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Green City Logistics: Systems of Innovation to Assess the Potential of E-Vehicles

1. Introduction

City logistics or urban freight deliveries in many cities have the image of large, slow and polluting vehicles. This is especially true in cities dominated by their historical centers, where freight deliveries contribute significantly to the existing high congestion levels as there is lack of space devoted to logistic activities (Dablanc, 2007). Recent empirical studies estimate that urban freight vehicles account for 6 to 18% of total urban travel (cf. Figliozzi, 2010), 14% of vehicle-kilometres, 19% of energy use and 21% of CO_2 emissions (cf. Schoemaker et al., 2006). This bears significant impact on the city environment and respective costs due mainly to traffic congestion of vehicles circulating for freight transport, reduction in road capacity caused by loading or unloading operations, and pollutant emissions (Russo and Comi, 2012).

Public authorities of varying levels of responsibility have a set of policy tools in order to overcome the negative externalities of distributing goods in cities. These aim at addressing different impacts caused by urban freight transport operations. They are designed to influence either demand or supply or both. In addressing environmental issues, cognitive and normative mechanisms are, also, being used by policy makers in order to "frame" the problem and create societal "values" respectively (Hillman *et al*, 2011). Stathopoulos *et al* (2012) classified policies proposed to mitigate urban freight problems into six broad groups: (a) market-based measures, (b) regulatory measures, (c) land use planning, (d) infrastructural measures, (e) management measures and, finally, (f) new technologies. In principle, the latter concern vehicles with improved environmental performance and societal benefits (Russo and Comi, 2012). The introduction of electric vehicles (EVs) is classified under new technologies. Their use contributes to the reduction of local air and noise pollution and reduces the CO_2 footprint of urban freight operations. EVs are in the same category as other environmentally efficient alternatives. More specifically, they compete with other alternative fuel vehicles, against which they are at an economic disadvantage (Sharma et al, 2012) but share less of the barriers to adoption (Steenberghen and Loppez, 2008) with respect to infrastructure needs and consumer expectations (Tran *et al*, 2013). Nevertheless, EV market deployment faces important barriers both on the supply and demand side.

On the supply side, EV technologies enabling major reduction in emissions are already well known and are being actively developed. However, environmental innovation vehicle production is still small scale, relative to conventional motor vehicles with Budd-type pressed steel bodies and internal combustion engines with mechanical transmission (Whitmarsh and Kohler, 2010). This lock-in effect, regarding internal combustion technology, was already identified in the 1990s (Cowan and Hulten, 1996). Addressing primarily this effect, governing bodies at the international and the national level, accelerated public funded programs both in support for fundamental and applied research in battery and propulsion technologies as well as for infrastructure and demonstration projects. Some funding programs were in the form public private partnerships, such as the European Green Car Initiative in the frame of the European Economic Recovery Plan (2008) or the European Industrial Initiative on Electricity Grids as part of the SET-Plan (2009).

On the demand side, the main barrier concerns cost competitiveness (Ball and Wietschel, 2009). Multiple efforts to (re)introduce electric vehicles have failed (Hard and Knie 2001). Many attribute this to their high purchasing cost, technological immaturity and/or low functionality characteristics (driving range), which is reflected in behavioral aspects (cf. Struben and Sterman, 2008). Considering these shortcomings, EV manufactures have been emphasizing sports cars (where cost is not an issue), small cars (where expected functionality is small) and low speed vehicles (LSV) commonly used in city logistics, indicating the expectation of a commercial adoption of the technology (Sierzchula et al, 2012).

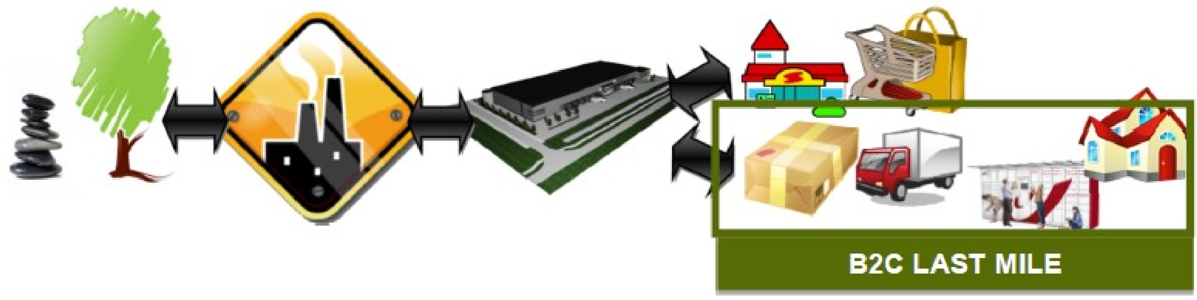
Examining potential policies to address barriers and promote alternative fueled vehicles, Browne *et al* (2012) suggest a range of options that policy-makers may consider including the identification of potential "lead adopters". Interestingly, other proposed policies ensure a consistent mix of policy and regulatory signals are already included in the set of policies used to address the negative externalities of distribution of goods in cities. Examples include the adoption of a new socio-technological regime through awareness campaigns and education programmes; change in the taxation structure by taxing negative externalities such as GHG emissions; and creating positive incentives through excise relief and subsidies. Zubaryeva *et al* (2012) through an expert opinion evaluation assessed the factors for the identification of potential lead markets. Experts agreed that well-to-wheel emissions, privileged access to dedicated lanes, parking lots and city centers, fuel savings and GDP per capita would be crucial factors for lead market assessment. The highest ranked factor for future development of EVs was fuel cost savings. These findings suggest that urban freight logistics may be a favourable lead market. However, while most studies conclude on the support required by government authorities of varying levels for the deployment of alternative fuel vehicles (cf. Browne *et al*, 2012), none provide guidelines as to *"who"* should act, *"how to act"*, *"what to act upon"* and "*when*" to intervene.

