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uCARe

You Can Always Reduce Emissions

because you care

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uCARe consortium

Document information

Additional author(s) and contributing partners

Name	Organisation
Samantha Jamson	University of Leeds
Sonja Forward	VTI

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Executive summary

In this report, eco-driving behaviours are defined using a hierarchical behavioural framework. Within uCARe eco-driving includes mainly pollutant emission saving and secondarily fuel consumption saving compared to normal average driving. The driving task is divided into strategic, tactical (or manoeuvring), and control (or operational) levels and collected under this framework.

A list of eco-driving behaviours was developed via a literature review, using a unifying typology, a review on travel behaviours and fuel savings, and a review of eco-driving instructions in driver training and testing. Behaviour can only be effectively understood once operationally defined so that it can be measured consistently and analysed systematically. Behaviour is defined in terms of its topography and in terms of its function (i.e. its effect/what it does). Eco-driving reduces fuel consumption and emissions without reducing the average speed of vehicles. Furthermore, it ensures a safer journey and increases social responsibilities.

It is concluded that it is worth recommending/developing not a generic but an environment/context and vehicle specific eco-driving behaviours guideline/toolkit. Financial, environmental, safety and social implications of these behaviours should be assessed. Eco-driving interventions should target positive, actionable behaviour. It may prove worth exploring relatively new concepts/techniques related to eco-driving in this project e.g. optimal use of wind speed, collective eco-driving, and eco-routing. Although this project is targeting a wide range of measures to improve the environmental performance of the vehicle including vehicle maintenance, use and driving, the current version of this report is focused at targeting behaviours, which drivers execute while sitting inside the car. More structured and coherent descriptions of these behaviours can help developing targeted interventions.

Table of contents

List of Tables

Definitions & Abbreviations

Term	Definition
COPERT	COmputer Programme to calculate Emissions from Road Transport
DoW	Description of work
EV	Electric Vehicle
HBEFA	Handbook of Emission Factors
HEV	Hybrid Electric Vehicle
HP	Horsepower
ICEV	Internal Combustion Engine Vehicles
PEV	Plug-in Hybrid Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
revs	Revolutions, refers to engine speed
rpm	Revolutions per minute, refers to engine speed
WP	Work package
WT	Weight

1 Introduction

1.1 Background to the uCARe project

With four million people dying annually due to outdoor pollution, improvement of air quality has become one of society's main challenges. In Europe, traffic and transport have a large effect on air quality, specifically passenger cars and commercial vehicles and to a lesser extent non-road mobile machinery. While technical improvements and more stringent legislation have had a significant impact, traffic and transport emissions are still too high and air quality is still poor. Although the use of electric and other zero-emission propulsion technologies may drastically reduce the pollutant exhaust emissions from traffic, the slow introduction of such vehicles as well as the trend of increasing vehicle lifetimes means that vehicles with internal combustion engines are expected to dominate the fleet beyond 2030. This project is the first opportunity to improve emissions of vehicles, not by improving vehicle technology, but by actively involving vehicle users and enabling their contribution to clean driving.

So far, expertise on pollutant emissions has mainly been used to advise European policy makers on limited effectiveness of emission legislation (through real-world emission factors such as HBEFA and COPERT) and how to reduce traffic and transport pollutant emissions. The numerous mitigation methods are rarely extended to include the perspectives of users uCARe enables a next essential step: providing user targeted emission reduction measures. These measures will be implemented and evaluated in real-life pilot projects.

The overall aim of uCARe is *to reduce the overall pollutant emissions of the existing combustion engine vehicle fleet by providing vehicle users with simple and effective tools to decrease their individual emissions and to support stakeholders with an interest in local air quality in selecting feasible intervention strategies that lead to the desired user behaviour*. The overall aim is accompanied by the following objectives:

1. To identify **user-influenced vehicle emission aspects** (such as driving behaviour and vehicle component choice).
2. To determine the **emission reduction potential** of each vehicle emission aspect with help of the uCARe model developed within a toolbox.
3. To develop a **toolbox**, containing models and emission reduction measures, that enable stakeholders to identify the most appropriate intervention strategies that reflect the specific users and their motivation.
4. **Support policy makers** and other **stakeholders with an interest in air quality,** such as municipalities and branch organizations, **in identifying intervention strategies** that translate the measures into desired behaviour of the user.
5. **To test and evaluate** intervention strategies in a set of pilot projects conducted with various target user groups in at least four European countries. The pilot projects illustrate effectiveness and feasibility of the toolbox and intervention strategies developed on its basis.
6. Perform an **impact assessment** of the intervention strategies effectiveness, in terms of cost, penetration, achieved emission reduction and lasting effects.
7. **Actively supply** European cities and international parties with uCARe learning and results, via awareness raising campaigns, communication tools, interactive web application and other dissemination activities. Open access to the broad public to the toolbox, data and developed tools.
8. Summarise the findings **in blueprints for rolling out** different user-oriented emission reduction programmes, based on successful pilots.

