



Report on Behavioural Interventions

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Short Description	This report reviews the literature in behavioural interventions available in different fields of study to address the following questions: <ol style="list-style-type: none"> 1) Factors which are found important in encouraging pro-environmental behaviours among individuals 2) Effects and significance of various behavioural interventions implemented in various parts of the world and their role in reducing air pollution. 3) What different methods are available to quantify the effectiveness of behavioural interventions. 		
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Table of Contents

1	Executive Summary	- 7 -
2	Introduction	- 8 -
2.1	Behavioural Interventions: Definition.....	- 9 -
2.2	Scope of Investigation.....	- 10 -
2.3	Layout of the Report.....	- 10 -
3	Changing Individual Behaviour.....	- 11 -
3.1	Encouraging Pro-environmental behaviour: Individual-oriented factors.....	- 11 -
3.2	Encouraging Pro-environmental Behaviour: Society-oriented factors	- 13 -
4	Behavioural Interventions and their effects.....	- 15 -
4.1	Mobility-based Behavioural Interventions.....	- 15 -
4.1.1	Linking Transport and Environment.....	- 15 -
4.1.2	Active Mobility.....	- 16 -
4.1.3	Promoting use of Public Transportation.....	- 19 -
4.1.4	Pricing Strategies.....	- 21 -
4.1.5	Low Emission Zones	- 23 -
4.1.6	Telecommuting	- 24 -
4.1.7	Other notable Interventions.....	- 25 -
4.2	Studies related to Energy Conservation and Recycling.....	- 26 -
4.2.1	Household Energy conservation Strategies.....	- 26 -
4.2.2	Recycling strategies.....	- 27 -
4.3	Passive Control Systems and Behavioural Studies	- 27 -
4.3.1	Green Infrastructure and Spaces	- 27 -
4.3.2	On-street Parking orientation	- 28 -
5	Methodological Approaches for Behavioural Intervention Assessment.....	- 28 -
5.1	Integrated Travel behaviour and Air quality models.....	- 28 -
5.2	Experimental Research Designs-Small Scale Behavioural Assessment Techniques	- 32 -
6	Conclusions and Recommendations.....	- 34 -
6.1	Exposure Analysis.....	- 34 -
6.2	Useful behavioural interventions and treatments.....	- 34 -
6.3	Use of Integrated Models for Policy Assessment.....	- 35 -
6.4	Passive control systems and behaviour	- 36 -
6.5	iSCAPE work packages and key findings matrix.....	- 36 -
6.6	Key Recommendations for WP 4	- 37 -
6.7	Recommendation for Recruiting citizens for Living Labs.....	- 38 -
7	References / Bibliography	- 39 -

List of Tables

TABLE 1: INTERVENTION BASED ON ACTIVE MOBILITY AND THEIR EFFECTS.....	- 19 -
TABLE 2 : SPECIFICATIONS AND EFFECTS OF ROAD PRICING STRATEGIES EMPLOYED IN VARIOUS CITIES	- 22 -
TABLE 3: SPECIFICATIONS AND EFFECTS OF LEZ EMPLOYED IN VARIOUS CITIES	- 23 -
TABLE 4: INTEGRATED TRAVEL BEHAVIOUR AND AIR QUALITY MODELS.....	- 31 -
TABLE 5: DEFINITION OF TREATMENTS USED FOR PRO-ENVIRONMENTAL BEHAVIOURAL CHANGE	- 33 -
TABLE 6: STUDY FINDINGS AND THEIR RELEVANCE TO DIFFERENT WP IN iSCAPE	- 37 -

LIST OF FIGURES

FIGURE 1: THEORETICAL FRAMEWORK FOR UNDERSTANDING THE ROLE OF COMMUNITY CAPACITY IN ENABLING RESPONSIBILITY FOR COMMUNITY ECOLOGICAL FOOTPRINT [MIDDLEMISS AND PARRISH, 2009, PP:7561]-	14 -
FIGURE 2: INTEGRATED TRAVEL BEHAVIOUR AND AIR QUALITY MODELLING FRAMEWORK.....	- 29 -

List of abbreviations

CBD	Central Business District
CO ₂	Carbon dioxide
EV	Electric Vehicles
EEA	European Environmental Agency
GHG	Greenhouse Gas
GPS	Global Positioning System
iSCAPE	Smart Control of Air Pollutant and Environment
LEZ	Low Emission Zone
MEDLINE	Medical Literature Analysis and Retrieval System Online
NO _x	Nitrogen Oxides
O ₃	Ozone
PCE	Perceived Consumer Efficacy
PCS	Passive Control System
PM ₁₀	Particulate matter with a cut-off diameter of below 10 μm
PM _{2.5}	Fine Particulate matter with a cut-off diameter of below 2.5 μm
SO _x	Sulphur Oxides
SUDS	Sustainable Urban Drainage Systems
TRID	Transport Research International Documentation
VMT	Vehicles Miles Travel
VOC	Volatile Organic Compounds
WHO	World Health Organization
WTP	Willingness To Pay

1 Executive Summary

This report reviews the literature in behavioural interventions available in different fields of study to address the following questions:

- Factors which are found important in encouraging pro-environmental behaviours among individuals
- Effects and significance of various behavioural intervention implemented in various parts of the world and their role in reducing air pollution
- What different methods are available to quantify the effectiveness of behavioural interventions?

The report focused more on mobility-related interventions in terms of defining their impacts as emissions from road transport is significant contributors to air pollution. The literature examined with intentions to recommend a way forward for other work packages of iSCAPE project, especially work package 4.

Among the factors for pro-environmental behaviours among individuals, literature indicated that socio-demographic variables are not a significant determinant of pro-environmental behaviour. However, factors that explain individual attitude, personal motivation, and altruism are more powerful in explaining these behaviours. Additionally, social context is also important as positive social norms can influence positive pro-environmental behaviour. Citizens involvement in the design and implementation stages are key to foster more positive and long-lasting results. There are a variety of different types of interventions employed, and they are classified in the literature as informational and structural strategies. Informational strategies are soft and mostly creating a “pull” effect. On the other hand, structural strategies are primarily hard measures designed to create “pull” or “push” effects. It has been shown in the literature that structural strategies are more effective, however, when these are employed in combination with informational strategies, the effect is more sustainable. Within the mobility field, interventions such as: promoting active mobility and public transportation, pricing strategies (tolls, congestion charging, Parking fee), telecommuting, vehicle restrictions in the form of introducing low emission zones and restricted ownership, electric mobility, car sharing and speed limits introduction are found to have been studied in relation to their effect on air quality. Interventions in relation to active mobility and public transportation are more likely to be used more aggressively due to their pull effects and acceptability among residents, and they are not only appropriate for air quality improvement but also produce healthy lifestyle among residents. In terms of measuring the effectiveness of these interventions, a variety of methods are investigated in the literature. There is a wide body of literature available that tests the efficacy of interventions (mostly informational) using small-scale experiment with individuals forming control and treatment groups. Commitment, goal setting and prompt type of intervention treatments are found more effective among informational strategies. However, at the same time, it is important that barriers and benefit associated with required behavioural change should be examined and selection of the type of treatment should also be based on this situation. Furthermore, integrated models (travel behaviour and environment model) also provide a framework to investigate various mobility-based interventions and their effect on air quality. It is, however, unfortunate that these integrated models have not been used extensively.

In relation to other work packages within iSCAPE, the following is recommended:

- Behavioural interventions related to active mobility and public transport should be examined using integrated travel behaviour and environment chain models.

- Exposure analysis should be carried out using space-time based consideration of individual and air pollutants. Tools such as GPS based mobile apps and mobile sensor kits are available for carrying out these tasks.
- Behavioural intervention needs to be designed considering social context and psychographic and altruistic characteristics of individuals. Identification of target audience along with barriers and benefit of required behavioural change need to be examined
- Interventions engaging citizens render fruitful results and foster pro-environmental behaviour among individuals.
- Some guidelines are provided considering objectives of WP 4 for designing an informational based behavioural intervention under the location-based framework. Further, few important points are mentioned to engage citizens in living labs activities in the target iSCAPE cities.

2 Introduction

This section defines the background and contextual information on which the deliverable of task 1.3 is based. It first explains the term “Behavioural Interventions” in the context of iSCAPE project and then defines the scope of this deliverable. The proposal defines task 1.3 as follows:

“Behavioural interventions are interpreted as all actions and initiatives an individual can take to reduce his/her own emissions. Contributing in this way to reduce the environmental pollution (and the improvement of its own health). Likewise, the aim of this task is to develop a comprehensive summary of the technical details of behavioural interventions, which are possible and provide suggestions for their testing and implementation in WP4. One important source of behavioural interventions from an individual point of view is actions to manage mobility participation. Obviously, the study of vehicle pollutants and their harmful effects is a well-established research domain. However, studies that investigate the environmental effect of more “complex” (direct) behavioural actions such as telecommuting, residential relocation, shopping during mornings and evenings, start time to work, speed reductions, driving behaviour (number of cold and warm starts) have been examined in mobility studies but have been used to a far lesser extent for assessing environmental and health impacts. Secondly, we want to investigate “easy-to-take” interventions like the evaluation of the effect of non-motorized transportation at city levels such as for instance the promotion of all forms of active transport. Also for this intervention, many isolated studies exist but there is yet a scarcity of exhaustive information based on real field studies in varying different environments. We will develop a state of the art review of various aspects of behavioural interventions and provide recommendations to deploy them in the location based framework that will be developed in WP4.”

Based on the above-mentioned explanation of task 1.3, the deliverable 1.3 is mainly following the stipulated definition of behavioural intervention, however, more elaboration on this is provided in section 2.1. The review of literature explained in this deliverable contains research papers published in esteemed scientific journals and published reports from government agencies/authorities. Furthermore, efforts have been made to understand the impact of environmentally friendly policies on changing an individual’s behaviour in terms of travel-activity participation. As team members from T6 are also involved in this exercise as partners alongside UH, the methodology followed for this exercise is as follows:

- Regular fortnightly meetings where reading tasks were distributed among team members, and for each relevant reading material, a template is filled by the reviewer to mention the key findings.
- Literature review includes papers/reports/documents from various specific fields of studies such as: Psychological and marketing fields to understand the deriving factors in changing individual's behaviour, Transportation policy and modelling studies, Environmental pollutants specifically in relation to mobility-related pollutants individuals are exposed, modelling and simulation framework that helps measure the changing behaviour of individuals in response to various policies etc.

2.1 Behavioural Interventions: Definition

Many of the environmental problems such as urban air quality, global warming, environmental noise and continuous scarcity of resources (like water) are linked with human behaviour. Studies have shown that with a variety of physical and technical interventions, human behaviour can be changed/managed to reduce the negative impacts of environmental problems. Based on the seminal work of [Geller *et al.*, 1990], the literature suggests two broad types of intervention approaches available for effecting behaviour change [Steg and Vlek, 2009]. These are described below:

1) Informational Strategies

Steg and Vlek [2009], defined informational strategies as an approach to change perceptions, motivations, knowledge and norms, without disturbing the external context in which decisions are made. Information campaigns, use of social support and role models to influence the behaviour of others can be categorised within this type of intervention approach. Sometime informational strategies are used to complement the structural strategies for producing optimal behavioural changes [ALR, 2016].

