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Incentives for modal shift towards sustainable mobility solutions: A review

Fawaz Salihou

Institut VEDECOM, 23 bis, Allée des Marronniers, 78 000, Versailles (France)
Laboratoire Genie Industriel, CentraleSupélec, Université de Paris Saclay, 9 rue Joliot-Curie,
91910, Gif-sur-Yvette (France)

Rémy Le Boennec

Institut VEDECOM, 23 bis, Allée des Marronniers, 78 000, Versailles (France)

Julie Bulteau

Université de Paris-Saclay, Université de Versailles Saint-Quentin-en-Yvelines, OVSQ,
CEARC EA 4455, Guyancourt (France)

Pascal Da Costa

Laboratoire Genie Industriel, CentraleSupélec, Université de Paris Saclay, 9 rue Joliot-Curie,
91910, Gif-sur-Yvette (France)

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Abstract: Despite its advantages, road transport generates negative externalities. To reduce them, the use of single-occupant vehicles (SOVs) must be limited to promote other transport modes (active modes, public transport and shared mobility). This paper aims to examine the economic and non-economic incentives (as persuasive technologies and psychological factors) for a modal shift to sustainable mobility solutions. The independent application of these two types of measures has revealed effectiveness but also limitations. Economic incentives pose a problem of social acceptability for economic agents and limit the freedom to drive. The boomerang effect and ineffectiveness in specific cultural and economic contexts are the main limitations of non-economic incentives. To maximize effectiveness in terms of modal shift towards sustainable mobility solutions, economic and non-economic incentives need to be combined.

Keywords: Economic incentives; Non-economic incentives; Persuasive technologies; Psychological factors; Externalities; Modal shift; Transport mode; Single-occupancy vehicle; Sustainable mobility; Review

JEL classification: R41, R48 H23, H39

Incitations au report modal vers des solutions de mobilité durable : un état de l'art

Résumé : Malgré ses atouts, le transport routier génère des externalités négatives. Pour les réduire, l'autosolisme doit être limité au profit d'autres modes de transport (modes actifs, transports collectifs et mobilité partagée). Cet article examine les incitations économiques et non économiques (technologies persuasives, facteurs psychologiques) en faveur d'un report modal vers des solutions de mobilité durables. L'application indépendante des deux types de mesures a révélé son efficacité mais aussi ses limites. Les incitations économiques, qui limitent la liberté de conduire, requièrent l'acceptabilité sociale des agents économiques. Effet boomerang et inefficacité dans des contextes culturels et économiques spécifiques sont les limites des incitations non économiques. Pour maximiser le report modal vers des solutions de mobilité durable, les incitations économiques et non économiques doivent être combinées.

Mots clé : Incitations économiques ; Incitations non-économiques ; Technologies persuasives; Facteurs psychologiques; Externalités; Report modal; Mode de transport; Autosolisme; Mobilité durable; Etat de l'art

Classification JEL: R41, R48 H23, H39

1. Introduction

Decades of urban expansion, economic development and demographic explosion have driven strong growth in travel demand (Diao, 2019). In France, domestic passenger transport reached 941 billion passenger-kilometers in 2017 against to 886 billion in 2012 (+6.2%), and the modal share of individual transport is 80.5% against 19.5% for public transport (Commissariat général au développement durable, 2019). However, increased car use generates negative externalities such as air pollution, road congestion, road accidents, and noise. The share of road transport in France's final-energy consumption was 94.7% in 2017. Road transport accounts for 94% of CO₂ emissions from the transport sector in 2019 (CITEPA, 2021). After several consecutive years of decline, the number of deaths among motorists in France no longer decreases over the recent period (2013-2019) (ONISR, 2021). Reducing these externalities is a major challenge that could positively impact both the environment and social welfare. The use of sustainable transport modes would reduce these externalities. Sustainable transportation generally refers to all combinations of government policies, infrastructure, technologies, and behaviors that reduce negative externalities (environmental and social) while maintaining or improving economic outcomes (Stephenson et al., 2018). Bannister's (2008) sustainable mobility paradigm presents actions such as reducing the need to travel, encouraging modal shift, reducing the trip length. All of these actions involve various policy measures. The modal shift involves measures that can reduce car use by promoting other transport modes that are sustainable.

Various types of measures can be designed and implemented by employers (Root, 2001), economic operators and local authorities (Aguilera-Garcia et al., 2021) to reduce the negative externalities associated with road transport and encourage modal shift. Economists advocate economic measures, such as road pricing (Arnott et al. 1985, 1990, 1993; Le Boennec, 2014; Bulteau, 2016), whereas scholars in other disciplines favor other types of measures, such as psychological factors and persuasive technologies (Steg, 2003; Cialdini, 2003; Donald et al. 2014, Bucher et al. 2019). Legal aspects will not be considered in the scope of this article.

Here we have assumed that sustainable mobility is described by the modes of transport used as an alternative to single-occupancy vehicles (SOVs) to reduce the negative externalities associated with road transport. These include public transport, shared mobility (carpooling and car-sharing), and active modes (walking, cycling, scooters, etc.).

This review aims to answer the following questions: what types of incentives can induce modal shift towards active modes, public transport and shared mobility, and to what extent? What is the most efficient incentive method—economic or non-economic? How can the effectiveness of these measures be optimized in terms of prompting modal shift? We answer these questions by combining bibliographic analysis with bibliometric analysis. To the best of our knowledge, this is the first review to analyze both economic and non-economic incentives for modal shift.

The article is structured as follows. Section 2 presents a review of selected types of economic and non-economic incentives for a modal shift towards sustainable mobility solutions. Section 3 presents the methodology. Section 4 compares the different forms of incentives in terms of effectiveness and discusses the results. Finally, Section 5 ends with conclusions.

2. Literature review

The presence of externalities related to road transport is characterized by the gap between social and private costs (Bontems & Rotillon, 2013). Policymakers then need to close this gap by

internalizing the externalities, which will positively impact both the environment and social welfare. The previous literature has shown that the application of specific economic measures can play this role by helping to change the costs of the behaviors that cause externalities. These include price regulations (taxes and subsidies), quantity regulations (tradable emission permits, allowances, etc.), and private internalization solutions (like Low Emission Zones). Nevertheless, as the focus of our study is solely on economic instruments able to induce behavior change, we consider only price and quantity regulation. Norms are prohibitions that constrain a class of users without allowing a tradeoff between modifying or not modifying one's travel behavior.

2.1. Economic incentives

2.1.1 Price regulations

Taxes. External costs represent additional costs imposed by drivers on other users and the rest of society when they decide to make more trips. These costs are not taken into account by drivers. (Nash & Matthews, 2005). To this end, economists propose to internalize the negative externalities of car travel by increasing the cost of driving. Road pricing can be used to encourage a modal shift from SOVs to other transport modes (Menon et al. 1993). The most common pricing measure is the fuel tax. Parumog & Acharya (2007) studied the characteristics of road-transport taxes and charges in East Asia and found a negative relationship between retail gasoline-price tax and congestion. Storchmann's (2001) study in Germany shows that fuel tax increases have three effects. First, the distance travelled by cars for leisure and vacations decreases. Second, the increase in tax revenue due to the time needed to adapt to the new conditions generates a positive tax effect in the short term. Finally, the modal shift from SOVs to public transport occurs only during peak hours. Ang & Marchal (2013) show that fuel tax can be useful for a modal shift if the authorities jointly invest in public transport and other alternative modes.

Other research proposes congestion charging as an economic instrument to reduce externalities such as congestion and pollution (Le Boennec, 2014; Bulteau, 2016; Wu et al. 2017). The most widely used instrument is the urban toll, which consists of charging motorists if they want to travel in urban or demarcated areas. Prud'homme & Bocarejo (2005) show that the introduction of the London toll increased the modal share of public transport from 50% to 60%. The ADEME report (2014) on air quality assessment shows that the introduction of Milan's green toll has increased the number of passengers on public transport by +3%, the commercial speed of buses by +8.1%, and the supply of public transport by an additional 1,300 daily trips.¹ In 2008, the average number of SOVs per day decreased by 21%, and there was a positive impact on the environment. However, there was a rebound effect in the following two years, as congestion in Milan increased due to the composition of vehicles crossing the toll plaza, where a massive influx of clean cars resulted in a 4% increase in SOVs in 2009 and 5% more in 2010 (Danielis et al. 2011). Another economic price regulation policy is high occupancy toll (HOT) lanes, which are instituted to allow carpool users to use these lanes for free. Those who do not carpool can borrow it for a fee (Guensler et al., 2019 a). Pessaro et al. (2013) showed that the implementation of HOT lanes resulted in increased transit ridership in the United States (23% in Minneapolis and 53% in Miami).

¹ ADEME is the French agency of ecological transition.

Parking policies are another widely-used strategy applied in economics to urban contexts. There is ample literature on the influence of parking policies on transport mode choices and the revenue they can generate for local authorities. Dell'Olio et al. (2014) proposed mobility policies as part of a package to promote the use of more sustainable transport modes at the University of Cantabria, on the Llamas campus, in Spain. They showed that university parking pricing can reduce car use and generate revenue that can be reallocated to the deployment and use of more sustainable transport modes, such as shared-bicycle systems and buses. Hammadou & Papaix (2015) showed that the application of a tax covering 50% of the price of a parking space reduces SOV use by 0.7% and increases public transport use by 4.5%.

