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Non-technological innovations for sustainable transport

Alexandra Hyard *

University Lille 1, CLERSE (UMR CNRS 8019), France

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ABSTRACT

Because they are subject to economic but also to environmental and social pressures, transport companies are forced to innovate. These innovations are commonly focused on technologies to improve fuel economy and ultimately transform the energy basis of transport. Our purpose is to focus on non-technological innovations for sustainable transport, i.e., a more environmentally and socially friendly transport, in order to provide a taxonomy of trajectories of them, which contribute cost-effectively to this transport. To achieve this objective, first, we base this on a conception of transport not only as a manufacturing industry, but also as a service industry. And, second, we use the data from the European project on transport: CANTIQUE. At the end of our study, we conclude that there is not a single trajectory of non-technological innovation for sustainable transport, but a variety and that each of them has a particular logic.

1. Introduction

Managing greenhouse gas (GHG) emissions from transport is a priority. According to the European Commission [1], an increase of 74% is projected for GHG emissions from the EU transport between 1990 and 2050. If we examine the global emissions of CO_2 by transport mode, we could note that the emissions from light-duty vehicles dominate and are projected to continue to dominate, but that growth rates in road freight transport and in aviation are equally large. To curb the expected growth in these emissions, transport policies promote innovation but, generally, only technological innovation. For example, the last International Transport Forum [2], which brings together Ministers, leading decision-makers and thinkers, emphasises technological improvements as the core of the climate change policy in the transport sector. The technological innovations that improve fuel economy and transform the energy basis of transport are essential for GHG abatement. But these innovations must not obscure the role of non-technological innovations in reducing emissions. For example, innovations in traffic management or "green logistics" [3] are non-technological innovations that could reduce emissions related to road transport. Compared to technological innovations, non-technological innovations are less visible. Perhaps this is why politicians prefer technological innovations rather than non-technological innovations. But the latter also contribute towards the abatement of environmental problems caused by transport. Moreover, non-technological innovations are generally less expensive than the others. Thus, for example, RAND Europe [4] shows that non-technical innovations may contribute cost-effectively to reducing transport emissions. In consequence, non-technological innovations in transport must be taken seriously.

This article will focus on non-technological innovations for sustainable transport. It is not easy to define non-technological

* University Lille 1, Faculty of Economics and Social Sciences, 59655 Villeneuve d'Ascq Cedex, France. Tel.: +33 3 20 43 69 92; fax: +33 3 20 43 66 55.
E-mail address: alexandra.hyard@univ-lille1.fr.

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innovation. The second edition of the *Oslo Manual* thus offers a definition of non-technological innovation by stating the negative: “non-technological innovation covers all innovation activities which are excluded from technological innovation” [5]. Technological innovation itself is defined as “the introduction of a technologically new or substantially changed good or service or the use of a technologically new or substantially changed process” [5]. This being the case, the *Oslo Manual* reduces non-technological innovations to two categories: organisational innovations and managerial innovations. These innovations consist of:

> “the implementation of advanced management techniques, e.g., TQM, TQS; the introduction of significantly changed organisational structures; and the implementation of new or substantially changed corporate strategic orientations” [5].

The third edition of the *Oslo Manual* tries to differentiate these two kinds of innovation. Thus it suggests defining a marketing innovation as “the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing” and an organisational innovation as “the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations” [6]. Even if they are no longer described as such, these two kinds of innovation always refer to non-technological innovations, whereas the other two kinds of innovation, “product innovations and process innovations, are closely related to the concept of technological product innovation and technological process innovation” [6].

Yet classifying all the non-technological innovations into only two categories can prove to be difficult. For example, an innovation in how a company's after-sales service functions has as much to do with commercial innovation as with organisational innovation. Consequently we will not follow the non-technological typology proposed by the *Oslo Manual*, which we believe is not precise enough, but by one of the typologies offered by studies which deal with innovation in services. These studies naturally address the question of non-technological innovation to the extent that the services sector is a sector of low technological intensity. One could make a particular reference to the functional analysis of innovation, which has two advantages. Firstly, it offers a precise breakdown of non-technological innovations. Secondly, the functional analysis allows a dynamic vision of innovation by combining different functional innovations in a “trajectory”. However, we should add that the existence of an irreducible minimum of technology in the services sector will prevent us from identifying the trajectories of “pure” non-technological innovations. So the expression “trajectories of non-technological innovations” should be understood as “trajectories of mainly non-technological innovations” in the rest of the article.

The article's aim is to suggest a taxonomy of non-technological innovation trajectories for “sustainable transport”. By the latter expression, we refer to a transport, “that meets the needs of the present without compromising the ability of future generations to meet their own needs”, to repeat the formula of the Brundtland Commission [7]. In other words, a sustainable transport is a transport, which seeks to limit its negative effects on the environment and society.[1] The innovations in favour of sustainable transport are varied, in particular because of the diversity of transport activity: passenger transport, freight transport… Consequently, a taxonomy of trajectories of these innovations could help the authorities to decide when implementing innovation policies to support sustainable transport.