2) Structural Strategies

Structural strategies are directly linked with changing external context, i.e. making circumstances under which adoption of pro-environmental behaviour is relatively more attractive [van Raaij, 2002, Steg and Vlek, 2009]. Congestion charging schemes and reduction of public transport fare are few of the examples under this type of behavioural interventions.

The review of literature reported in this deliverable is based on the above-mentioned two types of behavioural interventions. *Dwyer et al. [1993]* based on 54 interventions studies, found that informational strategies have the potential to produce significant behavioural changes and the effect of interventions can be retained up to 3 months with a view that these interventions are effective in circumstances where response cost is low or when there are other added advantages in changing the behaviour. Structural strategies are found to be more result oriented in short-run, however, as soon as these strategies are removed, behavioural changes among individuals are also found back to their previous situation. It is, therefore, concluded that techniques need to be ascertained to retain changed behaviour for optimal improvement in the environment.

2.2 Scope of Investigation

There are a variety of issues that have been addressed in the environmental literature under the umbrella of behavioural interventions. A majority of the studies are focused on mobility/transportation related interventions which have direct and indirect consequences on air quality. Another area where pro-environmental behavioural interventions have been studied in detail is household energy conservation and recycling behaviour along with the littering behaviour. In our literature review considering the objective of iSCAPE project, we considered studies which are mainly relevant in improving air quality. Emphasis is given to examining various deployed interventions under key issues raised by [Steg and Vlek, 2009] that provides a robust framework to understand and promoting pro-environmental behaviour. The following mechanism was used for the literature search:

- **Sources:**
 - Academic: Web of Science and Scopus, MEDLINE, Google scholar, snowballing procedure from selected references
 - Practical: reports of Agencies (e.g. Departments of Transport/ Road authorities, Regional Environmental agencies)
 - Both: TRID database, reports from European Institutes, EU project deliverables, WHO reports
- **Keywords used for searching:**
 - Pro-Environmental behaviours, environmentally relevant behaviours, behavioural interventions, behaviour change and its determinants , transport policies and their environmental effects, transport models, air quality models, Active travel and their air quality impacts, sustainable travel, Pollutants and their sources, transport emissions, pollutant exposure and health impacts, energy conservation behaviour, recycling behaviour, approaches for behavioural impact measurements
- **Language requirements:** English
- **Timeframe restrictions:** None

While reviewing the literature, we selected studies for a comprehensive review that can able to answer the following questions:

- Which factors are important that encourage pro-environmental behaviour?
- What are the effects of interventions?
- Which type of interventions is more effective and different methods/tools used to measure behaviour?

2.3 Layout of the Report

The report is structured into various key sections. Section 3 presents a review of the literature from marketing and psychological studies detailing key factors and methods that are helpful in understanding/investigating individual behaviour. Section 4 presents findings of the effects of behavioural interventions that are more relevant to travel-activity participation behaviour of individuals. This section also presents behavioural studies conducted in the areas of energy use, recycling along with a passive control system and green infrastructure in changing individual behaviour. Section 5 presents methodological approaches used for assessment of behavioural interventions in the form of integrated travel behavioural and air quality models and small-scale

interventions studies. Section 6 concludes the deliverable and puts forward recommendations for other work packages of the iSCAPE project.

3 Changing Individual Behaviour

In paragraph 2.2 the main questions under investigation in this report were mentioned. This chapter will mainly deal with the first question: i.e. how to successfully promote a behavioural change through dedicated interventions such as the one that iSCAPE will promote in its living labs and pilot activities. The literature reviewed in this chapter comes from social sciences: sociology, psychology and marketing, particularly green marketing, i.e. marketing of ecological/green products and services.

3.1 Encouraging Pro-environmental behaviour: Individual-oriented factors

Straughan and Roberts [1999] provided a review of green marketing studies discussing the efficacy of demographic variables in predicting green products' purchasing. Traditionally, a marketing strategy uses demographic segmentation (gender, age, income, the level of instruction, etc.) for predicting the market penetration of green products. The authors show how pieces of evidence are not supporting this approach. In fact, they review papers that demonstrated, for example, how age is an important variable in predicting who will buy green goods and other papers demonstrating the contrary; among those who show a correlation between age and green behaviours some papers demonstrate a negative correlation and other a positive correlation. The study carried out by the authors shows that psychographic variables are better predictors of green consumer behaviours. Psychographic variables consider consumers' attitudes, interest and opinions, i.e. soft variables if compared to demographic ones. Particularly, perceived consumer efficacy (PCE) and altruism are the most important variables in predicting green behaviours and choices. Perceived efficacy is defined as the perception of the consumer that his/her choices will have a positive impact on the environment.

"Roberts [1996] found that this (PCE) was the single strongest predictor of ecologically conscious consumer behaviour, surpassing all other demographic and psychographic correlates examined" [Straughan and Roberts, 1999]

Altruism has been studied by *[Stern et al., 1993]* that consider social altruism, i.e. an attention for the welfare of others and biospheric-altruism: "a concern for the non-human elements of the environment" *[Straughan and Roberts, 1999]*. Social and biospheric altruism are good predictors of green behaviours but are counterbalanced by egoism so that they are not a predictor of the willingness to pay higher gasoline taxes (that were also considered in the study).

With reference to the willingness to pay higher costs or taxes for the sake of the environment, *[Engel and Pötschke, 1998]* review several papers analysing the correlation between socio-economic and demographic characteristics and environmental concerns. They conclude that *"younger, well-educated, politically liberal, more affluent people, those who grew up in urban areas or are now living there, respectively, as well as those employed outside the primary industries worry more about the environment than their respective counterparts"* (ivi: 317). However, the fact that they are more concerned about the environment does not mean that they have more sustainable behaviours. There is a complete discrepancy, for example, reported for the wealthy middle classes that show pro-environment concerns but are "leading" non-environmental friendly lifestyles.

The authors go on analysing the relevance of values in shaping environmental behaviours and examine several aspects. The conclusions that are most useful for the sake of iSCAPE are mainly the following two:

- The first one is related to the relationship between individual and social groups. As we will see in paragraph 3.2, groups of belonging are seen as relevant in shaping pro-environmental behaviours. The social groups of the belonging need to be selected carefully because – as some authors pointed out [see [Beck, 1992]], classical social groups as classes are losing their centrality in determining individual choices. Never the less, other kinds of social groups are still relevant as for example neighbourhoods, social status and position within the social structure.
- The second finding, which is the most important one, is related to the relationship between value-rational behaviours and purpose-rational behaviours. In purpose-rational behaviours the ends of the action are not pre-defined, the subjects pursue its end and can choose different means to reach that end that is based on cost and benefits. The end in itself can be changed if the costs are too high. To the contrary, value-rational behaviours have a pre-defined end, which is based on values. Ethical, aesthetic, religious, or other forms of behaviour, determines the action independently of its possibilities of success or its costs. Considering this is very important because if driving a car instead of using public transportations is rooted in specific believes (i.e. is based on value-rational behaviours), economic incentives will not work in changing that behaviours. This is also supported by the work of [Taylor and Ampt, 2003]. Similarly, if protecting the environment is perceived as a value per se, individuals will be fine in bearing higher costs for protecting it. On this, it is worth mentioning [Inglehart and Abramson, 1999] post-materialist index. This index - even if debated – observe a shift in western cultures from materialist values, (priority on economic fulfilment and physical security), to post-materialist values, emphasizing autonomy and self-expression. This cultural shift is correlated with a growing concern for environmental issues; people socialized in a period of prosperity tend to have post-materialist values that remain unaltered for the rest of their life even if their economic situation gets worse (socialisation hypothesis).

Finally, other two concepts are interesting in helping understand those values that are positively linked with the willingness to pay (WTP) for environmental costs: these are “generalised trust” and “conditional cooperation”. *“Conditionally cooperating individuals only make a contribution to a specific public good such as environmental protection when they are convinced that others are also doing so. Conversely, unconditionally cooperating individuals make decisions concerning WTP for a specific good entirely independent of their expectations of third parties’ actions. One might argue that generalized (or social) trust turns people into unconditional co-operators or that it makes conditional co-operators confident that the others also contribute to public goods. In either case, those who have a high level of generalized trust are more likely to initiate cooperation and, hence, to contribute more to the provision of public goods than those with lower levels of generalized trust.”* [Meyer and Liebe, 2010].

In synthesis:

- Psychographic variables are better predictors of green consumer behaviours than demographic variables.
- Altruistic people are more inclined to green behaviours than non-altruistic persons; in this sense, persons can be described as social altruistic (when they care for other persons)

and biospheric altruists (when they care about the environment), both types of altruism matter in predicting sustainable behaviours.

- Perceived efficacy is crucial in fostering green behaviours and related campaigns: people have to feel that what they are doing has a direct and visible positive impact on the environment.
- Environmental concerns do not imply environmental friendly behaviours.
- Environmental friendly behaviours and the willingness to bear higher costs for the sake of the environment are valued dependent and are influenced by the social group of belonging.
- The preference for value-rational behaviours is the most important predictor when considering the willingness of people to pay extra costs for the benefit of the environment (for example higher taxes on cars or fuel).

3.2 Encouraging Pro-environmental Behaviour: Society-oriented factors

Paragraph 3.1 discussed the role of specific characteristics at the individual level to predict individual's willingness or capability to change behaviours towards more sustainable ones. In this paragraph, the focus will be on the role of society, a community of belonging and social norms in influencing individual actions and choices. From a sociological and anthropological point of view (also shared by the social psychology), in fact, individuals are not separable from the culture and the society they live in so that the factors influencing individuals' actions cannot be recognised only in intra-individual ones but have to take in due consideration group dynamics, the position of the individuals in the social structure, the culture and sub-culture of belonging, etc.

On this aspects, a study carried out in Australia on resident's choices about gardens styles is particularly effective in showing the relevance of community norms in orienting environmentally friendly behaviours. [Uren *et al.*, 2015], indeed, explore cultural and psychological drivers which prompt homeowners in Fremantle (a city in the Perth area) to adopt a native garden instead of a European-style garden which is the most common style followed in Perth areas even if environmentally not sustainable as it requires high water consumption, is not compatible with local biodiversity, etc.

Social norms can be defined as the understanding of what others perceive as acceptable and desirable. In this sense, "since caring for the environment was perceived as being highly valued within their community, many participants described feeling a sense of environmental guilt if they failed to care for their environment". Many of the persons interviewed in the study declared to have changed their gardens from European style to native gardens because they saw their neighbourhoods doing so and because local celebrities advertised local gardens. In this case, the changes are not fostered by economic incentives or by the provision of new information, but by the example of members of the community of belonging.

Middlemiss and Parrish [2010] discussed the importance of community as a space for realising pro-environmental change and especially low-carbon communities. They focused on the role of grass-roots initiatives in fostering low-carbon communities. Grassroots initiatives can be defined as initiatives carried out by communities with limited power and resources and that is large - if not totally - based on the voluntary work of few individuals/enthusiasts. The authors proposed a framework mapping the capacities needed by a community for supporting pro-environmental changes (see Figure 1).

