D5.5 Cross-Site Assessment of Case Study Design Packages

Start date of project:	1st September 2018	Duration:	**36 months**

Version:	**1**
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Checked by:	**x**
Verified by:	**X**
Status:	**x**
Dissemination level:	**CO**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769276

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1 Introduction

In urban street design, there is rarely one clear preferred solution—superior to all the other alternatives in all Key Performance Indicators (KPIs)—used for assessment. In most cases, the comprehensive satisfaction of all user requirements demands more space than available and it is rarely possible—at best—to provide the highest performance levels for all user groups. Specific street sections might work very well for one user group but are designed insufficiently for others. The provision of a dedicated cycling lane might, e.g., compete with the provision of a dedicated bus lane. Link users aim at moving fast and reliable whereas place users appreciate low traffic volumes and speeds. The challenging task of balancing the different user needs can only be solved on a case–by–case basis. Local stakeholders often discuss and negotiate possible solutions over long periods of time. Formal and informal procedures for getting relevant stakeholders, such as residents, local interest groups, business representatives or public transport providers, involved into these negotiations exist in all countries and cities and are investigated in MORE in WP2.

The MORE project convenes urban street designers from all over Europe and gives the unique opportunity to (1) exchange knowledge on current practices in urban street design and (2) to develop innovative solutions for the five MORE-corridors and particularly for the so-called stress sections within these corridors. The state-of-the-art is described in D1.2 (Gerike et al., 2019) including a review of guidelines and other relevant material for road function classification and urban street design, and additionally a comprehensive compilation of objectives and performance indicators for the design of urban roads and streets. D1.2 (Gerike et al., 2019) is based on a comprehensive desk research combined with intense discussions with all MORE partners.

This deliverable D5.5 *Cross-site assessment of case study design packages* is embedded in WP5 and focuses on the corridor case studies in the five MORE-partner cities Budapest, Constanta, Lisbon, London and Malmö.

First, this deliverable develops, based on the work done in WP1 to WP3, a concept for evaluating alternative design solutions for urban streets. This concept is called *Street Performance Assessment Scheme* (SPAS); it should be generally valid and applicable to any re-design task, it should allow to compare the performance of a street section (1) with the goals formulated for each specific case study, (2) in situations before and after the implementation of a re-design solution, and (3) between different case studies in cross-site assessments.

Second, The *Street Performance Assessment Scheme* is applied to the five MORE-corridors and particularly to the so-called stress sections defined within each of these corridors. The stress sections were chosen by the local partners; these are street sections within the MORE-corridors that are particularly important, interesting and/or challenging in terms of movement and place functions as defined in D1.2 (Gerike et al., 2019). Stress sections have major movement and major place functions, they are located in the inner-cities with limited space availabilities and are thus typical examples for the most challenging design tasks that urban street designers face. The MORE-stress sections are also examples for the most important parts of the street network when aiming at liveable future cities. Cities need to find solutions for these parts of the street network that strengthen the place functions and invite city life while at the same time ensuring smooth traffic and movement for all user groups including motorised public and private vehicles, bicycles and other types of micro-mobility, pedestrians and also delivery, loading and parking activities.

This deliverable builds on the work done in the first tasks of WP5 (T5.1-T5.3), namely:

- The detailed design specification for case study corridors as described in D5.1 and D5.2 for current and future conditions:
  - (i) Details of feeder route characteristics (spatial extent, interface with the TEN-T Network, current performance characteristics, land use patterns, etc.), plus delineation of wider corridor impact area and selection of ‘area under stress’ for detailed investigation;
  - (ii) Identification of stakeholder groups and the agreed local stakeholder engagement framework, including an exercise to identify current problems to be addressed, and
  - (iii) Design briefs for current and future conditions, drawing on (i) and (ii), which set out the objectives and conditions for developing design options, for each feeder route.
- The developed optimal street-space management packages for current and future conditions on each stress section as described in D5.3 and D5.4:
  - (i) The collation and collection of data for each corridor, as an input to option generation, modelling and appraisal;
  - (ii) The generated sets of design options, for current and future conditions;
  - (iii) The Vissim scenarios developed for each stress section;
  - (iv) Appraisal of design options for each individual case study.

The tools for generating design options, for stakeholder engagement, for the simulation of road user behaviour and for assessing and prioritising street design options created in WP4 are another important input for developing and assessing the proposed design solutions as described in this deliverable.

The remainder of this deliverable D5.5 is organised as follows: The conceptual framework for SPAS is developed in Chapter 2 as the basis for all subsequent steps. Chapter 3 gives an overview about relevant literature on street performance assessment in the urban context. Based on the conceptual considerations and the literature review, the *Street Performance Assessment Scheme* (SPAS) is developed in Chapter 4. Chapter 5 and Chapter 6 present the results of the application of SPAS for the cross-site assessment of the five case studies. Chapter 5 compares the current designs and framework conditions for the five stress sections in terms of street layout, users and usages. It is based on five factsheets that have been published already. Chapter 6 first compares the design process in each of the five cities, second compares the developed design packages, third presents main insights from the modelling exercises with Vissim and fourth summarizes results from the application of the appraisal tool. Chapter 7 summarises the main findings and develops recommendations based on the insights gained.