From a methodological viewpoint, this taxonomy will on the one hand rely on a preliminary re-assessment of the concept of transport. Indeed, in order to consider non-technological innovations in transport, it is necessary to re-assess this activity. This should be considered not only as an industrial activity but also as a service activity in order to be able to understand the innovations, which do not relate either to the product or the process. In contrast the taxonomy will be based on the results of the CANTIQUE (Concerted Action on Non-Technical Measures and their Impact on Air Quality and Emissions) project, which assess the effectiveness of non-technical innovations, based on a detailed review of past and present European experiences, and on the analysis and interpretation of results achieved so far.

Consequently, the article is structured in several sections. Section 2 will review the literature and explain the theoretical background. After a brief outline of sustainable transport and innovation (Section 2.1), we will look at the foundations of the non-technological innovations for sustainable transport (Section 2.2). Section 3 will draw up a typology of trajectories of transport innovation. Section 4 will present the CANTIQUE project. Section 5 will apply the taxonomy previously set out to the results of the CANTIQUE project and will try to provide reasons for the dominance of some trajectories of non-technological innovation over others in sustainable transport. Section 6 concludes with a summary of the key arguments and a proposed agenda for public decision-makers to develop non-technological innovations in transport.

2. Literature review and theoretical background

After a brief literature review of sustainable transport and innovation, we will look at the foundations of the non-technological innovations for sustainable transport.

2.1. Sustainable transport and innovation

The expression “sustainable transport” is recent, as it dates from the beginning of the 1990s. It is largely inspired by the definition of sustainable development provided by the

[1] This definition sums up the definition of the OECD [8], which defines a sustainable transport system as one that:

- “Allows the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations.
- Is affordable, operates fairly and efficiently, offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development.
- Limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise”.

Brundtland Commission, which emphasised three aspects of sustainability: economic, social and environmental [9–11]. As well as being recent, the expression "sustainable transport" is common. A quick bibliometric analysis in the *SCOPUS* database suggests that since 1992, 336 documents include this expression in their title.

But the expression "environmentally sustainable transport", which is closer than that of sustainable transport, is also widely employed in the economic literature [12–17]. Thus out of the 336 documents identified, 21 have the keywords "environmental impact", while 16 have the keywords "economic and social effects".

Focusing on the question of the implementation of sustainable transport, the economic literature subsequently addresses the theme of innovation [18–20]. Innovation is considered as the most promising way to introduce modes of transport that are more environmentally-friendly.

However, in most cases, innovation is often considered from the technological angle, in expert reports [21,22] and in the academic literature. To exemplify, let us look briefly at *Technological Forecasting and Social Change*. Many articles underline the role of technological innovation in transport in general [23–25] and in sustainable transport in particular [26–28]. This being the case, very few documents highlight the possibility of introducing non-technological innovations with a view to sustainable transport [29]. In this respect we can refer to the work of Kemp and Rotmans [30], which emphasises the role of institutional innovations which help to create social support, in order to accompany the establishment of more ecological modes of transport.

2.2. Foundations of non-technological innovation for sustainable transport

2.2.1. Transport: a manufacturing industry but also a service industry

Transport relates to communication networks and engineering structures but also to the fact of carrying to arrive at another place, a way of moving or arriving by means of a particular process.[2] Transport is therefore, by its nature, in both time and space. This dual position makes the transport product something that is both visible, because of the changes it can make to transported goods or people, and invisible. Although it is fundamental, these initial elements nevertheless highlight the ambiguous nature of transport activity: it is a material but also an immaterial activity.

In the history of economic thought, the definition of transport activity has varied over time. First, it should be noted that before the 19th century, this activity was not analysed as such. At that time, transport activity was linked to commercial activity, as the article "Transport", which Jaucourt [31] wrote for Diderot and Alembert's *Encyclopedia* (1751–1772), shows in particular. Several 18th century authors regarded this commercial activity as an important activity for economic affluence, that is, for the wealth of the nation [32]. With the rapid development of industrialisation during the 19th century and its impact on modes of transport (the growth in roads, hydro power installations, railways…), transport activity was gradually separated from that of trade. In a way, Say [33] contributes towards this movement by using the expression "transport trade", which he believed referred to the fact of "buying goods abroad in order to resell them abroad as well". By using this expression, the French economist thus shows that trade cannot be reduced to transport, which constitutes a particular activity of trade. But it is above all the works of engineers at the École des Ponts et Chaussées in the 19th century which encouraged transport to be set free from commerce. While seeking to provide the French territory with a bona fide transport network, these engineers also contributed conceptual advances in the field of transport. The most symbolic example of these engineers is, without doubt, Jules Dupuit [34], who laid the foundations for cost–benefit analysis by proposing the idea of a collective surplus to evaluate the net social impact of major transport infrastructure projects. Moreover, some engineers examined the question of knowing whether transport is a productive activity or not. This is the case with Clément Colson [35], who argues that transport is a productive activity, not of wealth, but of meeting human needs. Furthermore, he lists transport as a service since, in his view, every activity is a service. The concept of transport as a service, which Colson suggests at the very beginning of the 20th century, is not unrelated to that which Marx [36] bequeathed at the end of the 19th century, and which partly relates transport to an industrial activity:

> "The circulation, i.e., the actual locomotion of commodities in space, resolves itself into the transport of commodities. The transport industry forms on the one hand an independent branch of production and thus a separate sphere of investment of productive capital. On the other hand its distinguishing feature is that it appears as a continuation of a process of production *within* the process of circulation and *for* the process of circulation".