Various levels of public governance have introduced a mixture of measures, in support of EV uptake. These include subsidy to purchasers, subsidy to car manufacturers, subsidy to R&D, infrastructure development, introduction of EVs to government commercial fleets (e.g. La Poste), preferential access, measures to increase public familiarity and others (RAND Europe, 2012). These reflect common policy instruments available to the public promoter/ policy maker, such as Public Procurement, Regulations, R&D subsidies and the Scientific and Technological Infrastructure (Rothwell and Zegveld, 1981 and Geroski, 1990). These forms of public funding are suitable for all sectors of the economy. However, as opposed to evidence from other sectors, the transport sector displays poor innovative strength. A comparative study by Dialogic and NEA (2002) on behalf of the Transport Research Centre (AVV) in the Netherlands has shown the transport sector to score less than the average for the economy as a whole when it comes to innovation. More recent figures confirm the persistence of the problem (International Transport Forum, 2012).

Assessing the conditions, including policy support, under which innovative concepts have a high chance of getting adopted and being successful in the transport sector has, hardly been studied. Exceptions are Garrison (2000), who has also derived generic understandings in the relationship between innovation and transportation technologies, and Hoogma *et al.* (2002), who draw generic conclusions from the study of eight examples of innovation concepts in the field of sustainable transportation. The introduction of the EV and other alternative fuel vehicles has, however, recently generated considerable scholarly research.

This paper furthers the discussion on the deployment of EVs by examining the type and timing of public intervention in a market niche which, on the one hand bears the characteristics of a lead adopter and on the other already applies measures with respect to addressing the negative externalities of city logistics that have been suggested for the promotion of alternative fuel vehicles. Its approach differs from proposed socio-economic evaluations (cf. Figliozzi et al, 2011; Brady and O'Mahony, 2011), identification of barriers and proposed measures to overcome them (cf. Browne et al, 2012; Steenberghen and Loppez, 2008) or market simulations thereof (cf. Shepherd et al, 2012; Tran et al, 2013). Identifying policies by which to promote the adoption of EVs in city logistics requires the in-depth study of the (innovation) system, as "policies that do not take into account the complex interactions within the chain may yield suboptimal outcomes, based on inaccurate projections of the likely effects" (Hensher and Puckett, 2004). The way that urban logistics belongs to entire logistics chains is shown in Figure 1. In this context, researchers, with respect to EVs, have followed a system dynamics approach (cf. Bree et al, 2010; Kwon, 2012) but as there is no specific market focus, findings can only identify trends under various scenarios of market development.

Figure 1: The urban last mile within the total supply chain



Source: Gevaers et al. (2009)

The paper follows the *system-oriented* approach. The Systems of Innovation (SI) approach views innovation as an interactive, non-linear process, in which actors interact with other organizations and institutions (laws, regulations, values etc.). This complex process, characterized by reciprocity and feedback mechanisms, determines the success of innovation (cf. Lundvall, 1992; Nelson, 1993 and Edquist, 1997). By identifying the interactions between actors and institutions, the SI approach uncovers the actors and mechanisms that lead to successful innovation. The present paper proposes a framework model based on SI by which to study actors and their interactions, in order to address the central issue of *"who"* should act, *"how to act"*, *"what to act upon"* and "*when*" to intervene. The proposed framework model is applied for the introduction of EVs in city logistics and assesses their potential.

Following this introduction, the paper is structured as follows. Background to Systems of Innovation and the model are presented in the second section. The third section of the paper introduces EVs and applies the framework model. The paper concludes with policy recommendations as identified through the application of the model and suggestions for further development.

2. Systems of Innovation (SI) Approach

Innovation may be considered a technological or organizational (including cultural and marketing, as a separate sub-set) change to the product (or service) or production process that either reduces the product (or service) or production process costs or increases the quality of the product (or service) to the consumer. The definition is derived from the seminal work of Schumpeter and other scholars (cf. Smith, 1998; Sundbo, 1998) and leads to the introduction of two broad categorizations: commercial innovations motivated to achieve either revenue generation or cost reduction; and public innovations/policy initiatives aiming at achieving an increase in socio-economic welfare. In both cases, innovation is acknowledged to be a key driver of economic growth and, as such, has been included as an essential element of the Lisbon Strategy launched in 2000, further defined by the Barcelona Research Council in 2002.

Moreover, "change" may be incremental and, therefore, refers to improvements to products or processes; modular, whereby, parts of the product or process are novel or even radical, referring to totally new products and processes, which require a fundamentally new approach to organization (cf. Garcia and Calantone, 2002 for various definitions in literature).

The introduction of EVs to market leads to a Technology Innovation System (TIS). TIS are defined as socio-technical systems, which aim to enhance the development, diffusion and use of a particular technology (Bergek et al., 2008). The technology definition is used as a differentiation, as technology innovations will most probably trigger or require innovation in processes (management, operational, cultural etc.). "Technology" may refer to a knowledge field or a product (Carlsson et al., 2002). This is the case of EVs. Typically, a TIS may cut across national, regional and sectoral boundaries (Hekkert et al., 2007; Markard and Truffer, 2008) and this characteristic reflects on both the deployment of the technology and the interdependency of actors and their interrelations. However, their analysis at a specific level, application or "node" is important in understanding key mechanisms. This is the case of studying EVs potential uptake as a city logistics application.

2.1 Background

The SI approach has its roots in the evolutionary theory (Nelson and Winter, 1982). Ever since its emergence in the early 1990's, SI has attracted the interest of international policy think-tanks such as the OECD (Mytelka and Smith, 2002). In the SI approach, innovation does not take place in isolation. Actors, within the system, interact, cooperate and learn (Lundvall, 1992). Institutions, hard (regulations, laws etc.) and soft (cultural norms, values, codes etc.), are crucial to economic behavior and performance. Institutions formulate the "rules of the game" or "code of conduct" (Smith, 1997). The system evolves, generates variety, selects across that variety and produces feedback (Norgren and Hauknes, 1999). This process of novelty and variety creation is the result of constant interaction among heterogeneous actors in a population (Smith, 1999). It is necessary to maintain the diversity that makes selection possible (McKelvey, 1997). Hence, under the SI approach asymmetries are essential in providing novelty and variety. Different actors and/or different institutions form different Systems of Innovation. In all these basic elements, systemic imperfections (or systemic problems) can occur, if the combination of mechanisms is not functioning efficiently. If so, innovation by actors may be blocked. These systemic problems as summarized by Norgren & Haucknes (1999), Smith (2000), Woolthuis *et al.* (2005) and Edquist & Chaminade (2006) include failures in following domains.