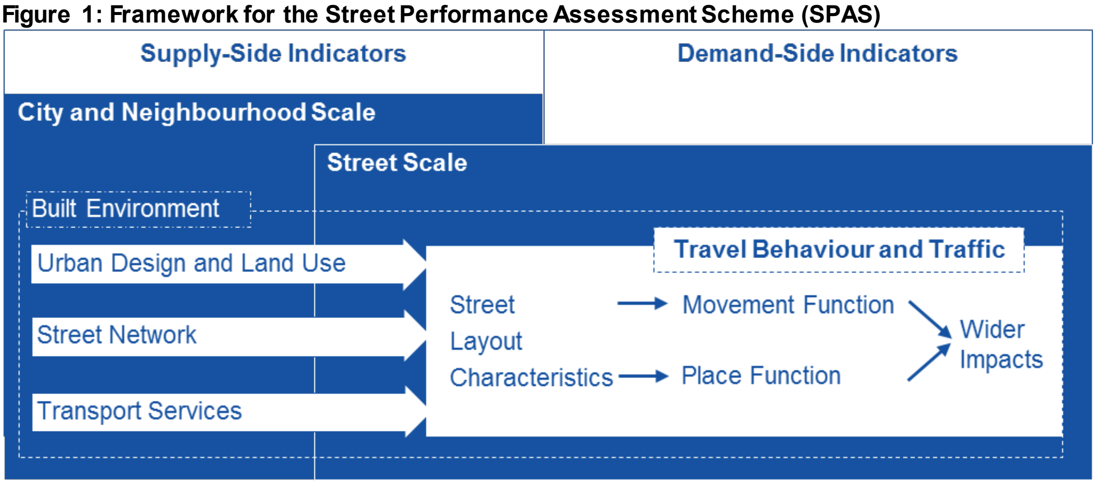
2 Conceptual Framework for Assessing the Design Packages

The *Street Performance Assessment Scheme* (SPAS) to be developed in this deliverable should allow comparing different alternative design solutions for specific street sections and it should also be a suitable basis for before-after comparisons when street design is modified. The three terms objectives, indicators and targets are defined for this deliverable as follows.

- Objectives: Objectives are qualitative goals and visions; this might be, for example, in the case of safety, the improvement of traffic safety as a very general goal on the aggregate level.
- Indicators: Indicators operationalise the qualitative formulated objectives; they make the objectives measurable and thus allow for the measuring of progress towards formulated objectives. Indicators for the objective of improving traffic safety might be, for example, the number of injured or killed persons in traffic.
- Targets: Targets combine objectives and indicators by setting specific values for the chosen indicators that wish to be achieved. For traffic safety this might be Vision Zero: no person killed or seriously injured until, e.g., 2030.

The different objectives, targets and indicators are not independent from each other: There are conflicts and synergies, and also causal relationships. Figure 1 shows the conceptual framework that is used as the basis for developing the street performance assessment scheme. The framework focusses on the influence of the built environment on travel behaviour and traffic. The various further determinants such as users' socio-demographic, socio-economic as well as socio-psychological characteristics (see e.g. Koszowski et al., 2019) are purposefully left out because these can be hardly influenced or changed by urban street design.

Figure 1: Framework for the Street Performance Assessment Scheme (SPAS)



The objectives, targets and indicators are grouped into the following two themes:

<u>Supply-side indicators:</u>

These indicators characterise the built environment on the city/neighbourhood scale, and on the street scale. For this study, supply-side indicators are grouped into *Urban Design and Land Use*, *Street Network* and *Transport Services* as described below.

The importance of the built environment for travel behaviour is high, particularly for walking and for the place activities. The “5Ds” of *density*, *destination accessibility*, *design*, *distance to public transport*, and *diversity* refer to the neighbourhood scale and have been shown in the literature consistently as more influential on walking than any other variable (Cervero and Kockelman, 1997; Ewing and Cervero, 2010; Garfinkel-Castro et al., 2017). In Figure 1, *Urban Design and Land Use* include the factors *density* and *diversity*. The dimension *density* is defined as number of residents or workplaces per analysed area unit and determines the spatial structure of the built environment. *Diversity* describes the heterogeneity respectively the homogeneity of land uses in a defined area. A high variety of land uses means a high amount of potential destinations, which can be reached at short distances (*destination accessibility*) (Cervero and Kockelman, 1997; Ewing and Cervero, 2010).

Street Networks contain the “D”-Variable *design* and describe the characteristics of the street networks (e.g. orthogonal vs. radial grids) and of their individual parts (e.g. intersections, streets, or squares). They include the provision of seamless street networks for all users (street network connectivity) and are measured by indicators such as link-node-ratio, intersection density, street network density, connected node ratio, block density, and average block length (Berrigan et al., 2010; Cervero and Kockelman, 1997; Mayor of London, 2018). A highly connected street network is usually formed by a dense urban grid and thus provides many route choice options to each one destination.

