URBAN TRANSPORT PLANNING, ITS AND ENERGY RESOURCES: A FRAMEWORK FOR SMART CITY CASE STUDIES

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ABSTRACT
The paper focuses on urban transport challenges related to the Sustainable Development Goals defined by the United Nations. Smart city is a possible way to face these challenges in order to increase sustainable development and quality of life in urban areas. Following the European approach, transport, Information and Communication Technologies (ICTs) and energy constitute the smart city pillars. An integrated planning process produces decisions about infrastructures and services related to each pillar and their interactions. The paper analyses an evaluation framework for supporting the integrated planning process, with a specific focus on decisions concerning urban transport infrastructures and services. The framework allows analysts to assess the potential decisions' effects, with particular attention to urban mobility. Transport System Models (TSMs), useful to simulate effects of planned decisions, are the core of the framework. By adopting technological solutions (ICT tools), it increases the TSM's accuracy level. This is possible with Intelligent Transport Systems (ITSs) that integrate information and data deriving from ICT tools with TSMs. The evaluation framework extends the analysis to energy effects, taking into account energy issues connected to freight and people mobility needs. Then the framework supports transport and energy decisions by means of ex-ante and ex-post evaluations. The presented study cases represent a framework of different urban application contexts.
Keywords: smart city, urban transport, freight mobility, city logistics, sustainable developments, ITS, energy resources.

1 INTRODUCTION

The seventeen United Nation's Sustainable Development Goals (SDGs) concern the present and future challenges to achieve sustainable development. The eleventh SDG (*11: Sustainable city and communities*) concerns challenges at an urban level. Today, at a global level about 50% of people lives in cities; by 2030, urban population should arrive at 5 billion [1]. Common urban challenges include road congestion, air pollution limited resources to provide basic services, like energy and transportation. People and goods mobility accounts for about 25% of the total world delivered energy consumption [2]. Without an efficient and effective urban planning, negative effects will increase.

At European level, urban challenges constitute the smart city's issues. Transport, Information and Communication Technologies (ICTs) and energy constitute the smart city pillars. The urban areas produce a great part of the EU's energy consumption and greenhouse gas emissions. The European Innovation Partnership for Smart Cities and Communities (EIP-SCC) indicated planning process as the one, of the main tools, to implement the smart city concept [3]. The integrated planning approach requires spatial, temporal and technical coordination of decisions connected to the three smart city pillars, in order to achieve sustainability goals, optimising the use of limited economic and financial resources [4]. The success of the process depends on the convergence among scientific theories developed by analysts, rules and laws developed by governmental players, and real implementations realised by private and public sectors [5].

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As far as concerns the transport pillar, a smart transport planning approach is needed. It is necessary to renovate the classical mobility model, characterised by unlimited public funds, traditional technologies and limited data and information, towards a smart mobility model where people and business needs are at the centre of the decision-making process [6]. Advanced technological solutions allow analysts to use a large set of data and information on mobility. Availability of these data also improves the quality of transport planning and management enabling ex-ante and ex-post evaluations of decisions' effects on transport system [7], [8] and more in urban systems [9], [10]. In the context of coastal cities, the smart city concept requires a specification in relation to the further complexity related to land-sea interactions [11].

In this context, the paper presents an evaluation framework for supporting decisions in an integrated planning process, aimed to promote smart mobility model with a specific focus on urban freight transport. Some study cases accompany the illustration of the framework's elements. The presented study cases regard two coastal cities in the south of Italy.

After this introduction, the paper has three sections. Section 2 identifies integrated transport planning approach in a European smart city context. Section 3 illustrates the main contents of the proposed evaluation framework. Section 4 reviews some case studies representing the application of the proposed framework.