Subsidies and aids. Individual behaviors can be changed through price increases (taxes) or price decreases (subsidies) (ADEME, 2016). Tirachini and Proost (2021) point out that subsidies applied primarily to public transport have economic and social justification. The first reason is that subsidies allow for economies of scale when the costs of users and public transport operators are considered in the price analysis. In addition, increased demand for public transport leads to increased frequency of service, reduced waiting time, and reduced delays in passenger schedules. The second reason is that transport operators need to reduce the unpriced part of the externalities associated with car use. Common types of subsidies used in the field of transportation include kilometer allowances, public transport subsidies, and bonus-malus-type subsidies. Cats et al. (2017) study the effect of free-fare public transport on a modal shift from car to public transport in Tallinn, Estonia. The implementation of this policy increased public transport use by 14%. The Cerema report (2016) presents an evaluation of the bicycle-mileage allowance in the French public-administration service showing that the implementation of this policy has resulted in a roughly 25% increase in bicycle use for commuting.² More than 60% of the initially non-cycling beneficiaries previously used private cars. Hilton et al. (2014) analyzed the effects of a bonus-malus system and injunctive norms on transport for students in the city of Toulouse (France) who have to travel either by train or by plane. Intention to choose train rather than plane increased by applying a bonus-malus tax.

2.1.2. Quantity-based regulations

Quantity instruments do not directly affect prices, and only consider the availability of the goods. Several studies propose solutions that will make it possible to reduce SOV use. Tradable emission permits or transferable allowances are the most intensively discussed quantity regulation instruments in research. Walton (1997) asserted that applying the concept of tradable emission permits in road traffic in the United Kingdom could reduce the number of cars on the road, increase public transport, and reduce pollution. The author proposed that car license tax discs (acquired through payment of vehicle excise duty) should be limited and auctioned. The total number of licenses in circulation should be continuously reduced, and the funds from these auctions should ultimately be reinvested in public transport. Bulteau (2012) studied the possibility of implementing a system of tradable emission permits for motorists and showed that the increase in price of motorists' tradable emission permits impacts the transport modes chosen. The increase in the price of tradable emission permits (due to the decrease in the allocated quantities of permits) increases the direct costs of the car ownership, resulting in a reduction in car use in favor of an increase in the use of public transport, and a decrease in CO₂ emissions. Another policy of quantity regulation is the modification to the road space. It allows

² Cerema is the French center for studies and expertise on risks, the environment, mobility and planning.

the reallocation of a portion of the roadway initially dedicated to SOVs (in terms of parking or traffic) to other modes of transport: walking, cycling, public transport, carpooling... or even to alternative uses (recreational). An illustration is given for carpooling by High Occupancy Vehicles (HOVs), which are lanes intended for multi-occupant vehicles but prohibited for single-occupant vehicles. (Guensler et al., 2019 b). Zhong et al. (2020) show that the HOV lane promotes carpooling and increases welfare through digital experiments.

The limits of economic incentives. The economic instruments described above contribute to a modal shift in favor of alternative transport modes to SOVs and provide an incentive to reduce negative externalities. They also generate income that finances local authority budgets. However, these economic measures are not readily accepted by the public (Jones, 1991, 2003; Schade and Schlag, 2003). The implementation of these policies on a large scale is not easily feasible (Schuitema et al., 2009). The attitude towards economic incentives is represented by either acceptability or acceptance (Bamberg and Rölle, 2003; Eriksson et al., 2006, 2008; Gärling et al., 2008; Jakobsson et al., 2000; Schade and Schlag, 2000). Acceptability describes the tendency to estimate an economic incentive in transport with some degree of favor or disfavor before application. Acceptance describes the tendency to value an economic incentive in transport with some degree of favor or disfavor after application (Schuitema et al., 2009). The attitude towards the effectiveness of economic incentives differs between local government authorities and the public. Studying the British transport policy context, Xenias and Whitmarsh (2013) show that authorities or mobility experts prefer technical-economic measures. According to Garling & Schuitema (2007), such measures would be acceptable if they did not limit driving freedom by making car use less attractive. For users, behavior change, and improved public transport are the best options. Nevertheless, both groups (mobility experts and users) agree on reducing transport demand through qualitative measures (Xenias and Whitmarsh, 2013). The work of Eriksson et al. (2008) is consistent with this. The authors analyze Swedish motorists and test the effectiveness of two forms of measures, push and pull measures. Steg and Vlek (1997) define push measures as measures that aim to discourage car use, while pull measures aim to improve people's travel possibilities by providing better alternatives. Thus, pull measures are seen as effective, fair, and acceptable, which is not the case for push measures. Schade & Schlag (2003) showed that social norms, personal expectations of outcomes, and perceived effectiveness are positively related to the acceptability of economic measures. Increased awareness of the positive consequences of reducing SOV use would be essential to improve social acceptability (Steg, 2003). Another limitation Oum (1989) pointed out is the time it takes for economic instruments to bring effects, which may be uncertain. According to Coulombel et al. (2019), behavioral change (leading to a modal shift) can lead to rebound effects that mitigate environmental benefits. Concerning tradable emission permits, Raux and Marlot (2005) identify costs that, when not minimized, can become obstacles to efficiency. These are transaction costs, administrative costs, and monitoring and control costs. The authors suggest that authorities monitor and reduce these costs to make them efficient. Finally, Bulteau *et al* (2021) showed that the limits reached by a financial incentive can be exceeded when a psychological incentive is added (to encourage carpooling for commuting in the Paris region).

2.2. Non-economic incentives

The reduction of negative externalities related to road transport and the modal shift towards sustainable mobility solutions can also be achieved through non-economic incentives. Here we limit the analysis of these measures to psychological factors (Ajzen, 1991; Matthies et al. 2002; Cialdini, 2003) and persuasive technologies (Bothos et al. 2014; Anagnostopoulou et al. 2018).

Psychological factors. Social psychology plays a vital role in shaping specific transport issues (Schneider et al. 2018). Along with sociodemographic and structural factors, it can explain users' mode choices. Psychological factors can be used to nudge more regular use of sustainable mobility solutions. There are three models widely used in the field of transportation to explain individual mode choices, decisions and behaviors. The first model is the theory of reasoned action (Ajzen & Fishbein, 1970), which aims to explain the relationship between beliefs, norms, attitudes, intentions, and behaviors. The second model—complementary to the first (Ajzen, 1991)—is the theory of planned behavior, which integrates the fact that individuals do not intend certain behaviors and adds perception of control over behavior to the starting model. Finally, the third model, Triandis' theory of interpersonal behavior (Triandis, 1977, 1982; Landis et al. 1978), is very close to the first two models but adds habits and contextual factors.

In the theory of planned behavior, intention precedes the decision to adopt the behavior. The intention is the result of three conceptual determinants: attitude, subjective norm, and perceived behavioral control (Figure 1). Attitude represents the extent to which the individual has a positive or negative judgment of his or her actions, and an assessment of his or her failure or success (Ajzen, 1991). Subjective norms are individual perceptions shaped by social pressures (from family, friends, relatives) and the ability to conform to others' opinions (Ham et al., 2015). Perceived behavioral control is the perceived degree of simplicity or difficulty concerning the feasibility of the behavior. Habits are automated, objective-oriented acts that are mentally represented (Aarts & Dijksterhuis, 2000).

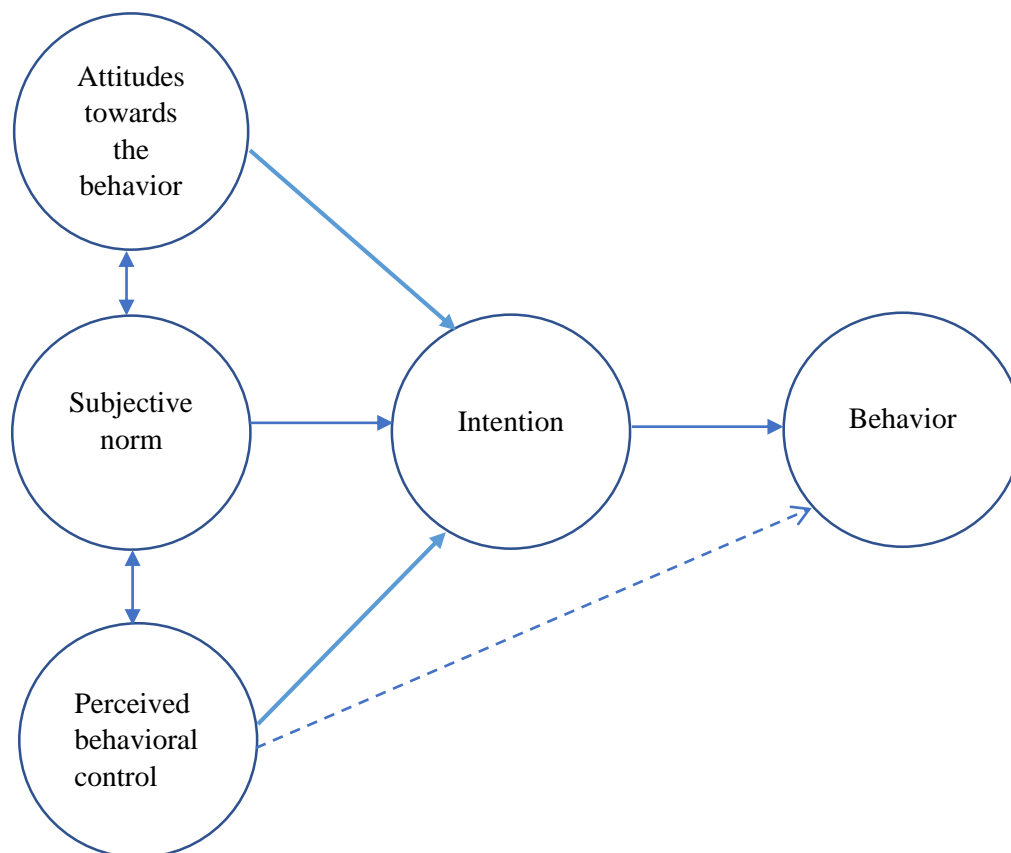


Figure 1: Theory of planned behavior (Ajzen, 1991)