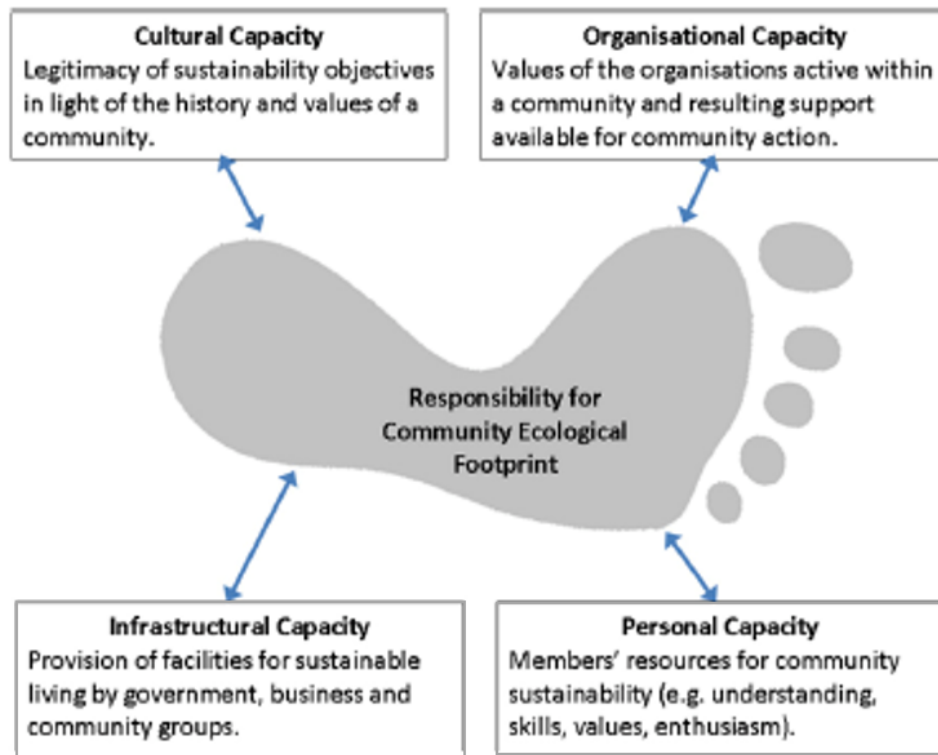


Figure 1: Theoretical framework for understanding the role of community capacity in enabling responsibility for community ecological footprint [Middlemiss and Parrish, 2009, pp:7561]

The article reported two successful cases of low-carbon communities created by grassroots initiatives and observes that they draw on multiple capacities within the community to create their activities and that the personal, organisational and cultural capacity were present and represented key success factors. This means that on one hand, communities can be an important starting point for fostering pro-environment behavioural change but, on the other hand, not all the communities have the needed capacities to succeed in doing so. Moreover, grassroots initiatives are normally spontaneous so that they can be supported by public-driven intervention interested in promoting a more sustainable lifestyle at the local level but cannot be created on demand, for example for a specific pro-environmental campaign. Similarly, studying grassroots initiatives is interesting but it has to be remembered that the observed dynamics cannot be generalised to all kinds of community.

A third study deserves to be quoted here as it considers the level of environmental concerns at society level by analysing national-based surveys. *Franzen and Vogl [2013]*, showed that there is a positive correlation between the wealth of the nations and environmental concern. By running a multi-level analysis of the 2010 International Social Survey, considering the data for 31 countries, they were able to re-test some of the hypothesis mentioned in paragraph 3.1 confirming a correlation between some socio-demographic characteristics such as gender, age, education and income, but also level of trust, party affiliation and post-material values but they also noted that respondents in countries with higher GDP per capita shown higher environmental concerns. The authors also observed that environmental concern decreased in almost all nations during the last twenty years; also in this respect, the correlation between national wealth and

environmental concern is respected because countries that improve their economic condition (in the same period) observed a more limited decline in environmental concerns. The economic crises of 2008 appear to have played an important role in moving the attention of the public away from environmental issues.

In synthesis:

- In order to have an effective intervention, it is important to foster pro-environment values in local communities: individuals are not acting in a vacuum but in social contexts which values influence their actions.
- Local celebrities can be of help in fostering pro-environmental behaviours as the example of friends and neighbourhoods especially if trusted, respected or perceived as having similar values.
- Grassroots initiatives are playing a role in building sustainable communities. In order to get the success they need to have certain capacities such as personal, organizational and cultural capacity.
- Citizens of wealthy countries show a higher environmental concern than those of lesser wealthy counties.
- Environmental concern decreased globally in the last 20 years and the 2008 economic crises have played a role in this phenomenon.

4 Behavioural Interventions and their effects

Behavioural interventions have been studied mainly in relation to individual travel behaviour, household energy conservation and recycling behaviours through different strategies aimed at improving the overall environment. As the iSCAPE scope of activities is limited to improvement of ambient air quality through smart control of air pollutants, the only individual-centric behavioural change which is of interest here is mainly the results of transport/mobility based interventions. This is due to the direct relationship of these interventions with individual exposure to air pollutants and the improvement of air quality with the increased use of sustainable transport options. As a significant amount of informational based strategies are examined for household energy conservation and recycling behaviour, we have also reviewed key review papers in this area to gain more insights in relation to the effectiveness of various strategies.

The information given under various interventions within this section is structured as follows:

- Type of intervention and strategy(ies) used for implementation along with their technical details
- The effectiveness of the intervention in terms of improvement of air quality and health
- Changes in behaviour and their determinants.

4.1 Mobility-based Behavioural Interventions

4.1.1 *Linking Transport and Environment*

Activities in relation to transportation are primarily one of the main sources of air pollution, together with: industry related emissions, volcano emissions, dust storms, natural fires and in-house activities. According to WHO report, levels of ambient air pollutants are estimated to have a profound impact on mortality rates. In 2012, More than 3 million deaths are attributed to this

situation worldwide and within Europe, the number is around 480,000 [WHO, 2014]. Human exposure to air pollutant is largely due to the traffic and transportation activity, which emerges as a direct link between respiratory problems (especially resident living around busy roads), increased allergies, birth defects and numerous forms of cancer [Int Panis et al., 2016]. Most important pollutants largely due to the transportation activity are identified in the literature as Ozone (O₃), nitrogen oxide (NO_x), Sulphur oxides (SO_x), Volatile organic compounds (VOC), particles (particulate matter with an aerodynamic cut-off diameter of below 10 and 2.5 µm (PM₁₀ and PM_{2.5}) and black carbon (mainly emitted from cars and lorries and are visible as black smudge on the filters of portable air pollutant measurement devices). Despite significant efforts within Europe, a significant number of city residents are still exposed to levels of air pollutants which exceed EU air quality standards [EEA, 2016]. It has been mentioned that implementation of EU Clean Air Policy framework by 2030 can evade more than 58000 deaths along with this it also brings savings of around 40 billion Euros in the health sector.

Vehicle emission from the transportation activity also contributes to the changing climate, worldwide the share of greenhouse gas emission from this sector is estimated to be around 23%. It is further stated that the contribution is growing at a much faster rate. EU legislation '20-20-20 by 2020' [Landis et al., 2012] proposed a reduction of greenhouse gas emissions of at least 20% by 2020 compared to levels of 1990 across all sectors. In relation to this, a reduction in on-road emission through a change in travel behaviour has been suggested as the most effective way of achieving it [De Nazelle et al., 2011]. It is also mentioned that transport demand management is an attractive strategy for reducing environmental impacts because of its inherent nature in addressing multiple impacts simultaneously, as demand for transport is derived from a large range of sources. European Commission's Green Paper on Urban Transport [UTIP, 2008] has realised this fact long ago, and therefore advocating policies that encourage higher use of public transport.

As the focus of this report is on reviewing interventions aimed at promoting pro-environmental behaviour among individuals, we are mainly discussing interventions which are individual centric. In relation to this, the next section examines several examples of mobility-based behavioural interventions employed in various part of the world and their effects on behaviour and the environment.

4.1.2 Active Mobility

There are many benefits of physical activity for the health of an individual. Active travel/mobility is considered as an easier way for fulfilling the needs of physical activity an individual required to remain healthy as active mobility can easily be integrated into the daily routine. Literature has established the norm that there exist positive impacts (health and air quality improvement) of travel policies and interventions to increase active forms of mobility such as cycling, walking and use of public transport [Pucher et al., 2010, De Nazelle et al., 2011]. It has been reported that annually around 1 million deaths are attributed to physical inactivity in the European region [Clark et al., 2011]. Alteration of travel mode in the form of active travel is significant in reducing environment-related problems such as vehicle emission, GHG, noise etc [De Nazelle et al., 2011]. It is estimated that 60,000 years of perfect health [definition could be seen in [GLA, 2014]] could be gained annually for London's habitants if their short motorised trips will be based on cycling and walking, and this could provide economic benefits of over 2 billion GBP [GLA, 2014]. Car travellers are exposed to higher levels of air pollution than cyclists or pedestrians. This is due to the selection of calmer and quite routes by active travellers, which are not heavily polluted [Int Panis et al., 2016].

There are a variety of interventions recommended/employed to promote active mobility (which can be categorised in both type of strategies), and often these interventions are employed together for creating effective change in the behaviour. It is recommended that the intervention package may include; infrastructure and facility improvement, pricing policies, and education programs to achieve a better result in increasing the share of active modes [Scheepers et al., 2014]. Due to this, it is difficult to isolate the impact of each specific intervention. Next paragraphs discuss different interventions employed to promote active mobility in different parts of the world.

The literature on activity mobility is more focused on measuring the effectiveness of these interventions in terms of health rather than quantifying positive environmental effects. According to the review report from [ALR, 2016], studies found that 16% risk of cardiovascular diseases is reduced for those individuals who walk 3 hours a week and 11% for those individuals who commute actively regularly. [de Nazelle et al., 2010] conducted a study to gauge air quality benefits for conversion of short car trips into walking and cycling trips. They do not discuss potential interventions for this change, however, concluded that converting short trip into active mobility will provide the following benefits across the whole USA in terms of improving the air quality.

- Reductions in CO will range in between 0.92% to 2.06%
- Reductions in NOx will range in between 0.38% to 0.84%
- Reduction in VOC (volatile organic Carbon) will range in between 0.91% to 2.04%
- The VMT (vehicle miles travel) reductions of 0.8–1.8% would translate into daily savings in GHG emissions of approximately 20,000–46,000 tons of CO₂ equivalent.

The study carried out by [Beckx et al., 2013] estimated the number of short car trips that can potentially be converted into active modes. They found that there exists a maximum potential of 10% of car trips that can be converted into active travel modes, and this could result in savings of 3% fuel consumption among the Dutch car drivers.

