finally, the requirements of local authorities in relation to data collection are identified, concluding with a summary of gaps and a SWOT analysis on data collection activities.

Table of Contents

1. SUSTAINABLE URBAN MOBILITY PLANS DEVELOPMENT. THE NEED OF DATA MOBILITY COLLECTION TOOLS.......10
1.1. RECOMMENDATIONS FOR SUSTAINABLE URBAN MOBILITY PLANS (SUMPS) DEVELOPMENT.........13
1.2. EUROPEAN RECOMMENDATIONS FOR SUSTAINABLE URBAN LOGISTICS PLANS (SULPS) DEVELOPMENT.......16
1.3. CONCLUSIONS.......17
2. STRATEGIES IN DATA MOBILITY COLLECTION IN EUROPE.......20
2.1. MANUAL METHODS.......20
2.1.1. Surveys and interviews.......20
2.1.2. Manual counts.......25
2.2. AUTOMATED DATA COLLECTION.......27
2.2.1. Traffic detection systems.......27
2.2.2. Specific passengers' data gathering methods.......39
2.2.3. Specific freight data gathering methods.......47
2.2.4. New approaches for data gathering based on ICTs.......50
2.3. CONCLUSIONS.......56
3. ANALYSIS STRATEGIES OF DATA MOBILITY IN EUROPE.......58
3.1. KEY PERFORMANCE INDICATORS FOR PASSENGERS AND FREIGHT MOBILITY ANALYSIS.......58
3.1.1. Passengers' mobility evaluation KPIs.......59
3.1.2. Freight mobility evaluation KPIs.......72
3.2. DECISION SUPPORT SYSTEMS (DSS).......81
3.3. OPEN DATA AND BIG DATA.......87
3.4. REVIEW ON CIVITAS URBAN MOBILITY TOOL INVENTORY FOR DATA GATHERING, ANALYSIS AND MEASURES SELECTION.......94
3.4.1. Evaluation of cities performance (methodologies for assessment and comparison) 95
3.4.2. General traffic data gathering and management tools.......95
3.4.3. Active modes data gathering and analysis.......96
3.4.4. Crowdsourcing methods.......97
3.4.5. Urban freight specific tools.......98
3.4.6. Public transport data gathering strategies.......98
3.5. CONCLUSIONS.......98
4. REQUIREMENTS AND NEEDS FOR TRAFFIC DATA FROM URBAN PLANNERS 102
4.1. GAPS ON DATA AVAILABLE IN 7 SUITS' CITIES.......103

4.1.1. Valencia 104
4.1.2. Roma (Italy)..106
4.1.3. Torino (Italy) 106
4.1.4. Alba Iulia (Romania)...104
4.1.5. Erfurt (Germany) 105
4.1.6. Palanga (Lithuania) 105
4.1.7. Kalamaria (Greece)..105
4.2. CONCLUSIONS..107
5. GAP ANALYSIS CONCLUSIONS 110
6. REFERENCES 115

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F. K. LIOTOPOULOS KAI SIA EE	GREECE	SBOING
LOGDRILL INFORMATIKAI ES SZOLGALTATO KORLATOLT FELELOSSEGU TARSASAG	HUNGARY	LOGDRILL
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List of Tables

Table 1. Types of data collected according to the suits data management plan (d1.1) 19

table 2. Technologies used to collection mobility data by partner cities in suits. *Own development.* 108

List of Figures

Figure 1. Modal split of inland passenger transport, 2014 (% of total inland passenger-km). *Eurostat.* 11

Figure 2. UK is Europe's third most traffic-congested country, study finds. *Express* 12

Figure 3. Planning cycle for a Sustainable Urban Mobility Plan. *Guidelines: Developing and implementing a Sustainable Urban Mobility Plan*..15

Figure 4. Guidelines: Developing and implementing a Sustainable Urban Logistics Plan. *Enclose project.* 17

Figure 5. Manual counts. w*ww.traffic-tech.com* 26

Figure 6. Pneumatic road tubes. *TSC for surveys.* 27

Figure 7. Piezoelectric sensors. *US Department of Transportation* 28

Figure 8. Magnetic loops. *Alistair Gollop: Traffic signals* 29

Figure 9. Inductive loops. *https://auto.howstuffworks.com* 30

Figure 10. Infrared sensors. *Osi Laserscan*...31

Figure 11. Microwave radar operation. *U.S. Department of Transportation*. 33

Figure 12. Lidor sensors to detect traffic. *Azosensors.* 34

Figure 13. Radio Frequency Identification. 35

Figure 14. Acoustic traffic sensors*. Roadsys, LLC.* 36

Figure 15. Ultrasonic range-measuring sensors. *Microwave sensors, Ann Arbor.* 37

Figure 16. Video Image Detection (VID). 37

Figure 17. The technology behind ITSO. www.*itso.org*..45

Figure 18. Data collection from bluetooth and wifi devices. *Libelium (http://www.libelium.com/*) 53

Figure 19. Bluetooth traffic monitoring design decisions. *M. R. Friesen and R. D. Mcleod (2014)* 54

Figure 20. How works a system based on wifi detection. *Worldsensing: Bitcarrier (http://www.worldsensing.com/product/bitcarrier/)* 55

Figure 21. Example of crowdsourcing data collection. *Evan Welbourne et al.* 56

Figure 24. Urban freight modelling structure. *Antonio Comia and Luca Rosatib (2013) Class DSS.* 83

Figure 25. Logistic profile examples for the inner area of rome*. Antonio Comia and Luca Rosatib (2013) Class DSS.* 83

Figure 26. Shopping trip production according to freight type. *Antonio Comia and Luca Rosatib (2013) Class DSS.* 84

Figure 27. Example of DSS use: Matrix of criteria, matrix of alternatives and results of the dss. *Valentin Grecua, Tudor Morarb (2013)* 86

Figure 28. SAE working scheme. *Ingenia.* 87

Figure 29. Big Data life cycle. *International transport forum.* 93

Figure 30. Characterization of cities completing T2.1. Survey. *Own development.* 103

Abbreviations

AADT: Average Annual Daily Traffic

APP: Application

DSS: Decision Support Systems

FCD: Floating Car Data

GPS: Global Positioning System

GDP: Gross Domestic Product

INE: Spanish National Institute of Statistics

HGV: Heavy Goods Vehicle

ITS: Intelligent Transportation Systems

KPI: Key Performance Indicator

LGV: Light Goods Vehicle

LTZ: Limited Traffic Zone

MAC: Media Access Control

MCVLZs: Multiple Commercial Vehicle Loading/Unloading Zones

O-D: Origin-Destination

PMR: People with Reduced Mobility

PT: Public Transport

RFID: Radio Frequency Identification

SAE: System Aid for Exploitation

SCVLZs: Single Commercial Vehicle Loading/Unloading Zones

SMS: Short Message Service

SUITS: Supporting Urban Integrated Transport Systems

SULPs: Sustainable Urban Logistic Plans

SUMPs: Sustainable Urban Mobility Plans

SWOT: Strengths, Weaknesses, Opportunities and Threats

VID: Video image detection

VKT: Vehicle Kilometres Travelled

WBCSD: World Business Council for Sustainable Development

Aim and scope

The aim of WP3 is to contribute to capacity building of urban planners and stakeholders through a better understanding of data collection, analysis and knowledge discovery methods to identify opportunities for improvement in urban transport efficiency and environmental impact.

The main outcomes of the WP3 are:

- A data analysis methodology to diagnose/discover problems and opportunities for mobility improvement when analysing the combined effects of freight and passenger traffic data.
- Guidelines for implementation of measures in a diagnosis-solutions-expected KPI values approach. Participant cities will be invited to apply these guidelines for a first assessment of the potential implementation of measures in each participant city.

These outcomes constitute methods to fill the gaps in stakeholder knowledge of tools which will be potentially transferable to any small to medium European city.

Different data collection and analysis methods have been analysed in **Deliverable 3.1.** to identify current shortcomings and gaps and to explore opportunities for greater integration of passenger and freight traffic information, the identification and analysis of the active forms of transport and the representation of “hard to reach” groups e.g. elderly, disabled, women, parents with children, low income and communication impaired and those who make complex journeys.

Inputs from WP2 regarding requirements and the needs for traffic data from urban planners from project participating cities to complement this gap analysis have been taken into account. Research was focused on existing commercial tools, results from mobility projects and on-going research. Re-use of already available open data, legacy data, real time data gathering or crowdsourcing has also been included.

In the upcoming tasks, two pilot experiences will be developed, showing the potential of the integration of freight and citizen traffics flows to support decision making on new transport measures and SUMPs.

1. Sustainable Urban Mobility Plans development. The need of data mobility collection tools.

During the last decades, global socioeconomic changes have substantially affected urban transport. Mobility in today's cities is characterized by more diffused mobility patterns, with longer travel distances and a continuous increase in the level of motorization.[1]

The urban mobility habits are characterized by a continuous expansion and a growing dependence on the private vehicle, producing negative effects such as traffic congestion or poor communication, environmental and social impacts.

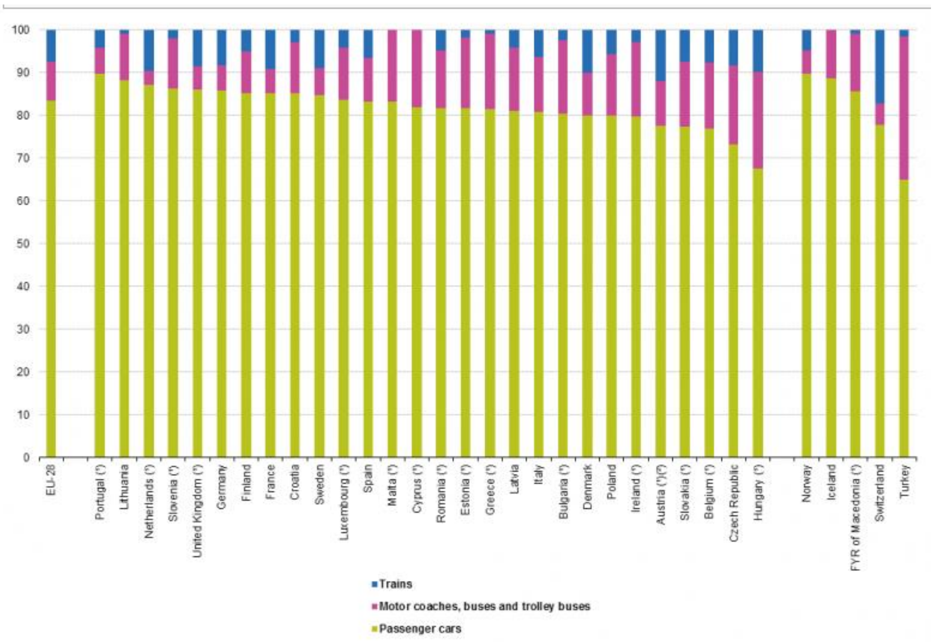

Figure 1. Modal split of inland passenger transport, 2014 (% of total inland passenger-km). *Eurostat.*

This trend has continued in the last years. According to a United Nations report[2], 80% of all European citizens will live and/or work in cities by 2030 (currently 75%).

As a consequence, urban transport has produced adverse impacts on sustainable development, affecting the environment, health and safety of the citizens, the economy, the society and, in general, the quality of life of the population that lives and works in the cities.

[1] Urban mobility, Pilar Perez del Real SAMA Sevilla. Environmental design in University Curricula and Achitectural Training in Europe. www.educate-sustainability.eu/kb/content/urban-mobility
[2] Freight transport statistics. Web: https://ec.europa.eu/transport/sites/transport/files/facts-fundings/statistics/doc/2014/pocketbook2014.pdf

Figure 2. UK is Europe's third most traffic-congested country, study finds. *EXPRESS*

This situation has increased the need to develop and implement sustainable and integrated urban transport systems which were less dependent on fossil fuels. In order to achieve this, resources have to be enabled, measures implemented and trends changed. This process requires a raise of awareness, changes at organizational levels of public administrations, and the involvement of the whole society, as well as, the collaboration between the different administrative departments and regions in order to attain integral solutions that will have significant impact on urban mobility.

European towns and cities face ever growing challenges to improve the performance of their urban transport systems, to reduce the negative impact of transport activities on the climate, the environment and citizens' health, and to render urban mobility more sustainable.

Consequently, an Action Plan on Urban Mobility[3] was adopted on 30 September 2009 and provides a coherent framework for 20 concrete EU-level actions, which could be implemented by the European Commission in the following years and through existing instruments and initiatives. The concrete actions were:

- Accelerating the take-up of sustainable urban mobility plans
- Sustainable urban mobility and regional policy
- Transport for healthy urban environments
- Platform on passenger rights in urban public transport
- Improving accessibility for persons with reduced mobility
- Improving travel information
- Access to green zones
- Campaigns on sustainable mobility behaviour
- Energy-efficient driving as part of driving education
- Research and demonstration projects for lower and zero emission vehicles
- Internet guide on clean and energy-efficient vehicles
- Study on urban aspects of the internalisation of external costs
- Information exchange on urban pricing schemes

[3] Action Plan on Urban Mobility, European Commission, 2009 (COM(2009) 490 final).

- Optimising existing funding sources
- Analysing the needs for future funding
- Upgrading data and statistics
- Setting up an urban mobility observatory
- Contributing to international dialogue and information exchange
- Urban freight transport
- Intelligent transport systems (ITS) for urban mobility

The European Commission is actively leading the implementation of the Action Plan on Urban Mobility. In 2012, they conducted a review of the implementation of this Action Plan. It also assessed the need for further actions in this area, considering the goals of the Europe 2020 Strategy and the vision for the future development of the European transport system outlined in the 2011 White Paper on Transport.

Sustainable Urban Mobility Plans (SUMPs) provide cities with a process through which they can develop and implement wide scale transport plans and integrated actions (transport measures).

Consequently, SUMPs have been increasingly adopted in EU cities to reduce the impacts associated with urban mobility. This is the reason why many European cities are developing their own SUMPs.

1.1. Recommendations for Sustainable Urban Mobility Plans (SUMPs) development

Following the European recommendations for SUMP development[4]:

The central goals of a SUMP is to improve the accessibility of urban areas and provide high-quality and sustainable mobility and transport, through and within the urban areas. It regards the needs of the 'functioning city' and its hinterland rather than a municipal administrative region. In pursuit of this goal, a Sustainable Urban Mobility Plan seeks to contribute to development of an urban transport system which[5]:

- Is accessible and meets the basic mobility needs of all users;
- Balances and responds to the diverse demands for mobility and transport services by citizens, businesses and industry;

[4] Guideliness: Developing and implementing a Sustainable Urban Mobility Plan. ELTIS (http://www.eltis.org/sites/eltis/files/guidelines-developing-and-implementing-a-sump_final_web_jan2014b.pdf)

[5] A concept for sustainable urban mobility plans to the communication from the commission to the European Parliament, the council, the European economic and social committee and the committee of the regions. Together towards competitive and resource-efficient urban mobility.

- Guides a balanced development and better integration of the different transport modes;
- Meets the requirements of sustainability, balancing the need for economic viability, social equity, health and environmental quality;
- Optimises efficiency and cost effectiveness;
- Makes better use of urban space and of existing transport infrastructure and services;
- Enhances the attractiveness of the urban environment, quality of life, and public health;
- Improves traffic safety and security;
- Reduces air and noise pollution, greenhouse gas emissions, and energy consumption;
- Contributes to a better overall performance of the trans-European transport network and the Europe's transport system as a whole.

In addition, a long-term vision and clear implementation plan is needed. A SUMP presents, or is linked to, an existing, long-term strategy for the future development of the urban area and for the future development of transport and mobility infrastructure and services.

SUMPs include a delivery plan for short-term implementation of the strategy, specifying the timing for implementation, clearly allocating responsibilities for each actor and identifying the required resources and finances.

The Plan should build a careful assessment of the present and future performance of the urban transport system by reviewing the current situation, establishing a baseline against which future progress can be measured, as well as defining performance objectives and related SMART targets to guide the implementation of the plan.

A SUMP fosters a balanced development of all relevant transport modes, while encouraging a shift towards more sustainable modes. The plan puts forward an integrated set of technical, infrastructure, policy-based, and soft measures to improve performance and cost-effectiveness regarding the declared goal and specific objectives. It would typically address the following topics:

- Public transport
- Walking and cycling
- Intermodality
- Urban road safety
- Road transport (flowing and stationary)
- Urban logistics
- Mobility management
- Intelligent Transport Systems

The development and implementation of a SUMP follows an integrated approach with a high level of co-operation, co-ordination and consultation between the different levels of government and relevant authorities. To facilitate this, appropriate structures and procedures should be put in place. A horizontal and vertical integration is required.

A SUMP follows a transparent and participatory approach. The Local Planning Authority should involve the relevant actors - citizens, as well as representatives of civil society and economic actors – in developing and implementing the plan from the outset and throughout the process to ensure a high level of acceptance and support.

The implementation of a SUMP should be monitored. The progress towards the goal and specific objectives of the plan should be assessed regularly through selected indicators. Appropriate actions should be taken to ensure timely access to the relevant data and statistics. A monitoring report should provide the basis for a review of implementation.

Quality assurance is needed: Local Planning Authorities should have mechanisms to ensure the quality and validate compliance of the SUMP with the requirements of the SUMP concept.

The next image summarises the steps recommended to develop a SUMP. The initial steps consist on defining a baseline scenario to know each city and situation, create measurable and effective objectives and assign responsibilities and resources for each actor involved. For the elaboration of an accurate baseline scenario it is crucial to count on the necessary information, including data for passengers' and freight mobility.

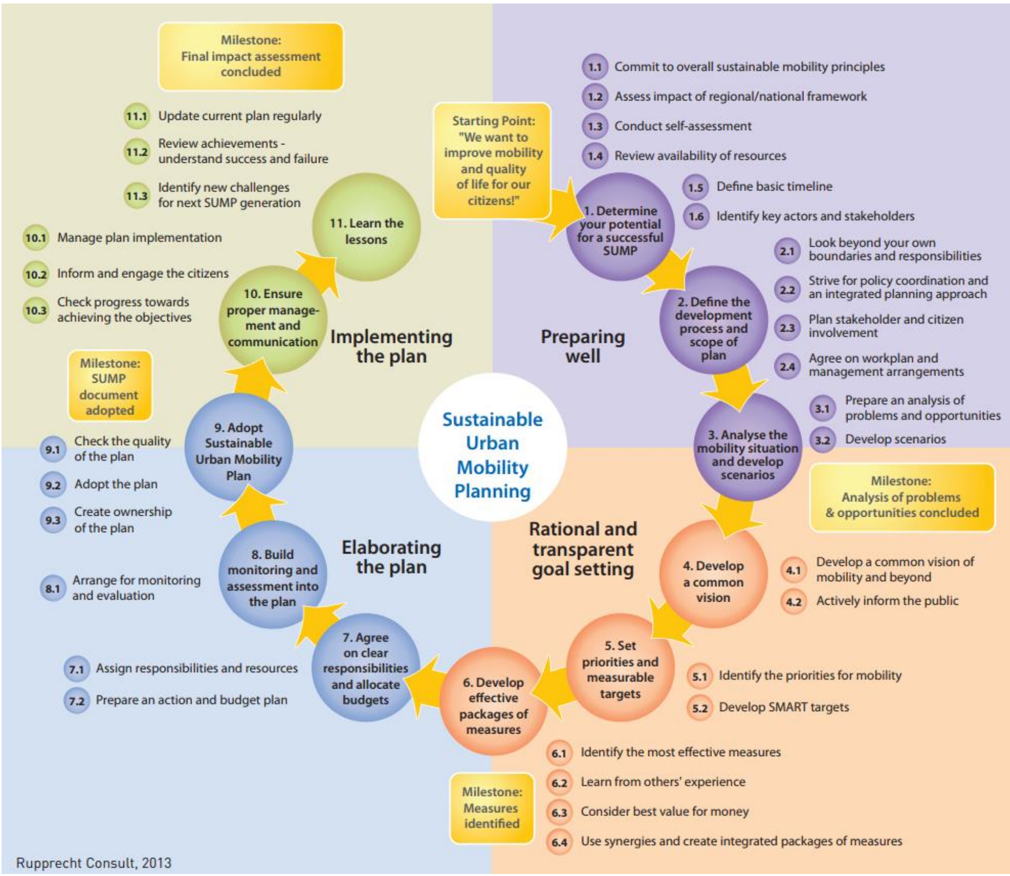

Figure 3. Planning cycle for a sustainable urban mobility plan. *Guidelines: Developing and implementing a Sustainable Urban Mobility Plan*

1.2. European recommendations for Sustainable Urban Logistics Plans (SULPs) development[6]

Cities have to guarantee citizens not only overall accessibility to different city and transport services, but also an efficient urban freight distribution with respect to economic and environmental factors. Cities have to face the challenge of combining economic growth, competitiveness and sustainable urban development by taking into account the economic and technological changes related to globalisation. Globalization leads to urbanization, but uncontrolled urbanization can lead to aggravation of social and environmental issues, as well as city's economy. According to *Krykavskyy and Woronina (2015)*, it is estimated that by 2050, approximately 70% of world population will live in urban areas. Moreover, considering current trends, more people are willing to use private motorized transport. Approximately 6.2 billion private motorized trips are made every day in cities. By 2050, an urban dweller will spend around 106 hours per year in traffic jams that is three times more than today. This would create significant challenges for city management and especially city logistics, which should provide both for the needs of residents and businesses operating in it. This challenge has also an important impact on issues dealing with urban quality, such as a sustainable mobility, urban transport, and social, economic and environmental conditions.

Sustainable Urban Logistics Plans (SULPs) try to optimise urban logistics efficiency, improving the links between long-distance, inter-urban and urban freight transport, aiming to ensure efficient 'last mile' delivery. SULPs focus on how to better incorporate freight transport in local policies and plans and how to better manage and monitor transport flows.

A **Sustainable Urban Logistics Plan** is a strategic plan designed to satisfy freight mobility needs of people and business in cities and their surroundings, in order to achieve a better quality of environment and of life. It builds on existing planning practices and takes into consideration of integration, participation, and evaluation principles.

The ENCLOSE project developed guidelines and defined recommendations to develop Sustainable Urban Logistics Plans[7]. According to it, the main elements to be included in a SULP are:

- Setting the objective and target
- Urban mobility scenario and priorities
- Analyse the logistics context and processes
- Setting requirements and logistics baseline
- Suitable measures and services vs. requirements
- Design of Identified solutions
- Business Model, actor role and responsibility
- Services/Solutions Assessment and Impacts

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[6] Guideliness: Developing and implementing a Sustainable Urban Logistics Plan. ELTIS.
[7] Sustainable Urban Logistics Plans (SULP) Guidelines G.Ambrosino, A.Liberato, I.Pettinelli http://www.enclose.eu/content.php?p=5

- Responsibilities, implementing plan
- Promotion and Communication Plan
- Roadmap to adopt the SULP

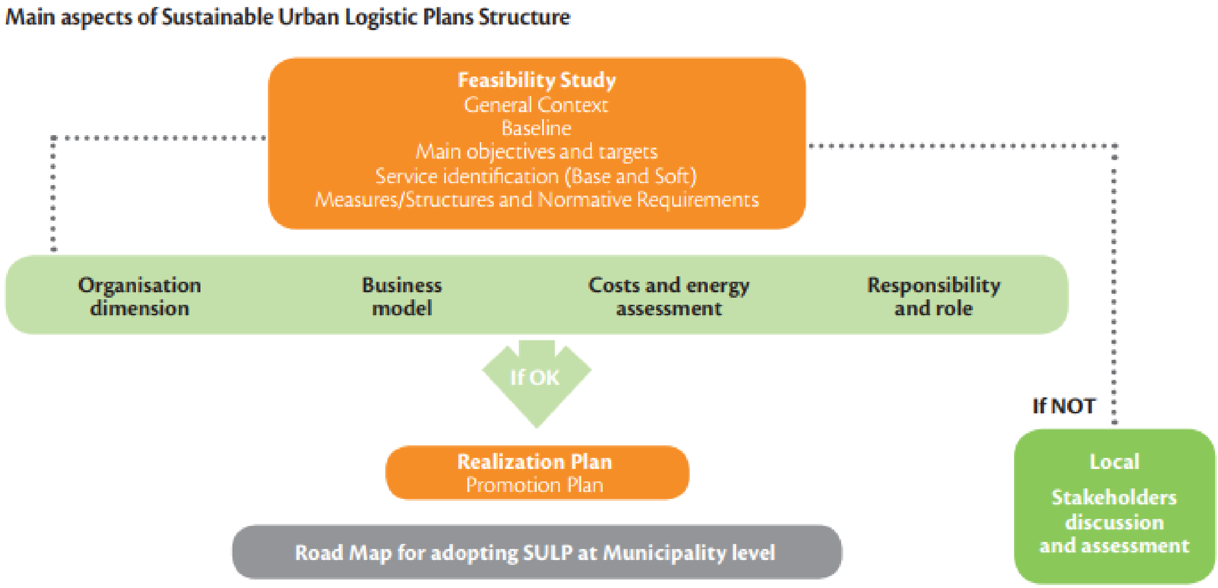


Figure 4. Guidelines: Developing and implementing a Sustainable Urban Logistics Plan. *ENCLOSE project.*

1.3. Conclusions

As we can see in the specifications to develop a Sustainable Urban Mobility Plan and/or a Sustainable Urban Logistic Plan a baseline scenario is essential.

One of the crucial parts of the methodologies for SUMPs and SULPs development is the analysis of the overall situation of the city to define and predict urban mobility and logistics scenarios. It is, therefore, needed to understand the city context from the mobility, transport and logistics points of view, in order to identify the specific issues and concerns that need to be tackled in the plan development.