This document reports the material produced within WP3 to support the development and execution of the pilots by defining eco-driving behaviours that, if applied, will lead to improvement of the emission performance of vehicles. Intervention strategies and methodological details for implementation of measures are being added in incremental versions of the document during the preparation and execution of pilots. Therefore, this is a live document to be constantly updated along the duration of the project.

1.2 Purpose of the document

The purpose of this document is to include intervention strategies and methodological details for the implementation of measures and the execution of pilots. It includes material for both pilots that will be setup for future executions beyond the uCARe project as well as pilots that will be executed during the duration of the uCARe project.

The pilots that will be executed during uCARe will be selected among the ones expected to be of the highest performance during a preliminary desktop evaluation in coordination with WP4. The material for these pilot projects will be updated using the experience collected during the execution of the pilot projects, therefore optimized for best performance and ease of application.

This deliverable is a dynamic document, i.e. when a new pilot is conceived, executed and results are analysed, the results will be added to this document. Therefore, the full version will be available close to the end of the project.

1.3 Document Structure

Chapter	Purpose of the document
Chapter 1	Introduction Purpose: This chapter provides a brief background to the project, the overall objectives of the project, and work package specific background.
Chapter 2	Methodology Purpose: This chapter provides information about the methodology to approach eco-driving behaviours in three levels.
Chapter 3	The three levels in more detail Purpose: This chapter describes in detail the three levels proposed to define eco-driving behaviours using the hierarchical behavioural framework as well as eco-driving behaviours falling into these three levels.
Chapter 4	Results and discussion Purpose: This last chapter provides key points which have been learnt and can be considered to maximise the outcome of the project.

1.4 Deviations from original DoW

1.4.1 Description of work related to deliverable as given in DoW

This deliverable aimed to provide the "interim description of intervention strategies and methodological details for implementation of measures".

1.4.2 Time deviations from original DoW

The deliverable was uploaded one month later than planned, in agreement with the project officer (PO), to include insights from the project plenary meeting of September 29th-30th, 2020.

The initial aim was to present the intervention strategies and the methodological details and include education material as well. Due to the COVID-19 pandemic, however, several actions have either being modified or delayed. More specifically:

- Focus group meetings were not possible to be performed. Therefore, the time and effort consuming pathway of personal, remote interviews was followed. Consequently, results were delayed, not allowing the production of detailed educational material. For more information on personal interviews see deliverable D3.3.
- Pilot projects were not executed due the COVID-19 retainment measures and the hesitation of stakeholders to hold such activities. As a workaround a pilot was compiled to be performed with existing material in parallel to an activity already permitted by local authorities in the city of Serres, Greece but was not successful as described in deliverable 3.2.

1.4.3 Content deviations from original DoW

This deliverable presents the interim description of intervention strategies as intended. In that sense, there are no deviations from the DoW. However, the foreseen available material from pilots has not yet been reached.

As already said, the initial aim was to also include education material in this deliverable. Due to the COVID-19 pandemic restrictions and as explained in the previous paragraph, several actions have been modified (see deliverable D3.3). Therefore, only methodological elements for eco-driving behaviour are included in this first version of the live document D3.1 as provided by Prof. Samantha Jamson, University of Leeds. The report will be updated upon availability of data and the completion of the processing of the personal interviews already performed.

2 Methodology

It is proposed to define eco-driving behaviours using the hierarchical behavioural framework proposed by Michon (1985) which describe 'cognitive' procedures to account for driver behaviour. Here, the driving task is divided into strategic, tactical (or manoeuvring), and control (or operational) levels (Sullivan, Flannagan et al. 2016). The strategic level governs overall journey goals and planning, the tactical level governs deliberate manoeuvres (such as overtaking), and the control level involves automatic actions such as lane discipline and speed control.