1. *Infrastructure*: The physical infrastructure that actors need for functioning (such as IT, telecom, and roads) and the science and technology infrastructure may not be available hindering further development.
2. *Transition:* The inability of firms to adapt to new technological developments.
3. *Lock-in/path dependency failures*: The inability of complete (social) systems to adapt to new technological paradigms.

4. *Hard institutions:* The failures in the framework of regulation and the general legal system to support the development of a new application.
5. *Soft institutions:* The failures in the social institutions such as political culture and social values that hinder the uptake of the innovation.
6. *Strong networks:* The 'blindness' that evolves if actors have close links and as a result miss out on new outside developments.
7. *Weak networks:* The lack of linkages between actors as a result of which insufficient use is made of complementarities, interactive learning, and creating new ideas. The same phenomenon is referred to as dynamic complementarities' failure.
8. *Capacities:* Firms, especially small ones, may lack the capacities to learn rapidly and effectively and hence may be locked into existing technologies/patterns, thus being unable to jump to new technologies/business patterns. In an extension, it can also include *financial* capacity as well as capable human resources.

Within the SI approach, policy interventions (Edquist & Chaminade, 2006) are needed either because: (i) there is no market mechanism operating at all and the activities are fulfilled through other mechanisms, e.g., regulation or (ii) the market mechanism does not lead to the fulfillment of the objectives established. In both cases, public intervention is expected to lead to "*additionality*" and not "*substitution*" of market activities.

2.2 Recent Developments

Woolthuis *et al.* (2005), in order to identify "system failures" and estimate the expected impact of innovation policy interventions, proposed a "Systems' Failure Framework". This concerned a matrix including all relevant market actors and the systemic problems, as identified previously. As such, the "Systems' Failure Framework" was proposed as a diagnostic tool, with respect to innovation failure.

The key characteristic of evolution is "time". Roumboutsos *et al.* (2011) introduced this temporal aspect by proposing the introduction of temporal frameworks representing the stages of innovation development. This allowed for the study of the evolution of the innovation adoption process as the innovation matures. They, also, added "market demand" and competitors to the market mechanisms to be studied (see tables 1 and 2).

A further improvement to the "Systems' Failure Framework" was proposed by Aronietis *et al.* (2012). It concerned the registration of both positive and negative correlations between actors and institutions as opposed to only the negative correlations of the Systems' Failure Framework. This allowed for the mapping of the positive system forces and their respective study through case studies. In this context, the Systems' Failure Framework is transformed to the Systems' of Innovation Framework.

Vanelslander *et al.* (2012), reporting on the analysis of case studies following this approach, introduced "layers" in the analysis in order to guide the focus of the analysis. The first "layer" concerned the characterization of the innovation as commercial or within the context of public policy depending on whether the primary aim was to produce profit or social welfare. This was important in order to focus on the potential innovation champion or leader. The second "layer" concerned the type of innovation: technological, managerial and/or cultural. The third "layer" was, finally, the Systems' Innovation Framework. This framework did not include *Transition* and *Lock-in/path dependency failures.*

2.3 Proposed Systems' Innovation Framework and Assessment Methodology

In addition to the above developments and in order to capture the impact of the global environment and respective competition, the proposed methodological framework foresees both the expected influence of these factors and the expected competitive advantage of competing technologies by introducing a *qualitative scale of assessment* in the framework. This is an important contribution as it allows the estimation of intensity of the interactions and may be combined with indicators of the TIS. Examples of such indicators may be found in Hillman *et al* (2011).

With this latter addition to the Systems' Innovation Framework (SIF), the innovation methodology is structured improving on the multi-layer approach presented by Vanelslander *et al.* (2012). More specifically, the proposed SIF methodology foresees three layers of analysis. The first layer concerns the distinction between commercial innovations and those seeking to increase welfare.

The second layer of the methodology involves the identification of its predominant component/aspect, i.e. technological, organizational, managerial, cultural or policy. For example, an innovation may be characterized as predominantly "technological" and also include organizational change. In this layer other typical characteristics are also identified. These include determining the timeline of development of the innovation process as presented in the scientific literature: initiation, development, and implementation. In reality, the innovation process is actually a continuous process. This layer also concerns the assessment of whether the application of the specific innovation requires trans-sectoral collaboration and/or forms of cooperation in the transport chain (example e-freight applications) or whether the adoption of the specific innovation influences only local stakeholders and, hence, the innovation is confined to a specific location. That is, the impact of the innovation is characterized as specific to the (business) unit involved or as having a wider market focus.

The third layer of the methodology involves the use of the SIF. This framework provides a means to identify the set of external factors (the so-called 'institutional environment' and 'rules') and the 'sets of actors' involved in the innovation being analyzed. Defining all of the components of the innovation is important as the focus of attention and intervention may alter as the innovation moves through the process from initiation to implementation. Finally, the role and importance of the initiator of the innovation is explored. The inter-relations of actors and institutions are assessed with respect to their support to the innovation process on a qualitative scale of [-3, +3] based on qualitative comparative analysis.

3. E-Vehicles in City Logistics

3.1 Introduction

Electric vehicles (EVs) are not new. EVs have been around in one form or another since the invention of the automobile. In general, they use an electric motor for propulsion with batteries for electricity storage. The energy in the batteries provides all motive and auxiliary power onboard the vehicle. Batteries are recharged from grid electricity and brake energy recuperation. Potentially, re-charging may take place from non-grid sources, such as photovoltaic panels. They are promoted as an environmental innovation. That is an innovation that leads to the reduction or avoidance of environmental impacts (cf. Beise and Rennings, 2005). Notably, environmental innovations bear as additional drivers regulatory push/pull factors (De Marchi, 2012). However, their overall impact on the environment depends on the original sources of energy production (Thomas, 2012).