Transport Services include specific services and facilities for each user group. For example, public transport supply is described by its accessibility, this means the distance to the nearest public transport stop from residence or workplace (“D”-variable *distance to public transport*) or the distance between public transport stops (Ewing and Cervero, 2010). Also within the street space, public transport stops need to be well accessible e.g. in terms of barrier-free access, suitable crossing facilities and separation from bicycle traffic.

All three groups of variables describing the built environment can be defined on the city and neighbourhood as well as on the street scale. For the street performance assessment scheme to be developed in this chapter, the focus lies on street scale; these are objectives, targets and indicators that characterise the street environment itself and that are sensitive to changes in the layout of specific street sections and junctions. Indicators on the city- and neighbourhood scale as described above should be added to the street performance assessment scheme if the activities for re-designing streets in the MORE-corridors go beyond the specific street sections and include also changes in transport services and networks or in land use on these higher level spatial scales.

Demand-side indicators:

Demand-side indicators characterise the usage of the built environment and the transport supply. Indicators for the *movement function* (also called movement function) describe the quality of movements as well as the quality of streets as conduits which allow movements of different user groups in passenger and freight. The overall ambition for the movement function is to achieve safe, fast, reliable and convenient movements (save time). Indicators for the *place function* indicate the quality of place activities and the quality of streets as destinations and as public spaces. For the place function, the main objective is to motivate place users to stay and to maximise dwell times in the streets. Link and place activities generate various impacts. These are summarised in the category *wider impacts* and include (1) environmental and safety effects of movements that should be minimised, (2) health benefits that result from higher proportions of the active modes walking and cycling as physical activity, and (3) economic indicators such as the costs of providing transport services.

In the following two chapters, tables are provided for demand-side indicators (Chapter 3.1) and supply-side indicators (Chapter 3.2). These tables give an overview of all relevant indicators identified in the process of researching literature and material with relevance for the evaluation in WP5. These tables are the basis for developing the Street Performance Assessment Scheme (SPAS) in Chapter 4. Objectives, targets and indicators are listed in the tables in each one column. The right-hand column lists the references for where each identified objective was found. For example, many references occur for safety since this was included in all researched documents, either on the strategic level such as SUMPs or on the street level of specific street sections. This clear commitment to safety improvements is a direct result of the prioritisation of this issue in political programmes but also from a legal standpoint. The Directive 2008/96/EC of the European Parliament and of the Council of 19 November, 2008, on road infrastructure safety management is mandatory for all EU member states. This ensures the establishment of procedures for continuously monitoring accidents in terms of location, type, severity, and involved user groups (e.g., vulnerable road users versus motorised vehicles) and also the implementation of measures for improving safety. Another frequently included objective is the decrease of greenhouse gas emissions; this was mentioned in nearly all researched references.

Chapter 3.3 gives an overview about output options provided in Vissim. These are a hard constraint for the evaluation in MORE which mainly rely on the Vissim simulations of the different developed design solutions. Audits and walkability assessments are a relevant input for evaluating the conditions for pedestrians and place users. These were therefore included in the literature review with the results being presented in Chapter 3.4.

Objectives and indicators for the planning processes have also been found, such as the type or number of events during a specific planning task, the number of participants, or the media coverage. These process-related indicators are covered in WP2 within the MORE-project.

3 Literature Review: Street Design Objectives, Targets and Indicators

3.1 Demand-Side: Street Users and Usage

3.1.1 Movement Functions

The following Table 1 lists objectives, targets and indicators for the movement function as identified in the research of relevant material. They describe different aspects of the quality of movements for the different user groups of pedestrians, cyclists, innovative micro-vehicles such as electric scooters, busses and trams, cars, vans and medium-sized delivery vehicles, heavy duty vehicles. The objective of maximising the quality of movements is similar for all these user groups; indicators are straightforward and easy to understand. The difficulty lies in the restricted availability of space and capacity in streets and junctions. It will hardly or never be possible to provide for unhindered movements for all user groups. The task of urban street designers is to find balances that ensure stable traffic flows. Political priorities for selected user groups and/or mandatory minimum LOS might exist as hard constraints for this optimisation task.