Urban mobility (passenger and freight) data is required for different purposes:

- To provide an understanding of operations and monitoring the effects of policy measures.
- To forecast future traffic conditions with the help of mobility or urban freight models.

The use for which the data is required can affect both the data collection methodology and the quantity of data required.

In addition, a thorough analysis of the problems and opportunities in the field of urban transport and mobility is needed for a proper management of passengers and freight flows in the cities. This is an important milestone for local and regional administrations as it feeds into the development of different scenarios. These scenarios help improve the understanding of how urban mobility could look like in the future.

The baseline scenario should be obtained with different data collections instruments, to know the current mobility schemes in each city. The tools used for data collection, analysis and mobility management in each city are different and also, the kind of information gained and the manner to obtain freight and passengers data.

The main objectives for collecting mobility data (passengers and freight) are to enable local authorities to obtain detailed information about habits of mobility of citizens, their perception of the state of urban services and facilities and the main routes of freight transport. This allows them to put in place policies that promote sustainable mobility, aimed at promoting sustainability through the efficient management of public and private passenger and freight transport.

Real time traffic information could lead many improvements in all areas:

- Reduction of traffic congestion and improved road safety.
- Reduction of fuel consumption, and consequently environmental pollution
- Increase in the quality of life of the inhabitants and visitors of the city.
- Improved Origin-Destination (O-D) matrices (commuter plans)
- Dynamic network traffic control
- New perspectives in transport modelling: real-time data could be used to set up dynamic transport models capable to provide forecasts in a very short period of time.

Data collected for mobility characterization in 5 medium-sized cities participating in SUITS project

In order get the information to develop the mentioned baseline picture and be able to make comparisons between different scenarios (after applying a specific measure, for example), cities participating in SUITS project are aware of the necessity of collecting traffic data for their mobility management.

Table 1. Types of data collected according to the SUITS Data Management Plan (D1.1)

TYPES of DATA collected	COVENTRY	KALAMARIA	ROME	TURIN	VALENCIA
Passenger data	✓	✓	✓	✓	✓
Freight data					
Citizen Mobility data	✓	✓	✓	✓	✓
Urban Traffic data	✓	✓	✓	✓	✓
Real-time data	✓	✓	✓	✓	✓
Historical (archived) data	✓	✓	✓	✓	✓
Artificially generated data / metadata	✓				

The analysis of **Table 1** reflects that although the characterization and information about freight flows is a key factor for the cities' mobility management, collecting these data streams is not always so easy.

In some countries, the national government is the main collector of freight transport data where it may take place as part of larger, national surveys that include an urban component and is reported at a national scale. Therefore, extracting urban freight data, at city and local level, from national surveys, although necessary, is sometimes a difficult task for mobility departments in local authorities.

2. Strategies in data mobility collection in Europe

Harmonised data collection is necessary to ensure comparability of data and statistics in the field of transport. According to the **INSPIRE directive** (EU Directive 2007/2/EC, 2007), the basic principles of harmonised data collection are:

1. Data should be collected only once and maintained at the level where this can be done most effectively (e.g. continuous or periodical collection).
2. It should be possible to combine seamlessly spatial data from different sources across the EU and share it between many users and applications.
3. It should be possible for data collected at one level of government to be shared between all levels of government.
4. Spatial data needed for good governance should be available on conditions that are not restricting its extensive use.
5. It should be easy to discover which data are available, to evaluate its fitness for purpose and to know which conditions are necessary to use them.

Data collection strategies have been originally based mostly in manual methods. Although these strategies are already in use, the increment and boost of Information and Communication Technologies (ICTs) allows the collection of data in a more automated way. Automated data collection has some advantages against manual methods the possibility of increasing the amount of data collected and analysed, and the increment on the quality of data gathered, due to[8]:

- Facilitation of scientific observation by displaying historical data and statistics.
- Elimination of errors due to oversight and transcription.
- More careful monitoring processes.
- Documentation of all changes made to the data after initial collection.

2.1. Manual methods

2.1.1. Surveys and interviews

Traditional methods for traffic data collection are based on surveys and interviews. These methodologies provide different useful information about traffic but it is necessary to have

[8] https://www.ncbi.nlm.nih.gov/pubmed/6578744

direct contact with people and time investment. In this chapter, different types of surveys targeted to passengers and freight transport data are analysed.

a) Passengers' transport data collection through surveys

Nowadays, the different countries of the European Union often carry out surveys on mobility with different purposes as well as scope. In general, the most common method to collect data is asking participants to complete "travel journals" in which they must carefully disaggregate their journey from the previous day or prior weekend.

In some cases, these surveys are conducted by telephone or, even if they are written, the agency in charge makes periodic phone calls to motivate or resolve doubts. It seems reasonable to suspect that if the design of a questionnaire is too complex the interviewer would not have very high response rates.

Data obtained through surveys allows modelling of the current situation and helps to implement the appropriate measures on mobility management. Surveys are especially interesting to measure active forms of transport (walking or cycling) that are difficult to identify with automatic methods. Surveys also allow to distinguish and characterize both passenger and freight flows

In addition, the characterization surveys bring qualitative information that is not always available with counting methods, for example:

- Gender
- Age bracket
- Income level
- Professional activity developed
- Other socio-demographic characteristics
- Main mode used for travel
- Modes available for travelling
- Attitudes of the user (e.g. willingness to change to alternative transport modes)
- Previous experiences
- Contextual factors (e.g. security)
- Mobility patterns (e.g. periodicity of travels)

Surveys are usually completed by passengers using internet, email, fax, telephone or postal. Stratified random sampling is commonly used, according to specific regions and type of transport in order to get a representative sample.

b) *Freight data collection via surveys*

National surveys of freight transport operations are conducted in many countries (such as the Continuing Survey of Road Goods Transport in Britain, and commodity flow studies in the USA). Although these surveys collect data about urban freight activities in the urban area they are usually not very useful for gaining a better understanding of how freight transport is working in those urban areas. According to research[9] developed by the University of Westminster, reasons that explain this situation are:

1. The sample size in any particular urban area is likely to be small.
2. It is often difficult to disaggregate the data from the overall dataset.
3. The type of data collected in the surveys does not provide the detailed information often required for urban freight analysis.

Therefore, specific data collection exercises are usually required to gain the necessary insight into urban freight transport.

This research also reviewed several urban freight surveys developed in Europe. Surveys considered included some basic aspects for freight data collection:

- Vehicle delivery/collection trips at establishments in the urban area.
- Goods flows to/from establishments in the urban area.
- Service trips to establishments in the urban area.
- Trip details and patterns of goods vehicles in the urban area.
- Trip details and patterns of service vehicles in the urban area.
- Loading/unloading activity of goods vehicles in the urban area.
- Parking activity of service vehicles in the urban area.
- Conveyance of goods between vehicles and establishments in the urban area.
- Origin location of goods flow/vehicle trip to establishment in the urban area.
- Ordering and stockholding arrangements at urban establishment.
- Supply chain management between establishments, their suppliers and freight transport operators.

Freight data is collected for a wide range of reasons including: policy-decision making, government monitoring and performance measurement, commercial monitoring, locally-based projects, to meet requirements of EC Directives, to produce national estimates, for modelling and forecasting, for understanding and research purposes, and for legal requirements (licensing and safety controls).

[9] Review of Survey Techniques in Urban Freight Studies. Allen, J. and Browne, M. *University of Westminster*

Freight surveys are usually conducted together with driver surveys and/or parking and loading surveys. On the other hand, some freight vehicle operators and parcel carriers have significant quantities of data about their operations, which they use for planning purposes. This data is potentially very useful in understanding urban freight activity in specific sectors of the freight market. However, this data may not be available due to commercial confidentiality.

The next paragraphs present different techniques commonly used performing freight surveys indifferent cities and countries.

Commodity flow survey	Collecting detailed information about type and quantity of goods flowing to/from particular establishments rather than focusing on goods vehicle trips.
Driver survey	Gathering data about the driver's overall trip pattern, as well as information about the loading/unloading activity in the street in which the survey takes place. Usually conducted at establishments receiving collections/deliveries, with the driver intercepted after carrying out work, before they drive away.
Establishment survey	Collecting data about total goods vehicle trips to/from particular establishments, and variation by time, day and month. Can also be used to capture data about type of goods delivered/collected. Also allows collection of information about the delivery/collection process.
Freight operator survey	Collecting data about the pattern of the companies' goods vehicle activities in the urban area. Allows opportunity to obtain data about the entire fleet rather than a single vehicle or round. Can be used to collect data about loading/unloading activity and movement of goods from vehicle to establishment.
GPS survey	Providing data on vehicle location at frequent intervals (thereby providing route information), as well as speed. Can also be used to record stops for loading/unloading/parking.
Parking survey	Capturing information about vehicle loading/unloading/parking activity, rather than total delivery/collection trips at establishments, and method of moving goods from vehicle. Can also be used to study use of space allocated for goods/service vehicles by other road users.
Roadside interview survey	Pulling over moving vehicles/drivers and interviewing them at the roadside about their current trip. Used to capture data about origin/destination, trip purpose, goods carried, and vehicle type. Usually a relatively brief survey so as not to disrupt drivers and avoid causing unnecessary traffic congestion.

Service provider survey	Providing wide ranging data about the pattern of the companies' service activities and supporting vehicle activity in the urban area. Allows opportunity to obtain data about the entire fleet rather than a single vehicle or round Can be used to collect data about vehicle parking activity.
Suppliers survey	Gathering information from suppliers about the goods they dispatch to urban establishments and the vehicle activity that supports this goods flow. Used in conjunction with establishment survey.
Vehicle observation survey	Placing surveyor/s on street at establishments to record data about total goods vehicle trips to/from establishments by time of day. It can capture information about vehicle type, time taken for delivery/collection, methods of moving goods from vehicle, etc. Only captures data for as long as surveyors are present. It can provide better quality information about vehicle activity on the street than establishment survey.
Vehicle trip diaries	Collecting detailed information about the activities of a single vehicle. Can provide data about exact locations served, route, arrival and departure times, time taken for delivery/collection/servicing, type of goods/service, etc.

Survey work can be carried out by different means, either through self-completion or by direct contact with the respondent (i.e. interview). Self-completion questionnaires were traditionally printed on paper and either posted/to and collected from respondents in person or sent via the postal system. However, the advent of the internet has now allowed the potential for online self-completion questionnaires. Interview surveys can be carried out either face-to-face or by telephone.

Although surveys are useful to identify and collect data from freight traffic flows, cities still find some gaps in urban freight data collection. BESTUFS project identified some gaps in data freight data collection in different European countries[10].

As an example, key gaps in urban freight data in the UK include:

- Vehicle routing/journey information,
- journey time/reliability of journeys (i.e. freight trip performance),
- environmental impacts at supply chain/sectoral level, information/data on loading/unloading activity,
- lack of linkage about freight modal interactions,

[10] BESTUFS Urban Freight Data Collection Roundtable. 22-23 September 2005, LET, Lyon

- supply chain stages between which freight is transported
- detail about land uses between which goods movements take place.

These gaps are mainly generated by the difficulties in freight data collection, including small samples size, which generates unreliable data sets; commercial confidentiality of data held by private companies or the fact that some data sources can only provide data at a national level, while some other data are only available at a city-wide level, which difficult comparison or integration between different data sets.

A second example of freight data gaps included in the BESTUFS project is the case of France. They saw some difficulties in getting:

- Non-road freight transport data,
- quantitative data about home delivery,
- operating cost data
- urban management flow data,
- traffic generated by warehouse activity,
- consumer purchasing behaviour data and commercial data (that is usually held by private companies and stays confidential).

2.1.2. Manual counts

Manual counting usually refers to the practice of counting classified traffic in a ‘manual fashion’. Some examples of traffic counting include vehicle counts at intersections, estimation of average daily traffic and annual average daily traffic.

Governments, developers, and transportation consultants conduct counts of vehicles frequently. On the other hand, many for-hire firms specialized in transportation-related data collection. Counts can be conducted by anyone who understands the steps involved to ensure the accuracy of the data collected.

Counting and classification are simply based on visual examination and judgments by individual observers. The data is usually recorded using tally sheets or mechanical counters. After data have been collected for an interval of time, totals are calculated and registered on a data sheet which can be input into a computer later.

In this case, trained observers gather traffic data that cannot be efficiently obtained through automated counts e.g. vehicle occupancy rate, pedestrians and vehicle classifications.

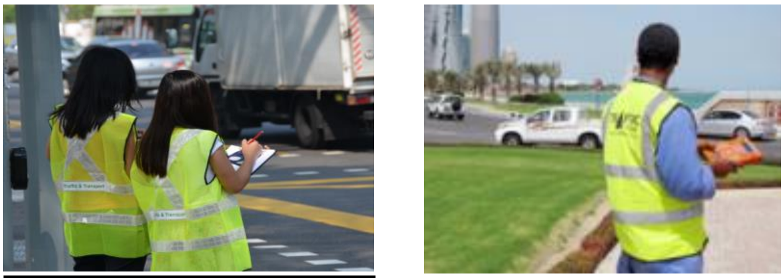


Figure 5. Manual counts. *www.traffic-tech.com*

Traffic counts are mainly conducted one of four ways:

Screenline counts: Conducted by establishing a visible or invisible line across a roadway or sidewalk and counting the number of vehicles, bicyclists, and pedestrians who pass over that line. Often, screenline counts indicate direction of travel for bicyclists and vehicles, but not for pedestrians. They are used to determine general use trends for a segment of trail or roadway.

Intersection turning movement counts: Conducted where two or more roadways and/or major driveways meet. At minimum, these counts capture vehicle turning movement counts. Many traffic counting firms can also capture bicycle turning movements and pedestrian crossing counts for little to no additional cost. They are generally conducted for safety or operational analyses under peak-hour conditions. The information from a turning movement count can also be converted to screenline equivalents for the purpose of analysing general use trends or making comparisons to screenline count data.

Occupancy counts: Conducted for parking data. Parking occupancy counts are generally conducted manually using a one-pass method of counting at specified times, although automated systems at parking garages and some on-street parking areas are enabling real-time, continuous occupancy information. Occupancy counts can be done for both vehicle and bicycle parking.

On-off counts: Conducted on transit vehicles to count passengers on board and alighting. On-off counts can also be done to count passengers who board the transit vehicle with their bicycles.

Manual counts are useful to collect information about both, passengers and freight, and also to take into account different transport modes, as set before, including actives modes of transport.

Research[11] has found that the accuracy of the manual count increases as the number of data collection tasks is reduced. Observers can be tasked with vehicle counting and noting characteristics about the user, such as age, gender, behaviours (helmet use for motorbikes and bicycles, mobile phones usage, etc.). Use of pencil and paper for counting may also lead to undercounting where vehicle counts are high, so other counting devices or multiple observers may be used at locations of high usage. Manual counts are usually recorded for one to four hours in discrete time intervals, generally 15 minutes.

2.2. Automated data collection

Automatic detection technologies have several advantages. They can provide ongoing and consistent data collection for less cost and time than manual ones. Longer duration of collection process help identify usage for larger sample sizes. It also provides more accuracy for extrapolation purposes.

2.2.1. Traffic detection systems

A wide variety of detection systems have been developed to collect mobility data.

- The collection of historical traffic volume data is used for a variety of purposes, such as historical trend analysis and forecasting to plan for future investments.
- Traffic volume measurements are also valuable indicators of congestion, exposure rates, potential air pollutant concentrations, expected fuel tax collections and as a general measure of economic conditions.
- The collection of other traffic parameters, such as speed and vehicle classification, is increasingly important as pavement design models become more sophisticated and new types of sensors are used for highway operations.[12]

The next section presents the most common traffic detection methods underlining their advantages and drawbacks.

a) Pneumatic road tubes:

Description: This has for many years been a popular method of vehicle sensing. It consists on rubber tubes which are placed across the road lanes to detect vehicles

Figure 6. Pneumatic road tubes. *TSC for surveys.*

[11] CONDUCTING BICYCLE AND PEDESTRIAN COUNTS
County and Beyond. *Southern California Association of Go*

[12] Evaluation of non-intrusive technologies for traffic detection. Web: https://www.lrrb.org/pdf/201036.pdf

from pressure changes that are produced when a vehicle tyre passes over the tube.

How it works: One or more rubber hoses are stretched across the road and connected at one end to a data logger. The other end of the tube is sealed. When a pair of wheels hits the tube, air pressure in the squashed tube activates the data logger which records the time of the event.

A pair of tubes can be stretched across several lanes of traffic. The data logger can establish vehicle direction by recording which tube is crossed first.

Advantages: Road tubes work well for short duration counts on lower volume roads.

They are relatively inexpensive.

The device can be easily installed and moved from one location to another.

They can capture directionality of traffic flows.

Drawbacks: This has the drawback that if two vehicles cross the tubes at the same time then the direction can't be accurately determined.

Should two cars be very close together when they cross the tubes, the system may see them as one multiaxle vehicle.

Vendors claim an accuracy of 99%. Studies show though, that the absolute error of a typical 15-minute count averaged closer to ten percent. This suggests that the level of inaccuracy is being masked by the positive and negative counting errors cancelling each other out.

The counts need to be physically downloaded onto a computer from the loggers at the roadside.

Installation requires working within the traffic lane.

They are not an effective solution on high traffic volumes or in multi-lane highways. This system may also not be efficient in measuring low speed flows.

Its efficiency is subject to weather, temperature and traffic conditions.

b) Piezoelectric sensors

Description: The piezoelectric sensor consists of a long strip of piezoelectric material enclosed in a protective casing. Sensors are usually placed in a groove along roadway surface of the lane(s) monitored.

How it works: Piezoelectric sensors collect data by converting mechanical energy into electrical energy. When a car drives over the piezoelectric sensor, it squeezes it and causes a voltage signal. The size of the

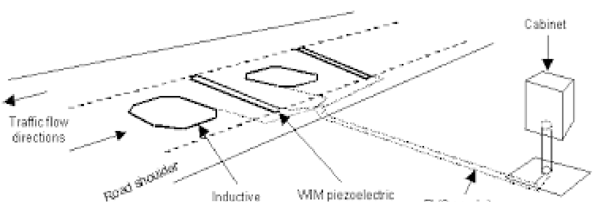


Figure 7. Piezoelectric sensors. *US Department of Transportation*

signal is proportional to the degree of deformation. When the car moves off, the voltage reverses. This change in voltage can be used to detect and count vehicles.

The counting device which is connected to the sensors is housed in an enclosure by the side of the road. Data may be collected locally via an Ethernet or RS232 connection to a laptop, or may be transmitted by modem.

Advantages: The piezoelectric detector has the advantage of indicating exactly when and where a vehicle passed by because it is a line detector perpendicular to the path of the vehicle.

They are extremely accurate at measuring axle strikes.

They can be used for vehicle counts, classification (speed and axle), weigh-in-motion (in combination with inductive loops), tolling and speed compliance monitoring.

Drawbacks: They cannot distinguish the type of vehicle.

Detectors require careful installation.

Every time the roadway is repaved, or if a pothole appears, the sensor would need to be replaced.

c) *Magnetic loops:*

Description: This is one of the most conventional technology used to collect traffic data widely deployed in Europe and worldwide over the last decades. It consists of a coil of wire wrapped around a magnetic core. It measures the change in the magnetic field caused by the passage of a vehicle.

How it works: Loops are embedded in roadways in a square formation that generates a magnetic field. This system detects vehicles by measuring a change in the flux of the earth's magnetic field caused by the passage of a vehicle. The information is then transmitted to a counting device placed on the side of the road.

Advantages: They have a fairly large detection range and thus can be used to observe multiple lanes of traffic.

They can be used where point or small-area location of a vehicle is necessary.

They remain invisible after installation and are not susceptible to tampering.

They are not affected by bad weather conditions.

Figure 8. Magnetic loops. *Alistair Gollop: Traffic signals*

They can be used for bicycle lanes counting.

Drawbacks: One of their disadvantages is that multiple detectors need to be installed to detect smaller vehicles, such as motorcycles.

In addition, the implementation and maintenance costs of magnetic loops can be expensive.

They also have a sort life expectancy because it can be damaged by heavy vehicles.

If vehicles are following each other very closely, the magnetic detector may have difficulty discriminating between them.

d) Inductive-loops

Description: An inductive loop is a square of wire embedded into or under the road. The loop utilizes the principle that a magnetic field introduced near an electrical conductor causes an electrical current to be induced. In the case of traffic monitoring, a large metal vehicle acts as the magnetic field and the inductive loop as the electrical conductor.

How it works: A loop detector consists of one or more loops of wire embedded in the pavement and connected to a control box. The loop may be excited by a signal ranging in frequency from 10 kHz to 200 kHz.

This loop forms an inductive element in combination with the control box. When a vehicle passes over or rests on the loop, the inductance of the loop is reduced. This causes a detection to be signaled in the control box.

Advantages: The advantages of inductive loop detectors are that they have a well-defined zone of detection

Novel inductive loops are capable of distinguishing types of vehicle (such as bicycles from cars).

They are generally reliable.

Drawbacks: The detectors are very sensitive to the installation process; they can only be installed in good pavement.

They must be reinstalled every time a road is repaved.

Embedded detectors are expensive to install

They require a nearby source of

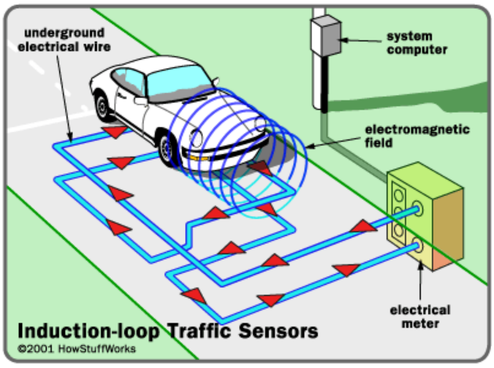


Figure 9. Inductive loops. *https://auto.howstuffworks.com*

electric power.

They are not suitable for some specific areas, they cannot be installed near sites of high electromagnetic interference; for example, on a bridge, inductive loop detectors would be disrupted by the steel struts, and it is necessary to have a point detector.

e) Passive and active infra-red:

Description: There are two types of infrared (IR) detectors, active and passive. Active infrared sensors operate by transmitting energy from either a light emitting diode (LED) or a laser diode. A passive infrared system detects energy emitted by objects in the field of view and may use signal-processing algorithms to extract the desired information.

The sensors are mounted overhead to view approaching or departing traffic or traffic from a side-looking configuration. Infrared sensors are used for signal control; volume, speed, and class measurement, as well as detecting pedestrians in crosswalks. Real-time signal processing is used to analyse the received signals for the presence of a vehicle.

How it works: Active infrared sensors illuminate detection zones with low power infrared energy supplied by laser diodes operating in the near infrared region of the electromagnetic spectrum at 0.85 mm. The infrared energy reflected from vehicles traveling through the detection zone is focused by an optical system onto an infrared-sensitive material mounted at the focal plane of the optics.

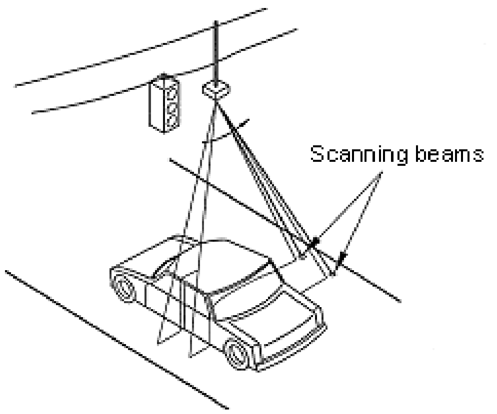


Figure 10. Infrared sensors. *OSI Laserscan*

Passive sensors detect the energy that is emitted from vehicles, road surfaces, other objects in their field of view, and from the atmosphere, but they transmit no energy of their own. Passive infrared sensors with a single-detection zone, measure volume, lane occupancy, and passage. The source of the energy detected by passive sensors is graybody emission due to the non-zero surface temperature of emissive objects. Graybody emission occurs at all frequencies by objects not at absolute zero (-273.15 ºC).

Advantages: Some of the advantages of infrared detectors are that they can be operated during both day and night, and they can be mounted in both side and overhead configurations.

Passive infrared systems can detect presence, occupancy, and count. Active IR detectors provide count, presence, speed, and occupancy data in both night and day operation. The laser diode type can also be used for vehicle classification because it provides vehicle profile and shape data.

Infrared sensors have multiple lane operation available.

Installation of infrared sensors does not require an invasive pavement procedure.

Drawbacks: Disadvantages are that infrared detectors can be sensitive to inclement weather conditions and ambient light. The choice of detector materials and construction of the system, as well as sophisticated signal processing algorithms, can compensate for the disadvantages.

Operation may be affected by heavy rain, snow and dense fog.

Installation and maintenance, including periodic lens cleaning, require lane closure.

f) Microwave radar

Description: The word radar was derived from the functions that it performs: RAdio Detection And Ranging. The term microwave refers to the wavelength of the transmitted energy, usually between 1 and 30 cm.

Two types of microwave radar sensors are used in traffic management applications, continuous wave (CW) Doppler radar and frequency modulated continuous wave (FMCW) radar. The CW Doppler sensor can be used to detect moving vehicles and to determine their speed. This CW Doppler sensors that do not incorporate an auxiliary range measuring capability cannot detect motionless vehicles. The FMCW radar operates as a presence detector and can detect motionless vehicles.