Throughout the 20th century, several models of electric vehicles (EVs) were produced, but none became widely adopted by consumers as the EV lost the competition for mass production of automobiles at the beginning of the 20th century. Since then, there were several unsuccessful attempts to revive EVs. The most significant (1960-1970s) was linked to congestion problems and the oil crises and was characterized by large publicly-funded programs for fundamental technical research and creation of EV markets in France, the US and Japan. Since the early 1990s a new attempt is in evolution, initiated by niche producers and large automotive manufactures, such as Think, Kewet, Ligier, General Motors, Volkswagen, Peugeot and Citroen. Coupled with the need to reduce GHG emissions significant public funds are once more supporting research and development, standardization of charging infrastructure, vehicle to grid communication and other efforts. These are accompanied by regulations on pollutant and CO2 emissions, urban mobility actions and taxation framework schemes for energy products and electricity. However, market take-up is slow and projections vary for the medium and long term (OECD, 2010).

Focusing on city logistics, in terms of innovation costs, promotes larger scale deployment. In terms of transport planning, city logistics is the “last mile” of the transportation of goods in city centers. Most attempts to reduce environmental impact of urban freight are concentrated on access restrictions (alternative or low emission vehicles are included under this category), traffic management, land use management and public infrastructure (cf. Dablanc et al, 2013; Dablanc, 2007). EVs are in the same category as other environmentally efficient alternatives, and more precisely, just like other alternative fuel vehicles. Moreover, alternative fuel vehicles are one of the proposed measures for reducing the environmental impact of city logistics and are viewed by transport city planners as a “combined” (supplementary) measure. This means that their impact is optimized when adopted in connection with other measures such as consolidated deliveries (achievement of high load factors), mini-warehouses, night deliveries, traffic management and others.

City logistics (urban freight) is organized through regulations imposed by city traffic planners for passenger vehicles in the cities they address. Regulations concerning urban freight are set at a municipal level reflecting the cultural attitude towards environmental issues of the specific locality (cf. Flämig, 2012). City logistics and respective measures are normally implemented within the local (municipal) legal framework conditions by using different legal premises such as ordinary traffic regulations concerning parking and loading/unloading as well as specific transport regulations such as weight limits on specific routes. However, in the case of fundamental changes like the use of environmental zones within a city, new traffic regulation orders are needed which are based on the limit values on air quality set by the European Directives (Directive 1999/30/EC).

3.2 The Case Analysis

The methodology as described previously is applied with respect to EVs in city logistics. This concerns the analysis on three layers as described. The first layer of analysis concerns the innovation drive (efficiency or welfare), so as to identify the innovation leader; the second refers to the type and stage of the innovation so as to anticipate the level of respective changes and the third layer is the SIF mapping the inter-relations.

3.2.1 Layer 1 Analysis

The key aspect of this introductory layer is to identify whether the innovation case concerns a commercial innovation seeking revenue increase or cost reduction or whether the ultimate scope is socio-economic welfare, describing a policy-driven innovation. The introduction of EVs is connected to the introduction of measures concerning the environment (emissions and noise measures). Within this context, EVs are supported. In addition, as noted in the introduction of the case, small demand and respective small production levels do not allow economies of scale. Therefore, EV market values are not comparable to conventional vehicles. The need for improved environmental quality in urban areas is the underlining rationale of the "policy driven" support to this innovative application and reflects welfare gains (Leiby and Rubin, 2003). The strong political drive for this innovation also targets the globalised automobile manufacturing industry. This policy support for city logistics is demonstrated in the many EU-funded research projects and initiatives. Examples are noted in Box 1.

BOX 1

Examples of EC Funded Research with respect to City Logistics: UTOPIA, REFORM, FV-2000, IDIOMA (FP4); BESTUFS, D2D, TURBLOG_WW (FP7), C-LIEGE (FP7). Demonstration projects within the CIVITAS I Initiative such as VIVALDI, TELLUS and MIRACLES, CITY FREIGHT, GIFTS, MOSCA and eDRUL etc. (FP5); projects within the CIVITAS II Initiative such as CARAVEL, MOBILIS, SMILE and SUCCESS, BESTUFS II (FP6).

EC Initiatives for EVs
European Green Car Initiative (EGCI, FP7) and projects under this initiative such as DELIVER, ESYBAT, ECOGEM, e-DASH etc.

Apart from these EU-funded programs there are a number of national initiatives. Such examples include the ELCIDIS project (1998 – 2002) introducing pilot actions of EVs for City Logistics. A best practice example has been recorded for the Municipality of Parma running the ECOLOGISTICS Project and the launching ECOCITY Service using methane-fuelled vans for city delivery within the restructuring of its distribution system. This is evidence of competitive innovations and implies that rather a welfare issue dominates for this innovation, supported by operational competitiveness.

As EVs are clearly considered a policy innovation, it is expected that the innovation champion should be amongst the policy makers.

3.2.2 Layer 2 Analysis

The second layer analysis refers to the characterization of the innovation. The introduction of the electric vehicle, as noted previously, is a technological one. As in most such innovations, its deployment requires managerial, organizational and cultural changes by all actors involved. Changes in city planning need to take place. Technological advancement in manufacturing is required with respect to EVs. In addition, the development of "support" infrastructure (e.g. a network of (re)charging points etc.) and the respective capacities (e.g. network of maintenance/repair services etc.) are required. This leads to the need for joint development of EVs and respective infrastructure (cf. Wirges *et al*, 2012).

The introduction of EVs in city logistics is a complex issue as it is dependent on the approach each municipality has towards the organization of its distribution system. This includes the incentives and disincentives introduced; the selected technology, as EV are in competition with other alternative fuels for powering vehicles; the advancement of the EV technology, which is highly supported by EU funds under FP7 and the EGCI; the cost (purchase and life cycle) of EVs, which is dependent on its mass production and consequently on the number of municipal distributors making the change. Finally, as the increase in distribution needs is dependent on city consumption levels, potential changes are also dependent on growth prospects and macroeconomic figures of the economy.