The following list of eco-driving behaviours was developed via a literature review, particularly using the unifying typology developed by Sanguinetti et al., (2017), a review on travel behaviours and fuel savings conducted by Muslim et al., (2018), and a review of eco-driving in driver training and testing conducted by CIECA (2007). The listed behaviours are then classified into three levels of skills and control: strategical (planning), tactical (manoeuvring), and operational (control) according to Michon's cognitive framework. For this, the work of Sivak (2011) is also referred to.

One can only effectively understand any behaviour once it is operationally defined so that it can be measured consistently and analysed systematically (Sanguinetti et al., 2017). In the field of behaviour analysis, two main ways of defining behaviour are acknowledged; behaviour may be defined in terms of its topography (its observable form/what it looks like) or in terms of its function (its effect/what it does). According to Muslim et al. (2017), eco-driving reduces fuel consumption and emissions without reducing the average speed of vehicles. Furthermore, it ensures a safer journey and increases social responsibilities.

3 The three levels in more detail

3.1 Strategic level

According to Michon (1985), the strategic level defines the general planning stage of a trip, including the determination of trip goals, route, and mode choice, and an evaluation of the costs and risks involved. Plans derive further from general considerations about transport and mobility, and from concomitant factors such as aesthetic satisfaction and comfort.

3.1.1 Vehicle type

Sivak and Schoettle (2012) offer a broad conceptualization of eco-driving that ranges from vehicle operations to route selection to vehicle selection. They recommend that purchase of fuel-efficient vehicles can have the most profound effect; however, given the selection of a vehicle, lack of attention to maintenance practices, route selection, and managing vehicle load, in addition to inefficient driving styles, can diminish fuel economy by up to 45%. Eco-driving can be considered in the context of hybrids (HEVs), plug-in hybrids (PHEV) and electric vehicles (EVs)—the latter two together referred to as 'PEVs'.

The relationship between ''aggressive" driving and fuel economy is dependent on a given vehicle's horsepower/curb weight (HP/WT) ratio—the more powerful the vehicle the less it is penalized in terms of fuel economy for driving styles characterized by high rates of acceleration and braking and high maximum speed relative to average speed. In vehicles with low fuel economy, there is little room for improvement gained from widely promoted eco-driving behaviours. Sivak and Schoettle (2012) pointed out that driving a vehicle rated as achieving on average 11 mpg (21 L/100 km) in accordance with all eco-driving practices would result in no fuel savings.

HEVs (hybrids) and PEVs (plug-in hybrids, PHEV) and electric vehicles (EVs) are exceptions to some eco-driving rules that apply generally to ICEVs (internal combustion engine vehicles). For example, repeating a cycle of heavy acceleration to top speed then coasting ('pulse and glide') can allow a HEV to run on battery power for longer periods without engaging the engine (MetroMPG, 2006, January 15), amounting to greater fuel savings compared to moderate acceleration and constant speed which are widely promoted as eco-driving for ICEVs (e.g., Barkenbus, 2010).

3.1.2 Vehicle maintenance

Some of the vehicle maintenance tactics which are recommend in the literature for eco-driving includes investing in low rolling resistance tyres (Sivak and Schoettle, 2011), keeping wheels aligned (Hall, 2008), a regular service of a vehicle and keeping tyres properly inflated (DfT, 2016). Sivak and Schoettle (cited in Sanguinetti, Kurani, et al., 2017) informed that tyres with 25% greater rolling resistance can decrease fuel economy by 4%, and four tyres underinflated by 5 psi can result in 1.5% decrease in fuel economy. Regular servicing of vehicle's engine is highly recommended to maintain efficiency. This includes keeping air filters, spark plugs and the engine oil clean (InteGreen, 2012; DfT, 2016). Energy-efficient Driving (2015) recommends addressing any other diagnosed malfunctions in the engine and related sensors, especially the oxygen sensor.

3.1.3 Fuelling

Efficient fuelling can entail using the proper grade/octane number of gasoline or renewable fuels, biofuels and ethanol blends, when the vehicle allows (e.g., Eartheasy, 2019; Steen, 2018). It also involves considerations of fuel evaporation. According to Sanguinetti et al., (2017) fuel evaporation can be minimized by refraining from topping off and making sure the petrol cap is intact and on tightly. Fuelling at night and parking in the shade is further recommended by Energy-efficient Driving (2015) to prevent evaporation.