2 INTEGRATED TRANSPORT PLANNING

Traditionally, decisions on transport infrastructures and services realisations are assumed verifying ex-post real people and freight mobility and business's needs. Ex-post evaluations allowed decision-makers to verify if the implemented transport and logistics infrastructures and services configuration respond to mobility demand. Following the smart planning approach, the process should start from ex-ante evaluations of demand estimated by means of Transport System Models (TSMs) [12]–[14]. Services and infrastructures are designed (adopting "what if" or "what to" approaches) in order to verify an optimal balance between demand and transport supply [15]. Mobility's needs influence decisions concerning transport and logistics services configurations. In relation to services configurations, decisions on transport infrastructures are assumed (Fig. 1).

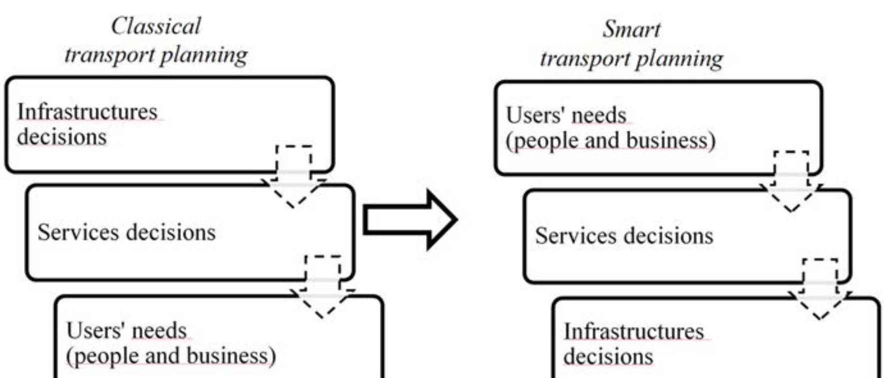

Figure 1: Classical vs smart transport planning.

The smart transport planning needs convergent transitions and a definition of new links among three factors, theories, rules and implementations:

- from theories that studies transport system and simulate their effects, to rules that should translate technical analyses into programmed decisions defined in terms of allocated resources and times for implementation (Section 2.1);
- from rules to real implementations that produce physical realization of infrastructures and functional schemes of transport, energy and logistics services (Section 2.2).

2.1 From theories to rules

Urban transport and logistics planning should derive from the application of scientific theories. Nevertheless, this is not a linear process, considering the following factors. A first relevant factor concerns the different rules and planning systems adopted by European Countries. Different legislative approaches (e.g. *Common Law* vs *Roman Law*) have impacts on decisions' effectiveness produced by urban transport planning process [16]. The second relevant factor concerns conflicting interests of involved urban stakeholders. Divergent objectives different city's actors (e.g. logistic operators and public administration) are often unbalanced. For instance, the objective of logistics operators, to increase speed in delivering processes, is in contrast with the objective of public administration to reduce environmental impacts [17]. This divergence could constitute an obstacle for the application of theoretical planning models.

Russo and Comi [18] focus on the transition from scientific literature concerning city logistics theories to city logistics planning. Guidelines for designing city logistics plans has been investigated focusing on the real case of Calabria region (Italy). A set of city logistics measures were proposed in order to address sustainability goals. In particular, methods, models and indications related to city logistics planning processes are summarised.

The European's concept of Sustainable Urban Mobility Plan (SUMP) has the main aim to overcome these limits. The SUMP comprehends a set of objectives and actions defined in an integrated planning process aimed to improve accessibility and quality of life of urban areas. It integrates long-term planning perspectives and short-term actions [19].

2.2 From rules to real implementations

The main product of a planning process is the decisions' implementations that modify real urban assets. In recent years, many smart city implementations have experimented in real urban contexts. Many cities are currently implementing smart city solutions realising material, immaterial infrastructures, managerial and institutional solutions to performances of urban supply chain, respecting environmental constraints [20]. Implemented solutions have the aim of enhancing quality of life and improving urban sustainability.