Table 1: List of Objectives, Targets and Indicators for the Movement Functions

Theme	Objectives	Targets	Indicators	Reference
Traffic Quality	Keep traffic flows stable, increase traffic quality, achieve defined Levels of Service (LOS, usually A-F, derived from quantitative indicators) per user group Minimise congestion	Achieve pre-defined LOS target levels, e.g. LOS D as a compromise that acknowledges that highest LOS (LOS A) cannot be achieved for all street users while at the same time keeps traffic flow stable	Traffic volumes (all user groups) [veh.-km] [veh.-trips/h] [ped.-trips/h] etc. Examples for quantitative indicators used as the basis for computing LOS: Traffic density [vehicle/km] Utilisation rate [vehicle/hour over capacity] Waiting times at junctions [min]	(Intraplan Consult GmbH, 2017; PTV AG, 2007; PTV Planung Transport Verkehr AG et al., 2016; Szabo and Schäfer, 2016) (Constanta Municipality, 2015; Mayor of London, 2018; Road Task Force, 2013; Transportation Research Board, 2016)
Speed, Delays	Increase speed for specific user groups, time periods, use cases; decrease delays and waiting times at junctions	For movement functions: hardly any specific target levels, rather comparisons of speeds in different alternatives In London, the goal is to reduce overall traffic levels while keeping congestion broadly at today's levels during peak periods.	[km/h] [minutes delay per km driven] [km] of street sections with certain speed limits Indicator applicable for sequences of street sections and junctions rather than for single elements (section or junction)	(PTV AG, 2007; Szabo and Schäfer, 2016) (International Federation of Pedestrians, 2012; Mayor of London, 2018; Road Task Force, 2013; Transport for London, 2019a) (International Federation of Pedestrians, 2012, 2012; Lisbon Municipality, 2015; Mayor of London, 2018; Transport for London, 2017a, 2017c, 2019b)
Travel Time	Direct correlation with speed, objectives: Reduce travel time for specific user groups (passenger versus freight, pedestrians, cyclists, motorised private vehicles, public transport) and trip purposes, reduce related monetary losses	Absolute values e.g. for maximum travel times to specific destinations or relative targets (e.g. improvement) compared to reference period	[person-h/year] [vehicle-h/year] Might be distinguished in peak vs. off-peak, might be weighted e.g. by the number of affected persons Monetised gains and losses in travel times [€/year]	(Intraplan Consult GmbH, 2017; PTV AG, 2007; PTV Planung Transport Verkehr AG et al., 2016; Szabo and Schäfer, 2016) (Budapest Municipality, 2014; Constanta Municipality, 2015; Road Task Force, 2013)

Theme	Objectives	Targets	Indicators	Reference
Reliability	Increase reliability, peak/ off-peak	Absolute targets such as percentage of journeys not exceeding specific delay values Relative targets (e.g. improvement) compared to reference periods	Average delay [min] or [€/year], frequency of delays above specific thresholds Might be distance-weighted Breakdowns in PT	(Intraplan Consult GmbH, 2017; PTV AG, 2007; PTV Planung Transport Verkehr AG et al., 2016) (Mayor of London, 2018; Road Task Force, 2013)
Traffic Volumes, Modal Split	Change of trip-based modal split towards walking, cycling, PT Objective formulated on city level but also for specific neighbourhoods or street sections	Target values for shares of specific modes in modal split Decrease or increase of traffic volumes per user group	[%] (e.g. target share of active modes walking and cycling), to be computed based on traffic volumes for each user group	(Budapest Municipality, 2013, 2014, 2017; Constanta Municipality, 2015; Mayor of London, 2018; Road Task Force, 2013; Transport for London, 2018a)

3.1.2 Place Functions

Place functions are more diverse than movement functions. They encompass all types of activities that do not use street as conduits for movements but as destinations. Place users come to streets because they like to spend time and to dwell in the public street space or because they want to carry out activities in the adjacent buildings. These different types of place activities (also called stationary activities) have different degrees of voluntariness as well as different determinants and requirements:

1. Place activities in the street as destination: Gehl (2010) and Gehl and Svarre (2013) distinguish the following types of place:

    - Necessary place activities: These activities have to been undertaken, they can be observed under all conditions even when facilities for these functions are poor. A typical example is waiting for the bus.

    - Optional place activities: These are activities that people might like and that people do voluntarily, e.g. recreational activities, walking down the promenade, standing up to get a good look at interesting and nice things, sitting down to enjoy the view or the weather.

    - Social place activities: These include all types of communication and require the presence of other people. Typical examples for social place activities are watching people and to what is happening, exchange greetings, to talk to and to listen to acquaintances, chance meetings and small talks at market booths, on benches or wherever people wait, people asking for directions, exchange brief remarks about the weather or when the next bus is due, young people hang out and use city space as meeting place. More extensive contacts and conversations might result from these short talks, acquaintanceships might sprout. Social place activities happen spontaneously and can hardly be predicted, but they can be invited and encouraged by suitable street layouts. Planned common activities such as markets, street parties, meetings, parades and demonstrations also belong to this category of social place activities.

Gehl (2010) demonstrates, based on various examples, convincingly that, with better conditions in the streets, people emerge from their buildings to stay in city space. Chairs are dragged out in front of houses and children come to play. Versatile city and street life largely depends on invitation; this holds particularly for place activities in the street as destination.

2. Access to adjacent buildings: Persons and in some cases also vehicles need to access the adjacent buildings. Space needs to be provided and needs be kept clear from other usages even if the access to the adjacent buildings is a rare event. Sufficient ranges of vision are paramount for avoiding conflicts with other street users and usages.