Several studies have shown that mode choices are explained by these factors: attitudes, subjective norms, perceived behavioral control, and habits (Table 1). Regarding the relationship between mode choice and psychological factors, De Vos et al. (2020) show the impact of attitudes on public transport choice. Using public transport for travel is 1.69 times higher for adults with children who have positive attitudes than for people with negative attitudes towards public transport. Matthies et al. (2002) found that women's preferences for public transport and reduced car use may be influenced much more by environmental concerns than by mode choice habits, which is not the case for men. However, the gender difference in transport mode choice cannot be attributed to environmental concerns and mode choice habits, and may revolve around other factors, such as stereotypes (Flade & Limburg, 1997). The orientation towards choosing to drive a car is already stronger among boys aged 10 to 16 than among girls. This implies that as adults, boys are already 'car-driven'. Bouscasse et al. (2018) reached the same conclusions regarding the effect of environmental concerns on car-use patterns. People who are highly sensitive to environmental concerns perceive public transport as more pleasant and comfortable than people with no little environmental sensitivity. Thus, environmental concerns significantly influence mode choice habits, and perceptions and feelings around public transport partially mitigate this effect.

Perceived behaviors and subjective norms can be used to influence mode choice habits and encourage use of public transport. Donald et al. (2014) reached this conclusion by testing an extended model of planned-behavior theory in mode choice. They also identified the factors influencing the choice to drive or use public transport to commute to work and found that perceived behavioral control is a better predictor of intentions to use public transport rather than private cars. They thus suggest that promotional campaigns in favor of adopting public transport will be effective if they target factors such as habits and intentions.

Injunctive and descriptive norms may also be useful to encourage sustainable mobility. Cialdini (2003) showed, through experiments, the difference between these two norms and their role in environmental protection. Injunctive norms are based on what individuals approve or disapprove of, while descriptive norms are based on what people do (Cialdini et al., 1990). Cialdini showed that the involvement of injunctive standards in a message is more effective when it concerns environmentally harmful behavior, while descriptive standards are more effective when a message concerns environment-protective behavior. For example, a campaign containing an injunctive standard that formally prohibits waste discharge into a natural park in order to preserve it would be more effective than a campaign that describes the actions that some people take for the same purpose. However, aligning the two types of norms jointly in messages can encourage mobility users to adopt pro-environmental behaviors.

Table 1: List of academic articles on the impact of psychological factors on modal shift towards sustainable mobility solutions

| Psychological factors | Description | References |
|------------------------------|---|--|
| Attitude | Environmental concerns | Matthies et al. (2002), Walton et al. (2004), De Groot & Steg (2007), Bouscasse et al. (2018) |
| | Stereotypes | Flade & Limbourg (1997) |
| | Personal standards | Bamberg et al. (2007), Doran & Larsen (2016) |
| | Personal beliefs | Steg (2003) |
| | Emotional and symbolic motive | Bouscasse et al. (2018) |
| | Perception of quality | Fujii & Van (2009) |
| Subjective norms | Social pressures | Xin et al. (2019) |
| | Descriptive norms | Cialdini et al. (1990), Cialdini (2003), Donald et al. (2014), Hilton et al. (2014), Kormos et al. (2015). |
| | Injunctive norms | Cialdini et al. (1990), Cialdini (2003) |
| Perceived behavioral control | Culpableness involved in using a transport mode | Donald et al. (2014), Xin et al. (2019) |
| Habits | Frequency of using a transport mode | Bouscasse et al. (2018), Xin et al. (2019), |

Source : prepared by the authors

Persuasive technologies. De Kort et al. (2007) defined persuasive technologies as a general class of technologies designed to change users' attitudes or behaviors through persuasion and social influence, and not through coercion.

There is a relationship between persuasive technologies and psychological factors, to the extent that persuasive technologies can manipulate psychological factors to encourage sustainable mobility solutions (Figure 2). Bothos et al. (2014) illustrated this relationship by analyzing how persuasion strategies in a smartphone application can provide travelers with itinerary-planning solutions that consider environmental impact. They found that technologies can encourage pro-environmental behavior by promoting the use of other modes of transport. However, this result cannot be confirmed in a context of a narrow set of alternatives. Anagnostopoulou et al. (2018) confirmed these results by analyzing all existing approaches, systems, and prototypes in terms of persuasive technologies. Their survey found that in 65% of studies, persuasive technologies were effective and encouraged a shift to sustainable transport modes. Nevertheless, all these studies shared the same main limitation, i.e. technology application lasted only one or two months, leaving no way to measure the long-term effectiveness of persuasive technologies. Bucher et al. (2019) show the effectiveness of ecological feedback via a smartphone application

on sustainable mode choice in Switzerland in an experiment that lasted six weeks. The authors found a decrease in-car use by 24% and an increase in public transport use by 7.9%.

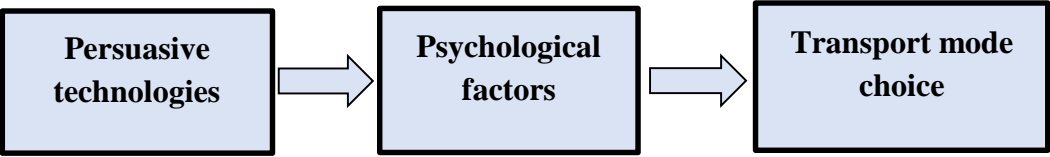


Figure 2: Relationship between persuasive technologies and transport mode choice (Source: prepared by the authors)

The limits of non-economic incentives. Like economic incentives, non-economic incentives have limits in terms of effectiveness. Baldwin (2014) analyzed the role of nudges in the overall state-control system and concluded that the effectiveness of norms at individual level may be limited if the cultural context, economic environment, and corporate policies encourage undesirable behavior. Moreover, responses to social pressures vary according to social context. Social norms may be negatively associated with behavioral intent (Perkins et al., 2005) as a boomerang effect. A boomerang effect occurs when an incentive or message produces a behavior or attitude contrary to what was initially intended (Cho & Salomon, 2007). Gardner & Abraham (2010) showed that drivers who expect others to drive less increase their driving time, as they anticipate a reduction in congestion-related problems. For these reasons, injunctive standards must be combined with descriptive standards.

3. Research method

This section is devoted to a bibliometric analysis. This analysis aims to produce a sample of articles for comparative study between economic and non-economic incentives in terms of modal shift towards sustainable mobility solutions. The methodology used for the bibliometric analysis requires two main steps: first, a descriptive analysis of the transport literature, and second, selecting articles for the comparative study (Figure 3).

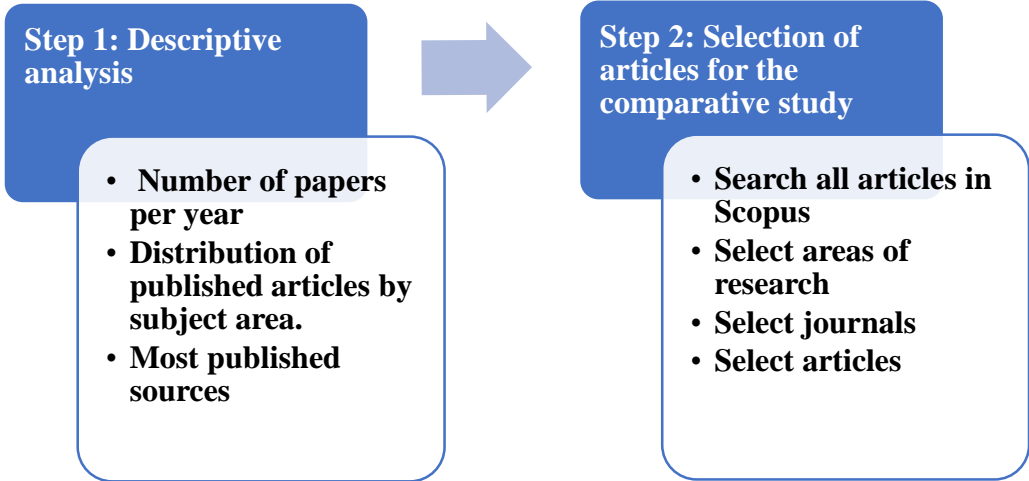


Figure 3: Research methodology for the bibliometric analysis (Source: prepared by the authors)

3.1. Descriptive analysis

- *Number of articles per year*

The bibliometric analysis is done by inserting 'transport' as a keyword in the Scopus database, and then searching the title of the article, the abstract, and its keywords. Then, a filter by field of activity is applied. The period considered is from 2000 to 2020, following the Kyoto protocol signed in 1997. The objective of this international agreement is to reduce greenhouse-gas emissions in the countries concerned. To focus on the transportation of people, we limited the analysis to research fields such as social sciences, economics, econometrics and finance, psychology, energy, and environmental sciences. This gave a total of 183,841 publications. The most significant year for publications was 2020, with 18,056 publications. Publication numbers tended to grow over the period, signaling the growing attraction of the topic (Figure 4).