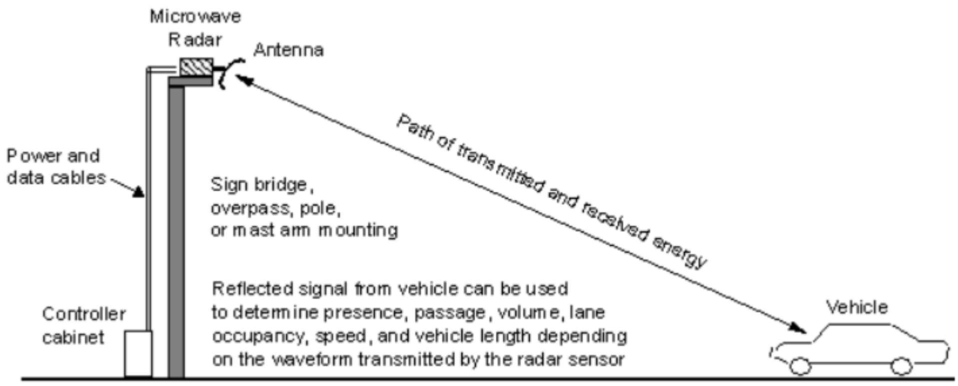


Figure 11. Microwave radar operation. *U.S. Department of Transportation*.

How it works: Roadside-mounted microwave radar sensors transmit energy toward an area of the roadway from an overhead antenna. The area in which the radar energy is transmitted is controlled by the size and the distribution of energy across the aperture of the antenna. The manufacturer usually establishes the design constraints of the radar sensor. When a vehicle passes through the antenna beam, a portion of the transmitted energy is reflected back towards the antenna. The energy then enters a receiver where the detection is made and vehicle data, such as volume, speed, occupancy, and length, are calculated.

Advantages: Advantages of microwave radar include insensitivity to inclement weather, especially over the relatively short ranges encountered in traffic management applications

Microwave radars can also directly measure speed.

Another advantage of this kind of sensors is the multiple lane gathering of traffic flow data.

Drawbacks: CW Doppler radar sensors cannot detect stopped vehicles unless equipped with an auxiliary sensor.

CW Doppler microwave sensors have been found to perform poorly at intersection locations as volume counters.

They do not accurately count groups of vehicles.

g) LiDAR sensors

Description: LiDAR is the acronym used for 'light detection and ranging' or 'light (laser) imaging, detection and ranging'. Lidar has a wide range of applications; one use is in traffic enforcement and in particular speed limit enforcement. Current devices are designed to automate the entire process of speed detection, vehicle identification, driver identification and evidentiary documentation. According to Grejner-Brzezinska and Toth, 2002, the LiDAR sensor can be considered as a new source with potential to evaluate traffic parameters.

How it works: LiDAR working process consists on shining a small light at a surface and measuring the time it takes to return to its source. Light travels very fast, therefore the equipment required to measure light reflection needs to operate extremely fast. Only with the advancements in modern computing technology has this become possible.

Advantages: LiDAR can provide higher resolutions than radar and can detect live objects and laterally-moving objects with a greater reliability. They also possess the ability of multi-object discrimination, and enable easy beam forming.

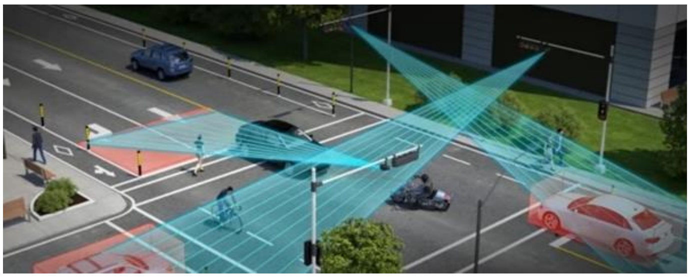


Figure 12. LiDOR sensors to detect traffic. *AZoSensors.*

As LiDAR is an active device that produces its own modulated signal, it performs equally well in day and night conditions, and is immune to sunlight or vehicle lights.

LiDARs count with a good performance in inclement weather conditions

LiDAR sensors can compile hundreds of measurements per second in order to accurately locate vehicles of all sizes, including motorcycles and bicycles, as well as pedestrians.

LiDARs can detect all of the incoming vehicles in all of the lanes.

Drawbacks: Normal weather conditions have negligible impact on device performance but may impede operator ability to target a vehicle. Bad weather may reduce the range of the device and in particular heavy fog will render it unusable.

Sweeping the device while taking a reading so that (particularly at long range where angular separation between targets is slight) returning pulses from more than one target creates a false reading. Sweeping along the side of a vehicle may also cause false readings.

h) Radio Frequency Identification (RFID)

Description: RFID stands for Radio-Frequency IDentification. The acronym refers to small electronic devices that consist of a small chip and an antenna. The chip typically is capable of carrying 2,000 bytes of data or less.

The RFID device provides a unique identifier for an object and must be scanned to retrieve the identifying information.

How it works: RFID uses electromagnetic fields to automatically identify and track tags attached to objects. The tags contain electronically stored information. Passive tags collect energy from a nearby RFID reader's interrogating radio waves. Active tags have a local power source (such as a battery) and may operate hundreds of meters from the RFID reader. Unlike a barcode, the tag need not be within the line of sight of the reader, so it may be embedded in the tracked object. RFID is one method for Automatic Identification and Data Capture (AIDC).

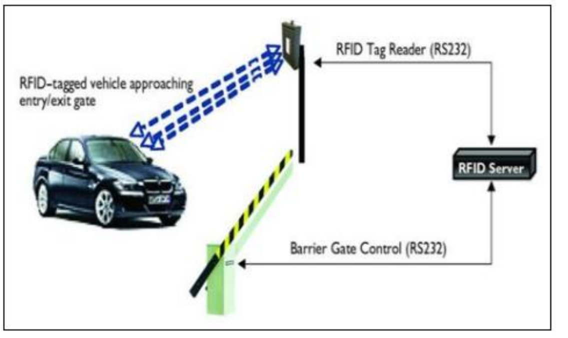


Figure 13. Radio Frequency Identification.

RFID tags are used in many industries, for example, an RFID tag attached to an automobile during production can be used to track its progress through the assembly line.

Advantages: RFID tags and labels enables cost efficient and reliable solutions for vehicle and traffic management.

It increases accuracy of positioning with respect to other tracking methods such as GPS. It is also more practical for scenarios like tunnels or underground parking where GPS is not available.

Vehicles can be detected remotely, even at high speeds.

With an appropriate number of readers, it allows to get a complete tracking for each element.

RFID tags can potentially be used to measure O-D freight/passengers' movements and vehicle travel times across a network.

It can identify each element individually (vehicle).

Drawbacks: Some common problems with RFID are reader collision and tag collision. Reader collision occurs when the signals from two or more readers overlap. The tag is unable to respond to simultaneous queries. Tag collision occurs when many tags are present in a small area.

It requires the installation of a RFID tag in every vehicle being tracked and installation of RFID readers across the road network.

i) Acoustic traffic sensors

Description: Acoustic sensors measure vehicle passage, presence, and speed by detecting acoustic energy or audible sounds produced by vehicular traffic from a variety of sources within each vehicle and from the interaction of a vehicle's tires with the road.

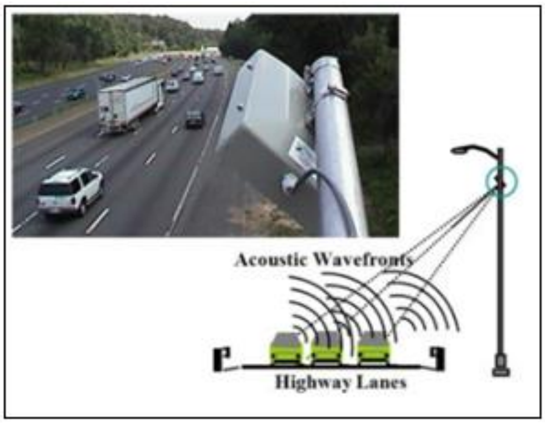


Figure 14. Acoustic traffic sensors. *Roadsys, LLC.*

How it works: When a vehicle passes through the detection zone, an increase in sound energy is recognized by the signal-processing algorithm and a vehicle presence signal is generated. When the vehicle leaves the detection zone, the sound energy level drops below the detection threshold and the vehicle presence signal is terminated. Sounds from locations outside the detection zone are attenuated.

Advantages: Installation of passive acoustic array sensors does not require an invasive pavement procedure.

Acoustic sensors are insensitive to precipitation.

Multiple lane operation is available in some models.

The output data provided are volume, lane occupancy, and average speed for each monitored lane over a user-specified period (e.g., 20s, 30s, 1 min).

This is a portable and inexpensive method.

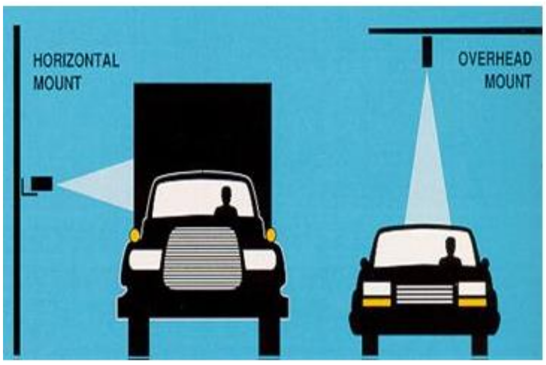
Drawbacks: Cold temperatures have been reported as affecting the accuracy of the data from acoustic sensors.

Also, specific models are not recommended with slow moving vehicles in stop and go traffic

This system has less precision than other methods.

j) Ultrasonic sensors

Description: An ultrasonic sensor is a traffic detection system that may be used in conjunction with other sensor technologies to enhance presence and queue detection,



vehicle counting, and height and distance discrimination.

How it works: Ultrasonic sensors transmit pressure waves of sound energy at frequencies between 25 and 50 KHz, which are above the human audible range. Most ultrasonic sensors operate with pulse waveforms and provide vehicle count, presence, and occupancy information.

Figure 15. Ultrasonic range-measuring sensors. *Microwave Sensors, Ann Arbor.*

Pulse waveforms measure distances to the road surface and vehicle surface by detecting the portion of the transmitted energy that is reflected towards the sensor from an area defined by the transmitter's beamwidth.

When a distance other than that to the background road surface is measured, the sensor interprets that measurement as the presence of a vehicle.

The received ultrasonic energy is converted into electrical energy that is analysed by signal processing electronics that is either collocated with the transducer or placed in a roadside controller.

Advantages: Installation of ultrasonic sensors does not require an invasive pavement procedure.

Also, some models feature multiple lane operation.

Drawbacks: Temperature change and extreme air turbulence may affect the performance of ultrasonic sensors.

Large pulse repetition periods may degrade occupancy measurement on freeways with vehicles traveling at moderate to high speeds.

k) Video image detection (VID)

Description: Present-day traffic management applications use video image processing to automatically analyse the scene of interest and extract information for traffic surveillance and control.

Figure 16. Video image detection (VID).

A video image processor (VIP) system typically consists of one or more cameras, a microprocessor-based computer for digitizing and processing the imagery, and software for interpreting the images and converting them into traffic flow data.

How it works: Video image processor systems detect vehicles by analysing the imagery from a traffic scene to determine changes between successive frames.

The image processing algorithms that analyse black and white imagery examine the variation of grey levels in groups of pixels contained in the video frames. The algorithms are designed to remove grey level variations in the image background caused by weather conditions, shadows, and daytime or nigh time effects and retain objects identified as automobiles, trucks, motorcycles, and bicycles.

Traffic flow parameters are calculated by analysing successive video frames. Colour imagery can also be exploited to obtain traffic flow data.

Advantages: A VIP can replace several in-roadway inductive loops.

VIP system provides detection of vehicles across several lanes

They incur in lower maintenance costs.

VIPs can classify vehicles by their length and report vehicle presence, flow rate, occupancy, and speed for each class.

Other potentially available traffic parameters that can be obtained by analysing data from a series of image processors installed along a section of roadway are density, link travel time, and origin-destination pairs.

Drawbacks: Some disadvantages of the video image processor include its vulnerability to viewing obstructions; inclement weather; shadows; vehicle projection into adjacent lanes; occlusion; day-to-night transition and vehicle/road contrast.

Some models are susceptible to camera motion caused by strong winds.

Furthermore, the installation of a video image processor may require huge camera mounting height for optimum presence detection and speed measurement.

A video image processor arrangement is generally cost effective only if many detection zones are required within the field of view of the camera.

On-road traffic detection systems are the most used alternatives for traffic detection and measurement. The wide range of detection systems offers different options for data gathering. This kind of methods offer a continuous and real-time measurement of traffic flows. However, they require the installation of a fixed infrastructure and the information collected only includes data form the locations where they are installed. Additionally, counting methods only include numeric data, but do not consider other qualitative aspects such as the purpose of the travel or the frequency on which it is done, however, they offer a good performance in combination with other data collection methodologies such as surveys.

In order to choose the best counting method, a Local Authority should take into consideration factors such as: the kind of infrastructure, the traffic supported by it, the strategic location, the kind of data that can collect, the costs and flexibility of the system or the interferences to the traffic during the installation.

2.2.2. Specific passengers' data gathering methods

a) Public transport operators' statistics

Statistics are sets of mathematical equations that are used to analyse what is happening in the world around us. When used correctly, statistics tell us any trends in what happened in the past and can be useful in predicting what may happen in the future.

The world today produces more data than ever before, and therefore statistics play an important role in data compiling. In this line, public transport operators play an essential role to provide information, which is usually available through report or data files on the operators' web site. This information includes, for example:

- Public transport services
- Fleet composition and management
- Users profile
- Financial aspects
- Trends and forecasts

This information is usually available

Although statistics provide valuable data and knowledge, their validity and reliability is questionable. Regarding the statistics provided by transport operators it is difficult to check the validity or to draw patterns and correlations from the data. In addition, statistical data is open to abuse and can be manipulated and phrased to show the point the researcher needs. According to the statistics expert, Jim Frost[13], there are some ways that produce statistical misleading conclusions:

- **Biased samples:** A non-random sample can bias the results from the beginning.
- **Overgeneralization:** The results from one population may not apply to another population. Statistical inferences are always limited and you need to understand the limitations.

[13] http://blog.minitab.com/blog/adventures-in-statistics-2/adventures-in-statistics-v1
http://www.worldofstatistics.org/2013/03/04/why-statistics-is-important/

- **Causality:** How do you know when X causes a change in Y? Statisticians require tight criteria in order to assume causality.
- **Incorrect analysis choices:** Is the model too simple or too complex? Does it adequately capture any curvature that is present? There are many ways you can perform analyses, but not all of them are correct.
- **Violation of the assumptions for an analysis:** If you perform an analysis without checking the assumptions, you cannot trust the results.
- **Data mining:** Even if everything passes muster, an analyst can find significant results simply by performing many tests. Statisticians keep track of all the tests in order to put the results in the proper context.

Using the annual bus statistics in England[14] as a case study to better understand how public transport companies are developing and producing statistics it can be seen that it provides information about the performance and use of their services but there is still a lack of information about the integration with other modes transport (e.g. active modes of transport) and also about the representation of "hard to reach" groups (e.g. measurement of the accessibility for elderly or disabled, or availability of special rates for unemployed or low income groups.

This statistical release presents the latest annual statistics on the local bus sector. Local bus services use public service vehicles (PSVs) to carry passengers paying separate fares over short distances. Most of the data are derived from the Department for Transport's (DfT) annual survey of local bus operators.

The statistics on the local bus sector in England provide information for monitoring trends in usage and provision for a mode of transport used for nearly two-thirds of public transport journeys. Most figures relate to local bus services. These are timetabled services using public service vehicles to carry passengers over relatively short distances, and usually eligible for Bus Services Operators Grant. Long distance coach services, private hire work and closed contracts are excluded but school services accessible to the general public are included. The majority of bus services in England are provided by private companies since deregulation of the industry in 1986 in England outside London. Services can be operated on a purely commercial basis or with financial support from local authorities (supported services). London services are operated by private companies but regulated by Transport for London (TfL). There are two broad passenger types: concessionary and non-concessionary passengers.

Statistics on UK bus transport services provide information about the evolution of users along the time, split on urban/metropolitan area travels, changes done in the public fleet (e.g.

[14] Annual bus statistics: England 2015/16. Department for transport. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/579855/annual-bus-statistics-year-ending-march-2016.pdf

accessibility modifications in vehicles), operation parameters (e.g. frequency, punctuality, etc.), financial data (e.g. fares, government grant, costs and revenues, etc.), strengths and weaknesses of data collected.

Another example of how public transport operators are offering data about their services is the case of the bus operator in Valencia (EMT Valencia). They develop a yearly report on their annual services[15].

This report includes information about:

- **Service provision** (km travelled, average speed, frequency and timetables, etc.)
- **Demand data** (number of passengers, evolution along time, vehicles occupancy, passengers/fare, etc.)
- **Fares information** (ticketing options, prices, discounts, evolution, etc.)
- **Transport scheme** (number of lines, length, number of vehicles/line, schedule/line, maps, etc.)
- **Marketing campaigns** (periodical vs. special campaigns, surveys performed, marketing investment, press releases, socialmedia activity, etc.)
- **Customer service** (visits received, lost & found objects, SMS and calls attended, etc.)
- **Staff characteristics** (number of employees and evolution, level of qualification, number of leaves, internal movements and changes, training activities, etc.)
- **Fleet characteristics and evolution** (number of vehicles, age, capacity, fuelling characteristics, etc.)
- **Economic activities** (economic KPIs, evolution, grant received, incomes and expenses, stock-in-trade, etc.)

Studies offered but public transport operators are usually available and useful for local authorities to understand how public transport services are working and which is the main use of them by citizens. Data collected by public operators include information about users' profiles (e.g. according to the ticketing options or the frequency and period of use of PT) that is relevant for Local Authorities in order to focus measures according to the different profiles or, depending on the operator, it is even possible to track users' routes (e.g. through origin-destination ticket validations), which help local authorities to complete origin-destination matrix.

[15] Memoria anual EMT Valencia: https://www.emtvalencia.es/ciudadano/images/stories/pdf/Publicaciones/Memorias/Memoria2014_baja.pdf

b) Smart ticketing

Another method for providing public transport information is smart ticketing. Smart ticketing is the name given to the system where a title to travel (or ticket) is stored electronically on a microchip rather than being printed on a paper ticket. In most smart ticketing schemes, the microchip on which a ticket is stored is embedded in a smartcard. For this reason, smart ticketing schemes are often known as smartcard schemes, although there is much more to the scheme than just the smartcard.

As a by-product of smart card use, large volumes of personal data are automatically captured, the processing of smart data requires a decision to be made on the sampling of the data, and, according to Bagchi et al.[16], it was found to be dominated by rules-based processing of the data. This new travel data source supplies transport service providers with continuous trip data covering longer time periods which were not possible to obtain using traditional sample surveys. Bagchi concluded in her doctoral thesis that the role of traditional surveys in the smart card data era will perform a complementary role to provide information that cannot be obtained from the smart card system, such as journey purpose.

Smart ticketing is usually associated with the interoperability of different public transport systems operated in an integrated way. As an example, smart ticketing in UK uses the Government backed ITSO[17] specification to allow seamless travel between, and within, cities and regions; and different modes of transport.

Smart ticketing can include some special benefits for the different stakeholders involved in the transport chain:

- Smart ticketing will make it quicker and simpler to buy and use tickets. They allow passengers to load tickets or credit in advance of travel, speeding up boarding times and reducing queuing.
- Smart tickets are far harder to replicate and can be electronically 'killed' the moment they are reported lost or stolen with any remaining balance refunded.
- They offer operators a view into their passengers' travel patterns. Operators will be capable of developing, for example, schedules and timetables that better fit passenger demand. Operators will also be able to run their own loyalty schemes and offer ticket types to suit individual customers' needs.
- Central government and local transport authorities can also benefit from smart ticketing. For example, certain savings could translate into reductions in government

[16] Use of public transport smart data for understanding travel behaviour abstracts.aetransport.org/paper/download/id/1707

[17] ITSO Ltd is a non-profit distributing membership organisation which aims to make travelling on public transport throughout the UK seamless and easier by enabling smart ticketing technology.

subsidies or grants. The bigger benefits lie in the increased use of public transport, which reduces road traffic congestion and improves the connectivity.

According to the recommendations made by the previously mentioned *Commission's Expert Group on Urban ITS*[18], it is necessary to consider some aspects when deploying and implementing a Smart Ticketing Scheme.

General	Smart Ticketing should not be seen as a simple replacement for traditional paper or magnetic ticketing. An important step is identifying which features and functionalities of Smart Ticketing will be adopted and how they will integrate with the customers' wider mobility requirements.
Distribution channels	Smart Ticketing must allow passengers to plan and book their travel through their choice of distribution and retail channels. This goal required a new system that can accommodate the speed, power and flexibility necessary to handle multiple distribution channels for ticket sales, including contactless payment and pre-loaded value.
Smart wallets	Smart Ticketing covers not just pre-payment and the loading of a ticket onto the smartcard or phone, but can also include post-payment where the customer is identified on entering / leaving a closed system and verified that they are authorised to travel or have suitable payment mechanism available.
Business models	Smart Ticketing is a global business and is, for the first time, being Standards led. This allows off-the-shelf technology to be adopted with only limited local tailoring to reflect specific tariff structures and cross-modal opportunities. By using open International Standards for Smart Ticketing, Public Transport Operators can access supply chains that are responsive, cheaper and address industry best practice.
Integration with travel information and traffic management	By creating an EU Ticketing Portal and operating a Europe-wide compliance scheme, including liaison with compatible mobile phone and contactless bankcard schemes in Europe, Smart Ticketing can ensure the customer experience consistently meets their highest expectation.
Marketing issues / public support	Urban ITS decision makers should now systematically look for integration in such wider organisations to take benefit from the

[18] Draft Guidelines "Smart Ticketing". Version 1.

	mutualisation of standard technical tool boxes as well as to insert their customer offer in a wider market.
Organisational and legal issues	Urban and national transport decision makers must actively support the development and implementation of European and international Specifications for Smart Ticketing to ensure mutual compatibility between all schemes.
Data privacy	Protection of the customer's privacy is an ethical requirement of confidentiality, un-linkability, un-observability and anonymity. A low level of protection not only could be punished as a violation of the law but would damage customer acceptance.
Interoperability and continuity of service	Interoperability in transport Smart Ticketing implies removing the obstacles for the customer to switching transport modes. All ticketing needs for through journeys should be in one place and on their local transport Smart Ticketing media even outside their home network. There should be simple registration so the customer has a standardised machine interface and easy access in own language.
Development of Smart Ticketing standards	The use of international and open standards can facilitate interoperability, the opening of global markets and compatibility between devices produced by different suppliers.

One case study of Smart Ticketing Scheme is the one applied in some areas of UK, based on the ITSO smart ticketing principles[19]. An ITSO smartcard allows passengers of public transport to seamlessly hop on and off buses, trams or trains without having to use traditional payment systems like cash or purchasing a paper ticket.

The contactless smartcard is scanned by the transport operator either at a static or handheld ticket machine, or barrier, to authorize travel.

Transport providers use the ITSO Specification to develop smart ticketing schemes for the national, government-funded English National Concessionary Travel Scheme (ENCTS) as well as for their commercial smart ticketing schemes. The smartcard might be called Swift, Pop, The Key or Stagecoach Smart, but the IT Specification behind it is ITSO.

By using the same ITSO Specification, transport operators can ensure that their fare charging systems speak the same language. So, no matter which form of transport you are travelling on, which operator is providing it, or where you are in the UK, in theory, one ITSO smartcard could be used for end-to-end journeys. In some areas of the country, ITSO-based smart ticketing scheme means that your smartcard is valid no matter whose bus you get on, because operators are working together to offer what is known as multi-operator tickets.

19 Smart Ticketing Enabled by ITSO.

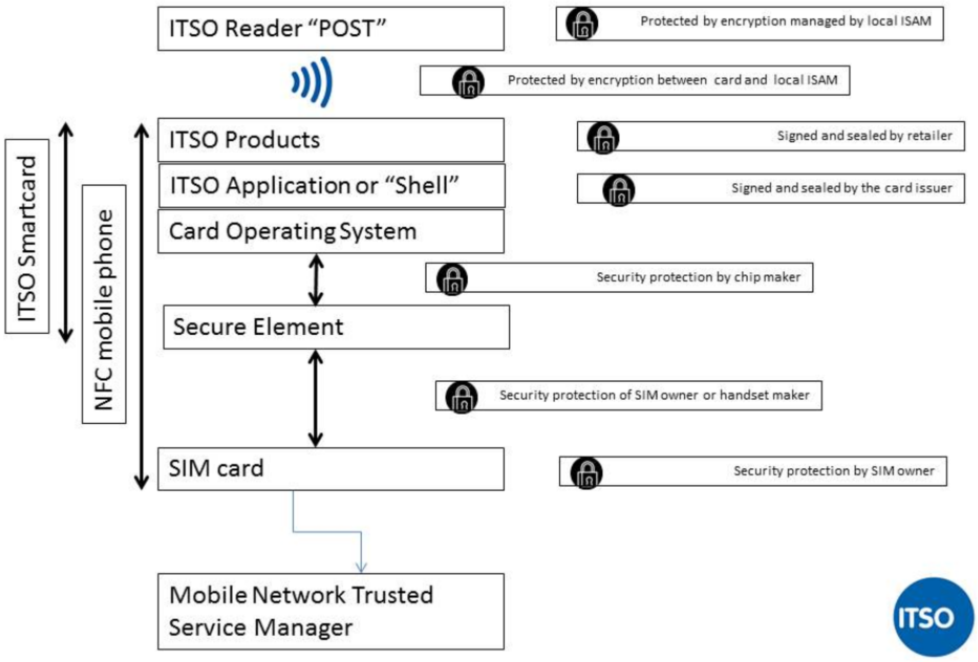


Figure 17. The technology behind ITSO. [www.*ITSO.org*](http://www.ITSO.org)

The electronic wallet within a smartcard that contains electronic tickets for ITSO-compliant schemes, similar to an 'app' on a smartphone, is known as a shell. The shell can be programmed to be read by machines to say 'yes this person has enough money on the card to pay for this ticket', or 'yes this person is a railway season ticket holder for this route'. This is programmed by individual transport operators to reflect their individual tickets and prices.