Integrated Planning, Policy and Regulations is one of the six *action clusters* defined in the context of European Innovation Partnership on Smart Cities and Communities (EIP-SCC). *From Planning to Implementation and Upscaling of Smart City Projects* is one of the main *initiatives* launched in this action cluster. The initiative aims at allowing exchanges of real experiences in smart city projects implementation among urban stakeholders (public urban administration, industry, and Non-Governmental Organization (NGO)). The *Smart City Guidance Package* supports these exchanges collecting successes and failures encountered by cities in implementing smart city projects [21]. Among these cities, the Italian city of La Spezia is experimenting with an integrated approach to combine urban innovation, urban regeneration, energy efficiency, sustainable mobility and social housing. Policies derive from a combination of *bottom-up (community driven)* and *top-down (municipal smart governance)* approaches.

At EU level, the European Institute of Innovation and Technology (EIT) supports the *Knowledge and Innovation Community* (KIC) for developing the *Climate-KIC* initiative aimed to guide the transition to a *zero-carbon economy* [22]. In this context, implemented solutions to the urban logistics challenges are collected. The focus is on the tested initiatives on urban freight in the Nordic capitals: Stockholm, Oslo and Copenhagen. The city of Stockholm, in the context of FREVUE project, is experimenting an Urban Consolidation Centre (UDC) located in the city centre that supports logistic, included reverse logistics, of retail, food and drink products. In 2012, the city of Oslo experimented practices of data capturing and information sharing in last-mile distribution in order to coordinate and to increase efficiency of logistical infrastructure and services to retailers. The final aim is to achieve environmental and economic benefits at urban level. The city of Copenhagen has optimised urban supply chains realising a UDC located outside the city. The last mile logistics is operated using vans that produce limited carbon emissions. Starting from this background, the main global logistics operators (e.g. FedEx, Nordic Edge) were launched an open innovation call to determine *how urban logistics can better support the sustainability goals of a smart city*. The call concerns issues relative to the balancing of increasing demand for urban deliveries and, at the same time, the respecting of environmental targets [23].

3 THE EVALUATION FRAMEWORK

To integrate smart city elements (transport, energy and ICT), an evaluation framework is proposed. The framework produces evaluations for supporting decision-making in the integrated planning process. Decisions regard the implementation of infrastructures and services constituting the integrated transport-energy system. Effects deriving from this implementation should achieve objectives (economic, social and environmental sustainability) respecting constraints connected to the use of a limited resource set (e.g. energy, financial and economic resources). For this reason, it is necessary to estimate transport-energy decision's effects before its implementation by means of an ex-ante evaluation. After their implementation, it is necessary to measure the same effects in the real context by means of ex-post evaluations (Fig. 2).

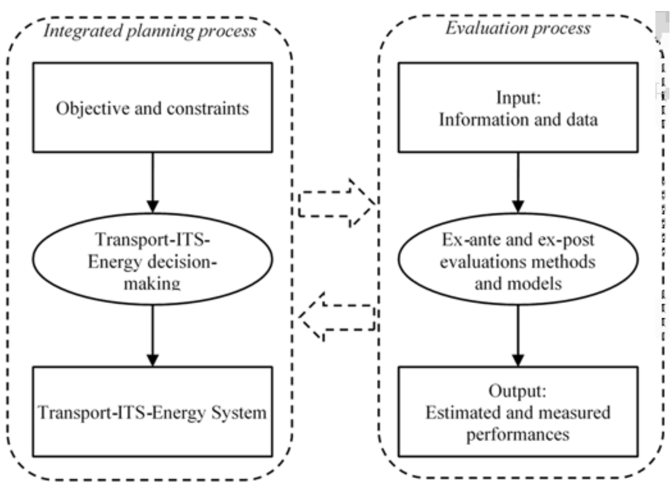

Figure 2: Planning process supported by the evaluation framework.