As transport is both outside and within the productive sector, for Marx, therefore, this activity is not only an industrial activity, namely manufacturing. In other words, transport is within the sphere of the entrepreneur, but it is also already within that of the consumer. In the end, it is this tension between these two spheres, which can explain the diverse interpretations on the nature of transport activity. And yet, as we will see in the next paragraph, these interpretations still have repercussions today.

Today the nature of transport activity can still be interpreted differently.

For a lot of authors [37,38], transport can be perceived as a material and therefore as an industrial activity. As Savy [39] shows, the idea that underlies this assertion is the following: transport is material through its effects and its means. These authors argue that transport changes the physical characteristics of the people or goods that it moves in space. Furthermore, the transport of people or of goods requires labour and equipment. We should note, however, that these authors accept a particular definition of industry and not the standard one, by which industry covers all economic activities which aim to exploit raw materials, energy sources and their conversion, as well as that of semi-finished products in production or consumption goods. In this case, transport does not transform raw materials but products that are already finished.

[2] This definition refers to the etymology of the noun "transport", which comes from the Latin *trans* and *portare*, *trans* meaning "through" and *portare* "to carry".

Table 1
The variety of operations coexisting in freight transport services.
Source: [45].

	Material operation (M)	Treatment of information (I)	Relational and contact operation (R)	Methodological operation (C)
Operations concerning	Physical transport, handling, loading, unloading	Treatment of information flows inside the firm and with other firms, tracing/tracking	Direct contacts between the driver and the shipper's customers, feedback on quality of products and distribution	Coordinance and organize the different operations; find necessary competencies

Conversely, according to other authors, notably Lefebvre [40], transport can also be regarded as an immaterial activity, and therefore as a service activity. We can thus take the definition of service provided by Hill [41] and say that transport is "a change in the condition of a person, or a good belonging to some economic unit, which is brought about as the result of the activity of some other economic unit, at the request or with the agreement of the first unit". We can also take the traditional features of services and apply them to the transport field. By following Stanback [42], we can say that transport is non-storable. Goods that have been moved can be stored, but we cannot store the act by which these goods are moved. By referring to Fuchs [43], we can say that transport is co-produced. The transport of goods therefore makes shippers and carriers act together: the former have to ensure a technical balance between the cargo and the vehicle, while the second have to deal with delivering the goods. By this time referring to the work of Gallouj [44], transport activity can be divided into four operations:

- Operations consisting of dealing with tangible objects, that is changing them, moving them… (M)
- Operations consisting of dealing with codified information, that is producing it, entering it… (I)
- Operations based on contact with and the relationship with the customer (R)
- Operations consisting of organising collective techniques or knowledge (C).

As Table 1 shows, such a breakdown for freight transport has already been completed. The same breakdown can also be applied to passenger transport (see Table 2).

This dual way of understanding transport activity, both as an industrial and as a service activity, also comes to light when we examine how transport is positioned in time. By using the distinction employed by Gadrey [46] between immediate output and mediate output (still called *outcome*), we can identify two different transport time horizons: one short term; the other medium and long term. These two time horizons refer to two ideas of transport activity that were previously mentioned. The industrialist concept of transport thus favours the immediate output of activity, whereas the service concept of transport considers output that is both mediate and immediate. This dual temporal positioning in relation to freight transport has recently been illustrated (see Fig. 1).

This dual time horizon of transport activity has several consequences. One of these concerns the definition of the productivity of this activity. Supporters of the industrialist vision of transport measure the productivity of transport by using immediate output, namely through the following ratios: tonne/km or passenger/km. But advocates of the service vision of transport show that these ratios are not suitable for measuring transport productivity (which, incidentally, they call "performance") because of the diversity of the transport service's temporal positioning, and thus propose other measurement tools concerning the transport of goods.

The dual temporal positioning of transport has several other consequences. If we have focused on this consequence in particular, it is because the problem of measuring transport productivity helps to conceal the process of innovation in this sector.

2.2.2. The debate on service innovation

When in the 1960s studies on innovation began to emerge as an area of research in its own right, innovation was primarily considered from the manufacturing viewpoint [48]. Thus, of the five dimensions of Schumpeterian innovation theory [49] — product, process, market, input and organisational innovation — only the first two dimensions were really taken into consideration. This interest in innovations of product and process, which emerged from 1966 onwards with Schmookler [50], who renamed these innovations respectively "product technology" and "production technology", continued over time, and still exists even today. Thus the concept of product innovation is still influential nowadays [51]. As for process innovation, this was divided into "technological process innovations" and "organisational process innovations" by the dynamic approach of Utterback and Abernathy [52]. Edquist et al. [53] still used this presentation.