As conclusion of this chapter, smart ticketing can assist authority in improving clearing mechanisms by providing detailed information on customer's mobility behaviour. If a check-in/check-out procedure is implemented, it becomes easy to distribute revenues according to the actual travel pattern. A direct impact is a saving on the cost of surveys which are periodically carried out to estimate how the different public transport networks are used. Through mining the smart ticketing related data, it becomes possible to get the network performance statistics. Mining on the public transport data collected provides valuable information on bus, rail, cards usage and travel patterns, which then could be utilized for policy, planning and marketing usages.

One of the main drawbacks of smart ticketing data is associated to the privacy of the information collected. Smart Ticketing Privacy must defend the following principles:

- Anonymous accessibility
- Protection against risks of abusive use of personal data from applications in the media
- Protection against risks of:

- Abusive use of personal data by staff
- Abusive usage of abnormal events
- Abuse of direct marketing tools
- Hacking and criminal use of personal data in back-offices
- Uncontrolled dissemination of identity data

Additionally, it is necessary to stablish interoperable schemes, which allow to compare information among the different modes of transport or areas.

Finally, although smart ticketing options offer the possibility of gathering data for journeys integrating different transport modes, it is only associated to public transport legs, not considering the use of complementary private vehicles or active modes of transport to complete the journey.

c) Car sharing data

Car sharing is becoming a popular means of transport in smart cities. In particular, the free-floating paradigm lets the customers look for available cars, book one, and then start and stop the rental at their will, within a specific area

This new paradigm in transportation and mobility, which bases its operation and management on the use of ICTs, offers an alternative way for data collection purposes and offers a great opportunity to transport planners to better understand new mobility patterns and traffic flows.

As a good case study of the data exploitation and management for car-sharing platforms, the Polytechnic University of Turin designed the Urban Mobility Analysis Platform (UMAP)[20], a platform to collect, process, augment, and store data in a data lake, where analytics let the analyst extract higher level information.

They built two crawlers to collect data from the *Car2go* and *Enjoy* platforms, both present in Turin. Every minute, the crawler checks which cars are currently available. Every time a given car “disappears”, it records the booking start time. The same booking ends when the crawler sees the car available back on the system. Some booking were actual “rental” in case the car moved from the prior parking position to another.

They let the crawler run to collect data for 52 days, from December 10th 2016 to January 31st 2017. They observed more than 104,000 bookings and 86,000 rentals for car2go, and 93,000 bookings and 81,000 rentals for Enjoy.

[20] UMAP: Urban Mobility Analysis Platform to Harvest Car Sharing Data (https://www.telematica.polito.it/sites/default/files/paper.pdf)

By analysing the data, they highlighted different aspects related to the system utilization, how people use these services, where they typically go, when, for how long the rental last, how users move in the city in different periods of the day, and what are the users' driving habits.

The analysis of the system utilization demonstrated that 'FreeFloating Car Sharing' (FFCS) cars are frequently used for short trips which last less than 30 minutes and 5 km. Exploiting the spatial analysis highlighted how users tend to move during different time periods. Finally, the users' driving habits showed that current charging policy may encourage users to drive fast.

Car sharing data are property of service providers. Local Authorities could establish agreements with car sharing companies in order to exploit data gathered. These data will provide valuable information about origin-destination journeys, average travel time depending on traffic conditions, users' profiles, etc.

2.2.3. Specific freight data gathering methods

a) Loading/unloading/parking infrastructure data for goods vehicle

The urban road freight transport requires specific and significant infrastructure in order to carry and distribute goods to the final destinations, such as dedicated parking places along the road network, designed by the local policy makers in such way to service as many as possible receivers.

Characterization of vehicle flows and movement offers a general overview of the amount and kind of products delivered in a local area. The analysis of loading, unloading and parking areas data can offer valuable information for a better understanding of freight operations.

According to some experts from the University of Southampton and the University of Westminster[21], it is important to understand the patterns of delivery found in urban centres, and some of this information could be collected through the analysis of loading, unloading and parking areas. Some of the aspects to be monitored are:

- Deliveries by time of day
- Deliveries by day of the week
- Deliveries by time of year
- Deliveries per business per week
- Types of vehicle used to make core goods deliveries
- The use of delivery vehicles for 'back-loading'
- Dwell times of goods delivery vehicles
- Unloading locations and characteristics

[21] Tom Cherrett, Julian Allen, Fraser McLeod, Sarah Maynard, Adrian Hickford and Mike Browne. "Understanding urban freight activity. Key issues for freight planning". ELSEVIER, July 2012.

Collection of loading/unloading information have traditionally been performed by surveys or in situ sighting, but the use of ICTs is helping to develop these tasks and to give a more reliable and continue information recording.

Two projects in Amsterdam are currently attempting to work in this line by using smart information systems. To deal with the problems arising from the loading and unloading of goods, the Amsterdam University of Applied Sciences (AUAS) and Technolution[22] are carrying out a pilot study involving reserved parking spaces for delivery vans. A sensor detects whether a loading and unloading zone is occupied or free and can assign the space to the driver. With a view to future environmental measures this could mean, for example, that carriers could only access the city if they have a reservation for a loading and unloading zone. Without a reservation, they would have to stay on the beltway.

Barcelona in Spain and Vienna in Austria also have projects with digital enforcement. By getting more data about the actual use of loading and unloading zones, local government can decide on a more flexible use of these zones according to day of week or time of tday.

A second project, known as ITSLOG[23], focuses on city logistics in Amsterdam. The emphasis lies on the delivery of supplies to supermarkets, convenience stores and consumers. The research is being carried out by the Amsterdam University of Applied Sciences (AUAS) and its knowledge partners Delft University of Technology and the Netherlands Research Institute for Mathematics and Computer Science (CWI). Other project partners include companies such as food-retailer Ahold Delhaize, Peter Appel Transport and logistics traffic analysts Simacan.

In the coming years ITSLOG researchers will look at whether the available loading and unloading capacity can be related to a truck’s current coordinates and its expected arrival time at the loading and unloading zone, the store, or the consumer’s address. That information, together with current traffic data, can be used to generate a uniform rerouting and buffering instructions that can be processed by on-board computer systems and communicated to the drivers. The researchers will analyse the effects of the real-time rerouting and buffering of trucks on the basis of current traffic information and the availability of loading and unloading locations. With these solutions, the logistics sector would be able to work more efficiently and save costs at the same time. Local Authorities will also benefit from the information gathered about freight operations, getting an updated picture of loading/unloading activities and goods movements inside the city, which could help to better planning the integration with passengers’ flows.

[22] http://www.citylogistics.info/research/will-smart-ict-solve-the-problems-around-the-loading-and-unloading-of-goods/

[23] https://www.researchgate.net/project/ITSLOG-using-real-time-traffic-data-for-city-logistics

Following with the research on loading/unloading planning and freight data collection, the University of Bologna has recently conducted an investigation[24] to finalize the methodology of analysis and a functional loading and unloading plan of the goods, in a mid-sized city, like Bologna. The study has several phases, starting with the quantification and location of parking spaces in the historic district and the characterization in terms of employment, through a detailed analysis of the areas served in relation to the time of stopping. This led to the definition of criteria of optimisation in the process of location and use of the spaces themselves.

The study of the existing logistic scenario in Bologna cannot be separated from the acquisition of information, data and graphic tools with which to analyse the state of affairs in terms of access of commercial vehicles to the city centre and the number, location and use of parking spaces.

The Municipality of Bologna is linked with a Geographic Information System called CityTrekWeb, a type of thematic map of the municipality on-line where the parking areas are reported together with road directions and addresses of both residential and commercial buildings. The Single Commercial Vehicle Loading/Unloading Zones (SCVLZs) employment was assessed for a period of 30 minutes, from 10.30am to 11.00am, during business days, on the basis of the freight transport data relative to the access vehicles at the 9 telematic gates that permit vehicles entering the Limited Traffic Zone (LTZ). It studied the time and the number of operations of the loading and unloading (l/u). To complete the study some researchers unanimously verified and photographed the location and the dimensions of the Multiple Commercial Vehicle Loading/Unloading Zones (MCVLZs), where they worked, the presence and position of their vertical and horizontal traffic signs, the adjacency of the SCVLZ to form a MCVLZ and their localization inside the LTZ. The data collected were rearranged in tabular form and returned on the same plan in order to facilitate the next phase of the analysis.

As a conclusion, freight data gathering is still a gap for Local Authorities, although an integrated passengers-freight planning is necessary for the improvement of cities mobility. Information related to goods movements is usually collected and property form private logistic operators, being sensible information for their own business. However, data gathered from loading, unloading and parking areas could be useful for the estimation of logistics activities in a city. One of the main gaps on freight data collection refers to the reliability and continuity of the information collected; in this sense, ICTs are helping to develop these tasks and increasing the level of trust on data collected.

[24] Urban freight transport in Bologna: Planning commercial vehicle loading/unloading zones. Giampaolo Dezia, Giulio Dondia and Cesare Sangiorgia

2.2.4. New approaches for data gathering based on ICTs

Other technologies are now being sued for real time data collection. Information and Communications Technologies (ICT) provides a greater range of traffic data information with the benefits of being relatively inexpensive, non-intrusive and real time. But they have also some limitations, such as the levels of the network coverage or the privacy concerns. Some examples are described below, including their main advantages and drawbacks.

a) In-vehicle Navigation Systems based on GPS devices

Global Positioning System (GPS) is a worldwide radio-navigation system formed from the constellation of 24 satellites and their ground stations. The system was initially designed for the operation of USA military. But today, there are also many civil users of GPS across the whole world. The civil users are allowed to use the Standard Positioning Service without any kind of charge or restrictions.

Global Positioning System tracking is a method used to give precise locations of objects. A GPS tracking system, for example, may be placed in a vehicle, on a cell phone, or on special GPS devices, which can either be a fixed or portable unit. GPS works by providing information on exact location. It can also track the movement of a vehicle or person. So, for example, a GPS tracking system can be used by a company to monitor the route and progress of a delivery truck or to monitor high-valued assets in transit[25].

The latest on-board systems installed in private cars provide GPS navigation and instant two-way communication to motorists. They can also be used to relay information about a car's systems to car producers.

As an example of in-car communication devices, **OnStar**[26] is the General Motors service that is available in new GM family vehicles. Some of the services available through the OnStar system include turn-by-turn navigation instructions, automatic crash response, and roadside assistance. Each OnStar system that is installed as original equipment is capable of gathering data from both the on-board diagnostics (OBD-II) system and built-in GPS functionality. They also use CDMA cellular technology for voice communications and data transmissions.

In order to provide turn-by-turn directions, GPS data can be transmitted via the CDMA connection to the central OnStar system. The same GPS data can also be utilized for emergency services functionality, which allows OnStar to summon help in case of an accident.

OnStar is also capable of transmitting data from the OBD-II system. This can allow OnStar to track car mileage for insurance purposes, provide vehicle health reports, or even determine if

[25] https://www.eetimes.com/document.asp?doc_id=1278363
[26] https://www.onstar.com

the vehicle has been involved in an accident. If a driver may find unable to reach a cell phone after a serious accident, the OnStar call centre is notified when the OBD-II system determines that car airbags have gone off. It may then request assistance if needed.

In this line, ABI Research[27] estimated that more than 60% of new cars worldwide are expected to have connected capabilities by 2017, up from 11.4% in 2012. At the same time, those "connected cars" hold the potential of divulging speed and a variety of data that could be used by law enforcement or others.

The main issue when recording information from private cars is the invasion of consumers' privacy. Aware of privacy concerns, developers of a proposed nationwide system of connected cars say they are trying to build in safeguards.[28] Tom Schaffnit of the Vehicle Infrastructure Integration Coalition[29] claims the system will be designed to let drivers stay anonymous, to constantly change designators for any particular vehicle every few minutes in order to make sure no driver can be tracked, says.

By contrast, because consumers often opt to give away data when it benefits them, some say privacy issues are no cause for concern. Fears have been "blown out of proportion," says Mukul Verma, a former top GM safety expert who is now a consultant. "I don't think there is any chance of it being used or misused without people's permission."[30]

Other weaknesses of GPS tracking systems are the degradation of signals by obstacles or the network overload. But the main gap on this technology is the restriction of data availability only to the vehicle manufacturer (e.g. in the specific case of OnStar, only Opel can access to this data). Local Authorities, so, would need to stablish agreements with car manufacturers or hardware/software developers in order to use this kind of data that could be useful for the traffic and urban planning.

b) Floating Car Data (FCD).

Aligned, and as an extension of previous point, Floating Car Data collects real-time traffic data by locating some vehicles via mobile phones or GPS over the entire road network. This basically means that the vehicle is equipped with mobile phone or GPS which acts as a sensor for the road network. Data generated by the equipped vehicles as a sample is used to assess the overall traffic condition. Some data such as car location, speed and direction of travel are sent anonymously to a central processing centre. After being collected and extracted, useful information (e.g. status of traffic, alternative routes) can be redistributed to the drivers on the road.

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[27] https://www.abiresearch.com/press/by-2017-60-of-new-cars-shipping-globally-will-feat/
[28] https://www.usatoday.com/story/money/cars/2013/03/24/car-spying-edr-data-privacy/1991751/
[29] https://www.usatoday.com/story/money/cars/2013/03/24/car-spying-edr-data-privacy/1991751/
[30] http://shariolefson.com/news/what-secrets-can-your-car-tell-about-you?page=2

Local Authorities can benefit from FCD by using the information provided by their own fleets moving in the city and also from the data transmitted by vehicles belonging to public and private companies with direct contracts with the local administration (e.g. waste collectors, public transport operators, etc.). This system will provide real-time data about traffic conditions, point-to-point travel times, congested areas, etc.

Floating Car Data is an alternative or rather complementary source of high quality data to existing technologies. Helping to improve safety, efficiency and reliability of the transportation system becoming crucial in the development of new Intelligent Transportation Systems (ITS). There are two different kinds of Floating Car Data being used:

- GPS-based (e.g. from taxi or buses): GPS-based FCD represents the location of vehicles collected by mobile sources using GPS devices installed in vehicles. In many cases the raw data is transmitted to a central facility for processing. In other cases, advanced GPS equipment with built-in digital road map carry out map-matching at the same time so that the system is capable of reporting the link name and trajectory at once, as is the case of navigation equipment.[31]
- FCD based on cellular phones: The mobile phone positioning is regularly transmitted to the network, then travel times and further data can be estimated over a series of road segments before being converted into useful information by traffic centres.

One of the weaknesses of this technology is that the continuous transmission of the speed of a large number of vehicles generates an important heavy load on the transmission channels and therefore constitutes a significant cost factor in using a fee-based communications system.

Moreover, the problem of determining the right number of vehicles tracked as well as the time intervals are critical issues to obtain reliable pictures of the traffic situation. A previous study on the network coverage and sampling development should be carefully established to reach the expected results.

Another issue to take into account, as highlighted previously, is the privacy concern. Although it is technically feasible to use FCD as a monitoring tool, the FCD service provider gives assurances about the data protection ensuring that all the data collected is anonymous. As this is a fundamental issue for probe vehicle systems, several technical approaches have been implemented to make FCD systems anonymous based on cryptographic mechanisms.

[31] G. Leduc, "Road Traffic Data: Collection Methods and Applications", Institute for Prospective Technological Studies, European Commission, 2008.

c) *Bluetooth enabled devices*

Bluetooth is a wireless technology standard for exchanging data over short distances (up to 100 m) from fixed and mobile devices, and building personal area networks (PANs).

A basic system configuration for data collection via Bluetooth consists of a Bluetooth device that scans for other Bluetooth-enabled device within its radio proximity, and then stores or forwards the data for future analysis and use. The scanned devices are typically on-board vehicular electronics and consumer devices carried by the driver and/or passengers which use Bluetooth communications, which reasonably proxy for the vehicle itself.

Traffic measurement applications will typically require installation of road-side measuring devices. So, although the scanned devices are mobile, measurements are limited to fixed points on the road network.

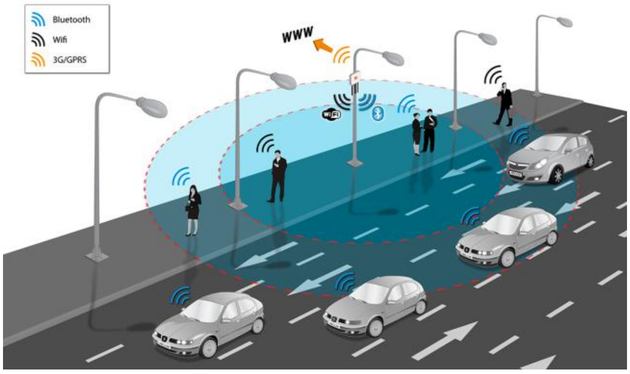


Figure 18. Data collection from Bluetooth and WiFi devices. *Libelium (http://www.libelium.com/)*

Bluetooth sensors can be used to collect OD data with a lower cost than using surveys or cameras. By setting up a network of sensors around the OD points of interest, these sensors use MAC address detection and matching to determine the travel origin and destination of individual drivers (or pedestrians). The combination of Bluetooth and Wi-Fi detections also improves the sample size of the data, which is an important factor in OD studies.

In addition, Bluetooth sensors can provide estimates of travel speeds and time, providing the information needed to extract a reasonable approximation of traffic presence, density, and flows.

According to Friesen and McLeod[32], when designing a Bluetooth sensor system for ITS applications, there are choices in system attributes that become design decisions unique to the context and objectives of the system in deployment. The basic configuration requires the

[32] M. R. Friesen and R. D. McLeod. 'Bluetooth in Intelligent Transportation Systems: A Survey'. May 2014.

designer to decide what type of device will be used, how many devices are required, and where and how they will be located and fixed in the environment.

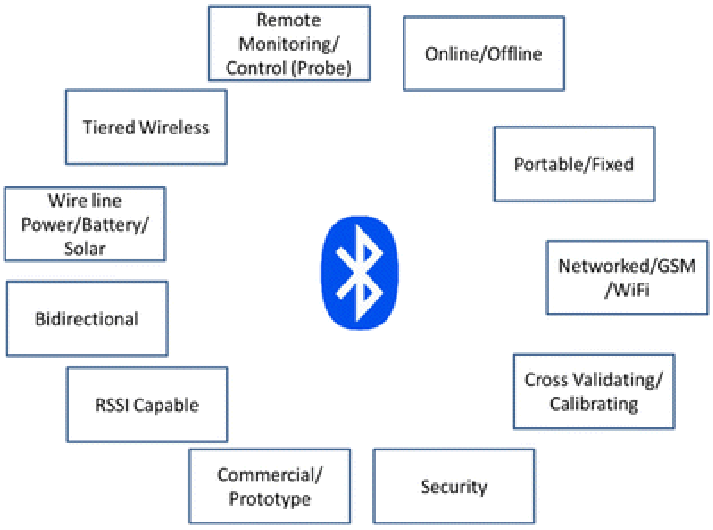


Figure 19. Bluetooth traffic monitoring design decisions. *M. R. Friesen and R. D. McLeod (2014)*

Currently, they have limited applicability in measuring total traffic volumes, as they are not present in all vehicles so vehicle expansion factors have to be estimated to compare Bluetooth with traffic data. The increasing inclusion of Bluetooth technology in modern motor vehicles means that it may be possible to more directly measure total traffic volumes across the road network via Bluetooth[33].

d) Wi-Fi detection

Wi-Fi or WiFi is a technology for wireless local area networking with devices based on the IEEE 802.11 standards. Wi-Fi compatible devices can connect to the Internet via a WLAN and a wireless access point. Such an access point (or hotspot) has a range of about 20 meters (66 feet) indoors and a greater range outdoors. Hotspot coverage can be as small as a single room with walls that block radio waves, or as large as many square kilometres achieved by using multiple overlapping access points.

In the same way that Bluetooth technology, WiFi technology allows the collection of traffic information and can visualize and analyse results to better manage traffic flows, basing the decision on the knowledge of traffic performance and their response to measures establishment.

[33] B. Araghi, K.S. Pederson, L.T. Christenson, R. Krishnan, and H. Lahrmann, “Accuracy of Travel Time Estimation using Bluetooth Technology: Case Study Limfjord Tunnel Aalborg”, ITS World Congress, (2012)

As an example of use of WiFi for data collection, Bitcarrier[34] captures vehicle movements with a network of smart sensors, which are placed at strategic locations in city streets, on roads and on highways. While drivers obtain instant updates about journey times and incidents, road operators receive all the data they need to develop agile mobility policies.

The next figure shows an example of working process for Bitcarrier tool.

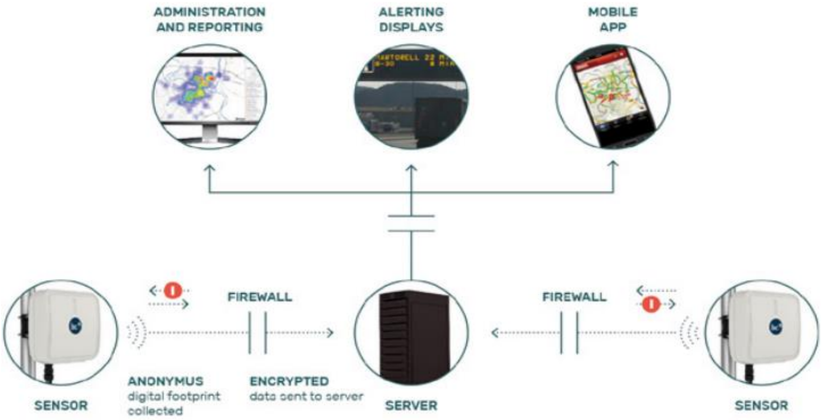


Figure 20. How works a system based on WIFI detection. *Worldsensing: Bitcarrier (http://www.worldsensing.com/product/bitcarrier/)*

e) Crowdsourcing data

As the term implies, crowdsourcing is the process through which an entity (individual or organization) requests specific resources from a group of people. Businesses, individuals and organizations commonly use these processes to solicit ideas and raise money as well as to consolidate and promote information.

These entities use the internet, social media applications and specially built platforms to elicit and receive the knowledge, goods or services they are looking for. This allows them to collect information or resources with a wider spectrum of sources than they would if they had used employees, suppliers and other traditional sources of expertise via conventional routes of engagement.

[34] Bitcarrier. Web : http://www.worldsensing.com/product/bitcarrier/

Figure 21. Example of crowdsourcing data collection. *Evan Welbourne et al.*[35]

As a case study for crowdsourcing data collection, the SETA[36] European project aims to develop new methods of crowdsourcing data and information from citizens over a large scale, via participatory (e.g. via mobile phones and low-cost sensors) and passive sensing (e.g. via large scale analysis of social media) that will enable pervasive, low cost, large scale high-granularity multimodal sensing over metropolitan areas.

- Pervasive transport information provided by static and mobile professional sensors (including traffic sensors, floating cars, GPS tracked bikes, street cameras, meteorological stations, mobile usage data, etc.).
- Data and information from social sensors (citizens) who willingly provide information/data e.g. either using their mobile phones or using low cost sensors (e.g. attached to their phones) or using social media.
- Large-scale data banks from business and government (e.g. open linked data, accidents records, metre by metre description of the layout of the road infrastructure - bridges, bending, and even street furniture such as lamp posts ad park benches - traffic flows records, maps, etc.).

2.3. Conclusions

This chapter has analysed different transport data gathering methods, starting from the most traditional ones, up to new approaches for data gathering based on ICTs.

Traffic information has traditionally been collected with manual methods (surveys or manual counting), road sensors and video cameras (see 2.2.1). The main inconvenience of these fixed installations is that they do not give any traffic information beyond the locations where

[35] Evan Welbourne, Pang Wu, Xuan Bao and Emmanuel Munguia-Tapia. “Crowdsourced mobile data collection: lessons learned from a new study methodology”. February 2014.
[36] http://setamobility.eu/

they are installed, and their coverage is usually confined to congestion-sensitive roads and a limited number of tunnels, bridges and intersections.

On the other hand, ICT-based technologies offer new possibilities for high amounts of data collection with a relatively low collection cost and with no affec on the infrastructure. ICT-based collection methods allow gathering of real-time information through the use of in-vehicle or personal devices or via voluntary-used applications. In addition, these alternatives are also useful for active modes of transport, which in some cases are not covered by traditional data collection systems (e.g. road sensors are not suitable for pedestrian traffic flows).

On board data capturing devices provide anonymous data such as car location, speed and direction of travel: information collected increases knowledge on status of traffic or alternative routes. Information can be transmitted in both ways: vehicle/user-general system and vice versa; it can then also inform drivers, passengers or even pedestrian of incidents, security problems or to advice of the most convenient travel alternative.

The main problem that service providers have to face is the compliance with the specific privacy laws, due to the fact that the data collected is private users' information. Therefore, systems should be designed to preserve anonymity.