The adoption of EVs in city logistics is culturally bound. No reported evidence was found with respect to their acceptance level as vehicles for urban freight. However, the adoption of EVs requires significant changes in patterns of organization, process and behaviour leading to a need to change pathways. The socio-technical regime undergoes some permanent changes, as EVs cannot fulfill the same range of functions as conventional vehicles. Instead, their functionality range limits their radius of activity. This again makes EVs attractive for city logistics. The need to regularly re-charge the fleet adds to the complexity of the organizational features. Finally, cultural changes in society and the emphasis on environmental issues; EU & international legislation focusing on air quality; the potential competitiveness of the EU auto industry and respective job creation may be considered "enablers". Lundvall *et al* (Lundvall 1992; Lundvall et al., 2002) recognize that the ability of countries to foster innovation is dependent upon social capacities that are not solely based on science and technology. Within this broadened context the system of innovation is constituted by the institutions and economic structure affecting the rate and direction of technological change in the society" (Edquist and Lundvall, 1993, p. 267). The Neo-Schumpeterian strand of literature is similar. It assumes bounded rationality of agents, the role of tacit knowledge, as well as the role played by institutions on economic activities. In addition, the EV innovation is applied at a local level and is rather independent of developments elsewhere, which are only influenced "culturally" as success or failure case reputation or "word of mouth" (Struben and Sterman, 2008).

EVs in city logistics may be considered to be in the initiation stage of the innovation, i.e. there are few such examples based on pilot activities. Examples of application of EVs in city logistics are scarce and not included in demonstration cases of respective networks such as CIVITAS (http://www.civitas-initiative.org).

As analysed, the introduction of EVs requires the introduction of multiple changes.

3.2.3 Layer 3 Analysis

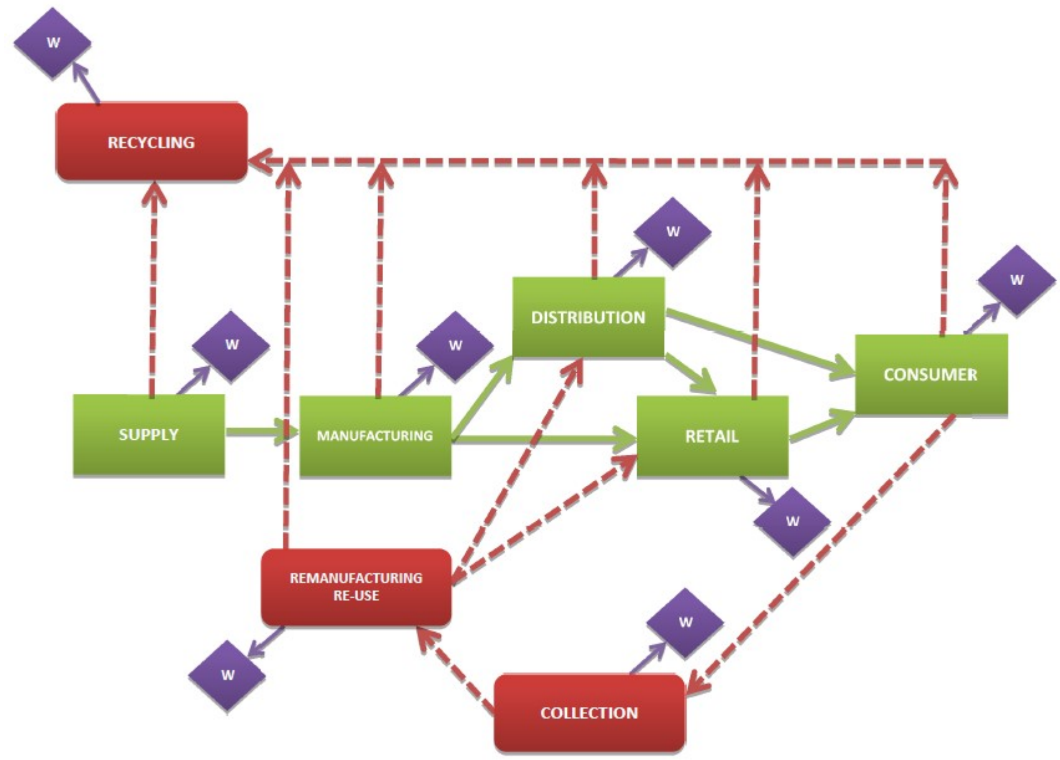
The third layer analysis concerns the application of the SIF, with the identification of actors and their relations within the context of the various mechanisms (institutions, networks, capacities). It also involves the assessment of existing measures taken and the potential trend in new measures in order to improve on socio-economic gains, which should be the driver for policy measures. Layer 3 analysis is illustrated in tables 1 and 2, representing the current stage of development (initiation) and the approach required to proceed to the next (implementation). The influence of a specific actor with respect to a "mechanism" in the system is depicted qualitatively within the range [-3, +3], describing the level of negative and positive impacts on the innovation adoption process. The assessment, in the current paper, represents the authors' own expert estimate based on reports and scholar publications as presented in the respective analysis to follow. The objective of the exercise is to identify the dynamics within the system and assess its ability to "change" in a desired direction. It may also indicate undesirable "lock-in path" tendencies of actors or the system as a whole.

In order to address layer 3 of the analysis, it is important to select the “system” upon which the analysis will focus. This ultimately concerns the governance level to be focused upon. As identified through the first layer analysis, policy maker levels may be considered ranging from global through national and regional to local. In the case of investigating the introduction of EVs in city logistics, the “system” could be the specific “city” in which the innovation takes place describing a “local” system. This would describe in the system at the anticipated implementation stage. However, as regulatory and other policy initiatives for innovation have gradually moved away from nation states to organizations at multilateral and regional levels it is important to investigate the respective system in the initiation stage. Within the EU the tendency to harmonize and align policy frameworks (Knill and Lenschow, 2005) justifies the selection of the EU level as the focal system at the initiation stage.