Today there is an extensive literature on innovation because of the developments suggested by orthodox economics, which no longer compares innovation to an exogenous factor of production, in this case technical progress,[3] but also by heterodox economics and, in particular, by neo-Schumpeterian economics. Because it is based, first and foremost, on Schumpeter's analyses, the neo-Schumpeterian economy has, of course, re-examined the idea of innovation. If we accept this simplification, innovation is presented here as a non-maximising process, interactive, cumulative, specific and institutionalised. One of the merits of this concept of innovation, whose characteristics reveal in particular the influence of the evolutionary perspective on the neo-Schumpeterian economy,[4] is to provide a realistic vision of innovation. However, this is mainly considered from the technological angle [56] because of the association made by Schumpeter between innovation and technical change. This is why research on neo-Schumpeterian economics in relation

[3] For an overview of this development, see [54].
[4] On this influence, see in particular [55].

Table 2
The variety of operations coexisting in passenger transport services.
Source: author.

	Material operations	Treatment of information	Relational operations	Methodological operations
Transport operations	Physical transport of passengers by plane, train…	Communication to passengers of the departure and arrival times of planes, trains…	Giving passengers directions in stations and airports.	The organisation of inter-modal transport for tourists.

to innovation, which has been carried out over the last 25 years,[5] has mainly been focused on the conditions in which technological innovation emerged [58] and on the models of technological innovation.[6]

Following the rediscovery of Schumpeter at the beginning of the 1980s by Nelson and Winter in an evolutionary perspective, in particular, and the studies carried out by neo-Schumpeterian economics on innovation, in general, the service economy has also sought to understand economic change, and notably the three dimensions of the Schumpeterian theory of innovation, which had previously been neglected. However, the service economy has an ambiguous relationship with the Schumpeterian economy [60]. On the one hand, in the tradition of Schumpeter, the service economy criticises the lack of realism of the orthodox vision of innovation. Indeed, even by having endogenised the technical factor, this is more concerned with the result of the process of innovation than the process itself [61]. On the other hand, a section of the service economy criticises Schumpeter for having favoured technological innovation over non-technological innovation.[7] This criticism is linked to the desire of some service economists to discuss the idea by which service innovation amounts solely to adopting new technologies developed by the manufacturing sector. This idea is found especially in the 1980s [63], when the first studies on innovation in the services appeared.[8] Because of its ambiguous relationship to Schumpeterian innovation theory, the service economy in fact appears to be closer to evolutionary economics, at least to that of Nelson and Winter,[9] than to the neo-Schumpeterian theory. It is doubtless this closeness, which leads Gallouj [67] to emphasise the evolutionary and non-neo-Schumpeterian basis of his typology. In a way, the closeness of the service economy to the evolutionary perspective is also discernible in the very concept of innovation. As we have already noted, the concept of innovation used by the service economy is that of “problem-solving” proposed by Nelson and Winter with reference to Simon. However, by favouring the concept of innovation as “problem-solving”, as inherited more from Simon than from Schumpeter, the service economy takes on a broad definition of innovation with blurred boundaries.

5 For recent developments, see [57].
6 For a survey of the theme, see [59].
7 Conversely, supporters of the neo-Schumpeterian approach to innovation in services [62] state the possibility of conceptualising service innovation as a specific case of service development with a reference to Schumpeter. This conceptualisation is based on the idea by which many service firms do not excel in the production of technologically advanced artefacts, but mainly in its creative use.
8 For a review of the literature on the subject, see [64,65].
9 For a survey of trends in evolutionary economics, see [66].

3. The trajectories of innovation for sustainable transport

Following Gallouj [68] and Coombs and Miles [69], we can reclassify the literature of innovation in services according to three main approaches:

- A technologist approach, focused on the diffusion of industrial origin technological innovation in services, the origins of which can be found in Pavitt's sectoral taxonomy [70].
- A service approach, which emphasises the particular characteristics of the services in relation to innovation [71].
- An integrationist approach, which rejects the good/service divide, suggests an analysis of innovation, either based on the Lancaster [72] work [73] or on a functional approach [74,75].

As the brief review of the debate on the literature on innovation that we have carried out shows, there are three main approaches to classifying the literature on innovation in services. In this study, we will focus on the integrationist approach because it is the most relevant to our area of study, the transport sector. Because of the blurring of the boundaries between goods and services, this approach allows us to deal with innovations within the transport sector, which are located between the industrialisation of its services and the expansion of the tertiary sector in its production [76]. Of the two types of integrationist approach, by the Lancasterian characteristic-based[10] approach, or by functions, we will choose the latter. The integrationist approach by functions appears well suited to the operational decomposition of service, as we have already seen.

Initially, the concept of the functional breakdown of the product was applied to services. By extension, it can also be applied to innovation in service. This innovation can be broken down into four types of function or of operation:

- Innovation that involves the material function of service (M)
- Innovation that involves the function of treatment of information (I)
- Innovation that involves the relational function (R)
- Innovation that involves the methodological/organisational function (O).