Scheepers et al. [2014] in their review paper on active mobility intervention effectiveness focus more on behavioural changes (i.e. more use of cycling and walking compared to private vehicles). Their review paper further concluded that most studies do not test the significance of differences obtained in various outcome measures after implementing a particular intervention. The interventions for active mobility can be classified into four broad categories, Table 1 presents this in more details:

Intervention broad category	Interventions with their specific technical details	Effects	Reference
Work-place Based Interventions	<i>Walk in to Work Out</i> – Informational pack (Educational and practical information to promote walking and cycling in local context)	Walking time significantly increased for intervention group. (Experiments conducted in UK)	[Mutrie et al., 2002]
	<i>Walk to Work Day</i> - written material and other tools such as newspaper ads, community service announcements through TV and Radio	Significant increase of 9% was found in trips that combined walking and public Transport. (Experiments conducted in Australia)	[Merom et al., 2008]
	<i>Workplace transport plan</i> - (Parking space limitations with increased parking prices, facilities for walking and cycling, subsidise bicycle purchases, car-sharing scheme, free shuttle service and discounted seasonal bus tickets)	Frequent walk to work trips were noted to be increased by 11% and cycling trips by 5%. (The plan developed for University of Bristol, UK)	[Brockman and Fox, 2011]

	<i>Bike Now Programme in 27 workplaces in New Zealand-</i> Information along with improvement of physical infrastructure for cycling	49% of car trips were replaced with cycling.	[O'Fallon, 2010]
	<i>Cashing out of employer-</i> Paid Parking - cash allowance was offered by employers to employees who are not using their parking spaces.	Solo-driver share decreases 13%. Car-pool share rose 9%. Public transport share rose 3 % and 1 % increase in walking and cyclins as combined mode. (Implemented in USA)	[Shoup, 1997]
Architectural and Urbanistic Adjustments	<i>Building New Railway Station</i>	Increase of 5% in travel using slow mode (In Netherland)	[Arentze et al., 2001]
	<i>Downtown Crossing project-</i> separating the vehicular traffic from pedestrian activity surrounding retail outlets	11% increase in pedestrians entering the intervention (study based in USA)	[Weisbrod, 1982]
	<i>Car-free city centres and automobile-restricted zones</i>	6% increase in Walking (noted for Aachen city). Bologna experienced 60% reduction in car within the restricted area.	[Topp and Pharoah, 1994]
	<i>Toll Ring implemented in Trondheim, Norway (limited operating hours)</i>	Shift in the timing of car trips was found.	[Meland, 1995]
	<i>Bicycle and pedestrian facilities- bike lanes and pedestrian sidewalks</i>	User was more willing to switch from car to use pedestrian paths and bicycle paths. 2% reduction of GHG emissions is noted for 7% increase in the length of bicycle network for Montreal, Canada	[Thakuriah et al., 2012], [Goodman et al., 2013], [Zahabi et al., 2016]
	<i>Reduction in traffic speeds- (30 kph) for residential streets adopted as an EU standard-</i> to create a safer environment for active transport	Fewer fatal accidents and more walking and cycling activity in urban regions	[Clark et al., 2011]
	<i>Design Street Project of Seoul – sidewalks, public spaces and other physical elements of streets</i>	Pedestrian satisfaction levels have increased, however, not too effective for increasing pedestrian volume	[Jung et al., 2017]
	<i>Connect2 Project: Several cities in UK such as Cardiff, Cambridgeshire and Southampton.</i> Construction of traffic-free bridges, boardwalk (actual construction was in year 2010) under iConnect project	Study measured that exposure to the infrastructure is positively associated to modal shift. Higher share of active modes	[Song et al., 2017], [Panter et al., 2016]
	<i>Introduction of Light Rail Transit – impacts on active travel was analysed before and after implementation of Light Rail Transit in California, US.</i>	Walking and physical activity levels increased among residents who resides near ½ miles of light rail transit service.	[Hong et al., 2016]
Informational and Educational Programmes (Population-wide Interventions)	<i>Annual Event of Bike, Walk and wheel Walk – bicycle proficiency education programme in classroom environment</i>	35% of the automobile trips were replaced with bicycle trips during the designated week. (implemented in Columbia, USA)	[Sayers et al., 2012]
	<i>Clean Air Force Campaign – to reduce individual vehicle-mile by not using car one day a week (TV, radio, newspapers are used for convey information, Rewards were also announced for participation)</i>	Increase of 1% was found in cycling for commuting purpose. Morning commute traffic was decreased by 2%.	[Alcott and DeCindis, 1991]
	<i>TravelSmart[®] - Individualised marketing strategy</i>	35000 people participated in Perth-Australia. Increase in 35%, 61 % and 9 % in walking, cycling and travelling as a car passenger.	[James and Brög, 2002]

	<i>School-based intervention on active commuting: Activity-based information delivery mechanism was introduced in the school such as: illustration on environment in the neighbourhood, story and performing scenes related to active commuting, illustrations on road safety</i>	Health related effects are monitored. Intervention was able to increase the bicycle use, however not able to increase walking among school children	[Villa-González et al., 2017]
Bicycle –renting Systems (Bike Sharing schemes)	<i>OYBike – London UK</i>	6% of overall mode shift was noted. Used majorly for recreational purpose, however, 11% individuals used it for commuting to work and school	[Noland and Ishaque, 2006]
	<i>Public bicycle share program – Montreal Canada</i>	Modal shift of 5% of the trips per day was noted.	[Fuller et al., 2013]
	<i>Bike share programs in Melbourne, Brisbane, Washington D.C, London and Minneapolis/St.Paul</i>	Car use is reduced in all places investigated except London. The situation is due to extra use of trucks for rebalancing of bikes.	[Fishman et al., 2014]
	<i>Bike share system now exist in 800 cities of the world. [Fishman, 2016] provides comprehensive review of literature in these areas.</i>	Impacts of bike share system need to be quantified appropriately in various fronts such as: mode choice, emissions, congestion and health.	[Fishman, 2016]

Table 1: Intervention based on Active Mobility and their effects

There is being a growing discussion about the negative impacts of walking and cycling, as individuals using these active modes may subject to higher exposure of air pollutants. This situation may offset some of the health benefits. *Int Panis et al. [2016]* mentioned the consensus that the protective health benefits of increased physical activity from cycling are much larger than the risks of air pollution, at least in European cities. Further, a study from *[De Hartog et al., 2010]* concluded that in terms of mortality, the cycling may cause a loss of life of only 21 days because of increased exposure to air pollution, however, regular use of cycling in new individuals may add up 8 months of life. *de Nazelle et al. [2016]* in their study also found that pedestrians on an average are less exposed to pollutants than car users and bus users and cyclist. This situation clearly outweighs the negative effects of increased exposure to air pollutants. *[Int Panis et al., 2016]* recommended the use of apps that are designed and developed at Flemish Institute of Technology (VITO), to help policymakers and commuters including those apps that find healthy routes while cycling and walking. However, there exists no such study at yet that describe the effectiveness of these behavioural tools.

4.1.3 Promoting use of Public Transportation

Benefits in investing and promoting public transportation system to reduce car travel are no doubt beyond comprehension. Many studies have attempted to quantify these benefits in terms of economic (i.e. reduced vehicles miles) and environmental (improved air quality) cost savings, and further translated into health impacts.

Fellermann [2015] mentioned that a particular car trip if altered with public transport can reduce the emission as follows:

- 140 g CO₂,
- 0.9 g carbon monoxide,
- 0.17 g VOC,
- 0.3 g NO₂ and

- 0.008 g PM per km

It is further concluded that in order to have a long-lasting effect of the public transport system, it should be embedded in an integrated approach of multi-modality and cooperation with cycling, car share and other mobility services. *Fellermann [2015]* mentioned a few exemplary interventions to promote the use of Public transport in a way that it is also effective for improving air quality. These are discussed below:

- A ‘Green Wave’ at Zurich, that was implemented in 90’s to give priority to trams and buses at traffic signals, the intervention reduces the travel time and waiting time which resulted in increased modal shares of public transport.
- Investments in trams, as they found to be more cost-effective compared to subways and less dependent on traffic congestion than buses. Many European cities have revived their tram network and in some situations, trams can use railway track to have more multi-modal integration.
- Separate bus lanes, almost all public transport system in the world are utilizing this intervention (at least at peak times), which are found helpful in creating less interaction among other traffic and buses and therefore reduces significant delays.
- Attractive fares and tariffs with the introduction of smart fare system are able to reduce barriers for using public transportation.
- Multi-and intermodality; the “Mobility Points” in Bremen (Germany) is exemplary. Public transport stops are integrated with car sharing schemes, bike rental, taxis and public phones.
- Smartphone applications/website to provide personalized information to passenger have seen to have profound impacts in encouraging people in switching their modes from the car. These apps are easy to download and very user-friendly. [*Watkins et al., 2010*] informed that their mobile application from Metlink within (Melbourne (Australia)) is on an average downloaded around 4000 times per week.

As it has been seen in the case of structural interventions, information-based campaigns have a significant role in increasing Public transport ridership. In Perth (Scotland) investment have been made in the public transportation system by introducing low-floor buses, more bus stops along with priority plans. Along with these interventions, informational strategies based on advertisements, interviews with potential clients by telephone and free-ride offers resulted in 56% increase in the use of public transport within two years [*Ibraeva and de Sousa, 2014*]. *Cairns et al. [2004]* reported that improvement in public transport services alone is not able to attract desire number of clients, however, with an efficient informational campaign the number of bus journeys increased by around 42%. Similar findings are noted for an informational campaign (branded as indiMARK®) to promote public transport in Germany, Australia and UK [*Brög et al., 2009*]. *Thøgersen [2009]* studied the effects of using a subscription to service (by providing a free month travel card) method for promoting public transport in Copenhagen. The study was based on the argument that often car drivers becomes habitual (due to their repeated use) and a key to influence change is to create circumstances in which it is either impossible to execute that behaviour or making that option unattractive. They concluded that the price promotion led to a doubling of the use of public transportation in the experiment group and a positive effect remained half a year after the intervention. Furthermore, results confirmed that a free month travel card is sufficiently noticeable to attract car drivers and unsettle their execution of travel mode habits and it is sufficiently attractive to encourage them to try public transportation. *Koo et al. [2013]* examined

the effects of the point card system employed in South Korea to promote green growth (i.e. more use of public transport) using stated preference data. They concluded that consumer low membership cost and use of accumulated points are the key factors for widespread participation. They further suggested that such a system may have the potential to reduce 190 to 920 kt of CO₂ emissions. Using a choice behavioural model estimated for Portland, Oregon metropolitan area in USA, *Shifftan and Suhrbier [2002]* investigated the changes in travel behaviour by improvement in transit service (through increase supply of buses and reduction in fare). Their model results in an overall increase of 10% in bus ridership, however, they noted that only part of this is coming from people who previously used car and rest of it is coming from other high-occupancy or non-motorized modes (cycling and walking).

4.1.4 Pricing Strategies

Road pricing strategies are being employed in many regions of the world as a structural intervention with a viewpoint that road user should pay for using the road network for correct allocative decisions between transport and other activities. *Ubbels and de Jong [2009]* in their comprehensive review of pricing strategies mentioned that road users respond in various ways in terms of their behaviour against road pricing which could be changed in all or some activity scheduling dimensions such as route, time-of-day, location, mode or changes in activity patterns along with long terms choices such as vehicle ownership, residential and work location etc.

Further, it is mentioned in the literature that different types of pricing methods can have different impacts. For example; tolls may affect travel routes and destinations, A time-based pricing may shift trips to other times. The increase in fuel prices tends to affect the type of vehicles purchased more than vehicle mileage. In addition to this, type of trip and traveller is also important. For example; commute trips are found to be less elastic compared to recreational or shopping trips, Individuals with high income are less sensitive compared to low-income individuals. Furthermore, the availability of quality alternatives may also increase the price sensitivity. Below is the example of a few regions where this strategy is implemented.