Despite the emergence of ICT-based technologies, traditional techniques are likely to remain useful in future. New techniques cannot replace the traditional collection of land use data and the behavioural qualitative data necessary for decision making. Consideration is required to determine how these new data sources and collection techniques should be used, how they should be supplemented with other data and how best to manage this data and integrate it with other existing data[37].

[37] Jesus Gonzalez-Feliu, Frédéric Semet, Jean-Louis Routhier. 'Sustainable Urban Logistics: Concepts, Methods and Information Systems'

3. Analysis strategies of data mobility in Europe

After finalising the review of data collection methods and technologies, it is important to report why this data are useful and how local authorities can work with them. This chapter tries to collect different alternatives for data management in order to help local authorities to extract conclusions form data collected and to serve as a quick guide on how this data are being used.

First of all, Key Performance Indicators (KPIs) provide a basis for a standardized evaluation of mobility systems and measure the improvements resulting from the implementation of new mobility practices or policies. Some projects and studies provide a set of suitable or most used indicators in passengers and freight mobility assessment. Section 3.1reviews these indicators and the main criteria for their definition.

Based mainly on KPIs measured in cities, Decision Support Systems (DSS) provide local authorities of the tools for the analysis and simulation of the effects of city logistics measures. Some example of DSS and how they are used and the results provided are included in section 3.2.

The development of new data collection mechanisms, the increment in storage capacity and the raise of computing power enable real-time use and transmission of massive amounts of data. For example, some European countries and local administrations count on their own open data portals, where public data are available for users to work with them. An important open data source in Europe is the European Data Portal. Big Data offers new possibilities for handling huge amounts of data available n.

Finally, CIVITAS platform has recently created a repository of main tools and projects for helping sustainable urban mobility practitioners on urban mobility management. Sectionr 3.4. makes a review on the available tools for data collection and analysis included in CIVITAS platform.

3.1. Key Performance *Indicators for passengers and freight mobility analysis

According to Fitz-Gibbon (1990) [38], a Key Performance Indicator (KPI) is a type of performance measurement, which evaluates the success of a particular activity. Often success is simply the repeated, periodic achievement of some levels of operational goal and success is defined in terms of making progress toward strategic goals.

The main objectives of KPIs summarized in[39] relate to:

[38] *Carol Taylor Fitz-Gibbon (1990),* "Performance indicators", *BERA Dialogues (2),* ISBN 978-1-85359-092-4

[39] Jump up^ Key Performance Indicators – What Are Key Performance Indicators or KPI

- Measuring the level of service
- Making a diagnosis of the situation
- Communicate and reporting on the situation and objectives
- Evaluating any progress on a continuous basis.

Accordingly, choosing the right KPIs relies on a good understanding of what is important to measure. One way to evaluate the relevance of a KPI is to use the **SMART** criteria[40]. The letters are typically taken to stand for:

Specific	It should be clear what the KPI exactly measures. There has to be one widely-accepted definition of the KPI to make sure the different users interpret it the same way and, as a result, come to the same and right conclusions which they can act on.
Measurable	The KPI should be measurable to define a standard, budget or norm, to make it possible to measure the actual value and to make the actual value comparable to the budgeted value.
Achievable	Every KPI should be measurable to define a standard value for it. It is important for the acceptance of KPI's and Performance Management.
Relevant	The KPI must give more insight in the performance of the organization in obtaining its strategy. If a KPI is not measuring a part of the strategy, acting on it doesn't affect the organizations' performance.
Time-related	It is important to express the value of the KPI in time. Every KPI only has a meaning if one knows the time dimension in which it is realized.

3.1.1. Passengers' mobility evaluation KPIs

Mobility data collected in cities is habitually used to calculate performance indicators, which allow the quantification of the added value generated by the application of a (set of) mobility measure(s).

The World Business Council for Sustainable Development (WBCSD) developed in 2016 a report[41] including a comprehensive set of sustainable mobility SMART Key Performance Indicators for cities in order to set the basis for a standardized evaluation of their mobility system and measure the improvements resulting from the implementation of new mobility practices or policies.

[40] KPI Portal http://www.kpi-portal.com/

[41] World Business Council for Sustainable Development. 'Sustainable Mobility Project 2.0 (SMP2.0) Indicators Work Stream - 2ndEdition'. January 2016.

KPIs were classified attending four dimensions of sustainable mobility. Three are inspired by the pillars of sustainable development and the fourth one has been added to consider the performance of the mobility system itself in the city:

1. Global environment
2. Quality of life in the city
3. Economic success
4. Mobility system performance

The next table presents the KPIs identified and developed by the WBCSD:

Affordability of public transport for the poorest group	Share of the public transport cost for fulfilling basic activities of the household budget for the poorest quartile of the population. Affordability index of public transport for the poorest population quartile based on the relation between the cost for 60 relevant public transport trips and the average monthly household income.
Accessibility for mobility-impaired groups	The accessibility for deficiency groups to transport and transport services. Average reported convenience of city transport for target groups.
Air polluting emissions	Air polluting emissions of all passenger and freight city transport modes. Total tailpipe harmful emission harm equivalent per year per capita.
Noise hindrance	Hindrance of population by noise generated through city transport. Percentage of population hindered by city transport noise based on hindrance factors for noise level Lden measurements.
Fatalities	Fatalities by road and rail transport accidents in the city. Number of deaths within 30 days after the traffic accident as a corollary of the event per annum caused by urban transport

	per 100,000 inhabitants.
Access to mobility services	Share of population with appropriate access to mobility services. Percentage of population living within walking distance of public transport (stop or station) or shared mobility (car or bike) system.
Quality of public area	Presence in the city of attractive areas such as pedestrian street or squares which facilitate social activities and encourage citizens' interaction. Reported social usage of streets and squares and subjective appreciation of the public area quality.
Urban functional diversity	Functional diversity refers to a mix of spatial functions in an area, creating proximity of mutual interrelated activities. Average presence (value 1) or not (value 0) of out of 10 spatial functions related to daily activities except for work in grids of 1 km x 1 km.
Commuting travel time	Duration of commute to and from work or an educational establishment. Average duration of the combined outward journey and return journey to work or an educational establishment expressed in minutes per person per day.
Economic opportunity	Degree of accessibility to the job market and education system. Citizens' perception of potential difficulties in accessing the job market and/or education system due to mobility network.
Net public finance	Net results of government and other public authorities' revenues and expenditures related to city transport. Net government and other public authorities' revenues from transport-related taxes and charges minus operational and other costs per GDP; investments are excluded from the parameter calculation.
Mobility space usage	Proportion of land use, taken by all city transport modes, including direct and indirect uses. Square meters of direct and indirect mobility space usage per capita.

Emissions of greenhouse gases

Well-to-wheels GHG emissions by all city passenger and freight transport modes.

Tonne CO2 equivalent well-to-wheel emissions by urban transport per annum per capita.

Congestion and delays

Delays in road traffic and in public transport during peak hours compared to free flow travel.

Weighted average per trip of the ratio of peak period travel times to free-flowing travel times with respecting rules inroad traffic and travel time adherence of public transport during peak hours on up to 10 major corridors for both transport modes.

Energy efficiency

Total energy consumed for city transport.

Total energy use by urban transport per passenger km and tonne km (annual average over all modes). .

Opportunity for active mobility

Options and infrastructure for active mobility, which refers to the use of the soft modes, namely walking and cycling.

The length of roads and streets with sidewalks and bike lanes and 30 km/h (20 mph) zones and pedestrian zones related to total length of city road network (excluding motorways).

Intermodal integration

Availability of intermodal connections and quality of the interchange facilities.

Number and frequency of the connections between the different transport modes and the reported good organization, information and physical access in the interchange facilities

Comfort and pleasure

The physical and mental comfort of citizens while using the urban transports and services.

Average reported satisfaction about comfort of city transport and of pleasure of moving in the city area.

Security

Risk of crime in urban transport.

Reported perception about crime-related security in the city transport system (including freight and public transport, public domain, bike lanes and roads for car traffic and other facilities such as car or bike parking).

The Guidelines developed by the **European Platform on Sustainable Urban Mobility Plans**[42] also introduce the necessity of selecting a set of suitable indicators to assess current and future performance of the mobility plan. KPIs are useful for different steps in the development and implementation process of a SUMP:

- Analyse the mobility situation and develop scenarios
- Set priorities and measurable targets
- Build monitoring and evaluation into the plan

These guidelines suggest some examples of projects where some different mobility indicators have been developed.

- **DISTILLATE PROJECT: Improved Indicators for Sustainable Transport and Planning**[43] proposes a core set of outcome indicators for use across the strategic decision-making process. The suite of indicators is drawn from only those indicators already in use but provides a fuller coverage of sustainability issues than could be achieved. It also proposes a method for prioritising the selection of these indicators. Not all of them appropriate for each area nor would it be resource efficient or necessarily useful to monitor them all.

  a. ENVIRONMENT

  i. Limits emissions within planet's ability to absorb them

  - CO_2 emissions by end user/per capita
  - Local CO_2 emissions
  - Acidification
    - Annual average nitrogen dioxide concentration
    - Annual sulphur dioxide emissions

  ii. Protects human health

  - Days when the pollution is moderate or high
  - Number of days when air pollution is moderate or higher for PM10
  - For rural sites, number of days per year when air pollution is moderate or higher for ozone

[42] GUIDELINES: Developing and implementing a Sustainable Urban Mobility Plan. European Platform on Sustainable Urban Mobility Plans.

[43] DISTILLATE: Improved Indicators for Sustainable Transport and Planning. Deliverable C1 Sustainable Transport Indicators: Selection and Use. Greg Marsden, Charlotte Kelly, Carolyn Snell, John Forrester. December 2005.

iii. **Uses of renewable resources**
   - Energy Efficiency of transport industry/economy

iv. **Minimises noise generation**
   - People rating the level of transport related noise as unacceptable

v. **Minimizing the impact on land/ water**
   - Net loss to sites of importance (historical)
   - Net Loss to land
   - Net Loss to Habitat/ air pollution/ loss of land
   - Net loss to water

b. **ECONOMY**

i. **Supports a competitive economy**
   - Total output of the economy (GDP and GDP per capita)
   - Regional GDP/GVA

ii. **Supports balanced regional growth**
   - Total output of the economy (GDP and GDP per capita)
     - Congestion: average time lost per vehicle-km
     - Real changes in the cost of transport
     - Principal Road Condition
   - Regional GDP/GVA
     - Congestion: average time lost per vehicle-km
     - Bus Punctuality
     - Pedestrian Delay (access of pedestrian crossing
     - facilities)

iii. **Operates efficiently**
   - Transport efficiency

c. **SOCIAL**

i. **Meeting society's needs safely**
   - Total killed and seriously injured casualties
   - Child killed and seriously injured casualties
   - Total slight casualties

- Death rates from cancer, circulatory disease, accidents and suicides
- Fear of crime
- % of residents surveyed who feel 'fairly safe' or 'very safe' after dark whilst outside in their local area
- % of residents surveyed who feel 'fairly safe' or 'very safe' during the day whilst outside in their local area
- People who think it is easy and safe to walk in their area

ii. Quality of life

- % of residents who are satisfied with their neighbourhood as a place to live
- Average satisfaction with the local community

iii. End user satisfaction

- % of highways that are either of a high or acceptable level of cleanliness
- Bus Satisfaction
- Rail passenger satisfaction
- % of users satisfied with local authority provided
- district transport services
- Principal Road Condition
- Non-principal Classified Road Condition
- Unclassified Road Condition
- Footway condition

iv. Basic Access

- Social participation/ sport/ learning
  - % of rural households within 13 min walk of an hourly or better bus service
  - Working age people in workless households (access to employment)
  - % of residents defined as within a distance of 500m (15min walk) of key local services

v. Fairness

- Accessibility

- **Cambridgeshire Local Transport Plan 2011-2031. Policies and Strategy[44].** Monitoring the effectiveness of the strategy and is a key part of the Local Transport Plan. Cambridgeshire has developed a monitoring framework to assess and review progress. The plan sets out the indicators and targets used to monitor progress towards delivering strategy and achieving objectives. The indicators reflect the transport issues which are most important to Cambridgeshire while at the same time enabling to compare progress against other local authorities in the country.

  a. **Road Safety**
     - People killed or seriously injured in road traffic accidents
     - Children killed or seriously injured in road traffic accidents
     - Pedestrians and cyclists killed or seriously injured in road traffic accidents
     - Road accident casualties slightly injured

  b. **Trends in travel**
     - Local bus passenger journeys originating in Cambridgeshire
     - Percentage of buses running on time
     - Excess waiting time for frequent bus services
     - Cycling trips index
     - Traffic travelling across the Cambridge radial cordon
     - Congestion: Average journey time per mile during the morning peak

  c. **Environment**
     - Emissions of Greenhouse gases from road transport
     - Trends in NO2 concentrations in the Cambridge Air Quality Management Area, expressed as a 5 year running annual mean
     - Trends in PM10 concentrations in Air Quality Management Areas in Cambridgeshire, expressed as a 5 year running annual mean

  d. **Road and footway condition**
     - Principal roads where maintenance should be considered
     - Non-principal classified roads where maintenance should be considered

[44] Graham Hughes. 'Cambridgeshire Local Transport Plan 2011-2031: Policies and Strategy'. July 2015

- **CONDUITS project**[45] aims to define a common evaluation framework for the performance of traffic management and ITS in the form of a set of Key Performance Indicators (KPIs), and to present guidelines as to its application.

  Four strategic themes of urban traffic management and ITS were tackled: traffic efficiency; traffic safety; pollution reduction; and social inclusion and land use.

  a. Traffic efficiency

  For the theme of traffic efficiency, three KPIs were defined for mobility, reliability, and system condition, respectively:

Index for mobility	Consists of the average travel time to different destinations in the highway and public transport networks expressed in time units, normalised by the distance to the destinations, and weighted by importance according to the goals and objectives of the application under consideration.
Index for reliability	Composed of different elements related to different modes of transport. Reliability deals mostly with system efficiency from the perspective of the suppliers who invest most of their efforts in reducing congestion hence providing better mobility.
Index system condition and performance	A system condition and performance KPI may be composed of different elements such as: km of infrastructures attending to their conditions or availability and status of public transport services.

  b. Traffic safety

  With respect to traffic safety, a performance evaluation based on the direct quantification of accidents was proposed on one hand (with a respective KPI), and on the general quantification of the impact of various traffic management measures and ITS on safety on the other.

Index for traffic accidents	The KPI for road traffic accidents takes into account the fact that each city has its own traffic and accident characteristics. As such, the importance of decreasing a specific type of accidents can be adjusted by using a higher weight w.
Index for applications	The key feature of applications with direct safety impact is

45 CONDUITS project. D3.5: Key Performance Indicators for traffic management and Intelligent Transport Systems. Imperial College London. June 2011.

w/ direct safety impact	the number of system interventions. A large number of system interventions indicate a lower safety level due to the higher frequency of interactions between road users, leading to a critical situation or to an accident.
Index for applications w/ indirect safety imp. in urban environments	It is based on the number of detected critical situations such as congestion or oversaturation of parking facilities, the cycle failure of traffic signals etc.
Index for applications w/ indirect safety imp. on urban motorways	It is based on the number of detected critical levels-of-service, including unstable traffic conditions and congested situations.
Index for car to infrast. communication-related applications	The calculation of an index for their safety impact is theoretical with the present means of infrastructure operators. For car-to-infrastructure communication systems the number of sent-out warning messages can be used as a significant figure for evaluating their safety impact.
Total index of traffic safety	Total index englobes all the previous indicators, taking into account a specific weight for each of them.

c. Indices for pollution reduction

The evaluation of the performance of urban traffic management and ITS with respect to pollution reduction was done by using well-established and widely-used emissions models.

Index for emissions from motor vehicles	A direct calculation of the energy demand can be carried out to assess transport energy and environmental impacts, including greenhouse gas emissions. The energy demand in the road transport sector is calculated as a product of several important driving factors, including the direct energy demand and the GHG emissions rate.
Index for emissions from electric vehicles	The environmental impact of vehicle fleets based on EV may be assessed taking into account: derivation of data on total emissions released in the considered region/country in the process of electricity production, derivation of data on total electrical energy supply in the considered region/country and calculation of specific emission values per unit of electrical energy consumed.
Total index of pollution reduction	It is suggested to define the pollution reduction KPI, as a sum of normalised emissions values of different pollutants.

d. Indices for social inclusion and land use

As concerns the evaluation of the performance of urban traffic management and ITS with respect to social inclusion and land use, four KPIs were defined.

Index for accessibility	The accessibility of activities can be considered solely at a spatial level calculating the opportunities for a specific activity that can be reached from a certain zone by the means of certain transport mode.
Index for social mobility of special groups	The mobility ratios of different population groups can hence express the extent to a system reach inclusion to enable all citizens to have the same mobility patterns on average.
Index for public transport usage of special groups	A practical way to assess modal choice patterns of people with mobility impairments is the comparison of the potential public transport demand to the realised demand.
Index for land use	a direct calculation of land consumption is feasible through GIS. Namely, defining the relative growth in vehicle-kilometres over five years,

- **West Yorkshire, Local Transport Plan 2011-2026. England[46].** Transport is of fundamental importance to the West Yorkshire economy and environment as well helping to determine many aspects of the quality of life enjoyed by residents and visitors. Transport issues vary in importance across West Yorkshire. Congestion is a significant problem in the main urban areas and on the motorways and other strategic routes. Safer roads are an issue for many inner city communities that experience traffic in residential streets. Accessibility is the key concern in the extensive rural areas to the west and south of the county and in former mining areas that border South Yorkshire. Air quality generally exceeds standards, but there are locations where action is required to address traffic related problems. Economic growth, regeneration and community cohesion are common priorities across West Yorkshire.

  An important part of the overall process of LTP implementation is the continuous assessment of indicators and targets. This is carried out on an annual basis as part of our performance management framework.

  Below are presented the main indicator considered in West Yorkshire Local Transport Plan:

[46] West Yorkshire Local Transport Plan 2011-2026 (LTP3). http://www.wymetro.com/wyltp/

- Accessibility
- Bus punctuality
- Satisfaction with local bus services
- Annualised index of cycling trips
- Average journey time per person mile on key routes
- Change in peak period traffic flows to urban centres
- Mode share of journeys to school
- Satisfaction with LTP funded public transport facilities
- Cycling trips to urban centres during the morning peak
- AM peak period mode split to urban centres
- Peak period rail patronage
- Patronage on Quality Bus Corridors
- Number of pedestrians KSI in road traffic collisions

Finally, taking into consideration the example of some **European Mobility Plans**, for the calculation on main indicators in the mobility assessment are used some factors considering the efficiency of the transport system, the accessibility of all users or the safety and security aspects.

Using as an example the case of the Valencia's Urban Mobility Plan, it includes a set on indicators for the characterization of the trips inside of the city and with the metropolitan area:

- **Offer and demand of transport**
  - Trips generated by the city (from the city to outskirts)
  - Trips attracted by the city (from outskirts to the city)
  - Modal split
  - Purpose of trips
  - Average distance/time per trip (for the different modes of transport)
  - Car parking provision (number of parking slots/inhabitant)
  - Bike parking provision (number of parking slots/inhabitant)
  - Number of travels (or travellers) per day for each transport mode
  - Offer of public transport (number of lines, net coverage, frequency, etc.)
  - Offer of public bikes (number of public bikes per inhabitant)
- **Efficiency**
  - Motorization index (nº cars/inhabitant)
  - Average age of vehicles fleet
  - Characterisation of vehicles fleet attending to the propulsion system

  - Number of bikes/inhabitant
  - Nº of users of public bike service/nº inhabitants
  - Pedestrian density in specific pedestrian areas
  - Cost-benefit rate for public transport services
  - Average Annual Daily Traffic (AADT)
  - Peak Hour Traffic Volume
  - Bike traffic volume
- **Safety and security**
  - Fatality rate: Number of fatal accidents/year
  - Injuries: Number of injured people/year
  - Criminality rate
- **Land use**
  - Length of transport infraestructures (km of bike lanes, km of pedestrian streets, km of PT lines, etc.)
  - Number of PT stops (including public bikes)
  - Space dedicated for parking areas
- **Inclusion and accessibility**
  - Accesibility to public transport (average distance to public bus/metro stops)
  - Accesibility to public bikes services (nº bikes/inhabitant, average distance to public bike station)
  - Accesibility to private transport (number of vehicles -including bikes- per home)
  - Adaptation to people with reduced mobility (PMR) (nº places for PMR available in adapted/conventional vehicles, nº accessible stops, nº of parking spaces for PMR, etc.)
- **Pollution and noise**
  - Sound levels in specific areas
  - Pollution rates (CO_2, NO_X, PM, O_3)

again this is just a list. How are these influencing data collection. what are the gaps in knowledge with respect to data on these KPIs. do we have sufficient data at city level to know if KPIs are being met. Which data is having most influence, so are people concentrating on one particular aspect e.g. because data is easier to collect e.g. pollution data

3.1.2. Goods mobility evaluation KPIs

Previous studies take mainly into consideration passengers' mobility, but not freight flows. According to the study developed by **BESTUFS project**[47], there are few indicators that are currently in use by national, regional or local governments to monitor the performance of urban freight transport. The most commonly used indicators are related to road freight and include: goods vehicle trips, and goods vehicle kilometres (usually based on traffic count data). However, even these indicators are not available in many European urban areas.

Other indicators that are commonly used by governments to measure and monitor freight transport at a national level include: tonnes lifted (by road and other modes), and tonnes moved (i.e. tonne-kilometres by road and other modes). However, these indicators are often not available at an urban scale. Several of them are less efficient at an urban scale than at a interurban scale (for example tonne-kilometre by road is not easily connected with road use due to the great variety of packaging and size of vehicles used in urban areas).

Other national freight transport indicators used by governments in one or more European countries include:

Freight Intensity[48] This is usually defined as the ratio of freight tonne-kms to an economic output measure such as GDP. Havenga and Simpson (2014) have shown that there are very wide international variations in the amount of GDP generated for each tonne-km of freight movement

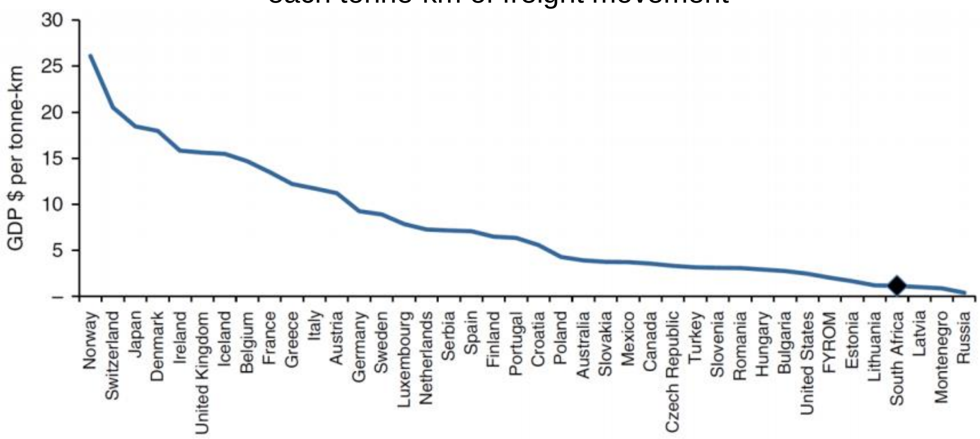


Figure 22. Freight Transport Intensity: amount of GDP generated per tonne-km. *Havenga and Simpson, 2014*

47 Mike Browne, Julian Allen, Allan Woodburn, Danièle Patier, Jean-Louis Routhier, Christian Ambrosini. **Comparison of urban freight data collection in European countries** - 11th WCTR.

48 Performance measurement in freight transport: Its contribution to the design, implementation and monitoring of public policy. Alan MCKINNON.

Loading factor[49]	Vehicle loading distinguishes two types of operational measures widely encountered in the freight sector: Productivity: defined as the ratio of outputs (such as tonne-kms or vehicle-kms) to inputs (such as fuel, vehicles or labour). They described this as 'transformational efficiency' as it measures the efficiency with which a resource is converted into an activity. Utilisation: the ratio of the capacity actually used to the total capacity available (such as the amount of space in a container actually occupied by a load) Both types of efficiency can be measured in several different ways, giving differing impressions of just how well a transport operation is performing.
Empty running[50]	Kilometres driven empty/Total kilometres driven. Empty running is defined as the relocation of an empty vehicle or trailer. It is used as a way to indicate that the company is being efficient in taking up backhaul opportunities
Fuel Efficiency[51]	Fuel accounts for a large share of operating costs in the freight transport sector and is the source of virtually all freight-related emissions. Policy-makers therefore need little convincing of the importance of fuel efficiency as a performance metric. The metric itself is a productivity measure showing the efficiency with which energy is converted into the movement of freight. This can either be done with respect to vehicle-kms (fuel efficiency) or to a denominator that takes account of the weight or volume of goods transported (often called 'energy intensity').
Loading/Unload density	Number of deliveries and pick-ups per km^2 in a zone. It measures the importance of the goods flows in a zone.
Distance covered for loading / unloading[52]:	Number of kilometres covered for one delivery or pick-up in a zone, per vehicle, per activity. Measures the contribution the running vehicles delivering cach industry sector to the road congestion.

[49] Caplice and Sheffi, 1994
[50] The transport optimisation report
[51] Performance measurement in freight transport: Its contribution to the design, implementation and monitoring of public policy. Alan MCKINNON
[52] How to improve the Capture of urban goods movement data? Daniele Patier, Jean-Louis Routhier

A few research projects have produced other indicators of urban freight transport. A selection of these from projects carried out in France and the UK are shown below.