The advantage of the functional approach is that it allows a lateral view of innovations, both of goods and of services. The disadvantage of this breakdown is that it presents a fragmented vision of the product. In fact, transport firms rarely carry out

10 For a brief history of the application of the characteristic approach to the innovation economy, see [77].

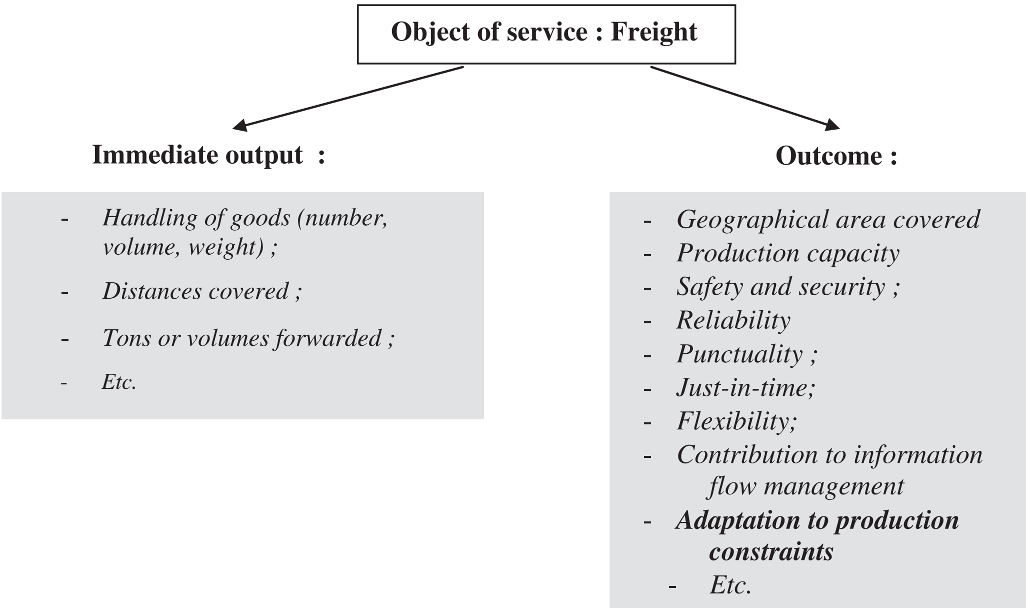

Fig. 1. Indicators of immediate output vs. outcome of freight transport services.
Source: [47].

just one function, instead they carry out a combination of functions. It is the same for innovations. When transport firms innovate, these innovations often involve several dimensions. So, to understand the multiplicity of transport innovations, our typology will be based on trajectories of innovation, each of which consists of a range of innovations, and not on simple forms of innovation. The typology is presented in the following way:

- Trajectory of mainly[11] informational innovation: (M) + I
- Trajectory of mainly relational innovation: (M) + R
- Trajectory of mainly organisational innovation: (M) + O
- Trajectory of mainly informational and relational innovation: (M) + I + R
- Trajectory of mainly informational and organisational innovation: (M) + I + O
- Trajectory of mainly relational and organisational innovation: (M) + R + O
- Complete trajectory of innovation: (M) + I + R + O.

The expression "innovation trajectories" is borrowed from the notion of technological trajectory [78,79]. This notion emerges from path dependency, which characterises the evolutionary vision of innovation, encouraged by the works of Nelson and Winter [80], Dosi [81] or also Rosenberg and Birdzell [82]. According to this interpretation, innovation is in fact considered as a process of learning, which is localised, partly tacit but also irreversible. In the same vein, Pavitt [70] outlines five technological trajectories with their typical core sectors, based on their sources of technology, tasks of technology strategies, requirement of users, and possibilities of appropriation. Pavitt's article was taken up by several authors [83,84], who try to rethink the category of *supplier dominated firms*, which initially included the whole of the services sector.[12]

4. Data

To illustrate and apply the typology below, we use the CANTIQUE project.[13] The main objective of this project is to inform policy-makers on the potential of non-technical transport innovations to improve air quality and reduce emissions of greenhouse gases.

4.1. The project's aims

The CANTIQUE project is a concerted action performed within the European Commission 4th Framework Programme — Transport RTD projects. Its main objectives are:

- to produce guidelines for policy decision makers for the selection of cost efficient non-technical innovations to reduce climate and pollutant gas emissions;
- to give input for policy development in the field of emission reduction and to indicate future research needs.

CANTIQUE was specifically designed to assess the effectiveness of non-technical innovations, based on a detailed review of past and present European experiences, and on the analysis and interpretation of results achieved so far. This project covers all transport innovations other than

[11] Insofar as we are only interested in non-technological innovations, we will leave to one side innovation, which concerns the material function. However, as we said in the Introduction section, we are aware of the fact that purely non-technological innovations are excessively rare. This is why we will use the term "mainly" and we will retain the letter M in the typology in order to recall the irreducible share of trajectories of non-technological innovations.

[12] Tether [85] has recently completed these studies in showing intra-sectoral and not only sectoral differences in service innovation.

[13] See [86].