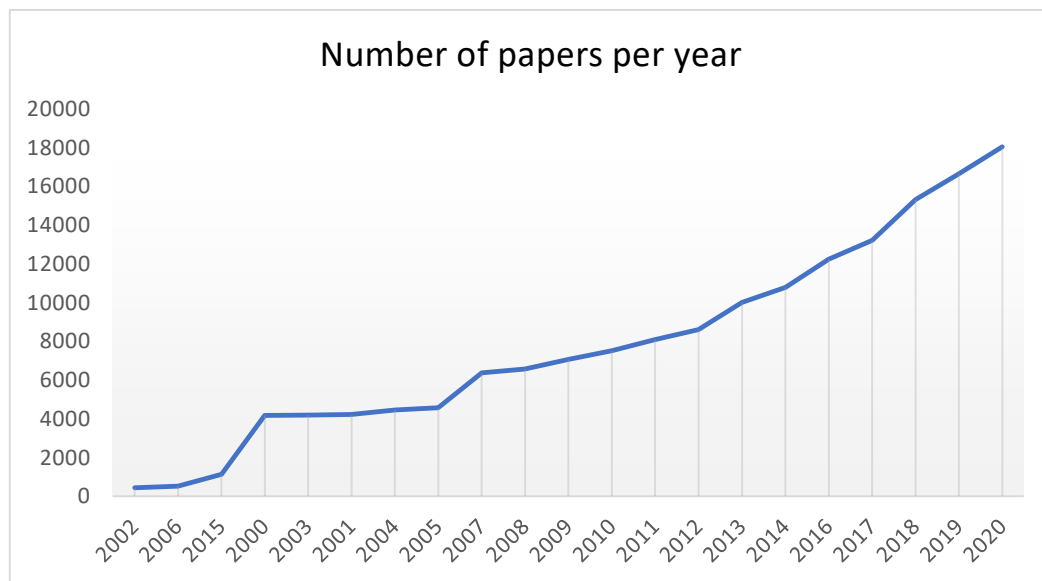


Figure 4: Annual number of articles considering the transportation of people, based on Scopus (Source: prepared by the authors)

- *Distribution of published articles by subject area*

Figure 5 presents the distribution of published articles by subject area. The highest share of publications was in the environmental sciences field (53% of the total), followed by energy (22%), social sciences (21%), economics, econometrics and finance (3%), and psychology (1%). This reflects a multidisciplinary approach to the development of knowledge in the field of transportation of people.

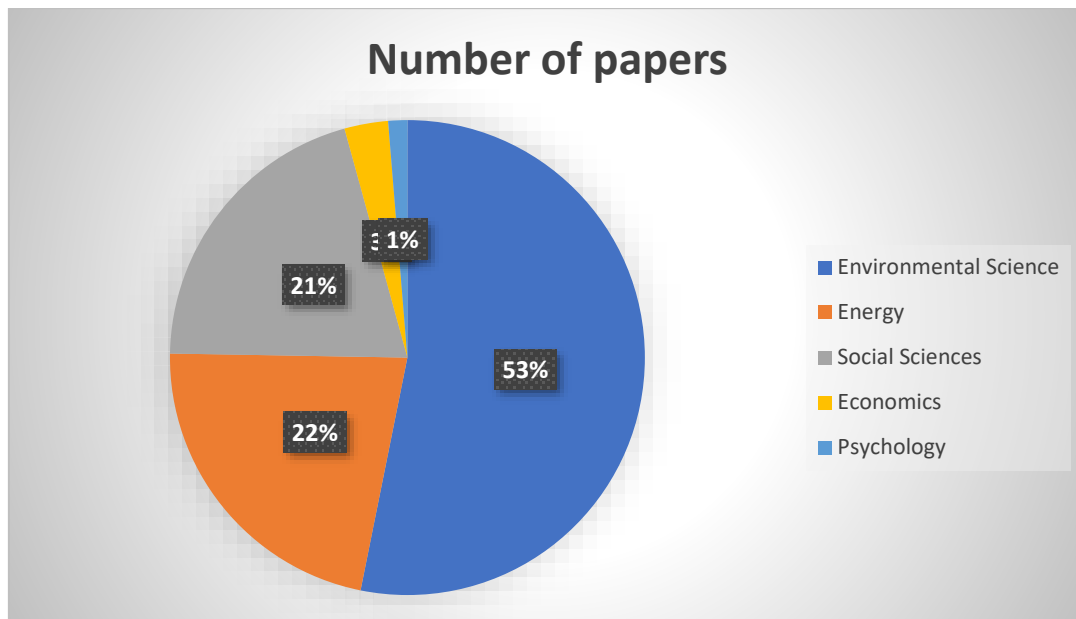


Figure 5: Distribution of published articles in the field of individual transportation, by subject area (Source: Scopus)

- *Most published sources*

Table 2 shows the 28 journals in economics, social sciences, and psychology ranked in descending order by AJG rank (Academic Journal Guides) and SJR score (SCImago Journal Rank). After applying the search field selection filter in Scopus, we selected the journals with the highest number of publications. The journals under consideration deal with the transportation of goods and people. Academic journals in the field of economics and social sciences are ranked according to the AJG 2018 and the SCImago Journal and Country Rank, while journals in the field of psychology are ranked according to the SCImago Journal and Country Rank. The AJG is a guide that classifies academic journals in the field of business and management according to issue and quality. Quality of the journal ranges from 1 (lowest) to 4 (highest). The SCImago Journal & Country Rank is a publicly accessible platform of academic journals and indicators from developed countries, based on information from the Scopus database. Quality of the journal is measured by the (SJR) indicator of prestige, impact, or influence of the journal.

There are more publications in the social sciences than in other fields. The top five journals are Transportation Research Part A Policy and Practice (1546), Journal of Transport Geography (1350), Transport Policy (1258), Transportation Research Part D Transport and Environment (1074), and Transportation Research Part B Methodological (730).

Table 2: List of the journals with the highest number of publications

| Journals | Research area in Scopus | AJG 2018' rank | SJR | Number of papers |
|---|--------------------------------|-----------------------|------------|-------------------------|
| Transportation Research Part B Methodological | Social sciences | 4 | 2.921 | 730 |
| Journal of Urban Economics | Economics | 3 | 2.724 | 57 |
| International Journal of Production Economics | Economics | 3 | 2.475 | 70 |
| Urban Studies | Social sciences | 3 | 2.115 | 233 |
| Transportation Research Part A Policy And Practice | Social sciences | 3 | 2.036 | 1,546 |
| Energy Economics | Economics | 3 | 2.003 | 87 |
| Ecological Economics | Economics | 3 | 1.767 | 101 |
| Regional Science And Urban Economics | Economics | 3 | 1.570 | 98 |
| Accident Analysis And Prevention | Social sciences | 3 | 1.481 | 344 |
| Transportation Research Part D: Transport and Environment | Social sciences | 3 | 1.448 | 1,074 |
| Transport Reviews | Social sciences | 2 | 2.138 | 410 |
| Transportation | Social sciences | 2 | 1.852 | 530 |
| Journal of Transport Geography | Social sciences | 2 | 1.668 | 1,350 |
| Transport Policy | Social sciences | 2 | 1.520 | 1,258 |
| Marine Policy | Social sciences | 2 | 1.242 | 52 |
| Journal of Transport Economics and Policy | Economics | 2 | 0.674 | 186 |
| Applied Economics | Economics | 2 | 0.499 | 66 |
| Journal Of Air Transport Management | Social sciences | 1 | 1.090 | 311 |
| Research in Transportation Economics | Economics | 1 | 0.983 | 458 |
| Actual Problems of Economics | Economics | 1 | 0.124 | 71 |
| Journal Of Environmental Psychology | Psychology | - | 1.961 | 16 |
| Social Indicators Research | Psychology | - | 1.685 | 28 |
| Decision Support Systems | Psychology | - | 1.536 | 15 |
| Technological Forecasting And Social Change | Psychology | - | 1.422 | 109 |
| Travel Behaviour And Society | Social sciences | - | 1.280 | 97 |
| Human Factors | Psychology | - | 1.094 | 17 |
| Transportation Research Part F Traffic Psychology And Behaviour | Psychology | - | 0.993 | 194 |
| Social Inclusion | Psychology | - | 0.276 | 17 |
| Total | | - | | 9,525 |

3.2. Selection of articles for the comparative study

Articles on economic (Figure 7) and non-economic incentives (Figure 8) were selected for the comparative study in four steps.

- **Step 1: Search all articles in Scopus**

We inserted the keyword ‘transport’ in the Scopus search field. As we previously mentioned, we limited the search to 2000 to 2020 for the time interval and to document-type articles (article, review, book, or book chapter etc.). The result was 939,640 publications.

- **Step 2: Select areas of research**

A selection was made by research area. The research areas were selected independently, and the analysis continued for each area. For economic incentives, we limited the search to social sciences (N=41,183) and economics, finance, and econometrics (N=5,952). For non-economic incentives, we selected the social sciences and psychology (N=2,688). N is number of publications.

- **Step 3: Selection of journals**

To select academic journals, we first inserted the keywords related to the different forms of incentive (economic and non-economic). The keywords for economic incentives were ‘tax’, ‘modal shift’, ‘parking’, and ‘subsidies’. For non-economic incentives, we chose the theory planned behavior and persuasive technology. Journals were then selected by applying a filter on name of the source and considering the score or rank of the journal. Using the AJG scheme, we considered journals with a rank of 3 or 4 and an SJR score greater than or close to 1 (economic incentives) (Figure 6). For non-economic incentives, only SJR score was considered (SJR greater than or close to 1).