The project results highlighted that there is little common understanding or agreement about what constitutes an urban freight transport indicator. Also, it is not always clear whether an indicator is currently in use or is being suggested as a potentially useful indicator.

- Loading/unloading density
  - Number of deliveries and pick-ups per km2 in a zone
- Loading/unloading intensity per activity
  - Number of deliveries and pick-ups per activity in a zone
- Loading/unloading time
  - Number of hours of on street double parking for delivery or pick-up in a zone, per vehicle, per activity
- Ratio: Number of Loading/unloading
  - Number of deliveries and pick-ups per week per employee in an activity
- Length covered for Loading/unloading
  - Number of kilometres for one delivery or pick-up in a zone, per vehicle, per activity
- Average length of the first trip from platform to the delivery area
  - Km travelled
- Average distance travelled per collection/delivery
  - Kilometres per collection or delivery
- Total distance travelled on roads in urban area transporting goods by HGV, rigid lorries, and LGV (<3.5 t) used
  - Total vehicle km per week in urban areas
- Average time taken per delivery
  - Minutes per delivery
- Average speed per round (including and excluding stops to make deliveries)
  - Km per hour
- Greenhouse gas and pollution
  - g pollutant per km travelled
  - g CO_2 per km travelled
  - Litre of fuel per km according to the zone, the vehicle, the activity.

McKinnon[53] highlighted the importance of freight movement analysis for the economic development of a country or city, but he also noticed that political acknowledgement of its importance often does not extend as far as the statistics bureau. As a result, little or no data is collected to establish the nature and scale of the freight task and how it is changing.

He also evidenced that there are some developed countries with a long tradition of collecting freight data but whose statistical base is never complete. He expressed that no country collects all the freight data that policy-makers and their analysts require to model, let alone understand, the detailed workings of the freight transport system. With the advent of Big Data there will potentially be a step-change in the availability of freight data, allowing many of the existing gaps to be plugged and permitting the macro-level analysis of freight flows and operations at a higher degree of granularity. For many countries, the immediate objective is to collect enough freight data to answer four key public policy questions about freight transport:

1. How much freight is being moved?
2. Where is the freight going?
3. What is the relative use of different transport modes?
4. How efficiently is freight being transported?

The paper explains why these performance criteria are significant and discusses the indices commonly used to use to measure them.

Freight transport intensity	Ratio of freight tonne-kms to an economic output measure such as GDP. It is an important indicator of an economy's dependence on freight transport.
Freight modal split	Most countries that publish freight modal split data express it in terms of tonne-kilometres (often referred to, quietly misleadingly, as 'transport performance') and / or tonnes-lifted. Using the former measure gives rail and waterborne transport a higher share as these are essentially long-haul models whose comparative advantage over road increases with the length of haul. All weight-based measures of modal split are deficient, however, in the sense that they take no account of the average density of the products carried.
Market diversity	Some countries compile data on the numbers of registered trucking companies and their fleet sizes, permitting an analysis of the changing degree of market concentration. Depending on the nature of the licensing system, it can also be possible to differentiate companies operating vehicles on an own account

[53] Alan McKinnon. Performance measurement in freight transport: Its contribution to the design, implementation and monitoring of public policy. International Transport Forum 2015.

as opposed to hire-and-reward basis and to distinguish carriers engaging in domestic and/or cross border work. Such statistics, however, offer very limited insight into the structure and dynamics of this complex sector.

In a mature logistics market one would expect to find a range of services differentiated by two criteria, consignment weight and distance range. Additionally, third and fourth axes would include the range of logistics services offered and speed of delivery.

Operational efficiency

One of the key aspects to define operational efficiency relies on choosing the right metrics. Alan McKinnon focuses for that purpose on vehicle capacity and fuel used in the freight sector.

Vehicle Loading Efficiency can be measured in several different ways. For example, tonne-km per truck per annum is a productivity index that generally presents the haulage industry. In most countries it has risen notably in recent decades because trucks have increased in size, weight and power rating. Higher productivity does not necessarily mean, however, that the trucks and wagons are on average running any fuller than before. It is, therefore, needed a separate set of utilization metrics to show how much of the available carrying capacity in vehicles is actually being used.

Fuel Efficiency Fuel accounts for a large share of operating costs in the freight transport sector and is the source of virtually all freight-related emissions. The metric itself is a productivity measure showing the efficiency with which energy is converted into the movement of freight. This can either be done with respect to vehicle-km (fuel efficiency) or to a denominator that takes account of the weight or volume of goods transported (often called ‘energy intensity’).

Service quality

There is a substantial academic literature on the measurement of logistics service quality at a company level (e.g. Gunasekaran and Kobu 2007), but little discussion of the metrics that should be used at a national level to assess the quality of a freight transport system. Basic criteria are essentially the same at the micro- and macro-scales, comprising average transit time, reliability (i.e. variance around the average) and the condition of goods on arrival. Quantifying these variables at a national level is very difficult. This is partly because the speed and reliability for freight services varies enormously by mode, carrier, route, consignment size and commodity type making it very hard to calculate average

	values. Carriers are also naturally reluctant to divulge information about as sensitive a competitive variable as service quality.
Environmental impact	Much of the environmental impact of freight transport is associated with energy consumption. Carbon dioxide emissions are a direct function of the amount of fossil fuel burned. On the other hand, emissions of noxious gases per litre of fuel consumed vary with the quality of the fuel and the emission standard of the vehicle engine. As tightening standards are introduced on specific dates, knowing the age profile of the fleet provides a crude indication of its emission performance. This information is deficient in several respects: - It needs to be supplemented with data on the distances travelled / fuel consumed by trucks of varying age. - The emission performance of vehicles generally deteriorates with age and not at a constant rate. Distances travelled, driver behaviour and maintenance levels all shape the emission profile over time. - The impact of vehicle-related pollution varies with the environmental sensitivity of the area through which the freight is moved and is at its highest in urban areas.

Finally, **STRAIGHTSOL[54] project** included in D3.3. 'Description of indicators, KPIs and measurement methods', new assessment framework for the evaluation of measures applied to urban-interurban transport interfaces. The objective of this document is to describe indicators, key performance indicators (KPIs) and methods to measure the indicators. The selected KPIs were classified in 6 main groups: economy, environment, society, quality of service transport system characterization and safety and security.

ECONOMY

Costs per delivered item	Costs per delivered item are the average costs paid by the shipper for the transportation of a good or service unit.
Costs per received Item	Costs per received item are the average costs (directly or indirectly) paid by the receiver for the transportation of a good or service unit.
Operating benefits	Operating benefits are the operating revenues minus the operating costs. The average operating benefits can be expressed by

[54] http://www.straightsol.eu/

	dividing the operating benefits for example by vehicle-km or by units of goods/services delivered.
Return on investment	Return on investments is the ratio of money gained or lost on an investment relative to the amount of money invested.
Enforcement costs	Enforcement costs are the amount of money spent by the local authority to enforce other parties to comply with changes in the transport system.
ENVIRONMENT	
Air quality	Air quality is the healthiness and safety of the atmosphere, which can be described by the level of pollutants in the air. The main air pollutants considered are: Sulphur dioxide (SO2), Nitrogen dioxide (NO2) and Particulate matter (PM2.5 and PM10).
Carbon dioxide	Carbon dioxide (CO2) is the most significant greenhouse gas (as it contributes to about 80% of total EU greenhouse gas emissions) and is considered as one of the most important causes of climate change. CO2 enters the atmosphere through the burning of fossil fuels in transport and industries.
Actual noise level	Actual noise level is described as the outdoor sound level caused by human activities, including transport.
Noise perception	Noise perception is people's perception on the noise level caused by transport activities.
SOCIETY	
Shipper's attitude towards environmental impact	The degree to which the shipper of goods is concerned with the environmental impact of the activities required for the shipment of goods.
LSP's attitude towards environmental impact	The degree to which the logistic service provider is concerned with the environmental impact of their transport activities.
Receiver's attitude towards environmental impact	The degree to which the receiver of goods is concerned with the environmental impact of the activities required for the delivery of goods.
Employee satisfaction	Employee satisfaction is used to describe whether employees are happy and contented and fulfilling their desires and needs at work.
Attractiveness of	This indicator describes how people perceive their surrounding

urban environment	environment, in terms of visual attractiveness and physical nuisance.
Space occupancy	Space occupancy refers to the amount of space that is dedicated to logistic activities such as loading, unloading and handling.
Business climate	Business climate indicates how state, regional and local policies, relationships and local communities support business development.
Easiness of compliance	The easiness of compliance refers to the degree to which people easily act in accordance with the relevant authority and their requirements.
Acceptance level	Acceptance level is the degree to which people are satisfied with the existence and/or use of the measure.

QUALITY OF SERVICE

Punctuality of pick-ups	Punctuality of pick-ups is described as the degree to which pick-ups take place at the appointed time.
Punctuality of deliveries	Punctuality of deliveries is described as the degree to which deliveries take place at the appointed time.
Accuracy of pick-up	Accuracy of pick-up is described as the degree to which the pick-up includes the appointed quantity of goods in the correct form. This means that no errors or damages are encountered by the shipper.
Accuracy of delivery	Accuracy of delivery is described as the degree to which the deliveries include the appointed quantity of goods in the correct form. This means that no errors or damages are encountered by the receiver.
Supply chain visibility	Supply chain visibility is defined as the traceability of goods in transit from the sender to the receiver. This includes the availability of accurate and real time information.
Suitability of service	Suitability of service is described as the degree to which the customer favours the time and location of the transport activities, based on its own daily activities.

TRANSPORT SYSTEM CHARACTERIZATION

Average vehicle speed	Average vehicle speed is described by the distance (km) travelled in a certain time period (hour).
Accessibility perception	Accessibility refers to the ease of reaching goods, services, activities and destinations.

Network use	The use of a network is described by the actual and potential traffic flow of a network.
<u>SAFETY AND SECURITY</u>	
Crime	This indicator refers to the number of goods that get stolen or deliberately damaged while being carried or stored between shipper and receiver.
Security perception	Security perception is the feeling people have on the security of their goods while being carried or stored between shipper and receiver. The indicator focuses on the perceived and/or experienced likelihood of thefts.
Traffic safety	Traffic safety is described by the number of traffic accidents, injuries and deaths.
Safety perception	Safety perception is the feeling people have on their safety when they participate in traffic. The indicator focuses on the perceived likelihood of traffic accidents and injuries.

The main issue when defining proper indicators for urban logistics assessment is the quantification of this KPIs. Information and data required are often not available at an urban scale and several of the measured indicators are less efficient at an urban scale than at an interurban scale. In many cities, there is a lack on data collection to establish the nature and scale of the freight task and how it is changing.

A disagreement in the definition of metrics for KPIs can difficult the comparison along time and for different areas and/or cities. Accuracy in data collected is also a problem that affects KPIs calculation and its assessment along time.

Susanne Balm et al (2014)55 identified a series of challenges for the assessment of urban freight services, that highlight some problems for the calculation of associated KPIs:

- <u>Diversity of stakeholders and objectives:</u> Urban freight transport involves many stakeholders. Citizens, logistic service providers, sender of goods and local authorities play a role in urban freight transport. Considering the diversity of the stakeholders and their criteria, it is very difficult to take into account all the stakeholders simultaneously as they do not aim for the same objective. This makes evaluation complex. A solution can be successful for one stakeholder, while having negative effects for another. The criteria of stakeholders may also differ between cities. Some authorities are for example more concerned with air quality targets than others.

[55] Susanne Balma, Michael Browne, Jacques Leonardi, Hans Quaka, 2014. 'Developing an Evaluation Framework for Innovative Urban and Interurban Freight Transport Solutions'

- Costs and benefits dispersed and difficult to quantify: The costs and benefits of a new solution are scattered among the stakeholders. When a substantial amount of money is invested to develop and test a new solution then it is important that the benefits can be identified. In urban freight solutions, the ones investing are not inevitably the ones that are receiving the benefits; also benefits are not just increased revenues or profit: while the investments are relatively easy to quantify in monetary values, the benefits can be obtained in terms of attractiveness, reliability or traffic speed. The same applies to indirect and external costs.
- Lack of data: Evaluating a new solution is also difficult due to the lack of data. We do simply not have the technologies to measure everything in practice. Also, as evaluations often focus on a pilot test that is carried out on a small scale, some effects are hardly noticeable. Much data therefore has to be derived, modelled or simulated.
- Diversity of context: Next to the diversity of stakeholders, the urban areas where freight transport takes place are very diverse as well. No two cities are alike. They differ in terms of geographic characteristics, density, legislation, culture, etc.

3.2. Decision Support Systems (DSS)

The complexity of methods and models for the investigation of mobility and urban freight systems has pushed researchers to develop **Decision Support Systems (DSS)** for the analysis and simulation of the effects of city measures and external scenario changes, such as demographic and socio-economic characteristics or land-use. These systems provide support to decision-makers to understand and simulate the structure of urban systems and to compute indicators for target setting and benchmarking to identify level of service.

Decision Support Systems are computer technology solutions that can be used to support complex decision making and problem solving. Shim et al. (2002)[56] list de components of a classic DSS tool design as:

- Sophisticated database management capabilities with access to internal and external data information and knowledge.
- Powerful modelling functions accessed by a model management system.
- Powerful and simple user interface designs that enable interactive queries, reporting, and graphing functions.

The Decision Support Systems of transportation planners cover a wide perspective[57], ranging from traffic control centres, passenger movements, public transport management for the scheduling and routing of cargo, automated transport systems, etc.

[56] Shim, J.P., Warkentin, M., Courtney, J.F., Power, D.J., Sharda, R., Carlsson, C., 2002. Past, present and future decision support technology. Decision support systems.

The progress in web based DSS technologies, in recent decades has given individuals many opportunities to make their business environments and daily lives easier in ways that would have been unimaginable until recently. Decision support systems are fed by many algorithms from computer science. Shortest path algorithms are among the most important ones in solving transportation problems.

In the next paragraphs are presented some examples of transport related DSSs in used in different European cities.

1. **CLASS**[58],is a decision support system developed by the University of Rome for the analysis and simulation of urban freight systems. The analysis of current scenarios allows investigation of logistics and freight transport in relation to land use, freight restocking demand and supply, logistic profile and road network performances and impacts.

CLASS has been developed to satisfy the requirements of:

- City Logistics Managers that want to identify the main characteristics and the critical stages of the actual City Logistics System (CLS)
- Land Use planners that desire to assess and to compare demographic, socio-economic and land use scenarios for defining optimal spatial distribution and accessibility of urban freight facilities (e.g. shopping malls, warehouses, distribution centers) able to improve city sustainability.

CLASS is mainly devoted to the identification of critical stages and the simulation of shop restocking. Additional features were implemented in order to link shopping and restocking mobility, including a shopping model sub-system that allows to take into account shop restocking satisfying the demand of end consumers. CLASS implements new advanced demand models that capture the effects on actors' behaviour of city logistics measures, land use scenarios and demographic changes

[57] Ebru Vesile Ocalir-Akunal, 2016. Decision Support System in Transport Planning.
[58] Antonio Comia and Luca Rosatib, 2013. CLASS: a DSS for the analysis and the simulation of urban freight Systems.

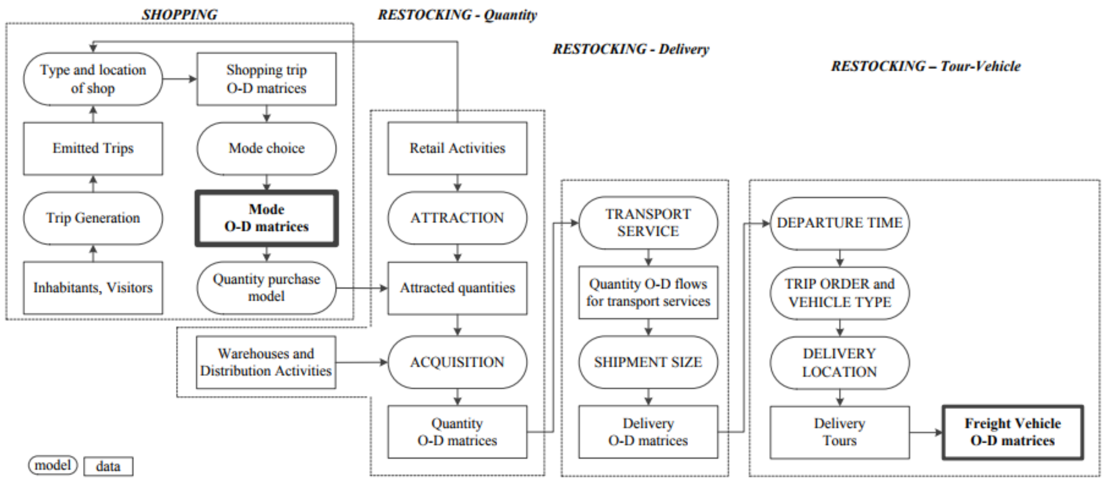


Figure 23. Urban freight modelling structure. *Antonio Comia and Luca Rosatib (2013) CLASS DSS.*

CLASS was used for the analysis and simulation of the current City Logistics System (CLS) of the inner area of Rome and for assessing the effects of freight activity location strategies upon transport costs in the medium-size urban area of Padua in northern Italy:

City logistics analysis and simulation

The analysis highlighted freight movements in the study area of Rome amounting to about 15,000 tons/day. To analyze the system, the area of the municipality of Rome was divided into 99 traffic zones with a level of detail which increases as the inner area was approached. The inner area consisted of 16 traffic zones.

The output indicators are separately described for land-use, demand, transport supply, logistic profile and road network performances. An analytic study of land use, freight demand and supply indicators have allowed CLASS to define for each zone the logistic profile zones according to classification proposed by Macario et al. (2008).

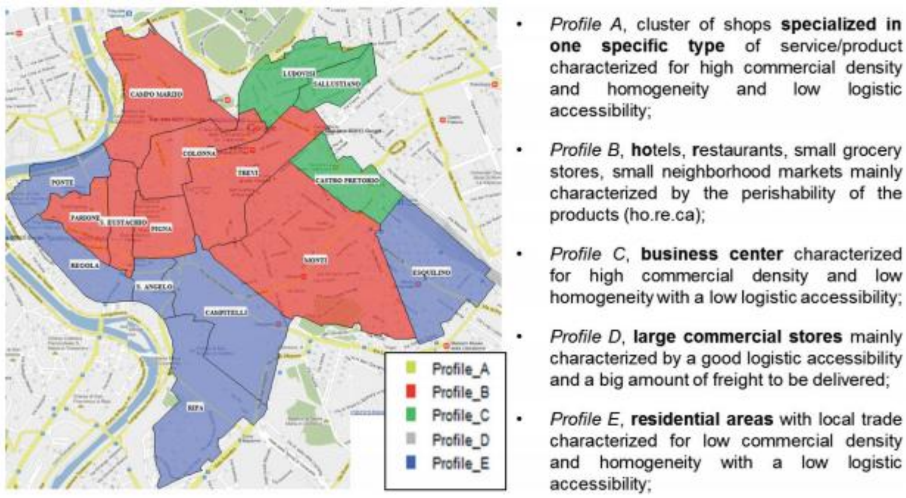


Figure 24. Logistic profile examples for the inner area of Rome*. Antonio Comia and Luca Rosatib (2013) CLASS DSS.*

- Location of warehouse and retail facilities in a medium-size urban area

The study developed shows the application of CLASS to a medium-size urban area of Padua for assessing freight facility location effects. The assessment was performed comparing three different land use scenarios. The definition of scenarios to be assessed were considered of the long-term results of some different land-use governance measures that local administrators could promote in order to improve the sustainability of the city.

The focus here is on the application of a joint modelling framework to an urban transportation networks when actions that can also change end consumers' shopping behaviors occur. Each scenario was defined hypothesizing shifting of both retail and warehouses employees among the three identified urban spaces:

- Central area (CA): Density of end consumers and small retailers is usually higher
- First ring (FR): Medium end-consumer density and the presence of warehouses
- Second ring (SR): End-consumer density is low and large shopping malls and freight distribution facilities are located.

The scenario definition was in terms of percentages of retail and freight employees with respect to their total number and initial scenario.

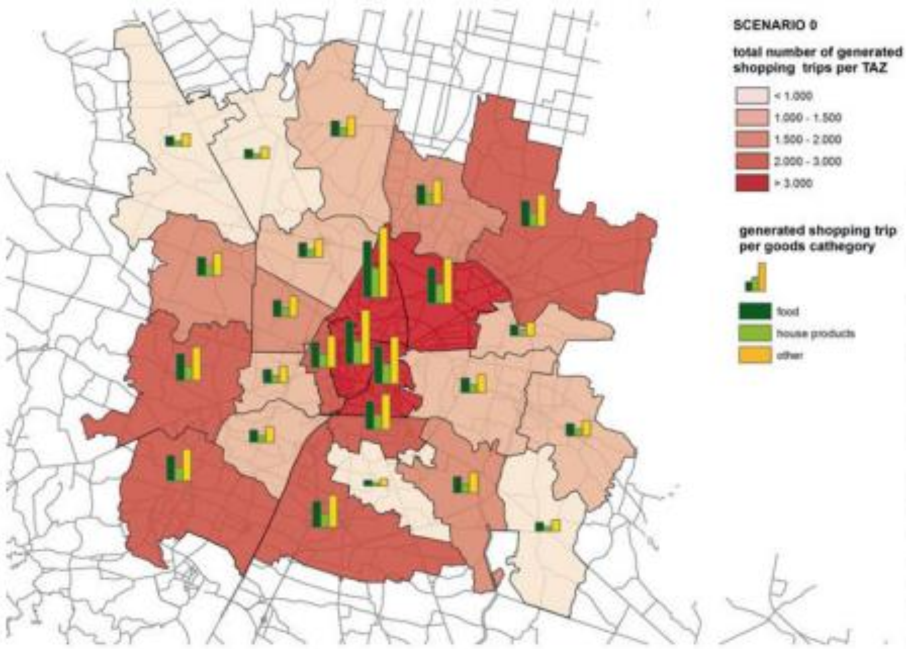


Figure 25. Shopping trip production according to freight type. *Antonio Comia and Luca Rosatib (2013) CLASS DSS.*

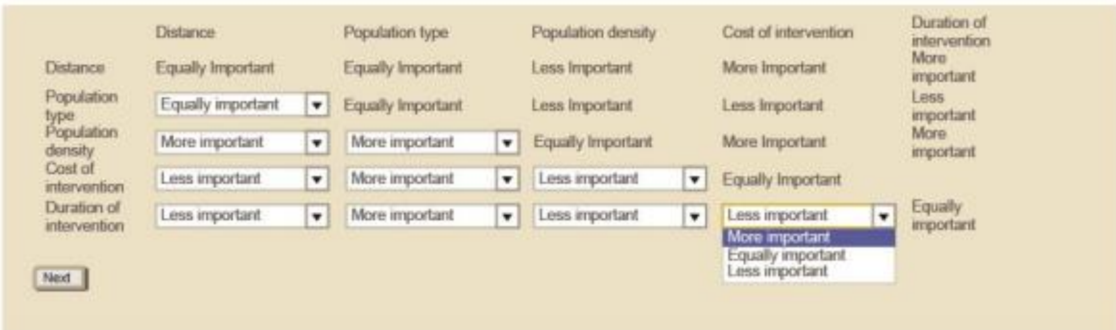
2. A new example of a **DSS** was developed in Romania for **improving pedestrian accessibility in neighbourhoods**[59]. The aim of this system was to address current planning obligations required by European legislation by aiding urban administrations to solve neighbourhood-scale problems through an objective approach.

The proposed decision support system allows the decision maker to choose the best alternative out of a set of possible interventions, based on a group of custom-defined criteria. Knowing that neighbourhood conditions may vary from one case to another, the system can be adapted to any situation.

The DSS was developed in a way that first of all, the user needs to enter the number of criteria and specify the name of each criterion. Then a quadratic matrix is generated and the user has to compare each criterion against the others, choosing whether each criterion is more important, equally important or less important than other criteria.

Then, the user is asked to enter the number of decision alternatives, to define/name them and then to compare each alternative against the others based on how they satisfy each criterion.

The software then uses the encoded mathematical algorithm and returns the optimal solution. This allows the urban planner to make an informed decision, based on the specific needs of the community and the particularities of the neighbourhood, rather than intuition.



[59] Valentin Grecua, Tudor Morarb (2013). A Decision Support System for Improving Pedestrian Accessibility in Neighborhoods.

Results:

Alternative:	Rank
Local food shop	2
Quarter green	4.5
Public space	1
School	3.5
Playground	4

Figure 26. Example of DSS use: Matrix of criteria, matrix of alternatives and results of the DSS. *Valentin Grecua, Tudor Morarb (2013)*

3. Another example of a Decision Support System is the **System Aid for Exploitation (SAE)**[60] used by some bus operators, such as EMT Madrid**.** It is a system that using the continuous, instantaneous and automatic location of a bus network, allows its control, regulation and exploitation. SAE provides the means to know and manage in real time the operation of available resources. Data collected and processed serves to inform customers, operators and public transport managers.

The SAE application gathers all the information provided from the different on-board systems available on the buses and manages the data of the vehicle fleet for better regulation and planning of the transport service.

The SAE software has a precise time prediction system that feeds back to the GPS positions of the vehicles and tunes with the data in each path. An intelligent system that allows the real-time tracking of the route and determines the on-route position of each vehicle, so that the information provided to the user in the boarding and stopping panels is accurate and useful.

The basic operation of SAE is based on four fundamental processes: localization, communication, regulation and information, which are produced in real time.