3.2 Tactical level

According to Michon (1985), at the tactical level drivers exercise manoeuvre control allowing them to negotiate the directly prevailing circumstances. Although largely constrained by the exigencies of the actual situation, manoeuvres such as obstacle avoidance, gap acceptance, turning, and overtaking, must meet the criteria derived from the general goal at the strategic level.

After subdividing driving behaviours as the major functions of driving (accelerating, cruising, decelerating, parking, waiting, and driving mode selection when available) at the control level using the guidelines of Sanguinetti et al., (2017), the topography of eco-driving behaviours—typically involving driver manipulation of pedals, gears, and other controls (e.g., cruise control, steering wheel, mode selection), as well as spatial regulation (i.e., maintaining distance from other vehicles and anticipating road conditions, traffic, and signals) can further be specified at the tactical level. For this purpose, another subclass termed 'trip planning' is also included. This covers decisions related to route selection (road type, grade profile, congestion, weight) (e.g. see Sivak and Schoettle, 2011), trip timing and trip chaining .

Table 1: Eco-driving at the tactical level derived from the general goal at the strategic level (Pre-trip behaviours)

Elements	**Description**	**Effect**
Eco-Routing	Road type	Urban vs rural, highways vs low-volume roads, paved vs unpaved roads
	Grade profile	Flat routes are better than steep gradients
	Traffic congestion	Avoid where possible
Trip Planning techniques	Trip chaining	Linking together multiple locations in a single tour
	Trip timing	Planning trip according to weather, optimal wind speed and direction
	Load management	Minimizing weight and maximising aerodynamics
	Vehicle occupancy	Higher vehicle occupancy is better

3.2.1 Eco-routing

According to Sivak and Schoettle (2011), a selection of route for eco-driving involves the selection of road type, grade profile and dealing with congestion. More recently, the term ‘eco-routing’ has started to be used for this purpose. Ahn and Rakha (2013) describe it as selecting routes with less congestion, roads types amenable to steady fuel-efficient speeds (above 70 km/h or 20 m/s according to Energy-efficient Driving, 2015), and flatter roads instead of those with steep gradients. Planning routes with more right turns and planning unfamiliar journeys to prevent getting lost are additional suggestions along these lines found on websites (AA, 2014, cited in Sanguinetti et al., 2017). These behaviours concern planning trips based on how you reach a destination.

3.2.2 Trip chaining

Trip chaining is described as visiting multiple destinations sequentially instead of making multiple separate trips. While eco-routing is typically defined as the most efficient way to get from point A to point B (Ahn and Rakha, 2013), trip-chaining as suggested by Sanguinetti et al., (2017) is the most efficient way to get to points A, B, and C. they suggest that trip-chaining is about cutting down on distance travelled and doing more driving and shifting trips while the engine is warmed up.

3.2.3 Trip timing

One of the less talked about techniques in eco-driving is making optimal use of wind speed and direction. Sanguinetti et al., (2017) mention that planning of trips according to weather cannot only save money but impacts also on overall efficiency, energy use, and emissions for ICEVs, hybrids, and PEVs. For instance, cold weather extends the time it takes for the engine to come to normal operating temperature and the engine will cool down quicker as well.

3.2.4 Load management

This simply means removing unnecessary extra (dead) weight and un-aerodynamic features of the car (e.g. roof racks) when not needed. Load management is about traveling prepared while minimizing weight and maximizing aerodynamics. Minimizing or removing excess cargo weight is commonly recommended as eco-driving. Necessary cargo should be stored inside the vehicle whenever possible as hauling cargo in roof racks and boxes adds wind resistance, increasing fuel consumption (e.g. see Sivak and Schoettle, 2011, 2012); Sanguinetti et al., 2017).

3.3 Control level

This section takes into account the control level of Michon's model and mainly focus on basic techniques for driving a passenger car in an environmentally-conscious way. The function of driving behaviours is straightforward: i.e., operating the vehicle to control direction and speed. Eco-driving literature mainly has subdivided driving behaviours into the major functions of driving: accelerating, cruising, decelerating, parking, waiting, and driving mode selection (when available) (e.g. see Sivak and Schoettle, 2011; Sanguinetti et al., 2017). This section classifies driving behaviours into operational and non-operational behaviours. Operational behaviours are those that make the vehicle operate while non-operational (also termed as 'cabin comfort behaviours' by Sanguinetti et al. 2017) are those which do not make vehicle operate (stop and go), and they are accessible to vehicle passengers as well as drivers.