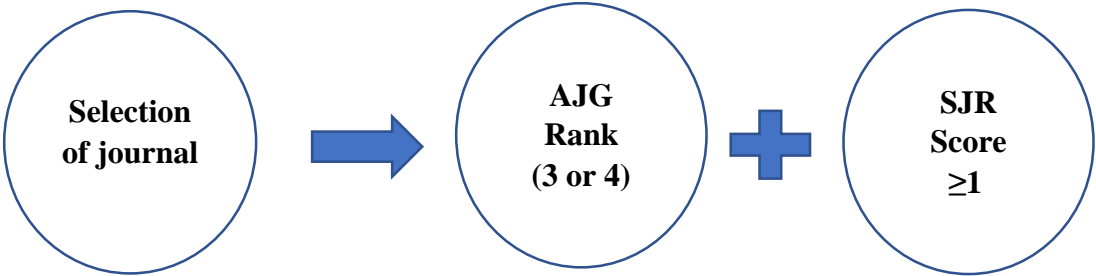


Figure 6: Method of journal selection

The selected social science journals are *Transportation Research Part A*, *Transportation Research Part B*, *Transportation Research Part D*, *Accident Analysis and prevention*, and *Urban Studies*. The selected economics journals are *Regional Science and Urban Economics*, *Energy Economics*, *Ecological Economics*, *International Journal of Production Economics*, and *Journal of Urban economics*.

For non-economic incentives, we selected academic journals psychology and social science journals: *Transportation Research Part F*, *Journal of Environmental Psychology*, *Transportation Research Part A*, *Travel Behavior and Society*, *Social Indicators Research*,

Technological forecasting and Social change, Journal of transport Geography, and Transport Policy.

- **Step 4: Selection of articles**

For the comparative study, we limited, after the reading of the abstracts, then the full-texts in case of relevant abstracts, the analysis to 15 empirical reports or theory papers presenting quantified results in terms of effectiveness of economic incentives (15) and significant positive results in terms of the effectiveness of non-economic incentives (15). The reports or papers that did not present quantified results (economic incentives) or significant positive results (non-economic incentives) were not retained in the final perimeter.

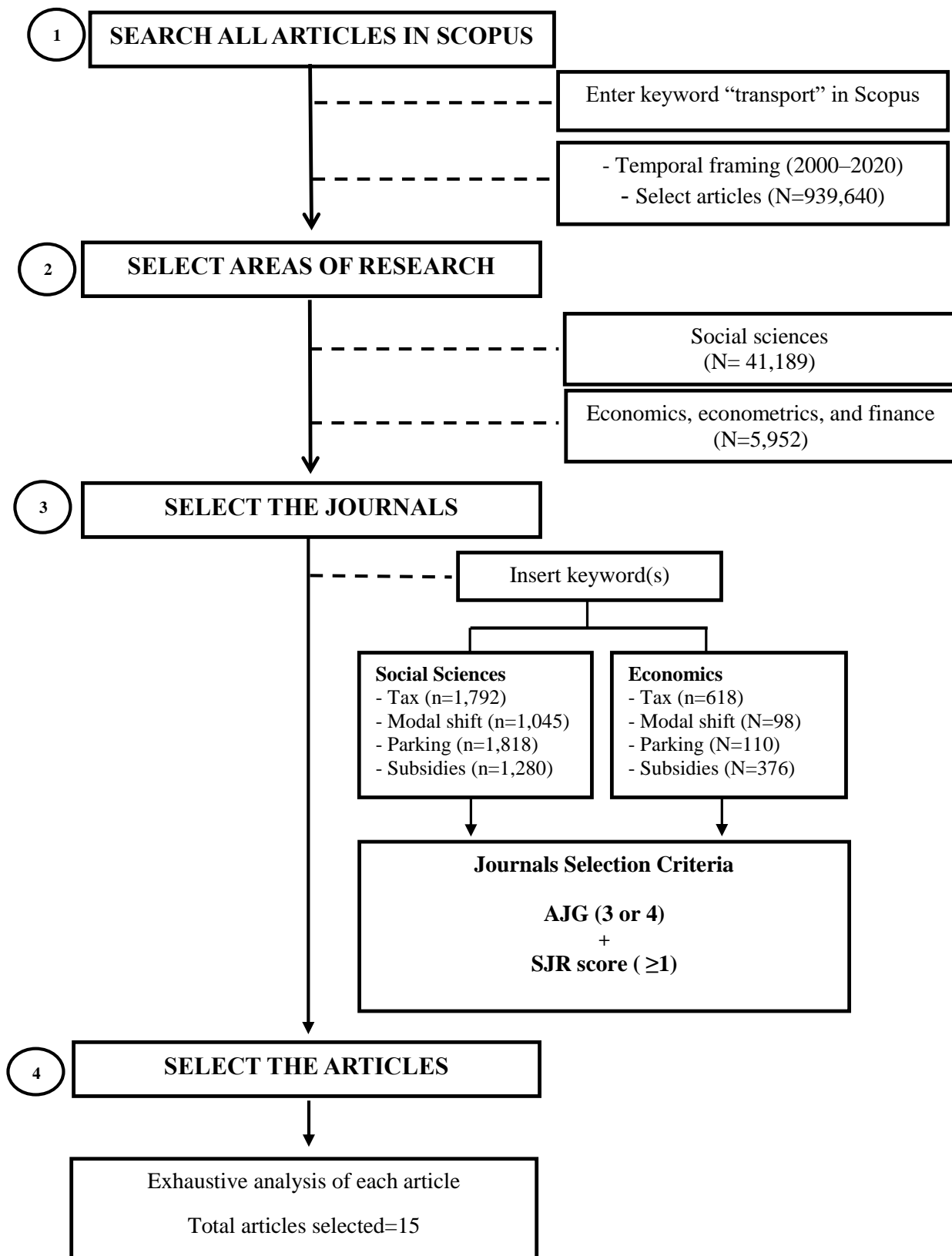


Figure 7: Methodology for the selection of articles (economic incentives)

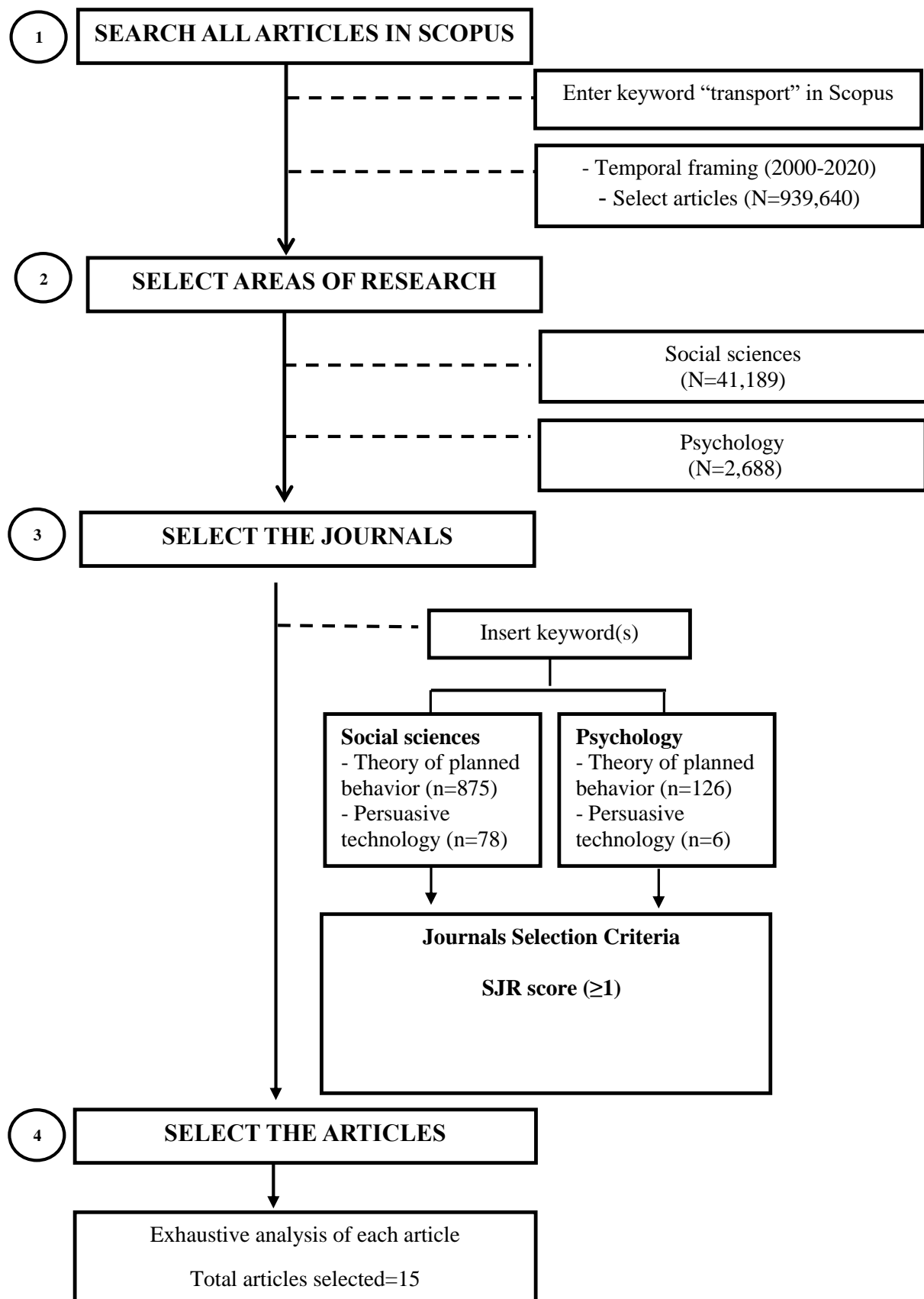


Figure 8: Methodology for the selection of articles (non-economic incentives)

4. Comparison and discussion on incentives for modal shift towards sustainable mobility solutions

Numerous studies have shown the contribution of economic and non-economic incentives in the modal shift towards sustainable mobility solutions. However, incentives (economic or non-economic) may prove less effective if applied independently. Comparing the two forms of incentives in terms of effectiveness thus gives an idea of which is more effective. These results have been drawn up in table 3 and 4 (appendix 1 and 2) which highlight:

- The author(s),
- The type of incentive,
- The method used,
- The sample size,
- The estimation period,
- The geographical perimeter,
- The variables observed,
- The results obtained in terms of modal shift towards sustainable mobility solutions.