3. Parking and stopping: Vehicles (busses, trams, cars, vans, heavy duty vehicles, motorcycles, scooters) stop in the street for loading or unloading goods or passengers, or for supplying shops and businesses in the adjacent buildings. Drivers do not accept long distances from the parked vehicles to the final destination; they tend to park illegally if no suitable parking space is provided. Indicators are suggested to monitor these activities in terms of number, type, duration and possible conflicts or interactions that might be caused by these activities.

Objectives, targets and indicators for the different types of place functions function, as identified in the research of relevant material, are listed in the below Table 2.

Table 2: List of Objectives, Targets and Indicators for the Place Functions

Theme	Objectives	Targets	Indicators	Reference
Traffic Volumes	Lower volumes of motorised traffic to improve safety and comfort for place users, also ease crossing of the street Increase volumes or achieve specific target volumes for waking/ cycling/ PT	Low volumes of (heavy duty) motorised vehicles High volumes walking, cycling, PT	Number of vehicles/ pedestrians per time at specific locations [veh/h] [ped/h] Peak, off-peak	(Transport for London, 2017b)
Speed of Motorised Traffic	Lower speed levels of motorised vehicles, this allows for re-allocating road space, increases safety levels and quality of urban space	Low speed of motorised vehicles	[km/h]	(Transport for London, 2017b)
Necessary Activities	Meet the needs of place users for carrying out necessary activities such as waiting for a bus	Increase the comfort for necessary place activities	Number, type and duration of necessary activities	(Gehl, 2010; Mayor of London, 2018; PTV AG, 2007)
Optional Activities	Increase the intensity of place usages in the street	Increase the overall duration (number of activities times their duration) of optional activities	Number, type and duration of optional activities: standing/ (in)formal seating/ strolling/ lying down Examples for optional activities: wait, work, eat, drink, window shop, use mobile devices, read, enjoy life/ the weather, smoke, walk pet, take photo, navigate, talk on the phone, feed pigeons, look at others/ something, rest, shelter, queue	(Gehl, 2010; Mayor of London, 2018; PTV AG, 2007)

Theme	Objectives	Targets	Indicators	Reference
Social Activities	Increase the intensity of place usages in the street	Increase the overall duration (number of activities times their duration) of social activities	Number, type and duration of social activities (all types of communication and interaction): standing/ (in)formal seating/ strolling/ lying down Examples for social activities: talk, sing, play, work, meet, engage in cultural activities/ performing, skateboarding/ rollerblading in groups, vending / commercial activity	(Gehl, 2010; Mayor of London, 2018; PTV AG, 2007)
Liveliness Index	Increase the number of people staying in the street and the length of their stay	Composite indicator for overall place activities, might be distinguished by person group (e.g. children, elderly)	Number of people times the duration of their stay (15s to <1min, 1min to <5min, 5min to <10min, 10min to < 15min, ≥ 15 min)	(Mehta, 2007; Mehta and Bosson, 2018)
Access to Adjacent Buildings	Allow for safe and smooth access to adjacent buildings and usages	Meet needs for access Minimise conflicts and incidents	Number of access activities to adjacent buildings Interactions and incidents	(FGSV, 2006)
Parking	Provide for parking	Meet parking needs Minimise conflicts, incidents, accidents related to parking (e.g. dooring, crossing) Reduce illegal parking	Number and location of parked cars (observation) over the day / week/ year, purpose of parking activities (on-site interview), duration of parking activities	(Transport for London, 2017e)
Stopping ((un-)Loading, Delivery)	Provide for delivery, (un-) loading	Meet needs for (un-) loading, delivery Minimise conflicts, incidents, accidents (e.g. dooring, crossing) Reduce illegal stopping	Frequency and location of stopping activities over the day / week/ year, purpose and duration of stopping activities, proportion of stopping activities during peak hours or other specific time periods, type of vehicle	(Transport for London, 2017e)
Satisfaction of Street Users, Perception of Streetscape	Improve satisfaction of street users with the street environment (demand and supply)	Indicator in between demand- and supply-side indicators; street users and respondents might assess all relevant aspects of the street environment	Subjective assessments of street environments from on-site or remote interviews or surveys	(Gehl Institute, 2019; Mehta, 2014a, 2014b; Transport for London, 2017d)

3.1.3 Wider Impacts

Indicators on wider impacts operationalise the consequences of any usage of the street space. These indicators are the basis for cost-benefit analysis or other methods used for assessing proposed street design solutions. The below Table 3 summarises typical indicators as identified in the researched material.