Table 2: Eco-driving behaviours at the control level - restricted to vehicle operations

Driving	Possible (positive) action – what a driver should do
Operational behaviours – focused on specific actions	
Accelerating	Decreasing accelerations, accelerating 'moderately',
Cruising	Maintaining a steady speed
Decelerating	Decreasing and smooth decelerations
Gear selection	The use of gear with pedals, rpms and shifting into higher/lower gears
Engine rpm	Avoiding excessive revs
Idling	Decreasing/avoiding idling - turning off the engine if stopped for at least one minute
Driving mode	Using appropriate driving modes depending on the context
Parking	Parking in the shade, in a warmer place, facing out
Operational behaviours - Driver manipulation of pedals, gears and other controls in context	
Driving away	Changing quickly into 2nd gear when moving off
Driving straight and around bends	Quickly changing up through the gears, staying in a high gear around bends, using built-up energy when having to stop on a straight road (coasting), the use of cruise control, if present and appropriate
Intersections	Possibility of not stopping when having priority and if no traffic coming, rolling up to the junction, taking into account traffic from the rear, not changing down through the gears on deceleration (and engaging the clutch at the latest possible moment)
Entering and exiting traffic	Skipping some gears (e.g. 2 or 3 to 5), avoiding explosions of speed (quick acceleration) (motorway). Exiting: releasing the gas pedal at early stage (looking behind at same time for safety reasons)
Overtaking/lane changing	Overtaking – skipping gears (rapid increase of speed)
Behaviour next to specific traffic features	Turning off the engine, e.g. at railroad crossings wherever legal to do so. Driving on roundabouts – in higher gear. Driving past public transport in higher gear for noise reduction purposes (where appropriate)
Driving uphill/downhill	Driving uphill in the highest gear with deep accelerator position while coasting downhill
Operational behaviours – Spatial regulation to maintain efficient cruising	
Headway	Maintain longer safety margins (e.g. 3sec)
Anticipating	Anticipate traffic flow and signals to drive smoothly and avoid braking, gear changing
Cabin comfort (non-operational) behaviours	
Air condition	Use of cabin air conditioner w.r.t high and low speeds
Heating	Avoid use with electrically heated seats, steering etc.
Accessories	Avoid use of accessories e.g. heated screens, demister blowers, entertainment equipment

3.3.1 Specific operational behaviours – focused on specific actions

3.3.1.1 Acceleration

According to Sanguinetti et al. (2017), there is a lack of operationalization and clarity in the literature while discussing acceleration. Energy-efficient Driving (2015) provides a general rule to minimize acceleration. However, Sanguinetti et al. (2017) argue that in order to reach a desired speed — the function of accelerating — there are more and less efficient ways to go about it. They further highlight that the eco-driving literature is unclear and confusing regarding the speed and steadiness of acceleration. While some sources recommend to accelerate gently or moderately (Barkenbus, 2010), others recommend swift acceleration to reach to cruising speed (CIECA, 2007).

3.3.1.2 Cruising

Cruising can simply be described as evenness in speed. Efficient cruising involves minimizing deviations in trajectory (steering straight and lane-keeping) and speed (by either a steady foot on the accelerator pedal or cruise control). In addition, it involves driving at an efficient speed (determined by vehicle model and constrained by speed limits, road and weather conditions), with an efficient gear choice (highest gear and overdrive when appropriate). It involves a critical interaction between spatial regulation, speed choice, and gear (CIECA, 2007; Sanguinetti et al., 2017; Muslim, et al., 2018).

3.3.1.3 Deceleration

The function of decelerating is either to reduce cruising speed or to stop (Sanguinetti et al., 2017) to minimize braking (Birrell et al., 2014). This is achieved with the efficient use of pedals and gears.

3.3.1.4 Gear

Shifting through the gears while driving is widely discussed in eco-driving literature. CIECA (2007) recommends change early into a higher gear and late into a lower one, and to use the highest gear with low engine rpm to maintain a steady speed.

3.3.1.5 Engine rpm

It is recommended to drive at low rpms because modern car engines (from about 1990 onwards) are more efficient, so driving at excessive rpms only wastes fuel and increases engine wear. Modern engines have a completely different torque to engines 30 years ago. The maximum torque is now a lot higher and is already reached between 1500 and 3500rpms. The torque in old petrol-powered cars only began at around 3500rpms (CIECA, 2007).