Actors: When studying the innovation at a European level (initiation stage), the actors to be considered are those acting at the specific level. Therefore, associations of involved stakeholders are considered. These may include: associations of manufacturers, distributors, retailers, environmental lobbyists (like The European Federation of Clean Air and Environmental Protection Associations (EFCA)), city planners, municipalities and city/local authorities, auto-manufacturers, the European Commission (EC), standardization bodies and research institutes. Their associations are the actors potentially involved at the EU governance level.

At a municipal level in the implementation stage, the actors involved are the key urban logistics chain actors, involved in the actual goods flow, as represented in Figure 2. Suppliers and consumers of course are the main actors in the chain. Closely linked to supply is manufacturing. Distribution services will cater for the connection with the customers, most often still via intermediation by retailers. The role of the other, facilitating actors is not to be underestimated, as is shown in the next subsections. Involved there are recycling, re-manufacturing and collecting services. Depending on the level of integration, and on who has the authority and power to decide over which part of the supply chain, innovation can be introduced by various actors of figure 2. Suppliers for instance may be interested in low-carbon distribution solutions, and may therefore push actors in that chain to follow suit. On the other, to make themselves more attractive, distribution services may launch their own sustainable innovation initiatives. Connection may be sought with other services like collection and recycling, for instance in order to make green distribution solutions economically viable, through avoidance of empty return trips.

Figure 2: actors in urban logistics chains



Source: Gevaers (2013) based on Beamon (1999

These actors are indicated in tables 1 and 2. Their relations with respect to institutions are also depicted. Their qualitative assessment with respect to "system mechanisms" is discussed in the following paragraphs.

More specifically, in table 1 relations and interactions are described as assessed with respect to the current stage of innovation (initiation stage), while table 2 describes how these relations are anticipated to develop in order to achieve the next stage in the innovation process uptake (implementation stage). These assessments are analyzed in the following paragraphs and quantified on *qualitative scale* of [-3, +3] based on authors' comparative analysis.

3.2.3.1 Infrastructure Conditions

In he *initiation stage* emphasis is placed on developing the technology and its peripheral components (e.g. battery cells, light automobile structures etc.). The EC, through the European Green Car Initiative (EGCI) and other programmes, is supporting the development of the technology. As noted earlier in this paper, major emphasis is placed on supporting change in the production basis of the automobile industry. Similar is the emphasis on city logistics and providing the initial platform. These research-funding initiatives are amongst the most reputed in the FP7 and are foreseen in the Horizon 2020 program (Sierzchula *et al,* 2012).

Table 1: SIF Applied at the Initiation (Current) Stage of Development

Actors / Institutions	EC	Municipal Authorities	Research Institutes	Stand. Bodies	City Planners	Assoc. Logistics (users)	Assoc. Retailers (users)	Assoc. Manu-facturers
Infra/cture	+2	-1	+1	+1		- 3	- 3	+1

Hard Inst/ions	+3	+1		+1				+1
Soft Inst/ions	+3	-1	+1		-1	- 3	- 2	+2
Weak Networks	- 1/ +1	+2	-1/ +1					
Strong Networks	+2							-3
Capacities	+1	-1/+2	+1	+1	+1	-1	-1	+2
Market Demand	+1	-2	+1	+1	+1	- 2	- 2	+2
Competition	-1	-1	-1	-1	-1	-1	-1	-1

In the *implementation stage* downstream infrastructure will be required such as charging units, maintenance centers, etc. This factor, especially with respect to retaining cultural processes, is important for the uptake of the technology (Wirges *et al*, 2012). In this effort industry is related as a partner forming public private partnerships. This is also the basis of the EGCI in the initiation stage.

When assigning values in the SIF matrix for the *Initiation Stage* (table 1), the European Commission is considered the major actor exercising *governance*. Assigning a positive value to its relation to infrastructure represents a "push" for the respective development. Slightly positive values are assigned to research institutes, standardization bodies and automobile and other manufactures as "partners" in building infrastructure. Logistics and retailer associations, as well as Municipalities during this stage have had limited involvement and are lagging in the respective infrastructure, which also includes re-charging units. In the Implementation Stage all infrastructure-related values need to be developed with respect to Actors. The positive values assigned in table 2 reflect this need.

Table 2: Anticipated Development of the Innovation in the Implementation Stage

Actors / Institutions	EC	Municipal Authority	Research Institutes	Stand. Bodies	City Planners	Distributors (users)	Retailers (users)	Manufacturers
Infrastructure	**+2**	**+2**	**+1**	**+2**	**+2**	**+2**	**+1**	**+3**
Hard Inst/ions	+3	+2		+2				
Soft Inst/ions	+3	+2	+1		+2	+2	+2	+2
Weak Networks	+1	+2	+1					
Strong Networks	+2	+2	+1	+1	+1	+1	+1	+1
Capacities	+2	+2	+2	+2	+2	+2	+2	+2
Market Demand	+1	+1	+1	+1	+1	+1	+1	+1
Competitors	-1	-1	-1	-1	-1	-1	-1	-1

3.2.3.2 Institutional Conditions

Hard Rules. This innovation case has both policy and technological components. Hard rules with respect to legislation have already been set and further activities are envisaged. Various legislation initiatives and EU Directives are designed to influence both demand and supply by introducing at a national or local level incentives (tax reliefs etc.) and disincentives (taxing, city entry restrictions, fuel tax etc.). On the supply side, delivery vans follow measures relevant to passenger cars. The main measure implemented so far for passenger cars is the European Automobile Manufacturers' Association (ACEA) voluntary agreement on increased efficiency of new vehicles (EU wide), which aims at reducing emissions for new cars sold in the EU to 130 g CO_2/km average by 2015, with an additional 10g reduction coming from 'complementary measures' including a greater use of biofuels. These measures are supported by a range of policies differentiated between Member States, which include standards, liquefied natural gas (LNG) subsidies and others. In general, Directives influencing the uptake of this innovation (but not specifically the electric vehicles) are shown in Box 2.