Table 3: List of Objectives, Targets and Indicators for Wider Impacts

Theme	Objectives	Targets	Indicators	Reference
Health				
Health	Increase in residents' physical activity (overall or in transport), reduce health costs, skim societal benefits from (increased) physical activity	WHO-targets for physical activity, e.g. 150min of moderate physical activity per week To meet certain durations of physical activity per week overall or only from travel Reduction in health cost compared to reference levels	[min moderate/intense physical activity per week], for specific person groups such as children, adults or seniors [min walking/cycling travel per week] [%] reduction in health cost, e.g. computed with WHO HEAT-tool (##)	(Lisbon Municipality, 2015; Mayor of London, 2018)
Economic effects				
Cost (Investment, Operation)	Reduce cost for investment and operation (vehicles, infrastructures), might be distinguished by user group (private versus PT, passenger versus freight transport,	Minimisation of cost	Total investment cost Total annual cost for operation Total annual cost for maintenance [€/year] Proportion cost for operation / investment cost [%] Relative cost, e.g. average cost per kilometre [€/100km]	(PTV AG, 2007; PTV Planung Transport Verkehr AG et al., 2016; Schäfer and Walther, 2008; Szabo and Schäfer, 2016) (Budapest Municipality, 2014; Constanta Municipality, 2015)
Economic Success of Adjacent Usages	Ensure economic success of businesses adjacent to the street	Maximise economic success and attractiveness of buildings	Number and type of businesses in adjacent buildings Annual turnovers of adjacent businesses Number of customers	(Mayor of London, 2018)
Safety				
Safety	Improve traffic safety For specific user groups (pedestrians, cyclists, motorised private vehicles, PT) For specific types of infrastructures or accidents (e.g. at junctions, at public transport stops, at pedestrian crossings) Subjective (perceived) vs. objective (measured) safety	Vision Zero (no death, no severely injured) Relative reductions in number and severity of accidents compared to reference level Improvements in user perceptions (e.g. based on intercept surveys)	Total number of accidents/injured per year (per 3 years for accidents with personal injury) Number of accidents/injured per length of infrastructure [km] Number of accidents/injured per length of infrastructure [km] and traffic volume [veh.-km] All the above indicators might be monetised (absolute accident cost, accident cost per km / veh.-km) Percentage reduction of accidents/ accident cost [%]	(Intraplan Consult GmbH, 2017; PTV AG, 2007; PTV Planung Transport Verkehr AG et al., 2016; Schäfer and Walther, 2008; Szabo and Schäfer, 2016) (Budapest Municipality, 2014; Constanta Municipality, 2015; Lisbon Municipality, 2015; Mayor of London, 2018; Road Task Force, 2013; Transport for London, 2017a, 2017c, 2018d, 2019b)

Theme	Objectives	Targets	Indicators	Reference
Environmental effects and resource consumption				
Energy Consumption	Reduce energy consumption in total or particularly for fossil fuels Improve efficiency of the transport system	Absolute or relative reduction targets for total fuel consumption / fuel consumption per kilometre Absolute or relative increase in the use of renewable energy	Total fuel consumption [t fuels/year] Relative fuel consumption per distance [t fuels/100km] Percentage reduction of fuel consumption [%] Proportion of renewable energy [%] Proportion of electric vehicles or zero emission vehicles in vehicle fleet [%]	(PTV AG, 2007; PTV Planung Transport Verkehr AG et al., 2016) (Budapest Municipality, 2013, 2017; Constanta Municipality, 2015; Mayor of London, 2018)
Air Pollutant Emissions, Air Quality	Improve air quality, reduce air pollutant emissions	Meet air pollution targets e.g. for NO2, PM, ozone Reduce environmental cost Reduce emissions from transport (absolute per year, relative per distance driven)	Number of days with exceedances of legal limit values given by the European Air Quality Directive Mean air pollutant concentration per year, e.g. [g NO2/m³] Tons of specific air pollutants emitted in transport [t NO2/year] [g NO2/veh.-km]	(PTV AG, 2007; PTV Planung Transport Verkehr AG et al., 2016; Szabo and Schäfer, 2016) (Budapest Municipality, 2013; Constanta Municipality, 2015; Mayor of London, 2018; Road Task Force, 2013; Transport for London, 2019b)
Greenhouse Gas Emissions	Reduce GHG-emissions from transport	Absolute or relative reductions compared to reference levels (e.g. current situation or BAU scenarios) Meet specific absolute targets Zero emission in London by 2050	[t CO2], [t CO2e] (as target values or as reduction values compared to reference levels) [%]-reduction compared to reference levels	(Intraplan Consult GmbH, 2017; PTV AG, 2007; PTV Planung Transport Verkehr AG et al., 2016; Schäfer and Walther, 2008; Szabo and Schäfer, 2016) (Budapest Municipality, 2013, 2014; Constanta Municipality, 2015; Lisbon Municipality, 2015; Mayor of London, 2018; Road Task Force, 2013)
Noise Emissions, Noise Exposure	Reduce noise emissions, meet targets for maximum noise exposure	Meet specific noise levels [dB(A)] Reduce number of persons affected by specific noise levels [dB(A)]	[number of persons affected by noise levels dB(A) above certain thresholds] Indicators of European Environmental Noise Directive	(Constanta Municipality, 2015; European Commission, 2002; Mayor of London, 2018; Road Task Force, 2013; Transport for London, 2019b) (Intraplan Consult GmbH, 2017; PTV Planung Transport Verkehr AG et al., 2016)
Micro Climate	Improve micro climate e.g. in particular hot time periods Monitor and minimise urban heat islands in a spatial and timely breakdown	Usually relative targets compared to reference levels (e.g. current situation)	Number of trees or other street furniture providing shade Temperature difference between unbuilt areas, green areas and built-in areas	(Budapest Municipality, 2013, 2017; Lisbon Municipality, 2015; Transport for London, 2017a, 2017c, 2019b)
Land Use, Space Consumption	Minimise land use, protect soil quality, protect water quality (groundwater, rivers or lakes in proximity), reduce risk of flooding	Reduce sealed surface, provide sufficient space for infiltration	Size or share of sealed surface for specific usages/ user groups [m²] [%] Size of infiltration spaces [m width in street-cross-section], [m²] Per capita green area	(Intraplan Consult GmbH, 2017; PTV AG, 2007; Schäfer and Walther, 2008; Szabo and Schäfer, 2016) (Budapest Municipality, 2013, 2017)
Nature Conservation	Minimise impairment to habitats	Protection of habitats from endangered animal and plant species	Size of affected areas [m²], number of cut (and so far connected) habitat areas for certain species, qualitative indicators	(PTV Planung Transport Verkehr AG et al., 2016) (Constanta Municipality, 2015)
Resilience	Improve resilience to severe weather and climate change or other disruptive changes in societal framework conditions			(Mayor of London, 2018; Vienna Municipality, 2015)
Streets as Ecosystems				See WP2