3.3.1.6 Idling

Waiting is comprised of opportunities to idle or to replace idling with more efficient options where the vehicle is stationary, such as upon starting and parking, during passenger and cargo loading, in drive-through establishments, and during traffic delays (Sanguinetti et al., 2017). Taking guidelines from several sources including Barkenbus (2010), Ericsson (2001) and Sivak and Schoettle, (2012), it is discussed by Sanguinetti et al. (2017) that implications of idling are straightforward: not every vehicle achieves 0 fuel consumption when idling. Therefore, it is recommended to minimize idling. This can be achieved by efficient acceleration, cruising, and decelerating. This involves efficient use of gears and the ignition. Stop start technology is also available in some vehicles.

3.3.1.7 Driving mode

Some vehicles mostly ones including an electric powertrain as well allow users to select specific driving modes, e.g., via a button on the dashboard. These modes typically alter the energy use of the vehicle. Selectable driving modes vary among manufacturers but are generalized here in four main categories including normal mode, economy mode, increased performance mode, and fuel management mode. It is important to bear in mind that although listed at “control level”, the strategy for use of these driving modes depends on the specific PHEV, however, their effective use relies on advanced trip planning techniques.

3.3.1.8 Parking

Sanguinetti et al. (2017) recommends parking in a warmer place (i.e., garage) in cold weather so the engine does not begin as cold. In warm weather, using a sunshade or parking in the shade keeps the vehicle cooler to reduce need for air conditioning (Eartheasy, 2019). It also minimizes evaporation of gasoline. It is further recommended to park facing the direction of initial travel to avoid idling time when departing. Being skilled in parallel parking is also considered good to save time searching for other options.

3.3.2 Driver manipulation

The term 'driver manipulation' is used to describe drivers' manipulation of pedals, gears, and other controls (Sanguinetti et al., 2017) to execute several manoeuvres including moving off, driving straight and crossing intersections. Muslim at al., (2018) discuss the association between driving behaviour and vehicular emission is not limited to driving characteristics. For instance, speed and acceleration can be used to visualize energy consumption and emission. Joumard et al. (1995 cited in Muslim et al., 2018) report that CO emissions decrease linearly with speed when expressed in per km terms. Likewise, at the peak engine torque, the fuel efficiency gets lower. However, efficiency gets higher at higher rpm (Revolutions per minute) i.e. low engine torque. Likewise, accelerating slightly when approaching an uphill road segment to maintain speed while minimizing accelerating during the grade change is efficient cruising via spatial regulation, as is releasing the accelerator on downhill segments, leveraging momentum to maintain speed (i.e., coasting); coasting in neutral or with the engine off (Sanguinetti et al., 2017).

3.3.3 Spatial regulations

According to Sanguinetti et al. (2017), topography of eco-driving not only involves driver's manipulation of pedals, gears and other control but also spatial regulations. This is described as maintaining distance from other vehicles and anticipating road conditions, traffic, and time signals. The regulation of one's space helps to minimize acceleration and braking and maximize coasting (Energy-efficient Driving, 2015).

3.3.3.1 Distance maintenance

Distance maintenance is one of the means to achieve spatial regulations. This can be done by monitoring and regulating the distance between your vehicle and the vehicle in front of you. More specifically, it can be defined as time to collision (TTC) i.e. dividing following distance by speed difference. According to Van der Voort et al. (2001, cited in Sanguinetti et al., 2017) efficient drivers have fewer small TTC values. DfT (2016) recommends maintaining a greater distance from the vehicle in front so that speed of the vehicle can be regulated when necessary without using the brakes. Ecowill (2013) regards maintaining a greater distance and make maximum use of the vehicle's momentum as one of the golden rules of eco-driving. More specifically, it recommends keeping a distance equivalent of around 3 seconds to the vehicle driving ahead and releasing the accelerator when traffic slows to keep this safety distance without braking.

3.3.3.2 Anticipate traffic flow

Spatial regulation is achieved by maintain distance and anticipation of traffic flow and/or driving situations. This also includes anticipation and regulation of the vehicle in line with traffic signals. This is important to cruise efficiently, avoiding unnecessary braking, stopping, and accelerating back to cruising speed (Barkenbus, 2010; Birrell et al., 2014; ECOWILL, 2013; DfT, 2016). Regarding timing traffic signals, Energy-efficient Driving (2015) describes how a driver can release the accelerator or even brake far enough in advance when approaching a red light in order to arrive at the intersection at maximum speed after the light changes to green, also accounting for the time it takes traffic stopped at the signal to move through. It is noted, however, that this could have adverse effects at the traffic network level and it does not work when signal lights are triggered by traffic rather than timed.