Location	Other specific technical details	Effects	Reference
Singapore	Time-of-day based pricing system in Central Business District (CBD)	Reduced 73% of private vehicles entering into the CBD, carpooling is increased by 30% and bus usage has been doubles	[<i>Schuitema, 2007</i>]
Trondheim (Norway)	Time-of-day based pricing system	10% decrease in traffic passing the ring both in the peak and non-peak charging hours	[<i>Langmyhr, 2001</i>]
Orange County (California)	High-Occupancy toll lane is available for car shares and any drivers willing to pay a toll to use a premium lane. Charges vary by time-of-day	Delays fell from 30 minutes to in between 5-10 minutes on non-tolled lanes.	[<i>Sullivan, 2000</i>]
Chicago skyway	Tolled alternative road to avoid congested road	Average time savings is around 22 minutes	[<i>Maunsell, 2005</i>]

M6 Toll (Britain Motorway)	Alternate tolled route to the most congested portions of the M6	Journey times faster between 4 to 18 minutes.	[Bowerman, 2008]
London Congestion Charge	Time- based pricing (Area wide)	Congestion dropped 30% after 1 year, however, reduction in delays noted after 3 years are just around 8%	[TfL, 2007a, TfL, 2007b]
Stockholm Congestion charging	Time- based pricing (Area wide)	20% reduction of traffic (in 2011) compared to based year (2006).	[Ubbels and de Jong, 2009]
Milan	Time-based (Area wide) Pollution charging (implemented in 2008 – charges were proportional to vehicle emission class) and in 2012 congestion charging is implemented.	More than 35% reduction is noted in traffic till 2014. Compared to base year	[Croci, 2016]
Beijing (simulation study)	Various method of congestion charging are explored i.e. distance based or cordon based, Additionally, for different size of area	Inside charging area: Public transit use may increase by 13%, CO and VOC may reduce by 60-70%, NO _x may reduce by 35%	[Wu et al., 2016]
Netherland (simulation study)	Effect of various distance-based charges scheme are explored on car purchase as charges are also based on emission produced from the car.	Schemes have potential to decrease in car use but car ownership has been noted to be increase by 3-6% in 2030.	[Meurs et al., 2013]

Table 2 : Specifications and effects of road pricing strategies employed in various cities

In terms of air quality improvement, [Croci, 2016] reported a reduction in air pollutant measured due to the implementation of three schemes (i.e. London, Stockholm and Milan). In Stockholm, the scheme resulted in a 15% drop in VMT leading to emissions reductions of 8.5% for NO_x, 13% for PM₁₀ and CO₂, and 14% for CO in the inner city (1 to 3% emissions reductions in greater Stockholm). London congestion charge has resulted in a decrease of 13% NO_x, -15% PM₁₀, -16% CO₂ emissions and within Milan, it has resulted in a decrease of 15% in PM₁₀ in 2011. Croci [2016] concluded as one of the important points that for last-long effects the specification of the charging schemes may need to be adapted and updated over time. This has actually happened in the case of Milan where first pollution charging scheme has been implemented, however, later when polluting vehicles were out of the circulation, authorities changes it to congestion charging scheme with some change specifications. In other study conducted by [Guzman et al., 2016] reported their findings by testing the combination of strategies including road pricing, increased parking fees and fuel taxes using a land use and transport interactive model for Madrid Region. They concluded that pricing measures in a local or central area are helpful in achieving local targets of air quality, however, they can cause negative impacts in surrounding areas. [Wu et al., 2016] also concluded similar findings from their simulation study for Beijing, China.

4.1.5 Low Emission Zones

Low emission zone (LEZ) is a monitored and defined area where access restrictions are employed for certain vehicles that do not meet emission class criteria, however, restricted vehicles can enter the area by paying a heavy monetary penalty (In the case of London, the penalty is around 100-200 GBP per day for large vehicles) [TfL, 2008]. Enforcement of the LEZ is usually done through an Automatic Number Plate Recognition (ANPR)-camera system. In Europe LEZ is a common intervention (classified as a structural strategy) employed to reduce vehicle emissions to improve air quality [Malina and Scheffler, 2015]. However, each LEZ in the different regions of EU has its own specifications in terms of restrictions, monitoring and enforcement mechanism and penalties. presents details and the effectiveness of this intervention in terms of reduction of different air pollutants in few cities as an example. There are a variety of added advantages reported for LEZ along with the improvement of air quality, these are as follows:

- Reduction in congestion within the LEZ area (usually these areas are internal areas of the cities where congestion is itself a significant problem), though in longer run other methods are required to maintain traffic volume levels.
- Gradual replacement/ of polluting vehicles into low emission vehicles (especially positive changes in the composition of fleet vehicles.
- More availability of parking spaces inside the LEZ, as the restricted vehicle will tend to use the Park & Ride option outside the LEZ area to avoid heavy penalties.

City	Other Specific technical Details	Year of Implementation	Reduction in Pollutants		
			NO _x	PM ₁₀	Others
London (UK) [Ellison et al., 2013, TfL, 2008]	Restriction only for heavy vehicles (Euro 4 and above buses, coaches and heavy goods vehicles can enter)	First implemented in 2008, standards were reset in the year 2012	37% (till 2015)	16% (till 2015)	N/A
Amsterdam (Netherland)[Panteliadis et al., 2014]	Euro 0,1,2,3 diesel engine and Heavy Vehicles (above 3500 kg) are restricted	January, 2009	5.9% (in two years, till Dec 2010)	5.8% (in two years, till Dec 2010)	12.9% (elemental carbon) (in two years, till Dec 2010)
Berlin (Germany) [Boogaard et al., 2012]	Diesel vehicles with euro 4 or above and Petrol vehicles with Euro 1 and above can enter	2008, standards were reset for 2010	12% (in first year)	N/A	N/A

Table 3: Specifications and effects of LEZ employed in various cities

The major behavioural response in relation to LEZ was noted in terms of change in ownership of vehicles allowed to enter in the restricted area. Majority of these ownership changes are noted in commercial/freight vehicles [Ellison et al., 2013]. There are no studies found that estimates the secondary effect of this intervention i.e. changes in travel behaviour (in terms of changing location

choice for conducting various activities, use of different transport mode to enter in LEZ). However, the interventions have been found to produce significant effect in terms of improving air quality (as depicted from). Because of these significances, recently this intervention is planned to be implemented in various other cities in Europe such as Antwerp (Belgium) and Prague (Czech Republic) [EU, 2016].

4.1.6 Telecommuting

An alternative to other measures for managing travel demand (reduction in vehicle trips), telecommuting measure is considered to have significant potential in reducing commute for work. The intervention mainly refers to employees who work from home instead of commuting to the central office. This structural intervention is found to be appropriate for work types that involve information management; such as research, software development and design, accounting and editing etc [VTPI, 2012]. Mokhtarian [2002] found that 6.1% of the workforce in California may telecommute on an average around 1.2 days a week, which result in a reduction of 1 % of total household vehicle travel. Nelson et al. [2007] investigated the outcome of a “National Telecommuting and Air Quality Act” under which 5 cities in the USA were commissioned to encourage telecommuting for emission reduction purposes as part of a pilot project named as *ecommuter*. Within this program, employers who initiate telecommuting within their organisation were supposed to receive credits in relation with the reduction in emissions. The findings of the investigation revealed the following results:

- Reduction of 0.142 pounds per telecommuting day is noted across all cities in VOC
- Reduction of 0.105 pounds per telecommuting day is noted across all cities in NOx.
- Emission reductions were relatively modest- City of Denver that has most telecommuters prevented around 1.0 to 1.5 tons of VOC and NOx in the period of 3 years.
- Across cities, this reduction varies with a number of participants in the program, number of days each participant telecommutes, emission factors of the vehicles owned by participants, and distance travel to work.
- The data also suggests drop-outs in telecommuting and therefore raises the question in relation with the sustainability of reported reductions.

In terms of modelling study, Shiftan and Suhrbier [2002] investigated the encouragement of telecommuting (by doubling the number of individuals working at home) from the behavioural model. They found that work trips have been reduced by 4%, however, that reduction came with the increase in 1.7% trips for discretionary activities and 2.9% maintenance activities. They also come up with the conclusion that extent of trip chaining has reduced and around 10% increase in short tours in morning peak period. In terms of mode choice for travel, they found that auto trips have been decreased by 2.2% in the downtown, however, the number is not that significant when this statistic is estimated for the entire modelled region. It is further noted in the literature that this intervention may have negative effects (which are classified as rebound effects). For example, this intervention tend to reduce peak-period traffic, however, it does not necessarily mean that it reduces the total vehicles miles travel due to the following reasons; employees may choose home location farther to their work places which results in travelling large distance for work and other activities, teleworkers often involved in additional trips for other purposes and the extent of trip chaining is reduced, vacant vehicle in the house can be utilised by other members. Although much of the studies support this intervention to have a positive effect on the environment, at the same time they suggested that significant reduction in vehicle travel can only be achieved if other

strategies are implemented in conjunction with this. Such as; Road Pricing, Parking management, Fuel tax increases etc. [VTPI, 2012].

Zhu and Mason [2014] investigated the impacts of telecommuting on personal vehicle usage and environmental sustainability using the national household travel survey (from the USA) for the two years i.e. 2001 and 2009. Their findings contradict the earlier studies, as they found that increases in vehicle travel for daily work and non-work purposes for the individuals who are telecommuters. The marginal effect of telecommuting on worker's daily trip is found to be 38 vehicle miles more in 2001 and 45 vehicle miles more in 2009 compared to non-telecommuters. They further translated these increased vehicle travel into GHG emissions and found an increase of CO₂ emissions of around 39,441,114 metric tons in 2001 and 41,934,732 metric tons in 2009. This is despite the fact that in 2009 fuel efficiency has been increased and the proportion of telecommuters was found similar between both years. [Kim, 2017] in another study found similar results of telecommuting. The situation clearly depicting the changing behaviour of the individual in a way which is undesirable and policy makers need to affirm this fact.

4.1.7 Other notable Interventions

There are various other notable interventions employed by the institutions/authorities to reduce air pollutions, we are discussing a few of them below:

➤ *Electric Mobility:* Use of electric vehicles (EV) is increasing at a high rate and many countries have set a target to replace internal combustion engine (ICE) based vehicles into EVs due to their potential in improving air quality. *Buekers et al. [2014]* studied the effects of changing 5% ICE vehicles into EVs in different EU-countries. They have concluded that benefits from the introduction of EV in a particular country are heavily dependent on the type of fuel mixes each country is using for generating required electricity production for these vehicles. In France the situation is positive, however, in Poland, it will cause negative effects. They suggested that along with the benefits associated with EVs, it is advised that policies for supporting active travel modes, public transportation should remain as it is. The similar conclusion is drawn by [Nichols et al., 2015] in their study of the adoption of EV in Texas, USA. *Hiselius and Svensson [2017]* studied the effect of E-bike (pedelec type) promotion campaign in Sweden. They found that e-bike is useful in reducing CO₂ emissions mainly by reducing car-usage. Individuals living in urban areas have a higher tendency to use e-bike compared to those living in rural areas, and at the same time use of e-bike may also cause a reduction in physical activity among its users.

➤ *Car sharing Schemes:* Car sharing schemes are rapidly emerging in developed countries due to their significant potential in relation to the increased use of public transport and active modes and car ownership reductions. Evidence of this has been noted in the USA and Europe. *Rabbitt and Ghosh [2013]* for their study of Ireland, concluded that organized car sharing can reduce 86 kt of CO₂ emissions per year. *Chen and Kockelman [2016]* examined the energy use and GHG emissions for a fraction of the US population that can be potential candidates for car sharing. They estimated that household transport-related energy use and GHG emissions may reduce by 5%. Concerns have also shown in the literature that most subscription of this schemes are made by individuals who do not own car at the first place and therefore car-dependency may increase. *Zhou [2012]* found that car sharing is more popular among the user of public transport, students and female workers.