The results were color-coded: green for a positive effect in terms of effectiveness, and blue for a negative effect. Effectiveness is viewed here as the ability of the incentive to achieve the objectives that have been assigned to it.

4.1. Effectiveness of economic incentives

Table 3 (see appendix 1) presents two main forms of economic incentives: taxes and subsidies. On taxes, there are environmental taxes imposed on the purchase of the vehicle, such as excise duty (Brand et al. 2013) and the tax linked to energy consumption (Ubbels et al. 2012). Then there are taxes related to private cars, such as the tax on gasoline (Hammadou & Papaix, 2015; Pavon & Rizzi, 2019). There are parking taxes (Evangelinos et al. 2018; Rotaris & Danielis, 2014; Hammadou & Papaix, 2015; Albalade & Gragera, 2020) and, finally, road pricing (Steininger et al., 2007; Agarwal & Koo, 2016). All these pricing policies have had the expected effect of either reducing SOV use (Evangelinos et al. 2013), increasing the use of sustainable modes (Pavon & Rizzi, 2019), or both (Ubbels et al. 2012). However, as Hammadou & Papaix (2015) demonstrated, using a direct policy instrument that aims at reducing CO₂ emissions (fuel taxes) appears to be more effective in dense urban areas than using an indirect policy instrument that does not originally aim at reducing CO₂ emissions (parking management policies, cordon tools). The application of a 1.6-euro-cent tax on gasoline led to a 1.1% decrease in SOV use, a 14.2% increase in public transport use, and a 1.3% increase in walking, while a 50% increase in parking tax only led to a 0.8% decrease in SOV use, a 4.5% increase in public transport use, and a 1.7% increase in walking. The application of road pricing (1.2 euro per day) only reduced SOV use by 0.7%, increased public transport use by 9.2%, and walking by 1%. This instrument is effective for those who depend on the car. Employees and managers are the main ones concerned in this study.

Some work has dealt with the effects of public transport subsidies on transport mode choice. Like pricing policies, public transport subsidies are useful for reducing SOV use (Rotaris & Danielis, 2014), increasing public transport use (De Witte et al., 2006), or both (Bueno et al. 2017). For example, Bueno et al. (2017) showed that public transport subsidies for New York and New Jersey metropolitan areas for commuting led to a 16% reduction in SOV use and a

15% increase in public transport use. The effectiveness of this measure lies in commuters' proximity to public transportation and the non-ownership of cars.

Comparing pricing policies and public-transport subsidy policies shows that road pricing has a more significant impact on changing sustainable transport modes than subsidies. Rotaris & Danielis (2014) analyze the effectiveness of parking pricing policies and subsidies allocated to public transport in urban areas precisely at the University of Trieste, Italy. They showed that paying 1 euro per hour for parking reduced SOV use by 23% against only 17% with total one-month-long public transport subsidy. However, these parking pricing policies have a more significant impact on the mode choice of faculty than that of administrative staff and students. Pavon & Rizzi (2019) reached the same conclusion. The chance of choosing public transport is 81% when there is a total subsidy for public transport in Santiago, Chile. However, the opportunity of choosing a car is only 21% when a gasoline tax is applied.

Globally, our analysis reveals that direct policy instruments such as the gas tax are more effective than indirect policy instruments such as parking management policies or cordon tolls in dense urban areas. The effectiveness of these policies on modal shift is for those dependent on the private car, mainly managers and employees. Public transport subsidy policies are effective in metropolitan areas for commuting, provided that the commuter is close to public transport and does not own a car. Comparing road pricing and subsidy policies in urban areas showed that road pricing is more effective than subsidies for managers and teachers. This effectiveness is not verified for students.

4.2. Effectiveness of non-economic incentives

Table 4 (see appendix 1) shows that transport mode choice can be influenced by three forms of incentives: psychological factors, persuasive technologies, and other means of persuasion, such as communication. Psychological factors include subjective norms (Shang-Yu Chen, 2016 ; Ingvaridsen & Nielsen, 2019), perceptions (De Vos et al. 2020 ; Shang-Yu Chen, 2016; Ingvaridsen & Nielsen, 2019 ; Gutierrez et al. 2020), and individual characteristics such as habits and attitudes (Lind et al. 2015 ; De Vos et al. 2020; Stark et al. 2019 ; Gutierrez et al. 2020). Subjective norms and perceptions have a greater and more positive impact than other psychological factors for users and non-users of active modes such as cycling in urban areas (Shang-Yu Chen, 2016). Subjective norms or perceptions are perceived and felt social pressures to engage or not engage in a use behavior such as public bicycling. Psychological factors are attitudes and beliefs that explain the choice to ride a public bicycle (Ajzen 1991). However, when comparing the effect of all psychological factors on the transport mode choice, most of the scholarship shows that individual specificities are the most significant factor explaining sustainable mode choice. De Vos et al. (2020) showed that attitudes are more significant and positively affect choice of public transport in urban areas than perceptions related to satisfaction. The odds of attitudes influencing the frequencies of those who want to use public transport are 27.83 while those related to satisfaction with public transport services are 1.73. For rural residents, the intention to use public transport is positively influenced by moving to urban areas because accessibility to the best transportation offered in rural areas is less straightforward. Stark et al. (2019) also showed, in urban areas, the significant and positive impact of attitudes on children's sustainable mode choice. Children's mode choice is related to feelings of well-being during the trip.

Persuasive technologies also have a significant and positive effect on sustainable mode choice (Bucher et al., 2019; Tsirimpa et al., 2019). However, their effect is more significant on users

of sustainable modes than on non-users, as demonstrated by Piwek et al. (2015) on competitive cyclists in suburban and urban areas. The need for performance feedback and self-assessment explains the significant and positive influence on cycling. Geng et al. (2016) and Pangbourne et al. (2020) show how persuasive information can promote walking in urban and rural areas. Argument value and personality traits are relevant tools for promoting walking via persuasive technologies. For older people, health benefits are arguments that influence the choice of walking. Environmental awareness is a motive for walking for younger people.

Finally, comparative analysis of these different forms of incentives points to the conclusion that individual specificities are the most significant factor explaining sustainable mode choice and are more easily influenced to change behavior through persuasive technologies or through information. Moreover, Stark et al. (2019) have shown that attitudes towards environmental and health-friendliness are already influenced in childhood and can have positive effects on the choice of sustainable modes. In addition, specific attitudes related to transport modes, such as wellbeing felt during travel, also help to increase the use of sustainable modes.

Overall, we find that subjective norms and perceptions are more effective than psychological factors in urban areas. Attitudes are more effective for public transport choice in urban areas. Accessibility and improvement of public transport and the feeling of well-being during travel encourage modal shift among rural residents and children respectively. Persuasive technologies are more effective on sustainable mode users than on non-users in urban and suburban areas. Personality traits such as environmental sensitivity and argumentative values such as health benefits may be useful in encouraging walking among young and older people, respectively, via persuasive technologies.

4.3. Comparative study between economic and non-economic incentives

Here, the comparative study between economic and non-economic incentives has shown that some economic policies are less effective than others, have limitations, and influence only specific categories of users. The same is true for non-economic incentives. Some work indicates that some non-economic measures are less effective than others (Shang-Yu Chen, 2016) or less effective in a particular context (Piwek et al., 2015). Thus, combining the two forms of incentives could optimize policy efficiency in terms of a modal shift towards sustainable mobility solutions (Hilton et al. 2014, Bulteau et al. 2021).

The aim of this research is to assess the respective effectiveness of economic and non-economic incentives to modal shift. Although such effectiveness may be considered primarily in terms of the results achieved, a proper decision support should not avoid to compare the respective costs of such measures to answer the question: “ Which measure should I implement in case of comparable results?” To answer this, a public authority should refer to classical socio-economic assessment tools, such as Cost-Benefit Analysis (Beria et al. 2012). Unlike MultiCriteria Decision Analysis, Cost-Benefit Analysis is based on a single criterion method (monetization). It has been applied for decades to assess a wide range of transportation projects or policies and inform decision-making at various geographical scales (Le Boennec et al. 2019).