The above measures introduce "hard rules" in the market. The introduction of "technological rules" so as to allow for the development of an upstream and downstream market has been initiated. This requires the collaboration of a great range of actors (standardizing bodies, initiators/ entrepreneurs, developers/ industry, transport operators and lobbyists) in all three stages of innovation. In order to introduce the *implementation stage*, municipalities will need to follow measures undertaken by standardization bodies and central European legislation concerning the environmental operation of vehicles within city limits. These, however, cannot be specifically in favour of EV but will concern emission and noise level values of all vehicles, in general.

As hard rules are gradually put into place, the EC, standardisation bodies, manufactures and municipalities are assigned positive values in both the *Initiation* and the *Implementation stage*.

Soft Rules. These are considered the most important for the promotion of a cultural innovation. It has been identified that changing the culture of cities and promoting a strong environmental image are important pre-requisites for the adoption of welfare innovations. When innovation takes place at a local level, it has been shown (Vanelslander *et al.*, 2012) that in this approach, strong leadership on the side of the "initiator" is required. Demand for the environmental innovation stems from a general cultural change. This requires radical behavioural changes as noted earlier. This latter condition sets the

BOX 2

EC, 2008:
CONCAWE, EURCAR (European Council for Automotive R&D), JRC (EU Joint Research Center) well-to-wheels analysis of future automotive fuels and power trains in the European context;

EC, 2009a :
Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reducing CO_2 emissions from light-duty vehicles;

EC, 2009b:
Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC

EC, 2009c:
Directive of the European Parliament and the Council on the promotion of the use of energy from renewable sources amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

EEA, 2009:
Environmental impacts and impact on the electricity market of a large-scale introduction of electric cars in Europe

municipalities as potential leaders of the innovation (table 2).

In the SIF matrix, this is reflected in the negative values assigned for the Initiation Stage (table 1) and the positive values that need to be achieved in the Implementation Stage (table 2).

3.2.3.3 Interaction Conditions

Weak Network Conditions. Weak networks may have a positive impact on this technology. A strong driver is the auto manufacturing industry in Europe, which must take a positive stand towards the EVs. If influenced by "strong network conditions", which do exist between manufacturers at a global level, efforts to introduce EVs in city logistics may be hampered by differential emphasis on other low–emission auto technologies. Weak network conditions between municipalities are positive at the *initiation stage* as shortcomings and teething problems are not communicated. In the innovation *implementation stage*, weak network conditions between municipalities have a negative effect, as a "push" for the innovation is not accomplished. These weak networks need to develop into "strong networks" in order to support the transfer of knowledge and experience as well as the creation of the "feeling of innovation lag".

This assessment is reflected in the respective values assigned in SIF matrices of tables 1 and 2.

Strong Network Conditions. Strong links between members of the global auto industry have played a negative role in the promotion of the EV. More specifically, depending on international trends, emphasis on R&D shifted. Patent analysis indicates relative homogeneity within the automotive industry in its focus of R&D: during the 1990s, this was primarily in favour of the battery-electric vehicle (EV); in the early 2000s, there was a shift towards fuel cell and hybrid vehicles; but more recently, there has been a reversal of this trend in favour of EVs again (Whitmarsh and Kohler, 2010).

The European Commission (EC) through various fora, technological platforms and EC-funded research is trying to develop network conditions between the actors involved in this innovation. As the EC is funding research in the initiation stage of the innovation, it is considered a "leader". However, sustaining strong links when conducting "competitive research" is questionable. The negative value assigned in the SIF matrix of the Initiation stage (table 1) reflects this judgment.

Strong networks need to be developed between similar actors in different municipalities. EC funded projects are implicitly contributing on this front but more emphasis has to be placed in the *implementation stage* mixing innovation initiators and those who lag behind. Furthermore, in the implementation stage strong relations need to be developed between manufacturers and municipality actors in order to support pilot/demonstration activities and secure commitment on both sides (supply and demand). This need for strong networks between actors is depicted in the values assigned in the SIF matrix of the *Implementation Stage* (table 2).

The development of strong networks on a local level (Municipal) also corresponds to the notion of "proximity" as described by Visser and Boschma (2004). In this approach institutional and social proximity are needed to address the coordination problem of infrastructure provision, market organization, regulatory regimes and governance. It is also important in the promotion of capacity building. Hall and Jacobs (2010) considered this aspect for the port sector.

3.2.3.4 Capacities

Training and development of respective capacity is considered important. The importance in capacity building is demonstrated in the findings of numerous reported surveys and studies. For the EU and US, recent industry surveys suggest that the profile of early adopters of EVs will be characterized by environmentally awareness, interest in new technologies, response to government incentives and knowledge about the fuel economy (Deloitte Development LLC, 2010; 2011). Early majority consumers are expected to be politically active and environmentally motivated. An interesting UK academic study (Ozaki and Sevastyanova, 2011) suggests that the typical EV adopter is not significantly distinct from other consumers except that they are better informed about the financial benefits associated with EVs such as improved fuel economy or different government incentives. This is also reported in respective EU industry surveys (Deloitte Development LLC, 2011).

The policy maker, when promoting the development of this innovation case, should take the capacities of the actors implementing the respective technologies into account. The support for development of capacities of the actors is needed mainly in the development and implementation phases of the innovation. It is interesting to note that while the natural leader and policy maker during the initiation stage is the EC policy maker, in the implementation stage, this would naturally be the municipal authorities. On the EU level, as noted, there have been significant efforts. At the municipal level efforts need to be undertaken.

In addition, capacities are also one of the driving factors of innovation identified by Filippetti and Archibugi (2011) in times of economic crisis.

The assessment of actor capacities and their deficit is depicted for the initiation stage in table 1, while their importance for the implementation stage stressed in table 2.