➤ *Vehicle Ownership restrictions:* *Li and Jones [2015]* investigated the effect of vehicle ownership restriction employed by Beijing government by issuing a restricted number of total license plates per year using a quota based lottery system. They concluded that restraining

policy currently employed by the government will reduce 8 million tons of CO₂ emissions by 2020, and if further tighter constraints are employed, the reduction will go beyond 10 million tons.

➤ **80km/h and variable speed limits:** Government of Catalonia (Spain) have employed speed limits program to their road network since 2008. Reduction of the speed limit to 80km/hr from 120 km/hr on motorways was found to be inappropriate in relation to air quality improvement as an increase is noted in NO_x and PM₁₀ by 3% and 5% respectively. Introduction of variable speed limits (incremental reduction of 10km/hr employed from 80km/hr to 40km/hr) based on a variety of different reasons such as incidents, traffic density and air quality is able to produce the positive impact. For example, NO_x and PM₁₀ have noted to be reduced around 7-17% and 14.5-17% respectively [*Bel and Rosell, 2013*].

4.2 Studies related to Energy Conservation and Recycling

Reduction in energy use and recycling have shown great potential in achieving carbon reduction commitments. It has been estimated that within the UK alone, changing household behaviour towards energy conservation and recycling can help decrease 30% carbon emissions in comparison with levels of 1990 [*Fisher and Irvine, 2016*]. *Steg [2008]* reported that in relation to energy use, literature is mostly focused on the effects of informational strategies. This section presents some findings from the literature that focused on household energy conservation and recycling strategies.

4.2.1 Household Energy Conservation Strategies

Abrahamse et al. [2005] presented a comprehensive review of behavioural intervention studies aimed at household energy conservation. It is reported that there are two broad categories of behaviours that help conserve energy within the household, which are as follows:

- Efficiency behaviour (represents the purchase of eco-friendly products and household appliances)
- Curtailment behaviour (represents repetitive actions for conserving energy, i.e turning off light when not in use)

Within psychological literature, many different ways of household energy conservation are examined through a variety of techniques that are categorised under informational strategies. For example; installing proper insulation, appropriate thermostat settings for heating and refrigerators, turning off lightings when not required, lesser use of TV, purchasing eco-friendly goods and appliances etc. *Gardner and Stern [2008]* reported the short list of effective actions and provided a rough estimate of energy saving from each action [*Gardner and Stern, 2008*] (pp:18). They further mentioned that these actions may decrease around 30% household energy consumption within the US. They further mentioned that efficiency behaviour has more potential compared to curtailment behaviour, however, later have an advantage of no financial burden on consumers. *Karlin et al. [2014]* explored the factors that drive energy conservation behaviour among individuals. They found that efficiency behaviour among individuals can be explained through demographic characteristics of the households and for explaining curtailment behaviour psychological factors are important. Section 5.2 gives a more detailed account of what different techniques need to be employed for ascertaining the required impacts of behavioural interventions.

4.2.2 Recycling strategies

Another dominant area where behavioural interventions (informal strategies) are examined in the literature is the actions of individuals towards recycling. The common recycling actions/policies studied are, for example, curbside recycling, drop-off recycling, deposit-refund systems, marginal pricing for household wastes and public recycling [Osbaldiston and Schott, 2012, Saphores and Nixon, 2014]. According to [EPA, 2013], within the US alone, 24.7 million metric ton of CO₂ equivalent has been saved to in 2012 through recycling of glass, plastics and recycling metals.

Saphores and Nixon [2014] investigated the behaviour of individual towards recycling through the national survey of U.S., they found that socio-demographic variables are not significant in explaining recycling behaviour, however, psychological variables such as perceived barriers and perceived benefits of recycling are found significant. Based on their analysis, they suggested that to foster recycling behaviour, it is necessary to make strategies/action more convenient. Furthermore, deposit-refund system and marginal pricing type behavioural actions are not as effective compared to curbside recycling. Findings from a study of Miafodzyeva and Brandt [2013], where 63 empirical studies were examined are also similar, as they suggested that psychological attributes e.g. knowledge, environmental concern are strong predictors of recycling behaviour along with the characteristic of action such as convenience. A recent study from Miliute-Plepiene et al. [2016], where they conducted a study in relation to recycling behaviour of household in Sweden and Lithuania, also presented similar findings, however, they suggested that for quick results it is important to increase moral obligation, social norms and trust among the individual regarding the benefits of recycling.

4.3 Passive Control Systems and Behavioural Studies

McNabola [2010] stated that physical infrastructure interventions that help manipulate air pollutant dispersion patterns in the urban environment should be considered as an alternative approach for developing a healthy society. Usually, this phenomenon is known as passive control of air pollutant emission and a significant number of studies has put forward a variety of ways. For example; low boundary walls (i.e. a wall between the roadway and walkway), tree plantation and other forms of vegetation, On-street Parking angles, barriers to reduce noise pollution and road geometry. The role of green infrastructure in the form of green spaces, vegetation barriers, trees, green walls and roof in improving air quality is also established in the literature. Within WP-1 of the iSCAPE project, separate deliverables are being prepared that outlines the impact of the various passive control system and green infrastructure, their complete specifications and their role in reducing exposure of individual to air pollutant with guidelines for implementing these systems. This section elaborates findings from the literature on behavioural studies that somehow relate with different ways of introducing these passive control systems and green infrastructure and their potential implications on individual behaviour.

4.3.1 Green Infrastructure and Spaces

The vast majority of behavioural studies are found in relation to green spaces and how it has been perceived by individuals in changing their habits in terms of physical activity. Mansor et al. [2010] explore the relationship of residents' experiences with diverse forms of green infrastructure in a small town in Malaysia. Their results suggested that provision of green spaces (such as home garden to large town park) provide an opportunity for residents for using them as a relaxation from stress and maintain positive energy, despite the ecological advantages in terms of environment. Sugiyama et al. [2013] explore the relationship of greenspaces in promoting walking habit among

individuals based on longitudinal data. It has been found in their study that proximity to green spaces and a large area of green spaces are positively correlated with maintaining the habit of walking. *Mytton et al. [2012]* investigated the association of green spaces (includes park and open spaces) with levels of different physical activities (walking, running, cycling etc.) across whole England using data sets such as the national Health survey of England and the national survey of environment type. They found that residents of the greenest area of England have a high likelihood of achieving the required standards of physical activity.

An interesting article [*Everett et al., 2016*] explored individual's perceptions in relation to *Bioswales* by conducting a questionnaire-based interview study from residents of the community. The intervention 'bioswales' also known as SUDS is primarily considered as a tool to reduce stormwater runoff and improve water quality, however, it has the potential to address other environmental problems. So far, the role of bioswales is not explored yet as a potential device for passive control of air pollutant. It is concluded in the study that general perception among the individuals was positive, however, general awareness is lacking. It is suggested that to instigate positive behaviour, these types of interventions need to be co-design by engaging the local community, which not only helps awareness but at the same time introduce a sense of belonging. On a similar notion, *Moskell et al. [2016]* reported results of the study that involve residents in street tree stewardship. The study concluded that postcards reminders mailed weekly in relation to watering the trees is an effective way to engage citizens. However, it needs to be ensured that residents do have enough resources to carry out the process.

4.3.2 On-street Parking orientation

Parallel parking has been found as a more optimal setting in terms of PCS in dispersing the natural air pollutant [*Gallagher et al., 2011*], however, study in relation to driver parking behaviour [*Douissebekov et al., 2014*] mentioned that parallel backward parking at residential streets has been considered as a most difficult parking manoeuvres. Due to this some individuals reject the parking spaces and drive the additional distance to find parking space where they feel comfortable. The study suggested the development of profound assistance devices in the form of cameras and ultrasound sensors that inform about the obstacles, especially for older drivers.

5 Methodological Approaches for Behavioural Intervention Assessment

This section presents the details on different methodological approaches followed to measure behavioural effects in response to various mobility interventions. Usually, in small-scale studies, some statistics of behavioural changes are measured before and after implementation of the interventions and these statistics are derived from the stated response from the individuals based on some questionnaire. However, attempts are also made to develop integrated modelling and simulation frameworks to predict changes in the travel behaviour and translation of these into changes in air quality. This section reviews some of these methodological approaches available in the literature.

5.1 Integrated Travel behaviour and Air quality models

Models of travel behaviour have a long history starting from aggregated trip-based models to more recent individual-centric activity-based models. The emergence of activity-based models is based on the premise that the modelling framework should answer emerging policy questions which are

primarily based on measuring air quality (i.e. appropriate emission analysis could become possible in response to behavioural changes) [Kitamura, 1996].

Within the last decade, it has been noted that the interest is grown in development of integrated activity-based models with air quality models for appropriate prediction of emissions/air pollutant concentrations and to estimate individual exposure to these pollutants [Beckx et al., 2009]. The prime argument for this integrated modelling framework is that the traditional exposure analysis techniques in the environmental literature are based on the assumption that considers population as static, however, pollutant concentration is different with respect to time-of-day and space. The use of activity-based models within (microsimulation framework) can provide individual's geographic location (involvement in a particular activity) at a particular time-of-day, and therefore, the population as a whole is considered as dynamic. This approach provides a more appropriate measure of exposure to air pollutants.

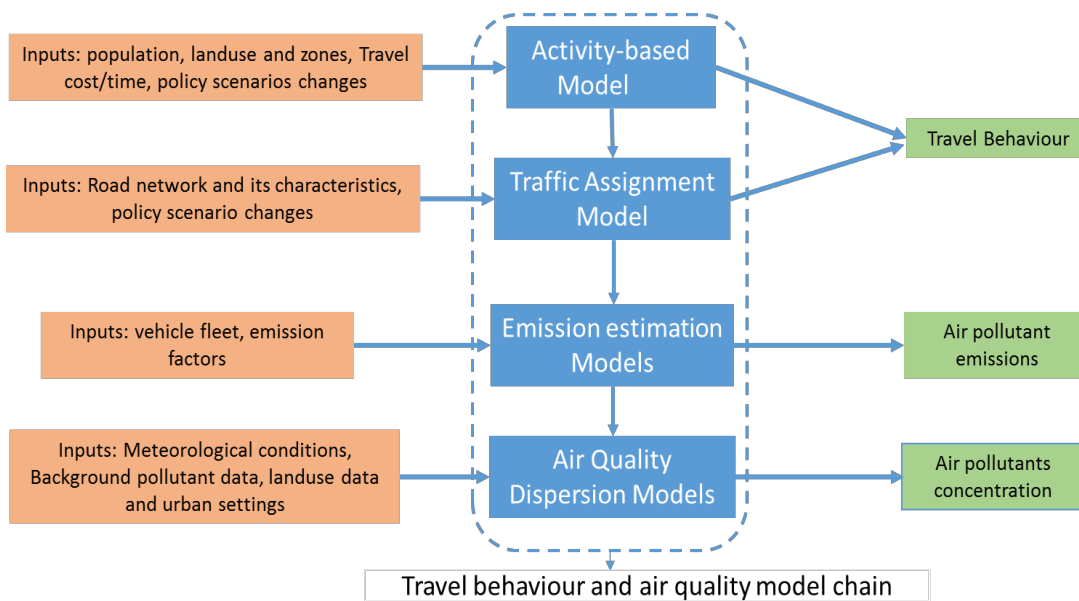


Figure 2: Integrated Travel behaviour and air quality modelling framework

Table 4 below describes efforts in relation to these integrated frameworks. It has been noted in all studies that different models were used from the field of Activity-based modelling and Emission/Air quality modelling to develop an integrated framework. However, all the integrated frameworks are developed as a one-way chain of models as depicted in Figure 2. Models in this chain required different inputs along with the outputs produced from the previous model.