The proposed framework has an increasing level of complexity according to smart city elements to integrate, and then the availability of technological and modelling tools. The complexity concerns:

- *inputs*, comprehending:
  - from the planning process side, objectives to pursue (e.g. sustainability) and constraints to respect (e.g. limited energy resources) defined by different stakeholders involved in transportation planning,
  - from the evaluation process side, data and information deriving from the real context, useful to measure performances of the current and historical configuration and to fed models for simulating future configurations;
- *evaluation methods and models*, comprehending:
  - from the planning process side, decisions concerning elements of the Transport-Energy System;
  - from the evaluation process side, decision variables, the quantification of objectives and constraints, methods to compare different scenarios comprehending non-parametric methods, e.g. Data Envelopment Analysis [24] and parametric methods, e.g. multicriteria analyses [25];
- *outputs*, comprehending indicators related to:
  - from the planning process side, planned and implemented transport-energy system configuration;
  - from the evaluation process side, simulated effects potentially produced by future planned transport-energy configurations and monitored effects produced by past or real-time implemented configurations.

The proposed framework modifies the ex-ante and ex-post evaluations methods and models phase, introducing three levels of complexity:

- the level a) performs evaluations with transport models simulating effects of planned transport system configurations (TS);
- the level a) and b) where evaluations of the level a) are integrated with big data deriving from ICT about mobility (process b) simulating and measuring effects of past or real-time implemented transport system configurations (TIS);
- the level a) and b) and c) where evaluations of the level a) and b) are integrated with big data about energy (process c) simulating and measuring effects produced by past or real-time implemented transport-energy system configurations (TIES).

In the following section, the three levels are illustrated.

3.1.1 Level a): Transport models

At level a), evaluation methods require information obtained from traditional surveys. The framework's elements are:

- *inputs* comprehending objectives, constraints, data and information deriving from historical configurations of TS (small data);
- *evaluation methods and models* referring to elaborations of monitored data of historical configurations, transport system models (TSMs) for simulating future configurations of TS;
- *outputs* referring to monitored and simulated effects with specific attention to transport supply, demand and their interactions.

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3.1.2 Level a) and b): Transport models and big data

At level a) and b) evaluation methods require information obtained from traditional surveys that can be enriched with big data on transport mobility. ICT tools can be used in order to collect big data relative to historical or real-time configurations of TIS. The framework's elements are:

- *inputs* comprehending information and data of the level a) enriched by those produced by ICT tools;
- *evaluation methods and models* referring to further elaborations enabled by big data availability; data feed monitoring and simulation methods and models applied in relation to past, real-time and future configurations of TIS; an Intelligent Transport System (ITS) integrates TSMs and ICT tools;
- *outputs* referring to monitored and simulated effects that can be obtained with a high accuracy level respect to the level a), by considering the large availability of data.

3.1.3 Level a) and b) and c): Transport models, big data and energy resources

At the most complex level a) and b) and c), evaluation methods require all information of level a) and b) and further specific information about energy production and consumptions related to a transport-energy integrated system (TIES). The framework's elements are:

- *inputs* comprehending information and data of the level a) and b) enriched by those relative to energy production from traditional and renewable sources and energy demand in relation consumptions adsorbed by people and freight mobility;
- *evaluation methods and models* referring to further elaborations enabled by energy production and consumption profiles; quantitative energy variables can be considered as objective or constraint in relation to the planning problem (e.g. energy allocation for mobility services);
- *outputs* referring to monitored and simulated transport and energy integrated system.

Fig. 3 reports a schematic representation of the evaluation framework.