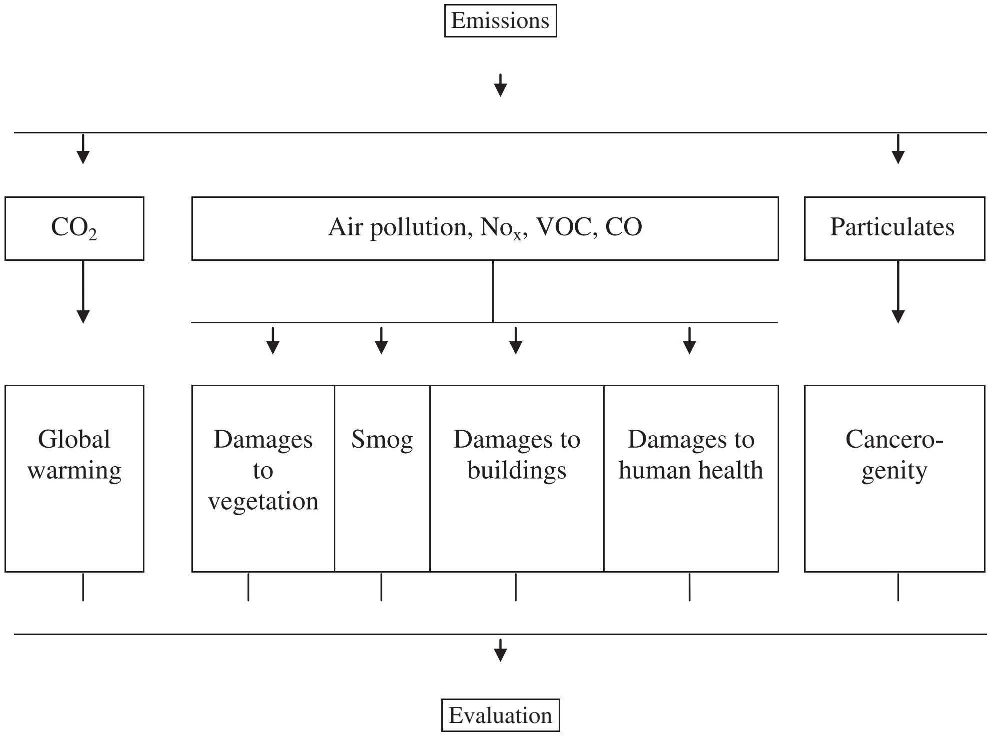

Fig. 2. Process of evaluating pollutant emissions.
Source: [86].

prescriptive new measures affecting vehicle and fuel technology supply.

4.2. The project's methodology

Because of the significance of the road transport in environmental problems, the majority of the innovations studied by the CANTIQUE project concerns this type of transport. The particular pollutant influence on air quality mainly depends on the concentration of emission components. The emission components studied are:

- CO_2 (carbon dioxide)
- NO_x (nitrogen oxides)
- CO (carbon monoxide)
- VOC (volatile organic compound).

To evaluate the impacts of pollutant emissions, the project adopts the economic view, i.e., the restricts of the emissions on the economic abilities and the level of welfare (see Fig. 2). The methods used comprise Multi-Criteria Analysis, Cost-Efficiency Analysis and Cost–Benefit Analysis.

The CANTIQUE project selects many non-technical innovations:

1. Park & ride
2. Car pooling
3. Dial-a-ride
4. Road pricing
5. Parking pricing
6. PT fare structure
7. Access control, including low emission zones
8. Parking management
9. Pedestrian and cycling
10. Public transport measures (priority, increased frequency)
11. Intelligent transport systems/urban traffic control measures
12. Ramp metering
13. Staggered activity time
14. Taxes (on fuel, vehicles)
15. Fleet and freight management
16. Tele-working
17. Information to users.

These innovations have been classified in three main groups (see Table 3):

- Pricing
- Regulation
- Infrastructure.

The data used in CANTIQUE for the evaluation of innovations have been drawn from the project, studies and experiments previously carried out on European as well as on national, regional and local levels: London, Stuttgart, Como, Athens, Lyon, Turin, Gothenburg, Cologne, Netherlands area wide and Germany area wide (see Table 4).

4.3. The project's results

In order to compare studies, which have analysed similar bundles of pollutants, the available case studies have been

Table 3
Three packages of non-technological innovations for sustainable transport.
Source: [86].

Category	Innovations
Pricing	- Road pricing - Parking pricing - PT fare structure - Taxes
Regulation	- Access control - Parking management - Fleet and freight management - Information to users - Car pooling - Dial-a-ride - Staggered activity time - Tele-working
Infrastructure	- Park & ride - Pedestrian and cycling - Public transport measures - Ramp metering - TS

divided into two sets of measures with the same combination of emission saved:

1. a larger group (14 occurrences) considering CO and NO_x together;
2. a more restricted group (7 occurrences) with CO, NO_x, VOC and CO_2.

Table 5 shows the cost–benefit ratio for reducing CO and NO_x emissions. In this group of measures are prevailing pricing and regulative measures.

Table 4
Projects and studies for CANTIQUE.
Source: [86].

- ADONIS
- AIUTO
- An evaluation of transport measures to meet NAQS objectives
- CAPTURE
- City Logistics Cologne
- CLEOPATRA TR 1012
- COST 321
- Effectiveness of alternatives to reduce traffic-related CO_2 emissions up to 2005
- ESTEEM
- EUROTOLL
- GAUDI Project
- INCOME
- MASTER
- Options to reduce NOx and NMVOC emissions
- Overall economic cost-effectiveness analysis of measures to reduce transport's CO_2 emissions in Austria
- Overall economic evaluation of rationalizing measures in road transport
- QUARTET PLUS
- REFORM
- Road pricing and toll financing
- SPARTACUS
- START
- SURFF TR 1053
- TRANSPRICE
- TRENEN II — STRAN

Table 5
Benefit/cost ratio assessment for reducing CO, NO_x — euro gained per 1 euro invested 1995 prices.
Source: [86].