5. Conclusion

The definition of sustainable transportation generally refers to all combinations of government policies, infrastructure, technologies, and behaviors that reduce negative externalities (environmental and social) while maintaining or improving economic outcomes (Stephenson et al., 2018). Bannister's (2008) sustainable mobility paradigm presents actions such as reducing the need to travel, encouraging modal shift, reducing the trip length. All of these actions involve various policy measures. Complementing these interventions, Stephenson et al. (2018) propose fundamentals in the procurement systems of transportation finance, the structure and culture of funding agencies, and transportation legislation. The modal shift involves measures that can reduce car use by promoting other transport modes that are sustainable. This paper set out to analyze the relative effectiveness of economic and non-economic incentives to make a modal shift to sustainable mobility solutions as alternatives to SOV-based mobility in an effort to reduce the negative externalities associated with road transport. We have shown that economic incentives can prompt a modal shift towards sustainable mobility solutions. These economic measures are classified according to two instruments: price regulation (fuel tax, road pricing through the introduction of urban tolls, parking fees, bicycle mileage allowances, bonus-malus system) and quantity regulation (tradable emission permits). However, the implementation and effectiveness of economic incentives can be challenged by public and political acceptability (Francke and Kaniok, 2013). In addition, economic incentives are also linked to environmental benefits that are mitigated by rebound effects and uncertainty about how the desired results will be achieved. All of these problems lie in the fact that there are various conditions for applying economic incentives in terms of categories of users that can affect the desired effectiveness. On the whole, the literature shows that pricing policies are more effective than subsidy policies. Our analysis has shown that direct policy instruments related to personal car use (fuel tax) are more effective, in dense urban, than indirect policy instruments (parking management policies, cordon tools) areas. Modal shift is observed among managers and employees. Subsidies are less effective than road pricing policies regarding modal shift for employees and managers, but not for students. These different variations in effectiveness of economic incentives suggest that psychological factors should be considered in policies providing incentives for sustainable mobility solutions.

Our analysis and discussion of non-economic incentives showed that transport mode choices are guided by psychological factors (attitudes, subjective norms, perceived behavioral control, habits), and persuasive technologies. Attitudes can potentially affect the choice of sustainable modes in rural and urban areas. This influence may be related to the accessibility of public transport provision, which is better in urban areas. Persuasive technologies encourage sustainable modes of transportation in urban, suburban, and rural areas through tools such as personality traits, value arguments, and competition. Self-assessment and performance feedback encourage cyclists to cycle more. Promotion of the health benefits of walking is effective among older people. Among younger people, sensitivity to environmental protection may help encourage walking. On the whole, the literature shows that individual specificities (attitudes, habits) are more significant than other non-economic incentives as factors explaining modal shift towards sustainable mobility solutions. However, the effectiveness of non-economic incentives depends on cultural context, collective policies, and economic environment. Furthermore, there is a boomerang effect that is associated with ineffectiveness of these measures.

The comparative study between economic and non-economic incentives finds that there are limits to independently applying these different forms of incentives. Economic and non-economic incentives need to be combined in order to prompt agents to adopt sustainable transport modes. Hilton et al. (2014) demonstrated this by analyzing the effects of a bonus-malus system and injunctive norms on transport choice in France, specifically in the urban area of Toulouse. Through two experiments in which students are confronted with the choice between traveling by train or by plane, they showed that intention to travel by train increases when a bonus-malus price is combined with injunctive norms (emoticons, and information on CO₂ emissions). Bulteau *et al.* (2021) explored the importance of financial and psychological incentives in promoting the use of carpooling for commuting, as a driver and as a passenger in the Paris region. They empirically demonstrated that the determinants of carpooling as a driver and as a passenger differ, and that incentives to encourage carpooling vary by individual profiles. Their results suggest that a policy combining economic and psychological incentives could be more efficient to promote carpooling. Wall et al. (2017) confirm the need for a combination of hard and soft measures to enhance modal shift to sustainable mobility solutions. His study combines subsidies for sustainable transport modes (public transport, Bicycles) and public awareness of the problems associated with private car use in Portsmouth (UK) for commuting. The hard measures are intended to change travel behavior by changing travel costs. These measures are consistent with utility maximization models (Eluru et al., 2013). The objective of soft measures is to modify travel behavior via user preferences and attitudes. They correspond to models using the theory of planned behavior (Anable, 2005). One advantage of combining push measures with non-economic incentives is that it increases social acceptability (Eriksson et al., 2008). However, integrating the behavioral dimension with restrictive economic measures requires a mix. Hilton et al. (2014) show that the condition for the effectiveness of this combination is that the financial incentive (bonus-malus) is low. A financial incentive that is too high would encumber the intrinsic motivation to choose a sustainable mode. Also, Eriksson et al. (2008) suggest that combinations of economic and non-economic policies need to be tailored according to the geographical context and also the target automobilist. Riggs (2017) found contrasted results. In an analysis of the impact of financial (donations, monetary incentives) and human (altruistic sense) incentives on active transportation habits (cycling and walking) in American universities, he found that combining these two forms of incentives makes them less effective. Economic agents tend to perceive a non-economic incentive as coercive when it is combined with an economic incentive. Further research on this issue is needed to disentangle the mixed conclusions on combining economic and non-economic incentives. For example, a selection of combinations of economic and non-economic incentives on modal shift could be analyzed via discrete choice models (Ben-Akiva & Lerman, 1985). One could model economic quantity control measures with subjective norms and analyze the effectiveness of this combination on modal shift. A mixed multinomial logit model would be more appropriate for the datasets we have collected because this type of model takes into account individual variation. This is left for further research.

Appendix 1

Table 3: Economic incentives.

In green, the results showing the effectiveness of the measures. In blue, the results showing the ineffectiveness of the incentives.

| Authors/Journal | Type of incentive | Method used | Number of observations | Geographic scope | Period | Variable observed | Results | |
|---------------------------|---|-----------------------------------|------------------------|------------------|-----------|--|--|----------------------------------|
| | | | | | | | PC | SM |
| Pavón & Rizzi (2019) | <ul style="list-style-type: none"> Fuel tax (2,237 CLP), CLP: Chilean Pesos | Simulation analysis | 21,000 | Santiago, Chile | | Mode choice probability | Car (21%) | PT(81%) |
| | <ul style="list-style-type: none"> Subsidies for public transport (100 %) | Simulation analysis | 21,000 | Santiago, Chile | | -Bus frequency, peak (bus/h) -Bus frequency, off-peak (bus/h) | | PT (+13 bus/h) PT (+ 1 bus/h) |
| Brand et al. (2013) | Vehicle excise duty (for CO ₂ >255g CO ₂ /km, the tax is GBP 2 000) | Simulation analysis | | England | 2010–2050 | Overall car use | PC (-1.7% in 2030) PC (-2.5% in 2050) | |
| Evangelinos et al. (2018) | Pricing workplace parking via cash-out. <ul style="list-style-type: none"> daily cash-out option from €1 to €2 | Discrete choice modeling approach | 690 | Germany | 2011 | The decreasing probability of choice for SOV use | PC (from -41% to -43%) | |
| | <ul style="list-style-type: none"> daily cash-out option from €2 to €3 | | | | | | PC (from -37% to -41%) | |
| | <ul style="list-style-type: none"> daily cash-out option from €3 to €4 | | | | | | PC (from -37% to -30%) | |

| | | | | | | | | |
|---------------------------|---|--|--------|--|-----------|--|-----------|----------------------------------|
| Bueno et al. (2017) | Benefits such as toll payments, mileage reimbursements or free parking | Discrete choice modelling approach (multinomial logit model) | 21,771 | New York and New Jersey, United States | 2010–2011 | The likelihood of choosing the private car and other sustainable modes for commuting | | PT (-82%) |
| | Private car benefits | | | | | | PC (+12%) | PT (-12%) |
| | Car ownership | | | | | | PC (+40%) | W (-10%) C (-2%) PT (-28%) |
| | Public transport subsidies | | | | | | PC (-16%) | PT (+15%) |
| | Bike related transportation benefits | | | | | | | C (+2%) |
| Rotaris & Danielis (2014) | Increasing the cost of the annual permit from the current level of €40 to €80 | Discrete choice modelling approach (multinomial logit model) | 372 | University of Trieste, Italy | | Change of car use in % terms | PC (-6%) | |
| | Setting an hourly parking tariff equal to €1 | | | | | | PC (-23%) | |
| | Increasing the time needed to find a parking space by 15 seconds | | | | | | PC (-4%) | |
| | Free monthly ticket | | | | | | PC (-17%) | |
| | One-way ticket 60% of variable costs (increasing price of ticket) | | | | | | PC (+2%) | |

| | | | | | | | | |
|--------------------------|--|--|-------|-------------------|---------------------------|--|-------------|---|
| Guzman et al. (2020) | Provision of facilities for bicycles | Discrete choice modelling approach (mixed logit model) | 475 | Bogota, Colombia | | Probability of choosing a mode | PC (-2%) | CP (-2%) PT (-2%) C (13%) W (-10%) |
| | Implementation of company bus services | | | | | | PC (-1%) | CP (-1%) PT (4%) C (0%) W (-1%) |
| | +30% parking fee | | | | | | PC (-8%) | CP (-3%) PT (3%) C (2%) W (2%) |
| De Witte et al. (2006) | Subsidies for public transport (100%) | Quantitative survey and analysis of the materials based on the structural method | 3,162 | Brussels, Belgium | 2003–2004 (academic year) | Share of new users of public transport | | T (17.55%) M (11.08%) B (13.69%) |
| De Borger & Wuyts (2011) | Optimal labor and congestion taxes (labor =86.45) | Numerical model | | Belgium | | Share of SOV use and public transport use | PC (-8.47%) | PT (+8.47%) |
| | Optimal labor and company car tax (labor =100) | | | | | | PC (+2.38%) | PT (-1.38%) |
| | Optimal congestion tax and free public transport (labor= 98.10) | | | | | | PC (-2.82%) | PT (+2.82%) |
| Ubbels et al. (2012) | Complete abolition of fixed taxes and application of kilometer charges | Discrete choice modelling approach (multinomial logit model) | | | 2008 | Share of kilometers travelled per transport mode | PC (-10%) | PT (+2%) |