3.2 Supply-Side: Streetscape, Urban Design and Land Use

Supply-side indicators were introduced in Chapter 2 as characteristics of the built environment on the city, neighbourhood scale, and on the street scale. For the MORE-project, mainly the street scale is relevant including all three groups of supply-side indicators *Urban Design and Land Use*, *Street Network* and *Transport Services* as described above. The below Table 4 lists all objectives, targets and indicators that have been identified as relevant for urban street design. Variables in the group *Street Network* describe the space that is provided to the different user groups, the types of separation between the user groups and the provided street furniture/equipment.

Variables in the group *Urban Design and Land Use* describe the proportions of the different elements of the street layout themselves (e.g. width of carriageway vs. widths of footways) but also the proportions of the street width vs. the type and height of the adjacent buildings. Further variables characterise the buildings, their usage (land use) and the transition spaces between the street and the buildings (soft vs. hard edges). The topics of security and protection are also covered in this group of supply-side indicators.

There are only few variables in the group *Transport Services* that are relevant on the street scale as this group is mainly about the quality, quantity and accessibility of services provided on the city and neighbourhood scale. However, most of these services eventually happen on streets. Therefore, two variables *Multi-Modal Transport Services* and *Innovative Transport Services* are included in the below list; these describe the provision of facilities for changing transport modes within a street or for using innovative services such as scooter sharing.

Table 4: List of supply-side objectives, targets and indicators characterising specific street sections

Theme	Objectives	Targets	Indicators	Reference
Street Network				
Space for Movement Functions	Provide adequate street dimensions and capacity for all user groups, respect minimum space requirements e.g. because of vehicle widths or geometric tractrix curves	Provide adequate space per user group	Space provision per user group in cross section [m] [m²] Percentage change [%] Share of street sections with dedicated lanes for PT/cycling	(Szabo and Schäfer, 2016) (Mayor of London, 2018; Road Task Force, 2013; Transport for London, 2017a, 2017c, 2019b)
Appropriate Facilities and Separation of User Groups (Link and Place)	Provide appropriate facilities for each user group as the core prerequisite for quality, safety, comfort, for street sections and junctions	Provide adequate facilities for each user group	Documentation of facilities for each user group, comparison with recommended values in guidance material	(Transport for London, 2019c)
Appropriate Signalising Schemes at Junctions	Ensure safe, smooths and comfortable movements at junctions for all user groups Prioritise selected user groups	Increase safety, reliability Decrease waiting time, detours while crossing a junction	Documentation of signalling scheme	
Space for Place Functions	Increase space for place functions (static or dynamic): sit, stand, dwell, stroll access to adjacent buildings park, stop	Absolute values or proportions of space dedicated to place functions (not including clear zones of sidewalks), relative targets compared to reference period e.g. increase in space for pedestrians	Width [m] Space [m²] Change in space for specific user groups Indicators might refer to specific time periods in case of dynamic solutions of allocating street space	(Constanta Municipality, 2015; Mayor of London, 2018; PTV AG, 2007; Transport for London, 2017c, 2019b, 2019d; Vienna Municipality, 2015)