Regulations traffic control (London Lez)	6083
Parking charges (Athene)	4932
Road pricing (Como)	2420
Parking charges (Lyon)	1666
Regulations traffic control (London)	1639
Packages TDM (Como — park pricing & car pool)	0420
Road pricing (Athens)	0394
Road pricing (Stuttgart)	0354
Parking charges (Como)	0319
Road pricing (London)	0315
Packages TDM (Como — park pricing & dial-a-ride)	0313
Infrastructure investment (Athens bus lanes)	0286
Infrastructure investment (Turin)	0163
Packages TDM (Como — park pricing & pub. transport incre.)	0067

Table 6
Benefit/cost ratio assessment for reducing CO, NO_x, VOC and CO_2 — euro gained per 1 euro invested 1995 prices.
Source: [86].

Parking charges (Athene)	10,676
Regulations traffic control (London Lez)	9300
Parking charges (Lyon)	3573
Regulations traffic control (London)	2507
Road pricing (Stuttgart)	0710
Road pricing (London)	0482
Infrastructure investment (Turin)	0255

Table 6 shows cost–benefit values for reducing CO, NO_x, VOC and CO_2 together. Pricing and regulatory measures show high cost–benefit values, while infrastructure investments show the lowest value (0.255 Euro gained per 1 Euro invested).

Table 7 gives average cost-effectiveness values in kEuros per tonne reduced and shows that lowest cost-effectiveness values are mainly in relation to pricing and regulatory measures, with the notable exceptions of CO_2 values, which are lower for pricing and infrastructure measures.

5. Results: the diversity of non-technological innovation trajectories for sustainable transport

If we apply the previously outlined taxonomy to the non-technological innovations studied by the CANTIQUE project, we end up with Table 8.

Before going further, we should note that the innovations contained in this table are mainly initiated by the State. These

Table 7
The average cost-effectiveness values in kEuros per tonne.
Source: [86].

Policy	Cost-effectiveness values 000/T		
	CO_2	NO_x	CO
Pricing	0127	25,562	4326
Infrastructure	0704	120,857	20,183
Regulations	1663	3669	1492

Table 8
The variety of operations in innovations for sustainable transport.
Source: author.

	Material innovation M	Information innovation I	Relational innovation R	Organisational innovation O
Park & ride	+		+	+
Car pooling			+	+
Dial-a-ride			+	+
Road pricing				+
Parking pricing				+
PT fare structure				+
Access control				+
Parking management				+
Pedestrian and cycling	+			+
Public transport measures (priority, increased frequency)	+			+
Intelligent transport systems/urban traffic control measures	+	+		+
Ramp metering	+			+
Staggered activity time				+
Taxes (on fuel, vehicles)				
Fleet and freight management				+
Tele-working		+		+
Information to users		+		+

top-down strategies have appeared because of the nature of innovations itself. Thus, if taxes and institutional innovations are largely of public origin, it is because only the State has the right to levy taxes and to fix the policies that are intended for the whole of the community. Furthermore, the State is the only one able to bear the financial cost of the infrastructure innovations; this is what explains the public origin of these innovations.

It is easy to establish that the non-technological innovation, which emerges from Table 8 in terms of sustainable transport, is of organisational form. The primacy of this form is not surprising. Indeed, in order to manage greenhouse gas from passenger transport and freight transport, innovations must take into account the links between these two forms of transport and the links between the actors within each form of transport.

But, the organisational innovation is sometimes combined with two other types of non-technological innovation: informational and relational innovations. Thus, several trajectories of mainly non-technological innovation emerge from Table 8:

- trajectory of mainly organisational and informational innovation: (M) + O + I
- trajectory of mainly organisational and relational innovation: (M) + O + R.

These trajectories of innovation have many sources, which are also very often interdependent. Firstly, the trajectories are closely linked to the nature of public authority. Indeed, a local public authority may create some trajectories of mainly relational innovations rather than a central public authority. Moreover, these trajectories are closely linked to the nature of

Table 9
The refined variety of operations in innovations for sustainable transport.
Source: author.

	Material innovation M	Information innovation I	Relational innovation R	Organisational innovation O	
				Pure	Mixed
Park & ride	+		+	+	
Car pooling			+	+	
Dial-a-ride			+	+	
Road pricing					+
Parking pricing					+
PT fare structure					+
Access control				+	
Parking management				+	
Pedestrian and cycling	+			+	
Public transport measures (priority, increased frequency)	+			+	
Intelligent transport systems/urban traffic control measures	+	+		+	
Ramp metering	+			+	
Staggered activity time				+	
Taxes (on fuel, vehicles)					+
Fleet and freight management				+	
Tele-working		+		+	
Information to users		+		+	

exogenous shocks sustained by the public authority (new external technologies, new markets, new institutional rules and new forms of competition). But they also, and in a crucial way, depend on the "path" followed by the authority, which determines both its internal constraints (flexibility and attitude in the face of change, degree of controlling the internal and external environment) and its abilities and competences in terms of adaptation and innovation.