3.2.3.5 Market Demand

Market demand is a very important component of this development and concerns both the ability of the manufacturing industry to reduce production and life cycle costs and “push” the local community for more efficient urban freight services. Growth rates and respective consumption levels may severely influence the enforcement of low-emission technologies as reduced consumption will, also, reduce emissions and the other impacts of city logistics on the environment. This factor influences all actors and the uptake of the innovation. Little can be done on this aspect, as it is dependent on local growth rates.

Filippetti and Archibugi (2011) in a recent study with respect to the impact of the recession on National Innovation Systems concluded that a substantial amount of firms have managed to maintain their investment for innovation, but the number of firms able to expand it has dramatically dropped, while the number of firms reducing investments in innovation has substantially increased. This trend is not distributed uniformly across the European economic space. This is in line with scholar expectations that severe recessions are prominently characterized by a major fall in demand and have negative effect on investment.

However, the ultimate effect on innovation investment can differ across countries, as there are forces driving both arguments.

In the SIF Matrix of the *Initiation Stage* (table 1), the deficit in market demand as identified in numerous studies is depicted as negative assessments. The need to turn positive in the *Implementation Stage* is shown in table 2.

3.2.3.5 Key Competitors

EVs a number of key competitors. Emission and noise control of urban freight may be also addressed by purely organizational /planning measures, which do not impose extra costs especially to distributors, or introduce, comparatively, less costly interventions. These approaches have been addressed in the city logistics literature and are promoted as best practices.

On the technology front, low emission levels are also achieved by other auto technologies, which in addition require less cultural change. From a welfare point of view they achieve similar results in terms of municipal objectives.

This negative effect in the promotion of EVs in city logistics is depicted in the negative assessment in both stages of development (Tables 1 and 2).

3.3 Policy recommendations as identified by the SIF Analysis

While analysing the current situation, the anticipated development of the next stage (implementation) along with the inter-relations required between actors and institutions in support of EVs uptake in city logistics was identified. This is illustrated in table 2 quantified with respect to the anticipated intensity.

One major change to be effected in order for the innovation to be implemented is the transfer of leadership (innovation champion) from the EC to the municipality authorities. The introduction of new local actors requires the development of strong networks and the gradual build-up of capacities. Standardization bodies need to proceed with the required "technology rules" in order to streamline the upstream and downstream market. Market demand is a crucial aspect related to all actors.

As EVs in city logistics reflect environmental measures to emission and noise reduction, market demand and competition is related to how these conditions could alternatively be met. Possibly, these conditions may be achieved independently of the adopted technology. For example the enhancement of relations between local actors, which is important in the process of adoption of innovation, might equally facilitate the adoption of other alternative fuel vehicles or even the implementation of managerial changes in support of city logistics. The result will then totally depend on the particular innovation leadership.

Already a number of leading municipalities have become active champions. Their intervention, as anticipated, is focused on providing preferential access for EVs (but also to other Alternative Fuel Vehicles) to city centers. Examples include: exempt from congestion charge (London); free parking (Copenhagen); single occupancy in high occupancy lanes (Ontario); the Autolib scheme for familiarization (Paris); La Poste commercial fleet (Paris);

the promise of introducing one thousand (1,000) EVs in government fleet by 2015 (London) (RAND Europe, 2012). However, while these are measures in support of EVs' adoption, the development of strong networks is needed for the deployment of the innovation, as shown in figure 2.

The continued economic crisis may have multiple effects. As described in the relevant section, it directly influences investments in innovation (Filippetti and Archibugi, 2011). It may also, however, reinforce the attractiveness of operational approaches in addressing city logistics issues or even decrease the problem overall as the economic crisis impacts consumption levels and overall mobility needs.

This latter condition also constitutes a threat for the innovation champions /leaders as having invested in the technology they may be "locked-in path", which may not prove to the benefit of society.

4. Conclusions

The present research takes a Systems of Innovation approach and proposes a "Systems of Innovation Framework" (SIF). This considers the actors and institutional factors of the framework as proposed by Woolthuis *et al.* (2005) and also the temporal conditions as introduced by Roumboutsos *et al.* (2011). The framework considers positive and negative correlations as introduced by Aronietis *et al.* (2012) and, finally, employs the socio-economic positive trend and the existence of the "initiator" as drivers of the respective analysis. In the current methodological development, the effect of other systems and markets is also considered, while inter-relations are quantified.

The proposed framework is used for assessing the potential of e-vehicles in city logistics[1]. Relevant information with respect to e-vehicles was collected through desk research. Findings indicate the dependence of the innovation uptake on the innovation leader/champion and the need to transfer leadership from central authorities to municipal authorities in order to move from the initiation stage to the implementation stage. The importance of strong networks between innovation actors and respective building of capacities, which may also work in favour of other competitive innovations, is also derived from the analysis. Hardly ever has the innovation process been addressed, especially in the transport sector, which is under-performing when it comes to innovation and technology transfer. The present research responds to this knowledge gap through the proposed Systems of Innovation Framework (SIF).

The Systems of Innovation Framework presented combines in a matrix the actors, the mechanisms and market conditions and provides a tool by which to qualitatively assess the current status and estimate future requirements and pre-conditions for innovation adoption. The approach is demonstrated to the specific innovation of introducing EVs in city logistics. Further testing and application of the methodology is expected to produce improved understanding of the innovation adoption process in transport as well as in other sectors.

The developed framework is interesting, both methodologically and from a social point of view. As to the method, it provides a novel approach for dealing with innovation processes rather than just outcomes. In that respect, the methodology is applicable to the various types

[1] The Case was initially studied for the INNOSUTRA, FP7 project «Innovation Processes in Surface Transport», contract: TREN/FP7TR/234076.

of innovation in transport and outside. For society and policy makers, it is relevant to see where and when innovations may be supported, by which actor. This is particularly true for the urban context, where transport may be becoming most innovative, and where social and environmental challenges are highest. At the same time, there is the economics of city logistics, where the city's last mile assumes the highest share of all chain costs. This supports the achievement of maximum results avoiding the negative impacts of inappropriate intervention.

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