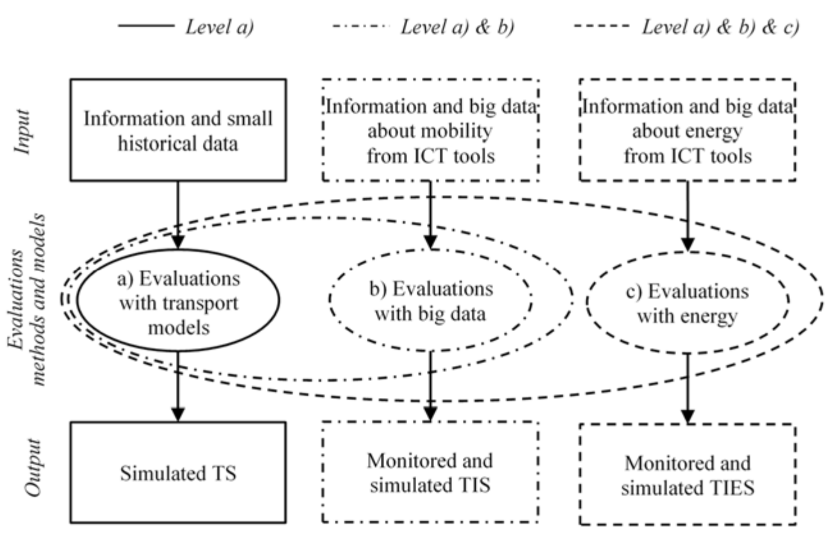

Figure 3: Evaluation framework.

4 STUDY CASES

This section reports some study cases where it is possible to identify the framework's elements introduced in Section 3. Section 4.1 reports principal results of a study case where transportation planning is supported by TSMs. In the case study of Section 4.2 TSMs and big data are integrated in a TIS to support decisions. Section 4.3 reports principal results of a study case where transport-energy evaluation is supported by ICT tools, TIES. The three cases regard two coastal cities in the south of Italy: Reggio Calabria and Roccella Jonica.

4.1 Level a): Transport planning with TSM to TS

The context is the city of Reggio Calabria. This is a medium-size urban area with about 200,000 inhabitants characterised by a set of economic activities located in the city centre. To perform these activities, retailers require transport and logistics services. In order to increase urban freight transport sustainability, a transport planning process is needed to locate an Urban Distribution Center (UDC), and at the same time, to design distribution and delivering logistics services [26].

Inputs are the objectives and constraints of two stakeholders' classes. From one side, there are transport operators and retailers that pursue economic sustainability promoting solutions increasing efficiency and reducing transport and logistics costs. From another side, there are city public administrators that pursue environmental sustainability imposing constraints in pollution produced by road transport.

Evaluation methods and models support decisions related to UDC location and related logistics services. A trade-off between the two sustainability components is needed. In this context, TSMs simulate potential effects produced by different decisions, providing ex-ante quantitative evaluations related to different freight transport system's configurations. The entire problem is studies considering two levels: the inner level studies solutions for freight delivering by means of vehicle routing problem (VRP); the outer level compares performance indicators that measure objectives achievement and constraints respect by means of multicriteria analysis.

Outputs of the simulation and evaluation process are the indicators that allow comparisons of freight transport scenarios defined in terms of UDC location and freight vehicle routes. These outputs will support final decisions assumed by city decision-makers.

Detailed results of this study case are reported in Musolino et al. [26].

4.2 Level a) and b): Transport planning with TSM and big data to TIS

The context is the territory near to the touristic port "Porto delle Grazie" in Roccella Jonica. The port has 450 nautical berths and, referring to the year 2017, more than 400 permanent contracts for mooring and about 1,600 transit users [17]. The territory around the port is characterised by a set of cultural and economic activities that could be of potential interest of nautical port users. Transport and logistics services for people and freight should guarantee accessibility to these activities. In particular, transit services should serve nautical tourist needs related to visit cultural heritage around the port. Logistics services, defined in terms of vehicles, routes and times should serve freights' needs of the port and their users. In order to define transit and logistics services' characteristics, a transport planning process is needed to individuate the type of vehicles and routes to perform.

Inputs comprehend objectives, constraints, information and available data on the transport system. Objectives and constraints concerning port's operator (e.g. resources minimisation), port's users (e.g. travel costs minimisation) and public administrations (national and local rules). Data and information on the port's supply and demand are available consulting the databases of the port's operator. Data from traditional transport surveys (small data) are integrated with Floating Car Data (FCD). These data provide information about spatio-temporal positions of road vehicles in the surrounding area near the port. Data refers to four non-consecutive weeks in two different periods (winter and summer of 2018). Recorded vehicles represent about 2% of all vehicles circulating in the province of Reggio Calabria. Database comprehends 5,311,407 records, one for each road vehicle detected position in the time and in the space collected during the observed weeks [27].