As indicated in Tables 4 and 5, the non-technical innovations, which contribute cost-effectively to reducing transport emissions, are traffic control regulations, parking charges and road pricing, i.e., pricing and regulative measures. These measures correspond to organisational innovation because these new measures tend to reorganise routines and procedures for the conduct of passenger or freight transporter. We can refine the typology again, notably by taking the distinction made by Hamdouch and Samualdes [87] between pure organisational innovations and mixed organisational innovations, i.e., organisational innovations of a commercial nature. Unlike the first, the second consists of the implementation of new organisational methods in the practices of individuals or firms, which also involve changes in the appearance or the price-setting of a product (see Table 9). Generally, the State develops pure organisational innovations (regulation innovations) rather than mixed organisational innovations (pricing innovations). In spite of the effectiveness of the pricing innovations, they have a continued effect on the corporate profitability and the income of households. Indeed, these innovations may restrict economic growth. Sustainable transport has three aspects: economic, social and environmental. Thus, the State cannot sacrifice economic development for resolving environmental problem.

6. Conclusion

6.1. Summary of results

Innovations for sustainable transport are plural: technological but also non-technological. It is the latter type of innovation on which we focus and which we try to reclassify. To do this, we proceed in the following way.

First, in Section 2, we review the literature on sustainable transport and explain the theoretical foundations of the non-technological innovations for sustainable transport.

Because of the service specificities of transport, in Section 3, we draw up a typology of forms of transport innovation based on the economics of services. Thanks to this approach, we are able to address the question of non-technological innovation in the transport sector, on the one hand in a more detailed way than that proposed by the *Oslo Manual*, and on the other hand in a dynamic way through the concept of "trajectories of innovation".

In Section 4, we present the results of the CANTIQUE project.

Finally, in Section 5, we identify several non-technological innovation trajectories. Because they mainly are organisational, these trajectories of innovations consist of reorganising the routines and procedures for the behaviour of transport users. This typology of sustainable transport trajectories of innovation gives a coherent description of the changes that the freight and logistics sector has undergone in the past 25 years — from moving heavy goods from A to B to managing complex logistic systems, including a rising share of information flows.

6.2. Policy implications and further research

We focus on the non-technological trajectories of innovation, because they seem to be the most promising for sustainable transport and thus they would be taken seriously by public decision-makers. However, that does not mean that the authorities should neglect technological innovations. These two types of innovation should be combined. Yet public decision-makers will doubtless still continue for some time to favour technological innovations to deal with the environmental and social problems posed by transport today. It will be difficult to change the situation just by using the argument we have observed of the correspondence between the innovation trajectories and the current development of transport. But, linked to the argument of a lower monetary cost, it will certainly elicit a favourable response from public decision-makers.

Because of the innovations contained in the CANTIQUE project, the taxonomy was applied to non-technological innovations, of the top-down type, focused on the environmental dimension of sustainable transport. It would be interesting to broaden the range of innovations to the economic and social aspects of sustainable transport and to apply the taxonomy to a lot of innovations of a bottom-up type. What would be the trajectories followed by the bottom-up innovations? One could suppose that the prevailing trajectories of these innovations are of organisational form again. This form is an answer to the pressure from shippers and the transformation of modes of production, in particular the development of more flexible modes of production, which rely heavily on flexible logistic systems and information flows [88]. However, it is not obvious that the companies are committed to innovations that seek to promote the different facets of sustainable transport. Admittedly companies can consider the objective of sustainable transport to be a commercial argument, which allows them to improve their profitability, and for this reason it can be pursued by the private sector. However, these innovations, which have a private origin, only necessarily affect some aspects of sustainable transport. It is not in a company's interest to develop major innovations, which respond to the environmental and social problems posed by transport. Only the State, driven by public interest, can develop such innovations.

Examining the different non-technological innovations reveals the predominant significance of organisational innovations. By their nature, these innovations seem to be well adapted to the complex character of sustainability. But these innovations mean long processes that are likely to encounter many obstacles. These obstacles include costs but also resistance to change, a lack of time (notably management time), or the lack of qualifications. As shown by the works of Mohnen et al. [89] and Galia et al. [90] these barriers can be interdependent and can reinforce each other. It is also against these organisational inflexibilities that the authorities must fight.

What also emerges from this typology is that the share of informational and relational innovations remains still too weak. Let us take the second innovation. It is surely not easier to develop an innovation consisting of dealing with the behaviour of a passenger or a freight transporter. However, there are several relational innovations, like the establishment of a new policy of freight logistics (new method of traceability launched…), that are in favour of sustainable transport, insofar as they involve the creation of new partnerships within the supply chain. Thus, the relational innovation that may be a source of non-technological innovations capable of promoting sustainable transport, that remains unexploited by the authorities. The latter could make more use of the individual transport user or the company to be the very support for innovations. For example, it would be a question of developing new user behaviour, a new offer of logistical services upstream and downstream of the supply chain. This source of innovations would merit all the more attention since it is cost efficient, as it involves technical mediums to a certain extent.

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Alexandra Hyard is Doctor of the Ecole des Hautes Etudes en Sciences Sociales of Paris. In 2005, she won the prize “Maurice Picard” given by the Chancery of the Universities of Paris. Now, she is Associate Professor at the University Lille 1. Her research interests are the economics of services (sustainable services) and the evolutionary economics (Neo-Schumpeterian economics).