[60] https://ecomovilidad.net/madrid/como-funciona-sae-emt-madrid/

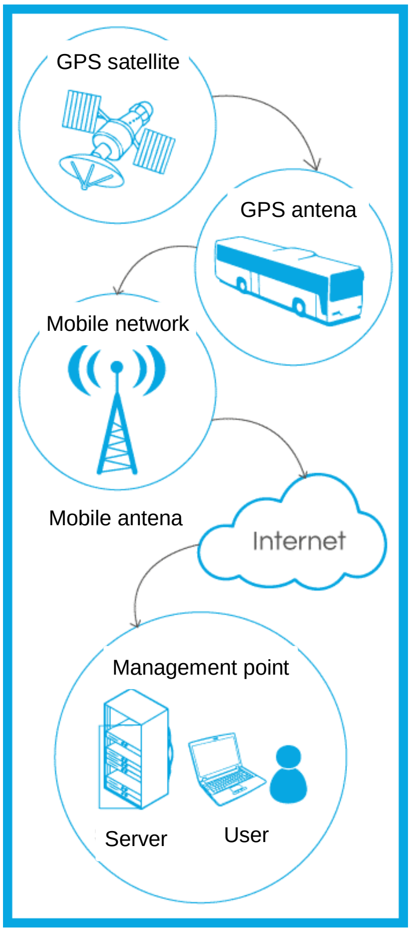


Figure 27. SAE working scheme. *Ingenia.*

In conclusion, DSS provide support to decision-makers for better understanding the structure of urban systems, building the decision process on the simulation of the effect of a measure basing in on the data available. DSS should overcome a series of gaps and drawbacks, such as: the information overload; the perception of transference to responsibility to a software program or the unanticipated effects of a measure application, although supporting data were used.

3.3. Open data and Big Data

According to Auer et al.'s (2007) [61] definition, **Open data** concept refers to the idea that some data should be freely available to everyone to use and republish as they wish, without restrictions from copyright, patents or other mechanisms of control. By making better use of data, urban traffic and transport can be improved and made more efficient and sustainable,

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[61] *Auer, S. R.; Bizer, C.; Kobilarov, G.; Lehmann, J.; Cyganiak, R.; Ives, Z. (2007). "DBpedia: A Nucleus for a Web of Open Data". The Semantic Web. Lecture Notes in Computer Science.* ***4825****. p. 722. ISBN 978-3-540-76297-3*

and cities can become more liveable and attractive. There is evidence from different countries showing that the provision of open data delivers benefits: t

- travellers and users by improving their journey experience and saving them time,
- transport organizations and authorities by enabling them to operate more efficiently while demonstrating openness and transparency to those who fund them.

An important open data source in Europe is the **European Data Portal**[62] which harvests the metadata of Public Sector Information available on public data portals across European countries. Information regarding the provision of data and the benefits of re-using data is also included.

European data portal provides many tools and APPs[63] that have been developed to encourage cities and (public transport) companies to open their data on real time traffic situations. APPs are classified attending: country, region, sector and use case. In the next paragraphs are included those concerning 'transport' sector:

Pedestrian:

Be Walking Be.Brussels	Belgium	Allows users to plan their own (walking) trail, and to navigate through Brussels. It also highlights points of interest.
BlindSquare	Finland	Helps visually impaired people navigate to a given location by alerting users to obstacles in their environment.

Bike:

Bike citizens	Austria	Less time waste by taking the best route to a favoured destination by bike. Stimulating bike use by favouring quiet roads and bike paths.
CityBike	Austria	Tells you how many bicycles are available at a specific CityBike station.
I Bike CPH	Denmark	Helps you to find your way on bicycle in Copenhagen. The app knows all the bicycle shortcuts, where you are allowed to bike, bicycle barriers and cobblestones.
Kiss my bike	Italy	The core service provided by the system is theft detection and tracking of bicycle location.
Bicycle counter	Poland	The city of Gdansk has installed a number of monitors which count and display the number of bicyclists passing by. By

[62] European Data Portal. Web: https://www.europeandataportal.eu/
[63] Open data apps. Web: https://www.europeandataportal.eu/es/using-data/use-cases?title=&body_value=&field_country_value=All&field_region_value=All&field_sector_value=Transport&field_type_of_use_case_value=All

		visually showing the number of bicyclists the project is part of a bicycle promotion campaign.
<u>Car:</u>		
Carambla	Belgium	Connects professional, public and private suppliers of parking spaces to drivers. Guides drivers to the nearest and cheapest parking in Belgium.
FSTR	Belgium	Offers an application bringing together travellers with the same destination to facilitate carpooling.
Never Run	Czech Rep.	Live transport map, showing the position of transport vehicles around you. Reduction of travel time for everybody who commutes daily in Prague.
Århus P-huse	Denmark	Shows the availability of parking spaces in parking houses in the centre of Aarhus
AutoUncle	Denmark	Second hand car market place in which each car offered is valued on the base of up to 100 indicators to determine its market price.
Bobby	France	Automates actions users do repeatedly during their daily commute, whether by car or by public transport. It streamlines the journey of users, making it safer and more time-efficient.
ParkingDD	Germany	Shows users the current parking situation in different European cities. Depending on the data, you will receive the current number of free public parking spaces and their locations
Umweltzone	Germany	Allows users to find out about the location of a low emission zone on their Android phone. Access for cars is restricted in these zones, depending on the cars' emission profile.
Smart Parking Systems	Italy	Guides users to the nearest available parking place and provides a direct payment channel for the found place. This saves both the driver in looking for a place and having to stop at a payment terminal.
GoOV	Netherlands	Provides the traveller with travel instructions at the right time, signals travel abnormalities and recommends alternative travel routes.
Bomstasjon.no	Norway	Provides an overview of all toll stations in Norway, allowing users to easily identify where they have to pay.
Ladeklar!	Norway	Provides information about charging stations for electric cars in Norway.

Wild!	Netherlands	Reduce individual travel times. Decrease traffic jams. Reduction of CO2 emissions by having less cars on the road.
Warszawski Ninja	Poland	Allows users to share all transport-related problems in real-time allowing them to make informed commute decisions.
Talkycar	Spain	Connects your vehicle with your smartphone to track all your trips scoring your driving style to detect fuel efficiency, providing advices or calling medical services in case of accidents. It also remembers you where you parked your car.
<u>Public Transport:</u>		
Urbonaut.at	Austria	Provides real-time information about the public transport in Vienna.
iRail	Belgium	Less time waste by allowing users to identify most efficient itinerary through Belgian railway stations. Less car use by stimulating public transport in combination with other types of transportation.
Cyprus by bus	Cyprus	Provides information about public transport buses, bus routes and bus time tables in Cyprus.
Tuup	Finland	Developed a fully fledged Mobility as a Service (MaaS) app with which users can plan and pay for all everyday trips beforehand or while they are on the move.
RailZ	France	Provides users with all the information (delays, cancellations, comfort on board) concerning the journey with TER (suburban trains) in real time.
Tranquilien	France	Improves quality and passenger comfort of public transport. The app promotes the efficient use of public transport. Stimulates streamlining public transport flows.
Ally	Germany	Stimulating public transport use in an efficient way. This reduces road congestion. People travelling efficiently, increasing revenue for businesses.
Busskart.no	Norway	Allows user to see where the bus they are waiting for is and when it will arrive at their stop.
Sanntidskart for bussar	Norway	Provides real-time information on bus positions, delays, etc.
Ifinity	Poland	Creates a digital grid, an additional layer of the city made of data. It is visible to the blind and it can be heard by the deaf. They provide means of navigation for citizens whose vision or hearing is impaired.

Hoje há Greve?	Portugal	Avoids waiting time by checking the occurrence of strikes before you travel.
Romanian Railways	Romania	Contains information on railway stations and timetables.
Res I Sthlm	Sweden	Less time waste by allowing users to identify most efficient routes by public transport in Stockholm. Less car use by stimulating public transport.
Swiss Transit	Swizerland	Travel companion for your trip in Switzerland, allowing users to search for instance about stations, departure times, etc. For different types of vehicles: trains, trams, buses, cablecars, boats, etc.
Delay explorer	UK	Inform individuals about the reliability of trains. Limit the time wasted by delays and cancellations.
<u>Various means of transport:</u>		
Moovel	Austria	Provides you with easy and intuitive access to all the information you need to quickly and effectively find your way through Vienna.
Moovit	Europe	Analyses mobility data in real time, providing updated information of the traffic that affect the various means of transport. Access to detailed and up-to-date information on the alternatives proposed for the optimum operation of public transport in cities and towns mainly affected by these diversions.
Open Transport Net	Europe	By aggregating, harmonising and visualising data, Open Transport Net makes it easier for innovators to develop new applications.
LeTrajetLe PlusSur.fr	France	Free traffic prevention platform based on open government data. With this data, the platform generates and compares in two clicks two routes: the fastest route (proposed by GPS) and the safest route (statistically considered least dangerous).
Wheelmap.org	Germany	Provides a map for finding wheelchair accessible places. All users are encouraged to contribute to the map by marking places around the world according to their wheelchair accessibility
Envirocar	Germany	Help to have public discussions about current traffic situations. Indicate needs for improvements in current traffic situations. The general impact of the individual driving behaviour.

Citius	Greece	Crowdsourcing solution for building smart transportation services without investing in large sensor networks. Cities can better support urban design decisions
MapReplace	Norway	Better local maps of Norway.
Trafikkflyt	Norway	Better flow of traffic, as the application indicates the traffic density and the location of events
Transport API	UK	One single comprehensive source of UK transport information. Data is free to use and copyright free.
Travel smarter	UK	Provides transport alternatives for routes that are entered, based on real-time information on the status of the transport system. Better use of transport networks, by balancing loads, reducing congestion, pollution and accidents.
<u>Freight transport:</u>		
Transmetrics	Bulgaria	Provides cargo companies with an accurate demand forecast and network optimisation based on Big Data and predictive analytics. This limits the empty space within cargo vehicles
PTV Group	Germany	Allows customers who are transporting goods to plan and optimise their transportation routes, trips and distribution structures.

The acceleration in both the growth and velocity of exploitable and often open data will trigger significant and disruptive change across a number of sectors, including transport. Compelling cases have been made for the value of Big Data analytics for urban planning (via the convergence of high definition geographic data with information regarding the observed or interpreted use of urban space by citizens), intelligent transport (via visualisation and analysis of the real-time usage of transport networks) and safety (via the processing of real-time data regarding vehicle operation and the surrounding environment to avoid or minimise potentially dangerous conflicts).[64]

In this line, the term ‘Big data’ is appearing most and most often. There are many definitions for Big data concept. Among the most widely-quoted, McKinsey define Big data as “datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyse”. According to Mayer-Schönberger and Cukier’s[65] Big Data can be defined as “the ability of society to harness information in novel ways to produce useful insights or goods and services of significant value”.

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[64] International Transport Forum (2015). Big Data and Transport Understanding and assessing options.

[65] Viktor Mayer-Schonberger and Kenneth Cukier (2013). “Big Data: A Revolution That Will Transform How We Live, Work and Think”

As mentions the study developed by International Transport Forum on 'Big Data and Transport'[66], compelling cases have been developed for the value of Big Data analytics for ;

- urban planning (via the convergence of high definition geographic data with information regarding the observed or interpreted use of urban space by citizens),
- intelligent transport (via visualisation and analysis of the real-time usage of transport networks)
- safety (via the processing of real-time data regarding vehicle operation and the surrounding environment to avoid or minimise potentially dangerous conflicts).

The collection and exploitation of large data sets is not new and is not linked to a single technological change. Rather, what has occurred is the confluence of new data collection mechanisms based on ubiquitous digital devices, greatly enhanced storage capacity and computing power as well as enhanced sensing and communication technologies. These technologies enable near real-time use and transmission of massive amounts of data. Some of these data streams are purpose-built to address well-defined questions and to resolve specific tasks. Big Data is seen as both an opportunity and a challenge. This is especially true for the management and governance of transport-related data.

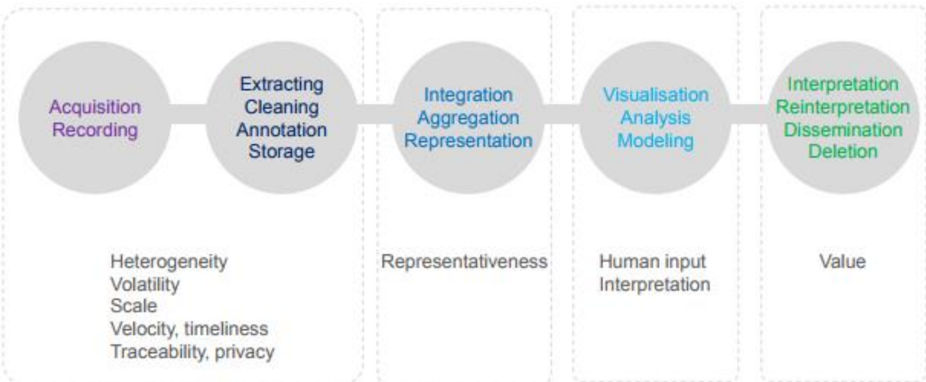

Figure 28. Big Data Life Cycle. *International Transport Forum.*

As an example of how Big Data is useful for mobility data analysis and management, the **TransformingTransport**[67] project (started in 2017) aims to demonstrate, in a realistic, measurable, and replicable way the transformations that Big Data will bring to the mobility and logistics market. To this end, TransformingTransport, validates the technical and economic viability of Big Data to reshape transport processes and services to significantly increase operational efficiency, deliver improved customer experience, and foster new

[66] International Transport Forum (2015) Big Data and Transport. https://www.itf-oecd.org/sites/default/files/docs/15cpb_bigdata_0.pdf

[67] TransformingTransport. Web: https://transformingtransport.eu/

business models. TransformingTransport will address seven pilot domains of major importance for the mobility and logistics sector in Europe:

- Smart High-ways
- Sustainable Vehicle Fleets
- Proactive Rail Infrastructures
- Ports as Intelligent Logistics Hubs
- Efficient Air Transport
- Multi-modal Urban Mobility
- Dynamic Supply Chains

The Transforming Transport consortium combines knowledge and solutions of major European ICT and Big Data technology providers together with the competence and experience of key European industry players in the mobility and logistics domain.

Although this project didn’t show results yet (it started in 2017), it could be considered as a potential source of transport information and offer a set of methodologies to better deal with huge amount of data coming from Open Data sources.

3.4. Review on CIVITAS Urban Mobility Tool Inventory for data gathering, analysis and measures selection

CIVITAS includes in its webpage a tools repository, which offers the possibility of accessing a wide range of guidance materials, software, mobile apps, approaches, and other tools for sustainable urban mobility practitioners.

This Tool Inventory includes both, data gathering tools, but also is focused on some analysing strategies and helping decision making processes. This repository review has been included as part of chapter 3, but it considers a useful review for both, chapters 2 and 3.

CIVITAS tool inventory offers the possibility of filtering initiatives/tools, taking into account some factors such as Application Area, Tool Type or Target Audience. For this analysis, only those tools for *‘Medium-sized cities’* and useful for *‘Data gathering’* or *‘Analysis, scenarios and measure selection’* have been chosen.

For a proper analysis of the provided information, the tool repository has been sub-classified according to the main purpose of the initiatives and/or addressed means of transport. This sub-classification contains 6 main groups:

- Evaluation of cities performance (methodologies for assessment and comparison)
- General traffic data gathering and management tools
- Active modes data gathering and analysis
- Crowdsourcing methods
- Urban freight specific tools

- Public transport data gathering strategies

As main conclusions of the information analysed, it is remarkable the high number of new initiatives and tools for active modes of transport data collection and analysis, but also for general traffic data gathering and management tools. Most of the identified tools focus on guidelines and strategies for improved measures selection and implementation. Regarding data collection tools, they pay special attention to those initiatives getting information directly from users (smartphones, gamification apps, GPS devices, crowdsourcing platforms, etc.). However, specific approaches for freight traffic identification and classification are still missing. In the next paragraphs is included the previously mentioned classification with a short description of the main tools included on each sub-section.

3.4.1. Evaluation of cities performance (methodologies for assessment and comparison)

ADVANCE Systematic evaluation method and guidance, for improving Sustainable Urban Mobility Plans (SUMPs) in cities and municipalities.
http://eu-advance.eu/

AMITRAN Assessment methodology, which provides a framework for evaluating the effects of Information & Communication Technologies (ICT) applications for transport in terms of CO_2 emissions.
http://www.amitran.eu/

KONSULT Guidance tool to understand the challenges of achieving sustainability in urban transport and to identify appropriate policy measures and packages.
http://www.konsult.leeds.ac.uk/

NODES Toolbox to allow practitioners to assess and benchmark their new or upgraded interchange (multi-modal mobility hubs) and to improve its performance.
https://nodes-toolbox.eu/

3.4.2. General traffic data gathering and management tools

EMPOWER ICT-TOOLS Tools for measuring mobility behaviour via manual or automatic sensing. They provide challenges and rewards to users, create communities and are an important tool for communicating with the user, two ways.
https://empowertoolkit.eu/
http://mobility-apps.eu/

MAPTITUDE	Geographic Information System (GIS) based tools, maps and demographic data necessary to analyse and understand how geography affects an area. http://www.caliper.com/Maptitude/MappingSoftware.htm
UCL STREET MOBILITY TOOLKIT	Methods to help local governments and local communities assess and value the costs of "community severance". http://www.ucl.ac.uk/street-mobility/toolkit
VOLTIA	Easy-to-use responsive website that recommends suitable electric vehicle models for your (or your company) driving profile and performance requirements. https://voltia.com/en
VISSIM	Microscopic multi-modal traffic flow simulation tool. http://www.ptvgroup.com/en/solutions/products/ptv-vissim/
VISUM	Software package for traffic analyses, forecasts and GIS-based data management on city, regional or national levels. http://www.ptvgroup.com/en/solutions/products/ptv-visum/
WHIM	MaaS-service for consumers combining all modes of transportation. http://whimapp.com/fi-en/

3.4.3. Active modes data gathering and analysis

BIKE BENEFIT	Tool to motivate people to travel by bicycle. It gathers data from bike users by rewarding them on using this transport. https://www.bikecitizens.net/
BIKE CITIZENS APP	Mobile apps and web-tools based on GPS bicycle tracking. https://www.bikecitizens.net/
BIKE CITIZENS ANALYTICS	Tool to visualise data and in the form of "heat maps", allowing in-depth insight into GPS cycling data, analysis, scenario building and evaluation of cycling infrastructure projects. https://www.bikecitizens.net/
BYPAD	Guidance tool for the evaluation of bike systems and policies. http://bypad.org/
FLOW	Guidelines on congestion impact assessment tool for walking and cycling. http://h2020-flow.eu/resources/publications/
GUIDELINES FOR THE PLANNING OF URBAN CYCLE	Guidelines for the planning and design of fast cycling routes in cities and agglomerations. http://kontextplan.ch/assets/Uploads/Forschungsbericht-VSR-

HIGHWAYS	170330.pdf
MIOVISION	Camera and video analysis tool for bike counting. https://miovision.com/
NAVIKI	Bicycle route finding and navigation programme / app. https://www.naviki.org/es/naviki/
PING	Users tool to detect and report incidents when cycling. http://pingifyoucare.brussels/nl/startseite/
RINGSTRASSE150	Mobile phone game and website encouraging users to get involved in supporting improved bicycle facilities in Vienna. http://ringstrasse150.com/
TATOO	Tracking for planning tool, which takes cycling or walking GPS data and produces relevant information for planners and decision makers. http://h2020-trace.eu/trace-tools/tatoo-tracking-for-planning-tool/
VISWALK	Microscopic pedestrian traffic simulation tool. http://vision-traffic.ptvgroup.com/en-us/products/ptv-viswalk/

3.4.4. Crowdsourcing methods

CIPTEC	New innovative measures and ideas on sustainable transport coming from citizens. http://crowdsourcing.ciptec.eu/
CROWDSOURCED-TRANSPORT	Website proving information about the use of social media, serious games and crowdsourcing applications to improve participation in the planning and operations of sustainable transport modes. http://crowdsourced-transport.com/
DIALOGZENTRALE	Citizen participation tool used for single-process use, multiple-phase participation processes as well as the realisation of different participation processes parallel to each other. http://www.streifentechnik.de/#products/%23products/dialogzentrale
NEXTSEVENTEEN	Crowdsourcing tool for geo-referenced postings. It is used for open bottom-up collection of ideas / problems / proposals. http://www.urbanista.de/nextseventeen/

3.4.5. Urban freight specific tools

CITY LOGISTICS LIVING LAB HANDBOOK	Guidance document to set up, implement and evaluate a city logistics living lab. http://www.citylab-project.eu/deliverables/D3_1.pdf
FRETURB	Software application for decision-making. It allows simulation of urban freight transport. http://freturb.laet.science/
NOVELOG TOOLKIT	Decision support tool aiming to assist cities in selecting the most appropriate city logistics measure for implementation in each specific case. http://www.uct.imet.gr/Toolkit
SMART CITY LOGISTICS PLATFORM	Wide range of easy-to-understand information to support the development of urban freight transportation plans. http://iguess-sl.list.lu/

3.4.6. Public transport data gathering strategies

BUSMEISTER	Serious game, wiki, reporting tool and information about public transport operations. http://crowdsourced-transport.com/our-projects/busmeister-project/

In conclusion, many tools presented in CIVITAS repository are focused on active modes of transport (walking and cycling) and also focused on ICT tools for better data gathering and management.

Urban freight specific tools focus on how better manage transportation systems and how to integrate logistics flows in the urban planning. There is still a gap regarding specific strategies on data collection for this kind of services.

Although ‘tool’ is usually associated to a ‘technological instrument’, some documents such as guidelines for mobility assessment in European cities are also included as tools available for Local Authorities and research bodies.

3.5. Conclusions

Being able to capture as much data as possible does not guarantee that the information will be valuable, accurate and useful. Data analysis methods allow local authorities to interpret data gathered in order to assess the current situation, support decision making and evaluate future effects of these measures.

Data analysis can offer the following benefits:

- Structuring the findings
- Break a macro picture into a micro one
- Acquiring meaningful insights from the dataset
- Basing critical decisions from the findings

One of the problems in collecting massive amounts of data (as it occurs with open data platforms) is that on its own it has no real value. It requires a pre-treatment to enable selection and pre-filtering of useful data. In addition, data collected does not follow the same pattern in every place or along time (e.g. data are not collected in the same way, frequency, amount, etc.), which difficult the analysis process and comparison.

KPIs are crucial for the assessment of current situation of urban mobility, but even more to be able to compare evolution over time (e.g. when introducing some measures). SUMPs elaboration guidelines put special emphasis on the importance of selecting adequate KPIs on urban mobility.

Many research and projects agree on classifying passengers KPIs in 6 main groups:

- Transport efficiency
- Safety and security
- Environment
- Accessibility
- Land use
- Quality

According to WBCSD[68], sustainable mobility indicators come within the complex system of mobility in cities. This system is characterized by its travel, transport and traffic patterns. It is shaped to provide supply corresponding to demand with the best mobility performance possible, using the least amount of resources, and provoking the least negative impacts possible. Taking this into account, indicators need to be related to the different components of the mobility system. The resulting scheme is useful for cities when looking for a broad scope of possible solutions and measures; when possible, interrelations between parameters must be identified.

Concerning freight transport KPIs, they can mainly be classified attending to:

- Efficiency
- Freight modal split
- Service quality

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[68] World Business Council for Sustainable Development Sustainable Mobility Project 2.0 (SMP2.0)

- Environmental impact
- Economy
- Quality of service

One of the gaps on KPIs definition and calculation is the necessity of data available for its quantification. A disagreement in the definition of metrics for KPIs can difficult the comparison along time and for different areas and/or cities. Accuracy in data collected is also a problem that affects KPIs calculation and its assessment along time.

Finally, the diversity in the cities context also influence the definition and establishment of KPIs to assess mobility in urban areas. Cities differ in terms of geographic characteristics, density, legislation, culture, etc., which affects to the performance of mobility services and which should be, in some term, considered.

On the other hand, Decision Support Systems (DSS) provide support to decision-makers for better understanding the structure of urban systems, through the analysis and simulation of the effects of city measures, giving them some tools to objectively decide. Nevertheless, the use of DSS also entails a series of potential problems that it is necessary to overcome. According to Power (2014)[69], Decision Support Systems present some limitations:

- Overemphasize decision making: Implementing DSS may strengthen the rational perspective and overemphasize decision processes and decision making. It is important to teach managers about the broader context of decision making and the social, political and emotional factors that impact organizational success.
- Unanticipated effects: Implementing decision support technologies may have unexpected consequences. It has been confirmed, for example, that some DSS reduce the ability needed to perform a decision task.
- Transfer of power and obscuring responsibility: Building DSS may be perceived as transferring decision authority to a software program. In addition, some people may deflect personal responsibility to a DSS. Managers need to be continually reminded that the computerized decision support system is an intermediary between the people who built the system and the people who use the system. The entire responsibility associated with making a decision using a DSS resides with people who built and use the system.
- False belief in objectivity: Computer software can encourage more rational action, but managers can also use decision support technologies to rationalize their actions.
- Status reduction: Some managers traditionally perceived DSS as ‘competitors’, diminish their status and force them to do clerical work. This perception may or should be less common now that computer usage is common and accepted in organizations.

[69] What are the advantages and disadvantages of computerized decision support? Daniel J. Power (2014) http://dssresources.com/faq/index.php?action=artikel&id=130

- Information overload: Too much information is a major problem for people and DSS contribute in some measure to increase the information load. However, DSS also help managers organize and use information. DSS developers need to try to measure the information load created by the system and DSS users need to monitor their perceptions of how much information they are receiving.