Out of 7 different efforts mentioned in table 4, only two studies have tested the few interventions in terms of predicting the changes in travel behaviour and translating these into changes in air pollutant concentration. Other studies are limited in terms of exposure analysis or validation of their study results with observations from monitoring stations. In addition to this, results from the exposure analysis are not translated in terms of health effects. There are no efforts noted within which feedback effects are used, which is due to the fact that models of travel behaviour are not responsive to changes in air quality measures. Research on this line of action is limited to qualitative research, where air quality information is given to individuals to influence changes in their behaviour. Quantitative travel behaviour models are not developed as yet that incorporate

air quality information, despite their significance noted in the literature for influencing changes in travel behaviour.

Reference	Activity-Based model Details	Emission/ Air quality Model	Application city/Area	Analysis results	Analysed Interventions	Validation
[Shifan and Suhriber, 2002a]	Econometric model (Hierarchical Nested logit model structure for predicting different travel behaviour dimensions) with application of TransCAD model for Traffic Assignment to measure VMT	EPA Mobile5 (emission factors based on a specified mix of cold and hot start VMT)	Portland, (Oregon Metropolitan Area)	Exposure not estimated (changes in travel behaviour and these are translated in terms of VMT based reduction in air pollutants such as VOC, NO _x , CO	Road pricing, Telecommuting, Transit Improvements and Combination of all	Results not validated using air pollutant monitoring station data even for base case.
[Beckx et al., 2009a]	ALBATROSS (Rule-based activity scheduler given population of an area) – Traffic Assignment Model was not used	Results from AURORA dispersion model are used which are in the form of hourly concentration maps in 3 x 3 km grid cell.	Utrecht city center (Netherlands)	Exposure is estimated using static population data and dynamic population using activity-based model, for PM ₁₀ and PM _{2.5}	Interventions are not analysed in this study	Validation not done using concentration from monitoring stations
[Beckx et al., 2009b]	ALBATROSS (Rule-based activity scheduler given population of an area) – with application of TransCAD model for Traffic Assignment	MIMOSA 2.0 emission model (hourly average speeds per road segment were combined with emission factors from the COPERT-III methodology for calculation of emission per road segment per hour). AURORA model is then used for dispersion modelling to produced concentration maps	The Netherlands (whole country)	Pollutant concentration based on integration of Activity-based and AURORA model is computed for NO ₂ , O ₃ and PM ₁₀ . Exposure is not estimated in this study	Interventions are not analysed in this study	Results are validated using 37 monitoring stations within Netherlands using four different statistical indices.
[Hatzopoulou et al., 2011, Hatzopoulou and Miller, 2010]	TASHA (Travel Activity Scheduler for Household Agents) is used with EMMIE/2 model for traffic assignment	Mobile6.2C (the Canadian version of emission factors from US Environmental protection Agency) is used along with CALMET/CALPUFF for air quality dispersion modelling for mapping pollutant concentrations	Greater Toronto Area (Canada)	Link-based NO _x concentrations and evaporative VOC for each Traffic analysis zones along with hourly gridded concentration contours for NO _x using dispersion model are produced and compared with concentration observed at monitoring stations. Population exposure is also estimated for NO _x .	Interventions are not analysed in this study	NO _x concentrations are validated with four roadside monitoring stations, the trend of variation in NO _x concentration levels are captured well by the model.
[Lefebvre et al., 2013]	FEATHERS (Activity-based model following a rule based framework) is integrated with TRANSCAD	MIMOSA 4.0 emission model (hourly average speeds per road segment were combined with emission factors from the COPERT-III methodology for calculation of emission per road segment per hour) is coupled with bi-Gaussian model (IFMD) integrated with land-use regression model (RIO) to make air pollutant concentration to very low resolution (1km x1 km)	Flanders and Brussels region (Belgium)	Hourly concentration maps for PM ₁₀ , NO ₂ , and O ₃ are produced and compared from observed data from monitoring stations. The NO ₂ is further decomposed into type of vehicle and activity responsible for these.	Interventions are not analysed in this study	Along with temporal and spatial variability, intra-daily, intra-weekly and intra-annual cycle are validated based on observation of concentration from all monitoring stations in Flanders and Brussels region (More than 25 stations)
[Dons et al., 2014]	FEATHERS (Activity-based model following a rule based framework) is integrated with TRANSCAD	Hourly Land use regression models, in-traffic exposure model and in-door air model for mapping Black Carbon Concentrations	Flanders Region (Belgium)	Black Carbon exposure assessment is made and compared among low income and high income classes (contrast to other studies no differences are found in inhaled dose of Black Carbon among two classes)	Interventions are not studied	Result of Black Carbon concentration are not validated from monitoring stations
[Hülsmann et al., 2014]	MATASIM (Activity scheduling model integrated with traffic assignment) in an agent-based modelling framework	HBEFA emission factors are integrated within MATSIM to produce pollutant concentrations that is coupled with street canyon approach for atmospheric dispersion modelling (Operational street pollution model)	Munich (Germany)	Change in travel behaviour in terms of reduced Vehicle miles travel and its effect on NO ₂ is examined	Car use cost is studied (by raising fuel cost/taxes)	Validation of the results are based on previous studies

Table 4: Integrated travel behaviour and air quality models

5.2 Experimental Research Designs-Small Scale Behavioural Assessment Techniques

Most of the literature within this section comes from psychological and social science studies, where careful experiments are designed to study the behavioural intervention being considered. These experiments are conducted on a small scale with limited sample size to gauge the benefits of the interventions. Both different types of interventions (informational and strategic strategies) are studied in the literature, however, a vast majority of the literature focused on informational strategies. *De Young [1993]* concluded that the dominant paradigm in conserving the behaviour of the individuals is found as interventions that are being implemented in a forceful manner (i.e. most strategic interventions such as pricing, low emission zone etc.). He further argued that promotion of conservation behaviour will require techniques using both kinds of intervention strategies.

Steg and Vlek [2009] in their review paper mentioned that effectiveness evaluation of behavioural intervention usually follow the method that involves conducting an experiment considering treatment group and a comparable control group for single or combination of multiple interventions. Usually the designs are based in such a way that it made a comparison between groups (treatment vs control) or made a comparison across time (pretest – posttest, baseline-treatment, or ABA designs), some studies use both such as comparison between groups and across times as well [*Osbaldiston and Schott, 2012, Schmidt, 2016*]. Measurement of behaviour usually carried out through self-reports in response to questionnaire items, however, in order to increase the reliability of self-reports, other methods need to be employed to measure their biases. Examples of such experimental studies are; putting a recycling bin in individual offices or at a central location, energy use feedback to household members and an incentive to encourage the use of public transport by providing free travel card etc.

Osbaldiston and Schott [2012] in their meta-analysis of 253 studies mentioned 10 types of treatment and then they further squeezed them in four broad categories i.e. convenience, information, monitoring and social-psychological processes. Table 5 explains the definitions identified treatments/techniques used in the studies of experimental research design for assessing pro-environmental behaviour. In relation to the definition followed in this report, all these interventions may be classified under informational strategies. Majority of the studies in relation to experimental research design are based on promoting pro-environmental behaviour in recycling and energy conservation. There are a handful of studies, which relate to travel behaviour of individuals e.g. indiMARK® [*Brög et al., 2009*] and study of [*Taniguchi and Fujii, 2007*] uses a travel feedback program to provide a customized information to participants for choosing sustainable travel modes.

Treatment broad Category	Specific Treatments Studied in literature	Definition	Effectiveness Rank (1,2,3) – 1 being highest and 3 means lowest
Convenience	Making it easy	This involve making behaviour easy to do based on situational conditions; such as moving recycle bins to appropriate location	2
	Prompting Individuals	This relates to non-informational reminders to perform certain action; such as turn off lights when leaving room	1

Information	Justifications	In this technique reasons are provided for executing specific behaviour in the form of written material such as booklet, brochure etc.	2
	Instructions	Procedural information is provided to carry out specific behaviour; such as sort plastic according to their code etc.	3
Monitoring	Feedback	It provide information about a specific behaviour which can be measured though some means, such as use of resources in some time frame (electricity, water etc.)	3
	Rewards or incentives	It includes monetary benefits for engaging in an experiments, such as; cash, rebates, bus passes etc.	2
Social-psychological processes	Social modelling	Disseminating information via discussion and demonstration by the initiators	1
	Cognitive dissonance	Intervention designed in a way that are consistent with existing beliefs and attitudes	1
	Commitment	Asking participants to make a verbal or written commitment about specific behaviour	2
	Setting goals	Asking participant to set a goal to influence their behaviour for achieving that	1

Table 5: Definition of Treatments Used for Pro-Environmental Behavioural Change

Osbaldiston and Schott [2012] presented some measurements for the effectiveness of these techniques and attempted to rank them in some manner (shown in Table 5) as most of the studies used a combination of these techniques and it is difficult to ascertain the effectiveness of a single treatment technique. *Schultz [2014]* based on the work of [*Osbaldiston and Schott, 2012*] answer the question in relation to the effectiveness of these treatments in different circumstances using a community-based social marketing framework. *Schultz [2014]* classified intervention techniques in terms of target behaviour along with benefits and barriers associated with them. He identified four distinct classes i.e. *low benefit and low barriers* (target behaviour is relatively easy and few barriers that impede the action), *low benefits and high barriers* (target behaviour is relatively difficult and the target audience see few benefits of performing an action), *high benefit and low barriers* (target behaviour is relatively easy and the target audience is motivated) and finally *high benefit and high barriers* (target behaviour is difficult and the audience is motivated). He argued that focusing on the barriers and benefits, psychologists can guide better for the development of conservation programs. The treatments classified in these categories are presented below:

- *Social Modeling* work best in a situation of low benefits and low barriers
- *Incentive/Rewards* work best in a situation of low benefits and high barriers
- *Information, Feedback, prompts and cognitive dissonance* work best in situations of under high benefits and low barriers
- *Make it easy, commitment and setting goals* work best in situations of high benefits and high barriers

It is further mentioned that efforts need to be made in terms of obtaining information about changes in *behavioural determinants* as this help increase understanding about a success of particular intervention program. Environmental psychologists studied the perceived effectiveness and acceptability of various environment-friendly policies in the mobility domain (discussed in section 4.2). The studies revealed the following findings:

- The policies are more acceptable when they are designed considering equity within the society and individual freedom is not restricted.
- The policies are more acceptable to people whose awareness regarding the environmental problems are high, and they feel a strong obligation to reduce the problems
- Policies that increase the attractiveness of pro-environmental behaviour are more acceptable compared to those which are aimed at reducing the attractiveness of environmentally harmful behaviour.
- Initial resistance to policy does not necessarily mean that policy is not effective and acceptable and therefore it does not mean that it should not be implemented.