Evaluation methods and models support decisions related to transit and logistics services' characteristics. TSMs with ITS data simulate potential effects of different services configurations. TSMs are fed by small data and FCD. Respect to the case presented in Section 4.1, available data increase TSM accuracy providing an increased quality of quantitative evaluations. For instance, FCD support TSM's construction (e.g. zoning, graph construction to represent road supply, parameters' calibration of a demand model to represent mobility needs).

Outputs are the indicators that allow comparisons of transit and logistics services' performance. Transport performances measures regard historical and current configuration of transport facilities and services for people and goods mobility connected to the port. Moreover, TSMs allow analysts to obtain potential effects' estimations of designed transport and logistic services to increase economic sustainability, reducing transport costs and social sustainability, increasing port accessibility. These evaluations support final decisions assumed by port decision-makers. Detailed results of this study case are reported in Musolino et al. [17] and Croce et al. [27].

4.3 Level a) and b) and c): Transport planning with TSM, big data and energy resources to TIES

The context is the same as the case presented in Section 4.2. In the current situation, the port has high and certificated environmental sustainability. In a future port's configuration, a technology to produce energy from sea waves is planned. The port's decision-makers want to use a part of the produced energy to feed Electrical Vehicles (EVs) dedicated for people and freight mobility related to the port [28].

Inputs comprehend objectives, constraints, (small and big) data described in Section 4.2 and energetic issues. Other than the people and mobility needs described in the previous case, the objective is to optimise the use of renewable energy powering EVs. Information on the quantity of the produced energy in the time are available.

Evaluation methods and models support decisions related to transport-energy design. Small and big data, and information on energy production profiles feed TSMs. Respect to the previous case (Section 4.2), available data allows analysts to evaluate effects produced transport services characteristics (routes, timetables, etc.) but also to quantify energy consumptions related to people and freight mobility. These evaluations enable transport planners to optimise the use of energy resources deriving from traditional and renewable sources.

Outputs are the indicators that allow comparisons of transport-energy scenarios defined in terms of the type of EVs, routes that serving mobility needs related to the port. These evaluations support final decisions assumed by port decision-makers about the allocation of energy resources produced by the port. For instance, it is possible to evaluate the quantity of energy is needed for allowing nautical tourist to visit the territory around the port; at the same time, it is possible to evaluate the quantity of energy consumed by logistics services; these quantitative evaluations allow the port's manager to find an optimal energy allocation between different port's needs.

Detailed results of this study case are reported in Croce et al. [28]. Table 1 reports a summary of the evaluation framework's elements relative to the three study cases.

Table 1: Summary of the three study cases.

	Level a)	Level a) and b)	Level a) and b) and c)
Input	• Economic and environmental sustainability • Small data	• Economic and social sustainability • Small data • ITS	• Economic, social and environmental sustainability • Small data • ITS • Energy data
Evaluation methods and models	• VRP at inner level • Multicriteria analysis at outer level	• TSMs • Models using ITS	• TSMs • Energy consumption modelling
Output	Simulated freight transport system (TS)	Simulated and monitored freight and people transport system (TIS)	Simulated and monitored freight and people transport-energy scenarios (TIES)

5 CONCLUSIVE REMARKS AND FURTHER DEVELOPMENTS

The paper presents an evaluation framework supporting an integrated planning process where pillars (transport, ICT and energy) of European smart city are considered. The implementation of the smart city concept requires a convergence among theories, rules and real implementations. The convergent achievement can be support by the evaluation framework. The framework integrates traditional TSM, information and big data about mobility and energy systems. The final aim is to increase the accuracy's level of evaluations and then to provide an increased quality of information that constitutes the basis of planned and implemented decisions of a smart city. The results of the three study cases, specific for two coastal cities, show the incremental level of quality that could be produced adopting the proposed framework.

The research perspectives are related to the framework's extension towards other mobility segments (e.g. maritime passenger and freight mobility) other energy sources (traditional vs renewable) and other big data sources.

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