Finally, regarding the CIVITAS tool repository, it is remarkable that most of tools presented refer to passengers' data gathering and analysis and they specially emphasize the importance of active modes of transport, by providing specific tools for managing and gathering data from them. On the other hand, numerous tools included in the repository are related to macro- and micro- simulation tools which helps to show the effects of proposed interventions before they are implemented in the real world. Additionally, most of tools included in the CIVITAS inventory are based on ICTs and many of them use as a basis smartphones or other personal devices.

4. Requirements and needs for traffic data from urban planners

Data traffic is different in every city and every country has different needs and approaches to this matter. Urban planners from the cities who participate in the project have been questioned about their gaps and needs regarding passenger and freight urban data collection in WP2 surveys.

Questionnaires were completed between January and April 2017 by a minimum of two representatives for each city (Change Agent[70] and Site Evaluation Assistant[71]). The profile of respondents are mainly technical experts working for the city administrations or associated bodies.

Cities analysed cover different European areas (north, south, east and western regions) with different traffic characteristics (concentrated population vs metropolitan areas, static vs dynamic population, etc.). Moreover, different cities in SUITS project have different levels of availability and implementation of mobility plans. Next map shows the position, population and level of SUMPs development for each of the cities analysed.

[70] CHANGE AGENT is someone who live and work in your city and who is, in some way, responsible for governance and/or administration at some level (i.e. local authorities, stakeholder organisations, citizen's groups...). This person will be in charge of evaluate and accompany the city cultural change, changes in work practices and the development of tools to better understand and integrate mobility data, in close collaboration with SUITS team. Please insert CHANGE AGENT contacts in the following spaces (name, email, phone number, your role in the organisation).

[71] SITE EVALUATION ASSISTANT will be a representative of each city that will form part of the Evaluation Team, which will meet at each consortium meeting. The main task is to evaluate changes in attitudes, work practices, openness to change, uptake of tools and resources as well as enhancement of capacities of the cities to successfully plan and implement sustainable urban mobility measures. Please insert SITE EVALUATION ASSISTANT contacts in the following spaces (name, email, phone number, your role in the organisation).

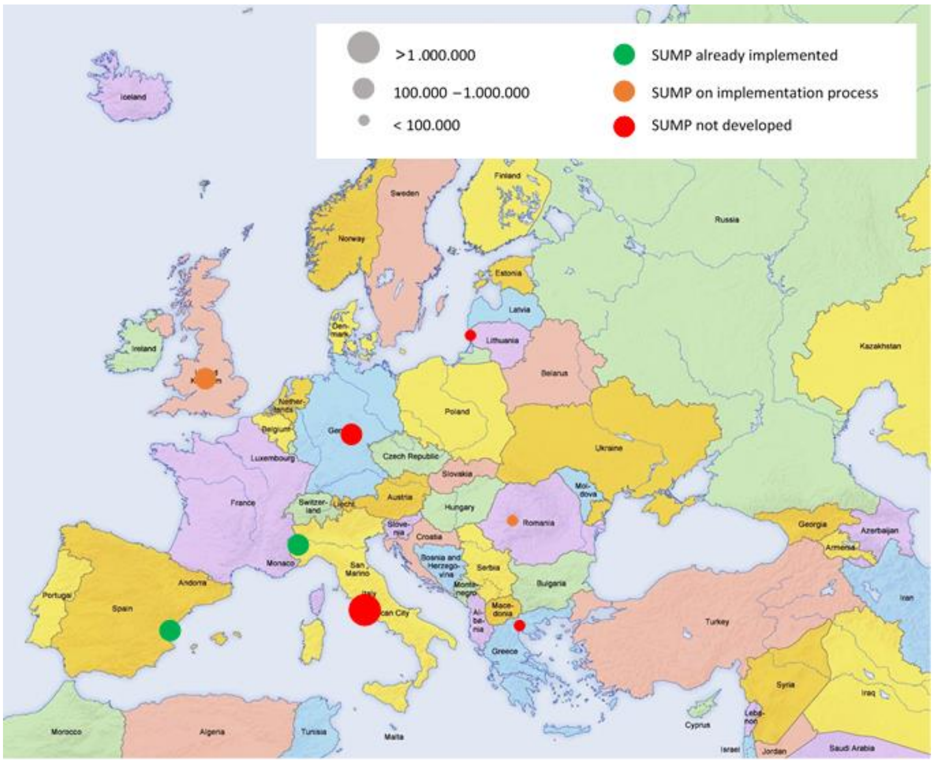

Figure 29. Characterization of cities completing T2.1. survey. *Own development.*

4.1. Gaps on data available in 7 SUITS' cities

As set before, the cities analysed cover different areas of Europe (from North -Coventry or Palanga- to south -Valencia, Rome or Thessaloniki-). This territorial expansion confers them also different climatic and cultural characteristics, which sometimes influence transport schemes.

Additionally, cities analysed have different demographic characteristic, with different extension and population. In both extremes, Rome is a city, with an ancient city-centre which have a population reaching 3,000,000 inhabitants and an extension of 1,200 km2. However, Palanga is a small city of 18,000 inhabitants and 79 km2, which quadruples its population in peak season. This situation affects notably to the mobility management and the special necessities of each specific city.

SUITS focuses mainly in small and medium-sized cities, recognising that smaller local authorities, citizens and stakeholders have shortfalls in capacity which limit the extent to which they can act as 'equal partners', placing them at a significant disadvantage in challenging, leading, promoting or implementing new sustainable transport measures[72]5, to the detriment of the social and economic well-being of their cities. This capacity gap is not

[72] http://www.bestufs.net/download/BESTUFS_II/key_issuesII/BESTUFS_RecommendationsII.pdf

recognised in technology oriented projects, which may inadvertently result in further widening existing gaps in knowledge and capacity.

4.1.1. Alba Iulia (Romania)

Alba Iulia Municipality has recently (2016) developed its SUMP which is nowadays under implementation[73] with the main aim of increasing public transport usage and also to improve the walking and cycling environment.

After the collection of data for the SUMP development, Alba Iulia municipality still requires more information related to pedestrian and bike mobility in the city (modal share for public transport and actives modes). They also found a gap on the traffic coming to the city from other areas, regions or countries (for passengers and freight vehicles) and the time spent in Alba Iulia.

Additionally, regarding private transport modes, they missed some information regarding the time distribution of traffic flows (e.g. number of private cars during peak hour) and about the amount of people never using public transport.

4.1.2. Coventry (UK)

Coventry City Council's current plan is under consultation (from March-September 2017). The plan refers to issues and risks pertaining to Energy Generation, air quality, congestion and lack of green spaces highlighting issues in mobility and transport.

Individual transport needs can vary significantly. It is therefore important to ensure that everyone who lives in, works in or visits the city is able to access a choice of accessible and high quality transport modes and make well informed and appropriate decisions about how and when they travel.

Concerning data gather by Coventry City Council, they focus on:

- • National data collection (car data, automatic counters, etc.) developed by the Department for Transport (DfT).
- • Surveys for specific projects done by Coventry City Council commission.
- Bus surveys and cordon counts conducted by Transport for West Midlands (TfWM).
- Annual cycle and walking cordon counts (March and October).
- Test of new ways to collect and store data developed under the Intelligent Mobility and Smart Cities programme, including new Bluetooth and ANPR camera technology to collect journey time and duration, innovative air quality measurement devices and cloud based storage.

[73] http://www.apulum.ro/index.php/primaria/document/2645

4.1.3. Erfurt (Germany)

In Germany, urban transport plans have been common in most cities since the 1960s. Although they are not legally binding, most cities and urban regions are developing such plans as an important part of general land-use planning. These plans were previously called *Generalverkehrsplaene* (GVP); today they are known as *Verkehrsentwicklungsplaene* (VEP). Elements of Sustainable Urban Mobility Plans (SUMPs) are increasingly included in most VEPs. However, other planning documents (e.g. for land-use, ambient air quality improvement, noise abatement) still exist separately with sometimes slightly different objectives.

Although some mobility data are usually collected in Erfurt, there are still some gaps and needs in data collection. Destination and purpose of journeys is an outstanding issue (e.g. traffic flows relating to workplaces/commuting). Also, information about parking spaces is required (e.g. kind of private parking spaces: public space/street, own property/ground, rented parking space from private, etc.).

Concerning freight data needs, Erfurt lacks information about delivery needs, frequency and type of load in the city centre and tonnage of freight transport in the city.

In addition, regarding active modes, there is a lack of information on pedestrian and bicycle flows and bike owners.

4.1.4. Kalamaria (Greece)

Kalamaria city is nowadays working in the preparation of the Sustainable Urban Mobility Plan.

Some gaps in data collection have been identified, mainly in the O-D matrix development, but also on the freight transport data collection and pedestrian and bicycle flows. In the specific case of freight movements, they need to collect data about freight traffic flows and their spatial and temporal distribution.

In addition to the quantitative information, also qualitative data are required as the fleet characteristics for passengers and freight (e.g. age, size, propulsion system) or passenger satisfaction data for all modes of transport.

4.1.1. Palanga (Lithuania)

The local parliament of Palanga has addressed the development of the SUMP. By the middle of 2018 every Lithuanian city with more than 25,000 inhabitants as well as cities with a resort status must prepare their SUMPs.

In this preparation process, Palanga has identified some lack of information concerning paths travelled by vehicles, bicycle owners and freight data form the demand side (data from retail shops).

4.1.2. Roma (Italy)

Roma is nowadays elaborating its Sustainable Urban Mobility Plan.

They noticed the necessities regarding data movements knowledge and flows characterization. They consider it crucial to collect data on the demand for passenger transport. In addition, their needs on freight data collection focus on the knowledge on O/D traffic flows. They particularly miss the development of a freight distribution survey.

Data from active modes of transport are not collected in Rome. They express their need to know information about bicycle and pedestrian travels (e.g. distances travelled in km).

4.1.3. Torino (Italy)

The Turin Urban Sustainable Mobility Plan (developed in 2008) aimed to rebalance transport demand between the individual and collective transport, in order to reduce congestion and improve accessibility to different urban functions. The pursuit of this strategy involves an incisive mobility policy, which favours the use of collective transport. To describe the state of the mobility system, a database was set up to systematize on shared media all the information held by the various Mobility Bodies in the City of Turin. The collection of information has allowed to define a representative picture of the mobility system (year 2008), structured in statistical and territorial data (population, employees, driving rates), qualitative characteristics of the demand for mobility of people and goods, environmental data (air quality, noise levels, ...), traffic data and network traffic loads (traffic flows, model assignment, traffic monitoring, incident, ...)[74]

Nevertheless, they are still working on the collection of integrated information about the passengers loads on PT. Piemonte region promotes a law requiring the use of an integrated card, called BIP, on all means of transport (mandatory from May 2017), this card will allow access to all data from all transport companies at regional level. These data will be collected and managed by a centre certificated by the Region itself, i.e. 5T.

Regarding freight transport, there are still some gaps in the data availability, especially on the demand side (retailers), but also from the supply chain.

Finally, for the actives modes, Torino needs to get more information about the demand on this kind of modes of transport and the accidents density.

[74] http://www.comune.torino.it/geoportale/pums/cms/banca-dati-mobilita.html

4.1.1. Valencia (Spain)

Valencia developed its Sustainable Urban Mobility Plan in 2012 with the main aim of collecting and developing the strategies and necessary instruments to achieve a coordinated and efficient use of different modes of transport.

The development of the SUMP entailed an increment in mobility knowledge for the local authority and enabled a holistic vision of the traffic flows and movements inside the city and within the metropolitan area to be gained

Despite having available a data set about mobility flows and characteristics for the SUMPs development, they noticed there are still some gaps to cover regarding data collection. They have a lot of information about urban mobility, nevertheless they miss most of the data related to metropolitan mobility. Additionally, they need to get data about vehicle occupation and mobility organized by big corporations (e.g. peer-to-peer where employees share the car), in order to identify possible improvements.

Concerning freight mobility, there is a gap on the identification of these movements. Most of traffic data collection in Valencia is done through magnetic loops, which only differentiate between light and heavy vehicles, but don’t distinguish between a public bus and a truck, a light van and a car or a cargo-bike and a passenger vehicle.

Finally, regarding active modes of transport, the technology used (magnetic loops) does not allow them to identity in a bike lane (2-ways) if a bike enters orleaves that area. They would need this information to be able to create O-D matrix. Additionally, they would need to have an exhaustive characterization of bike flows: type of bike, speed and social aspects regarding cyclist (gender, age...)

Traditionally, Valencia used surveys for mobility characterization, but they find it crucial the use of new technologies to have a large sample, which will help them to reduce cost and increase dataset and frequency.

4.2. Conclusions

As a final summary, the table below shows how cities participating in SUITS project are performing data collection in their own territories.

Table 2. Technologies used to collection mobility data by partner cities in SUITS. *Own development.*

Type of data collection	Alba Iulia	Coventry	Kalamaria	Palanga	Rome	Torino	Valencia
TRAFFIC COUNTS							
Manual traffic counts (for passengers or freight transport)	X	X	X	X	X		X
Pneumatic road tubes		X					X
Piezoelectric sensor		X					
Magnetic loops		X	X		X	X	X
Passive magnetic		X					X
Passive and active infra-red		X				X	X
Microwave radar					X		X
Ultrasonic and passive acoustic							
Video image detection	X				X	X	X
Floating Car Data (mobile phone or GPS)		X	X		X	X	X
SURVEYS							
Driver surveys	X	X		X			
Mobility surveys	X		X	X	X	X	
Shipper surveys					X		
Distribution industry surveys							
Receiver surveys							
Employment surveys in freight transport and logistics industry	X						
STATISTICS AND OTHER DIRECT MEASUREMENTS							
Public transport operators' statistics	X	X	X	X	X	X	X
Bus Operators Data		X		X		X	
Taxi sharing data						X	
Car sharing data						X	
Intelligent cards for mobility		X				X	X
Loading/unloading/parking infrastructure data for goods vehicle		X	X		X	X	X
Freight informatics data (from cameras, sensors & other automatic data capture devices)	X		X			X	
Port freight traffic data in the urban area							
Rail freight traffic data in the urban area	X	X					
Inland waterway freight traffic data in the urban area							
Airport freight traffic data in the urban area		X		X			
INDIRECT MEASUREMENTS							
Fuel consumption measurement for calculation of Vehicle Kilometres Travelled							
Good vehicle fleet licensing data						X	
Land use databases for town/city needed for freight modeling		X	X	X			X
Data on road accidents involving goods vehicles	X	X	X	X	X		

In general, it is observed the concern of these cities for the current mobility problems. As general trend, it is shown the necessity of getting more information about some specific aspects: bike mobility and bike lines, freight traffic flows, O-D matrix, etc.

In relation to data collection from freight transport, as already mentioned, this is an important deficiency in most SUITS cities. Data on passenger mobility are generally available, but not on goods, thus this is a field where much remains to be improved. The main problems to collect this type of data are confidentiality reasons of the companies and inaccuracy of the traditional methods to identify the logistic vehicles (the magnetic loops don't differentiate between the public bus and a truck). In addition, new business models for urban freight distribution also consider alternative means of transport for goods deliveries (e.g. private vehicles or bicycles) which entails difficulty in their identification. Therefore, it would be interesting to find a method for collecting this type of data e.g. though RFID tags on small packages

Another common need is for information related to active modes of transport (pedestrian and bicycle flows). Some technologies, such as magnetic loop, can be used for the identification of bicycle flows, but they have imitations in the collection of information about the direction of travel, type of bike, speed and social aspects regarding the cyclist (gender, age...) and also for the pedestrian flows identification. For this case, it could be useful to try some different methods for collecting these data, such as smartphones with GPS, specific applications, different types of sensors, etc.

Also, the characterization of passengers and freight movements is a key issue for local authorities involved in SUITS project. It is not only on knowing about traffic flows and their spatial and modal distribution, it is more about identifying transport patterns and demand characterization (e.g. purpose of journeys, frequency and type of freight loads, vehicle propulsion systems, fleet characteristics or passenger satisfaction data).

Finally, SUITS cities have been asked about the strategies and technologiesused for data collection in their own cities. The survey reflects that cities that have implemented a SUMPs are those using a higher variability of tools for data gathering. In addition, cities are mainly using statistics and traffic counts for data collection.

Among traffic counts, the most used technologies are manual counts and magnetic loops. Regarding statistics, all the respondents collect information from public transport operators and most of them gather freight data from loading, unloading and parking infrastructures; while only Turin is getting inputs from car/taxi sharing platforms.

Although not so extended, surveys are also used but only focusing on general mobility and drivers, in fact, only Rome is performing a shipper survey and none of the cities are collecting information from the demand side (receivers and distribution industry).

Finally, regarding indirect measurement of traffic flows, cities are collecting information about road accidents involving freight vehicles.

5. Gap analysis conclusions

Nowadays, urban mobility patterns are characterized by a continuous expansion and a growing dependence on the private vehicle. According to a United Nations report, 80% of all European citizens will live and/or work in cities by 2030. Urban transport is producing adverse impacts on sustainable development, affecting the environment, health and safety of the citizens.

Because of this growing situation, the need of developing and implementing sustainable and integrated urban transport systems has increased in the last years. In September 2009, the European Commission adopted and Action Plan on Urban Mobility, which provides a coherent framework for 20 concrete EU-level actions, including the acceleration of sustainable urban mobility plans development, the upgrade of data and statistics, the improvement of urban freight transport or the increase of travel information.

According to the recommendations for the development of SUMPs and SULPs[75], it is necessary, as a first step, to understand the city context from the mobility, transport and logistics points of view, in order to identify the specific issues and concerns that need to be tackled in the plan development. The development of a baseline scenario requires the collection of transport data. In addition, the use for which the data is required can affect the data collection methodology, and the quantity of data required.

According to ERTRAC & ALICE Urban Freight research roadmap[76], developed in 2014, urban freight flows represented 10-15% of urban traffic and 25% of urban transport-related CO_2; nevertheless, commonly used data collection methodologies do not include freight flows. With this regard, research[77] has revealed gaps in data collection which have implications both for understanding urban freight transport activity patterns and also for developing urban freight models. Issues that have been identified in considering urban freight data gaps include:

- Even when urban freight data is being collected, it is common for different data collection processes to use different data collection methodologies. This results in data gaps when comparisons between datasets are attempted. In addition, reporting of freight data and analysis of data varies between studies carried out.
- Data about light goods vehicle activity are not always available.
- There is still some lack of data about the supply chain as a whole (i.e. the links between urban freight activity and the freight activity upstream in the supply chain)
- There is insufficient geographical detail about goods vehicle trips in urban areas.

[75] ELTIS. Guidelines: Developing and implementing a Sustainable Urban Mobility (Logistics) Plan Plan
[76] ERTRAC and ALICE platform, November 2014. Urban Freight research roadmap.
[77] Mike Browne, Julian Allen, Allan Woodburn, Danièle Patier, Jean-Louis Routhier, Christian Ambrosini. 'Comparison of urban freight data collection in European countries'

- Data collection concerning the trips carried out by consumers for the purposes of shopping usually are not considered.
- There is insufficient freight data for non-road modes.
- Often there is relatively little information is available about how data was collected and processed, and about the reliability and representativeness of the data.

Following with the data collection systems in use, as included in section 2, traditional data collection methods are based on manual systems or fixed road sensor, providing specific information on the location where they are installed but not a general overview of the different transport flows. The extended use of ICTs in the last years opened new possibilities for high amounts of ‘real-time’ data collection with a relatively low collection.

One problem to face by service providers is the compliance with the specific privacy laws when collecting private information form users’ (in-vehicle devices, GPS position through smartphone detections, etc.). In addition, ICT-based technologies for automatic data collection should be combined with other traditional techniques for the inclusion of some additional factor relevant for the mobility system characterization, such as land use and behavioural qualitative data necessary for decision making.

Finally, regarding active modes of transport, although these are increasing in importance in the transport systems, there are still some gaps in the data collection for them. Traditional traffic data gathering systems usually don’t consider active modes of transport (especially pedestrian flows) and some other alternatives need to be considered. Traditionally, data for this modes have been gathered via surveys or national statistics. Nowadays ICT-based technologies also play a relevant role on it. For example, smartphones or other small devices can act as a data provider for active mobility. Working on this line, CIVITAS European platform has recently launched a tool inventory, including some specific applications for this kind of data gathering. More information has been provided in section 3.4.

On defining best data collection methods, it is important to decide the proper analysis strategies. Large amounts of data need to be treated as they can be useful for local authorities and decision making bodies, in order to implement, assess and compare measures on mobility management.

One of the problems in collecting massive amounts of data is that many of them have no real value, which requires a selection and pre-filter to get those really useful data. In addition, different data collection methodologies result in data gaps when comparisons between datasets are attempted. In this regard, Big Data systems has been conceived as an opportunity for improving management of larger amounts of collected data.

One of the most used methodologies for data analysis is the use of KPIs (more information provided in section 3). KPIs are crucial for the assessment of current situation of urban mobility and to compare the evolution over the time. Although the use of passengers related

KPIs are notably extended, there are still some gaps for the definition of most useful KPIs for urban freight analysis[78].

Other strategies to support local authorities, based on the use of data gathered, are Decision Support Systems, which provide support to decision-makers to understand and simulate the structure of urban systems and to compute indicators for target setting and benchmarking to identify level of service. Nevertheless, Decision Support Systems need to be considered as a helping tool, but never as decision systems as itself. The entire responsibility associated with making a decision using a DSS resides with people who built and use the system.

To conclude the gap analysis, according to the data provided by Local Authorities from cites participating in SUITS project, there is a latent need of increasing information about freight flows, O-D traffic matrix and active mobility (especially about bike trips and infrastructures). Cites find especially difficult the collection of information about freight flows due to the difficulties to access to private companies' information, due to confidentiality reasons. On the other hand, information about traffic flows needs to be addressed from the point of view of better knowing transport patterns and demand characterization (e.g. purpose of journeys, frequency and type of freight loads, vehicle propulsion systems, fleet characteristics or passenger satisfaction data).

Finally, in the next page is included a Strengths, Weaknesses, Opportunities and Threats analysis (**SWOT**) of the situation in data collection in Europe. SWOT analysis is an extended methodology that can serve as a precursor to any sort of action, such as exploring new initiatives, making decisions about new policies, identifying possible areas for change, or refining and redirecting mid-plan efforts. Performing a SWOT analysis is also great way to improve business operations.

The SWOT analysis developed in this chapter, summarizes the work done in ***'Task 3.1. Research and gap analysis on data collection and analysis methods'*** andcollected in this deliverable. It provides insights for the introduction, properdefinition and justification of the upcoming tasks and pilots to be developed during the project duration.

[78] Alan McKinnon (2015). Performance measurement in freight transport.

W
Weaknesses

- Current methods such as government surveys do not differentiate between urban and non-urban transport.
- Continuous transmission of data generates an important heavy load on the transmission channels.
- New technologies do not provide all the data that would have been collected in a traditional survey, so they need to be combined.
- There is still some lack of information related to pedestrian and bicycle flows.
- Commonly used data collection methodologies doesn't include freight flows, which generates some gaps in freight data collection methods.
- It is common for different data collection processes to use different data collection methodologies. This results in data gaps when comparisons between datasets are attempted.
- Data about light goods vehicle activity are not always available.
- Data collection concerning the trips carried out by consumers for the purposes of shopping usually are not considered.
- There is insufficient freight data for non-road modes.
- Often there is relatively little information is available about how data was collected and processed.
- Passengers related KPIs are notably extended, there are still some gaps for the definition of most useful KPIs for urban freight analysis.

S
Strengths

- Creation of Sustainable Urban Mobility Plans (SUMP) has increased because of the awareness of cities in relation to their mobility problems.
- European Commission is concerned about the necessity of developing SUMPs and SULPs and push local authorities for it.
- Greater investments have been done for the development of new systems for data collection and analysis.
- Analysis techniques such as Decision Support Systems provide support to decision-makers to understand and simulate the structure of urban systems.

O

Opportunities

- The extended use of ICTs in the last years opened new possibilities for high amounts of 'real-time' data collection with a relatively low collection.
- Local authorities are requiring more information about freight flows, O-D traffic matrix and active mobility
- Potential of new technologies to improve the collection of mobility data.
- Long-term economic savings for cities, companies and people.
- Real-time traffic information could lead to many improvements such as congestion reduction or dynamic network traffic control.
- Active modes relevance in modal share is notably increasing.
- Some technologies such as pneumatic road tubes or piezoelectric sensors can be also useful for bicycle traffic gathering.
- Information about traffic flows needs to be addressed from the point of view of better knowing transport patterns and demand characterization (e.g. purpose of journeys, frequency and type of freight loads, vehicle propulsion systems, fleet characteristics or passenger satisfaction data).
- KPIs are crucial for the assessment of current situation of urban mobility and to compare the evolution over the time.

T

Threats

- Limitation of traditional traffic collection systems and manual gathering methods for getting the whole vision of the mobility scheme
- Privacy concerns when using ICT-based solution for data collection (in-vehicle devices, FCD, smartphones information).
- Combination between ICT-based technologies for automatic data collection and traditional collection methods for the inclusion of some additional factor relevant for the mobility system characterization
- Mistakes in the level of accuracy of data collected.
- Public organisations need to work closely with private companies to overcome issues concerned with funding and confidentiality to obtain access to it.
- Complexity of methods and models for the urban freight data collection and analysis.
- Collecting massive amounts can generate data with no real value, which requires a selection and pre-filter to get those really useful data.
- Good data analysis strategies are crucial, especially when large amounts of data are collected (e.g. open data).

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