| | | | | | | | | |
|--------------------------|--|--|-------|-------------------------------------|-----------|---|----------------------------|------------------------------------|
| | Tax on new cars modified to make it dependent on the car's environmental performance with an average level of fl 5000. (fl= Femtoliter; 1 fl= 10 ⁻¹⁵ liter. | | | | | | PC (-8%) | PT (+1%) |
| | Kilometer charges+ incentive included to buy fuel-efficient cars | | | | | | PC (-10%) | PT (+2%) |
| | Extra high level of a kilometer | | | | | | PC (-9%) | PT (+9%) |
| Qi Sun et al. (2020) | Adoption of e-bikes | Econometrics of panel data | 5,258 | Netherlands | 2013-2016 | Modal share in distance travelled after the adoption of e-bikes | PC (-5.6%) | E-bikes (100%) C-bikes (-38.3%) |
| Hammadou & Papaix (2015) | Carbon tax (1.6€/ liter) | Discrete choice modelling approach (multinomial logit model) | 8,990 | Lille and Roubaix-Tourcoing, France | 2006 | Effect on modal shares (%) | PC (-1.06%) CP (-6.43%) | PT (+14.21%) W (+1.26%) |
| | Parking charges (10%) | | | | | | PC (-0.19%) CP (-0.37%) | PT (+0.50%) W (+0.42%) |
| | Parking charges (50%) | | | | | | PC (-0.77%) CP (-3.03%) | PT (+4.50%) W (+1.70%) |
| | Cordon toll (1.2 €/day) | | | | | | PC (-0.70%) CP (-4.57%) | TP (+9.21%) W (+1.01%) |
| | In-vehicle travel time improvements of 10%. | | | | | | PC (-0.04%) CP (-0.62%) | TP (+1.40%) W (-0.02%) |

| | | | | | | | | |
|---------------------------|---|--------------------------------------|-----------|------------------|-----------|---|-----------------------------|----------------------------|
| | Parking charge (50%) & Cordon toll (1.2 €/day) | | | | | | PC (-1.69%) CP (-7.73%) | PT (+16.02%) W (+2.64%) |
| | Parking charge (50%) & Cordon toll (1.2 €/day) & in-vehicle travel time improvements of 10%. | | | | | | PC (-1.91%) CP (-8.66%) | PT (+19.52%) W (+2.62%) |
| Agarwal & Koo (2016) | Congestion toll tax (increasing by \$1 in the morning) | Multiple regression | 77 | Singapore | 2 months | Increasing bus use | | B (+8%) |
| | Adjusting the tax from \$0.5 to \$1 in the evening | | | | | | | B (+10%) |
| Albalate & Gragera (2020) | Regulated spaces (Parking spaces per 1000 inhabitants: commercial, mixed-use, resident-exclusive) | Panel data modeling | 72 | Barcelona, Spain | 2007-2014 | Car ownership ratio measured by number of cars per thousand inhabitants | PC (number of cars = +0,26) | |
| | Parking fee (average weighted curbside parking fee) | | | | | | NS | |
| Steininger et al. (2007) | Road pricing 5 euro-cents/km without time differentiation | Computable general equilibrium model | 1 country | Austria | 2000 | Modal shift (in terms of number of passengers/km) | PC (-6.5%) | PT (+6.3%) |

| | | | | | | | | |
|-----------------------|---|------------------|----------------------|-------|------------|--------------------------|------------|-----------|
| | 10 euro-cents/km | | | | | | PC (-14%) | PT (+15%) |
| Asensio et al. (2014) | Reduction of 5% in commuting and regional train fares | Panel regression | 48 Spanish provinces | Spain | 2008- 2011 | Gasoline consumption (%) | PC (-2-3%) | |

Legend: AC=Active mode/B=bus/C=cycling/CP=carpooling/PC= private car/ PT=public transport/M=metro/NS=No significant /SM=sustainable mobility/S=scooter/T=tram/W=walking

Appendix 2

Table 4: Non-economic incentives.

In green, the results showing the effectiveness of the measures blue, the results showing the ineffectiveness of the incentives; (**) = low significance, (***) = high significance, NS=not significant.

| Authors | Type of incentives | Method used | Number of observations | Period | Geographical area | Observed variables | Results | |
|-----------------------------|---------------------------------------|---|------------------------|-----------------------|--|---|---------|----------|
| | | | | | | | PC | SM |
| Ingvardson & Nielsen (2019) | Overall satisfaction | Structural equation modeling | 38,537 | 2009–2015 | Stockholm, Sweden; Oslo, Norway; Helsinki, Finland; Copenhagen, Denmark; Vienna, Austria; and Geneva, Switzerland. | The use of public transport | | PT (***) |
| | Norms | | | | | | PT (**) | |
| | Recommendation to others | | | | | | PT (*) | |
| Shang-Yu Chen (2016) | Perceived green value of public bikes | The modified technology acceptance model (TAM) and structural equation modeling | 522 | August-September 2014 | Taipei, Taiwan | Green loyalty to public bikes for non-users | | C (**) |
| | Perceived pleasure to use | | | | | | | C (***) |
| | Perceived green usefulness | | | | | | | NS |
| | Subjective norms | | | | | | | C (***) |
| | Perceived behavioral control | | | | | | | NS |

| | | | | | | | | |
|-------------------------|-------------------------------------|---|-------|---------------------|-----------------|--|----------------------|--------------------------|
| Geng et al. (2016) | Information and communication | Questionnaires | 452 | November 2015 | Xuzhou, China | Differences in attitudes towards transport modes before and after the experiment | NS | Green modes (+0,85%) *** |
| De Vos et al. (2020) | Satisfaction with PT | Ordered logit model | 986 | 2013 | Canada | Desired PT frequency | | PT (1,73) odds ratio |
| | | | | | | Actual PT frequency | | PT (1,70) odds ratio |
| | Attitudes towards PT | | | | | | Desired PT frequency | PT (27,83) odds ratio |
| | | | | | | | Actual PT frequency | PT (4,58) odds ratio |
| Kroesen & Chorus (2018) | General attitudes | Structural equation model and cross-lagged panel model | 1,082 | July 2013–July 2014 | Netherlands | Mode choice behavior | NS | NS |
| | Specific attitudes | | | | | | (***) | SM (***) |
| Gutierrez et al (2020) | Habits to use bicycle (spontaneity) | Discrete choice modelling approach (hybrid ordinal logit model) | 805 | March–May 2018 | Santiago, Chile | Significance on bicycle use | | C (***) |
| | Perception of use of bicycle (Risk) | | | | | | | C (***) |
| | Bicycle facilities | | | | | | | C (***) |
| Stark et al. (2019) | Age (+) Kids | Descriptive-exploratory analyses | 129 | | Vienna, Austria | | PC (***) | B (***) |

| | | | | | | | | |
|--------------------------|---|--------------------------------------|-----|------------|---------------------|---|-----------|-------------------------------------|
| | Age (-) Kids | | | | | | PC (***) | W (***) |
| | Attitude towards respect for the environment and health | | | | | | PC (***) | W (***) C (***) S (***) |
| | Specific attitudes related to transport modes (wellbeing during a trip) | | | | | | PC (***) | W (***) C (***) S (***) |
| Piwek et al. (2015) | Self-monitoring for competitive cyclists | Qualitative and quantitative methods | 23 | Five weeks | England | Frequency and long distances travelled by bicycle | | C (***) |
| | Self-monitoring for non-engaged cyclists | | | | | | | C (*) |
| Bucher et al. (2019) | A more accurate tracking with eco-feedback via an smartphone app | Surveys | 261 | Six weeks | Zurich, Switzerland | Modal shift after use of application for systematic loops | PC (-24%) | PT (+7,9%) C (+12,5%) W (+5%) |
| Pangbourne et al. (2020) | type of argument in the persuasive message: 'Authority' | A linear mixed effect | 406 | | England | Impact on behavioral change for walking adoption | | W (***) |
| | Value of argument in the persuasive message: 'Health' | | | | | | | W (***) |
| Gardner (2009) | Intention | Surveys | 102 | 2 weeks | Netherlands | Behavioral change for the use of a mode | | C (***) |
| | Habit | | | | | | | C (***) |
| | Strong habit x low intention | | | | | | | C (***) |

| | | | | | | | | |
|------------------------|--|------------------------------------|-------|---------|------------------------------------|---|--|---|
| | Low habit x strong intention | | | | | | | C (***) |
| Kang et al. (2019) | Convenience | Structural equation modelling | 307 | | Malaysia | Intention to switch to public transport | | PT (**) |
| | Flexible service | | | | | Intention to switch to public transport | | PT (**) |
| | Commute impedance | | | | | Intention to switch to public transport | | PT (*) |
| | Intention to switch for public transport | | | | | Behavioral readiness to adopt public transport | | PT (***) |
| Tsirimpa et al. (2019) | Reward system via a mobile application | Discrete choice modelling approach | 706 | 6 weeks | Vienna, Austria and Birmingham, UK | Average travel time by mode of transport for car users (Birmingham) | | PT (+108 min) C (+15 min) W (+67 min) |
| Lois et al. (2015) | Social identity | Structural equation modelling | 595 | 2012 | Victoria-Gasteiz, Spain | Intention to begin cycling among car users | | C (***) |
| Lind et al. (2015) | Personal norms | Structural equation modelling | 1,043 | 2013 | Norway | Predicting transport mode | | PT (***) AC (**) |
| | Ascription of responsibility | | | | | | | PT (*) AC (***) |

Legend: AC=Active mode/B=bus/C=cycling/CP=carpooling/PC= private car/ PT=public transport/M=metro/NS=No significant /SM=sustainable mobility/S=scooter/T=tram/W=walking

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