3.3.4 Cabin comfort behaviours

The term ‘cabin comfort behaviours’ is introduced by Sanguinetti et al. (2017) as a separate function than driving behaviours. The basic distinction is that these behaviours are related to vehicle movement (start, go and stop). These are accessible to both drivers and passengers e.g. regulation of comfort (use of A/C or window heaters) and use of electronics for entertainment and communications. that can add load to the engine. Eco-driving literature recommends conservative use of air conditioning (e.g. Sivak and Schoettle, 2012; DfT, 2016), especially in case of older, hybrid and plug-in electric vehicles (Sanguinetti et al., 2017; Eartheasy, 2019). However, its efficient use is also context dependant. Rolling the windows down for ventilation and cooling is a more efficient alternative at low speeds, but air conditioning is more efficient at high speeds as an alternative to windows down, which increases aerodynamic drag. According to Hall (2008), air conditioning is less costly than open windows, but it still saps power and can increase the fuel thirst of a small engine by up to 10 per cent. He further suggest to run it once a week to keep the system healthy. Likewise, limiting the use of cabin heater and other features, such as heated seats and windscreens, demister blowers, headlights, entertainment equipment (stereo, video player) and anything plugged into cigarette lighters (phone and tablet chargers, navigation systems, etc.) is also highly recommended.

Table 3: List of eco-driving behaviours and their functions in different driving contexts and levels of the driving task

Level		Context	Eco-driving behaviours	Description	Aspect for campaign marketing			
					Fuel cost savings	**Emissions**	**Road Safety**	**Social aspects**
				Eco-driving behaviour typology				
Control	Driver behaviour associated with driving style/characteristics	Driver action (Restricted to specific vehicle operations) / operational decisions	Action specific	Accelerating				
				Cruising				
				Deceleration				
				Gear				
				Engine rpms				
				Idling				
				Driving mode				
				Load management				
		Driver action *(manoeuvres in context)*	Skills and awareness focused	Use of controls, or combination				
				Spatial regulation, including green wave				
				Cabin comfort behaviours				
				Collective eco-driving				
				Eco-driving behaviour associated in context (Pre-trip)				
Tactical	More inclusive driving behaviour	*Planning*	Eco-routing	Route selection including road type, grade, congestion				
			Trip planning	Trip chaining, trip timing, and load management				
Strategic		Vehicle	Vehicle type	ICEVs, PEVs				
			Maintenance	Wheel and tyres, engine maintenance, tuning				
			Fuelling	Using proper grade/octane, prevent evaporation				
			On-board tools	Fuel saving in-car devices e.g. rev counter, cruise controller, on-board computers				

4 Results and discussion

Based on the review conducted for this project, we listed some of the key points which have been learnt and can be considered to maximise the outcome of the project:

i. It would be worth recommending/developing not a generic but an environment/context and vehicle specific eco-driving behaviours guideline/toolkit. Also, financial, environmental, safety and social implications of these behaviours should be assessed. Apparently, there is a gap in the literature exploring implications of eco-behaviours especially from a road safety perspective.

ii. Based on the recommendations, given by Sanguinetti et al. (2017), eco-driving interventions should target positive, actionable behaviour. This is because low rates of behaviour can be reinforced but absent behaviours cannot be. This is in agreement with the literature on behavioural psychology. Therefore, as suggested by Birrell et al. (2014) “obey speed limits” is preferable to ‘‘don’t speed”; ‘‘turn off the engine if you think you will be stopped for at least one minute” is preferable to ‘‘avoid idling”; “accelerating at no more than half throttle” is preferable to “refraining from accelerating”.

iii. It may prove worth exploring relatively new concepts/techniques related to eco-driving in this project e.g. optimal use of wind speed, collective eco-driving, and eco-routing.

iv. However, a big part this project is focused at targeting behaviours which drivers execute while sitting inside the car. This is important to take into account decisions taken at strategic and tactical levels as these eventually lead to operational decisions taken inside the car. More structured and coherent description of these behaviours can help developing targeted interventions. Some limiting evidence in the literature can be found to classify these behaviours (e.g. Ecowill, 2013 coined the term ‘golden and silver rules of eco-driving’). However, not much is being done to theoretical conceptualise and classify these acts.

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