6 Conclusions and Recommendations

This section concludes the discussion presented in section 3 to section 5. The conclusions are made in such manner that it provides a framework for recommending a set of activities that are required to be conducted in other work packages of iSCAPE and especially work package 4.

6.1 Exposure Analysis

Exposure analysis (measuring individual exposure to air pollutants) traditionally being done assuming the static condition of individuals (most of the time considering their location at their respective homes) in relation to time and space. Usually, air pollutants concentration is available through different monitoring stations and tools and applications are available to disperse these pollutants given meteorological data. In addition, there are strong evidence reported in the literature that individuals are exposed to different levels of pollutants in difference micro-environments. Consideration of individual as dynamic provides a more appropriate measure of their exposure. Recent literature attempted to solve this using variety of different methods such as using activity-based model (provides a complete activity-travel schedule of the individual in a given day) or through the GPS-based mobile app that keeps track of individual daily routine. *Gariazzo et al. [2016]* explored the use of mobile phone data as a source for tracking individuals in space and time, and use this data to appropriately measure their exposure to air pollutants. Studies in this context are quite limited and yet to be matured. The wealth of information generated by combining time-space based air pollutant concentration and individual movement will provide appropriate means of exposure analysis, however at the same time, strategic use of this information through effective treatments discussed within behavioural studies (such as prompts) will engage individuals in making an informed decision about their daily activity-travel patterns. This approach could be useful for task 4.1 in work package 4 given the timely availability of required data.

6.2 Useful behavioural interventions and treatments

There are a variety of interventions being employed within mobility, energy conservation and recycling. The literature pointed out the usefulness of structural strategies (usually used as mobility based interventions) over informational strategies (or in other words soft strategies) [*Richter et al., 2011*]). It has also reported that informational strategies are always helpful if implemented in conjunction with structural strategies. Literature does not report perfect guidelines about what will be the most effective intervention, however, mentions that success depends on identifying the target audience first and then barriers and benefits perceived by them for required changes in behaviour. Ranking of these interventions reported in table 5 can be used as a rough guideline.

To design effective behavioural interventions following need to be considered (important for WP2, 4, and 5)

- Ascertaining barriers and benefits perceived by individuals for required behavioural change
- Demographic variables are not found as good predictors of behavioural change, focused should be on psychographic variables (attitudes, interest, opinions) in designing interventions
- Social context and community involvement is also found important norm for fostering pro-environmental behaviour

Within mobility-based intervention employed, significant improvement in air quality is noted for careful implementation of LEZ, road pricing and strategies to promote public transport and active mobility. Furthermore, their effects are long lasting provided that these are intact and informational strategies are periodically being conducted for their supplement. However, policies such as telecommuting have not resulted in advantages as expected. In addition, pricing strategies have been found effective in a particular locality, but it has the potential to create a problem elsewhere, and in some situations, the net effects are not positive. Literature mostly used observational or experimental data-based studies to examine the effectiveness of these interventions in relation to improving air quality. Modelling based studies are limited, mainly due to the doubts in the validation of the results. In relation to work package 4, where behavioural interventions are required to be investigated through simulation frameworks, it is recommended that attempts need to be made to examine policies in relation to the following:

- 1) Active mobility strategies (such as bicycling infrastructure provision and promoting walking given some health information)
- 2) Promoting public transportation (fare reduction, free travel, higher frequency etc.)

Travel demand models (used in practice) are not given enough consideration to the above two types of behavioural interventions, and their effects therefore not appropriately estimated so far especially for walking mode. In addition to this, the above two types of interventions are inlined with the findings that these would be more acceptable to individuals as they tend to increase the attractiveness of pro-environmental behaviour and on the other hand not restricting individual freedom.

6.3 Use of Integrated Models for Policy Assessment

There are a variety of integrated models (travel behaviour and air quality models) used in the literature (see table 4), however, studies so far limited only in terms of estimating exposure of individuals or validating the model-chain results with observed data. Despite the potentials, these models are not used extensively in terms of examining the effects of behavioural interventions onto air quality and health. In addition, the models used in practice for travel behaviour are not sensitive to the effect of information in relation to environmental pollutants, however, studies have shown that informational strategies are successful in changing individual behaviour. Recently, [Yin *et al.*, 2016] investigated the effect of household residential choice due to the levels of air pollutant, which in turn also changes the travel behaviour of individuals in an integrated land use, transport and environment model.

This gives the prime opportunity to conduct experimental research in relation to change in travel behaviour given information about environmental pollutants or some other indices. Data generated through these experiments help develop models that are sensitive to this new information. This experimental research will be key to appropriately conduct task 4.2 in WP 4.

6.4 Passive control systems and behaviour

In relation to Physical Passive Control System for air quality improvements, behavioural studies are limited to ascertain impacts of vegetation and green spaces in terms of walking activity. Numerous studies have indicated that the habit of walking can be maintained if green spaces are provided. Furthermore, individual perceive these spaces as an opportunity for using them for relaxation from stress and maintain positive energy, despite the ecological advantages in terms of environment. Involving citizens for maintaining PCS related interventions may result in increased social responsibility towards environment (A successful example of this has been studied in relation to watering of street trees by residents with a reminder about this process through postcard from the city council).

6.5 iSCAPE work packages and key findings matrix

This section presents an overall summary of the key findings from the above sections that are helpful for the other work package in iSCAPE.

Key Findings	Relevance to WP
Structural strategies are more effective and have long-lasting effects. However, when implemented with informational strategies may result in optimal behavioural change.	General
Within informational strategies; prompt, social modelling, goal setting, commitments are found more effective treatments than others (e.g. Instruction and Feedback).	Important for WP 2, 4 and 5 , while designing behavioural intervention
Informational strategies are mostly examined for household energy conservation and recycling behaviours, while, structural strategies are employed to change mobility behaviours.	Important for WP 4, within task 4.2 structural strategies should be examined via modelling framework
In behavioural intervention Perceived Consumer Efficacy (PCE) is key in motivating participants in changing their behaviours. It is therefore important to show them that their changes will have a tangible positive impact on the environment.	Important for WP4 but more generally for all the pilot actions engaging citizens.
To design effective behavioural interventions following needs must be considered <ul style="list-style-type: none"> • Ascertaining barriers and benefits perceived by individuals for required behavioural change • Demographic variables are not found as good predictors of behavioural change, focused should be on psychographic variables (attitudes, interest, opinions) in designing interventions 	Important for WP 2, 4, and 5 while designing behavioural intervention. For WP 2 and 5 social context and community involvement are more relevant. To be considered also for the setting up of living labs in target iSCAPE cities.

<ul style="list-style-type: none"> A social context and a community with pro-environmental behaviour/attitudes is also an important factor for fostering pro-environmental behaviour in the rest of the community. 	
<p>Within Mobility-based interventions, LEZ (low emission zones), promoting public transport and active mobility are found effective in relation to air quality improvement.</p>	Important for WP 4
<p>Use of Integrated (travel behaviour and air quality models) tools for intervention assessments; studies are very limited in this regard owing to associated complexities. Models need to consider environment related variable for better predictions.</p> <ul style="list-style-type: none"> It is recommended to test interventions based on Active mobility (bicycling infrastructure/ walking given health indicators) and public transport promotion (fare reductions, higher frequency etc.) 	Important for WP 4, task 4.2 should follow this approach
<p>In relation to PCS/infrastructural interventions, behavioural studies are limited to ascertain impacts of vegetation and green spaces in terms of walking activity (relationship has been found positive). Involving citizens for maintaining PCS related interventions may result in increased social responsibility towards the environment. (An example of this has been studied in relation to watering of street trees).</p>	Important for WP 2 and 5, where PCS based interventions are studies.

Table 6: Study Findings and their Relevance to different WP in iSCAPE

6.6 Key Recommendations for WP 4

Within WP 4, task 4.1 requires to develop a location-based framework. The framework that utilises the living labs setups in each target iSCAPE cities in a manner that GPS based trajectory data will be collected and analysed in aspects of individual exposure to air pollutants. It is recommended that a more meaningful study can be established in the form of utilising different successful treatments already mentioned under informational based behavioural interventions. The main features are described below;

- Within the project scope of iSCAPE, a structural strategy based intervention in relation to mobility is difficult to analyse, however, informational strategy based intervention can be studied in great detail using state of the art GPS based tracking applications
- Informational based behavioural intervention strategy could be devised in the framework of encouraging sustainable (pro-environmental) travel behaviour. Treatments that could be used are as follows:
 - Commitments or goal settings (as the benefits and barriers associated with changing travel behaviour can be categorised as high).
 - If commitment and goal setting treatments are used along with Feedback treatment, the results of the intervention may be more effective.
 - The inclusion of social norms/modelling can make the overall intervention more robust as often when barriers are high for certain behavioural change, social modelling may provide an appropriate approach.

- The information provided to the participants should cover the following aspects:
 - Exposure to different concentration of air pollutants and their effect
 - Car-use and emission of CO₂
 - Physical activity involvement of individual
 - The efficacy of a particular behavioural action in terms of improvement in the environment
- A stated-choice experiment could also be devised that works under the contextual information obtained through GPS-based tracking of individuals. Different hypothetical scenarios can be established to get a choice selection from individuals for various travel behaviour dimensions such as mode choice, departure time choice and activity-addition/deletion in a pattern. These experiment along with the traditional travel information should contain information related to air quality, CO₂ emissions and physical activity indicators. These experiments will be helpful to develop models that can be incorporated within activity-based microsimulation model FEATHERS, which will be used to predict the effect of different structural strategies based on behavioural interventions in task 4.2.
- As the **location-based framework** entails that for each target city, the instrument should be based on matching the city needs. The above framework that defines the behavioural intervention can *only* be effective when the provision of information (via any treatment) is customized and according to the needs of an individual. This could easily be done based on individual's socio-demographic and psychographic attributes and also studying the general mobility trends of the city (such as availability of public transport, the extent of bicycle use and the available infrastructure).
- Behavioural interventions based strategy required the engagement of citizens. The literature on behavioural studies also gives guidelines for this. Next section mentions some useful guidelines for recruiting individuals for the experiments.

6.7 Recommendation for Recruiting citizens for Living Labs

Thanks to the literature review done in this deliverable it is possible to provide some suggestions for the recruitment of citizens to the Living Lab activities. Few important points are discussed below:

- Of course, it is not always easy to select participants. It is important to have an entry questionnaire mapping not only their demographic characteristics (which we saw are not good predictors of pro-environmental behaviours), but their psychographic characteristics. This will help evaluate the success of the interventions against the participants' characteristics.
- If it is possible to select participants, it may be useful to start with a pre-existing community already committed in pro-environmental actions even if not directly linked to air quality improvement. For example, it may be interesting to engage urban farmers, a club of cycling, groups of critical consumerism or collaborative purchasing groups or pro-environmental activists. It would be then advisable to ask them to engage other people; by doing so the iSCAPE activities will be built on pre-existing pro-environmental social norms.

This may positively influence the project activities and will also build on pre-existing grassroots movements that can have a good potential in terms of influencing other people.

- If the interventions are planned at the neighbourhood level, it is useful to engage first leaders of the community or persons recognised as significant members and ask them to act as testimonials of the iSCAPE living lab activities. If they act as first adopters, this will help engage more people.
- As mentioned it is important for participants to have the feeling that their actions will have a positive impact on the environment. It will be useful to provide feedback possibly using the iSCAPE preliminary results or expected impacts.

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