Theme	Objectives	Targets	Indicators	Reference
Opportunities to Stand/Stay	Provide attractive zones for standing/ staying considering the edge effect Provide support for standing	Encourage place activities, increase overall dwell time	Width [m], Space [m²] Change in space for specific user groups	(Gehl, 2010)
Opportunities to Sit	Provide zones for sitting, utilising advantages such as view, sun, people Provide seating facilities such as benches	Encourage place activities, increase overall dwell time	Number seating facilities per kilometre, distinguished by private/ commercial seating, formal (e.g. benches)/ informal seating (e.g. stairs) Distance between each two seating facilities Availability of toilets	(Gehl, 2010)
Opportunities for Play and Exercise	Provide inviting street furniture for creativity, physical activity, exercise and play, day and night, in summer and winter	Encourage place activities, increase overall dwell time	Width [m] Space [m²] Change in space for specific user groups	(Gehl, 2010)
Provision for Parking and Stopping (loading, delivery)	Meet demand for parking and stopping (short/long-term, for different user groups (e.g. sharing, private) and vehicle types (e.g. delivery vans, bicycles, scooters)	Meet demand with reduced space consumption for parking Reduce illegal parking	Number of parking lots per type Number, location, time of illegal parking activities	(Constanta Municipality, 2015; Mayor of London, 2018; PTV AG, 2007; Transport for London, 2017e; Vienna Municipality, 2015)
Community Severance, Crossing Facilities	Improve crossing facilities for pedestrians, cyclists and place users	Decrease detours for crossing Decrease waiting times for crossing Increase number of crossing facilities Guarantee high safety of crossing facilities	Number of crossings Suitability of crossing locations (should meet desire lines) Share of street sections with mid-link crossings (in places with high crossing needs) Appropriate detection and optimisation technology for active mode users at traffic lights	(Mayor of London, 2018; Transport for London, 2017c, 2019b)
Inclusive Design	Enable all user groups to use public street spaces Guarantee access to transport services to all user groups Ensure accessibility of adjacent usages / buildings for all user groups (pedestrians, delivery, PT users)	Provide seamless guidance systems for visually impaired persons, ensure even surfaces and crossing facilities for physically impaired persons, consequently apply design-for-all principles for all street design tasks Achieve completely accessible PT services	Share of street network and (crossing) facilities that is accessible for all user groups Quality of surface Share of vehicles and PT stations that are accessible also for persons with reduced mobility	(Intraplan Consult GmbH, 2017) (Budapest Municipality, 2014; Constanta Municipality, 2015; Lisbon Municipality, 2015; Mayor of London, 2018; Transport for London, 2017a, 2017c, 2018e, 2019b)
Overall Quality of Streetscape	Composite indicator for quality of streetscape	Improve overall quality of street space	Sidewalk coverage x pavement quality x street amenity (as total of benches, bike racks, trees)	(Lai and Kontokosta, 2018)

Theme	Objectives	Targets	Indicators	Reference
Urban Design and Land Use				
Human Scale/ Dimension, Enclosure	Buildings and spaces designed to human dimension Degree to which streets and other public spaces are visually defined by buildings, walls, trees and other vertical elements	Choose proportions and size of buildings according to human dimension and distances for social interaction as introduced by Gehl (2010)	Ratio of widths of footway / width of carriageway / widths of footway should be appropriate [30 % / 40 % / 30 %] Ratio width of street/ height of adjacent buildings should comply with human dimension Qualitative assessment by users Enclosure: proportion of the section with buildings or other static vertical elements such as trees	(Ewing and Handy, 2009; FGSV, 2006, 2011; Gehl, 2010; Mayor of London, 2018; Transport for London, 2017c)
Attractive and Active Frontages, Transparency, Permeability	Provide things to see, open/ transparent usages of buildings, appeal to many senses, interesting texture and details, mixed functions, varied façade rhythms, soft edges, allow people to see or perceive human activity beyond the edge of a street	Suitable façade length of 5-6m (15-20 shops per 100m), vertical façade articulation better than long horizontal lines Personalisation of building façade, entrances, shop-windows (how are these embellished with personal touches such as displays, decorations, signs, banners, planters, flower-boxes, and other wares)	Proportion of facades with active frontage/ soft edges/ windows/ active uses Façade length, proportion of street wall Qualitative assessment of façade designs Articulation of facades (nooks, corners, alcoves, small setbacks, steps and ledges)	(Gehl, 2010; Mehta, 2014b)
Mixed Usages of Adjacent Buildings	Support liveable street 24/7	Achieve diversity in type of usages of adjacent buildings Availability of community places (stores that are places to meet neighbours, friends etc.)	Types of usages in adjacent buildings, particularly in ground floor	(Gehl, 2010; Mehta, 2014b)
Imageability	Quality of the street that evokes a strong image in an observer, that makes the place distinct, recognizable and memorable	Achieve high imageability urban design qualities for each street section	Imageability: proportion of historic buildings; number of courtyards/ plazas/ parks; presence of outdoor dining; proportion of buildings with non-rectangular silhouettes Complexity:	(Ewing and Handy, 2009; Gehl, 2010)
Complexity	Visual richness of a place, depends on the variety of the physical environment, the numbers and types of buildings, architectural diversity and ornamentation, landscape elements, street furniture, signage and human activity	Provide many interesting things to see, e.g. building details, signs, people, surfaces, changing light patterns and movement, signs of habitation, trees, greenery, street furniture	Number of people in the street/ pieces of public art/ buildings/ accent colours, presence of outdoor dining (yes/no)	(Ewing and Handy, 2009)
Security, Protection against Crime and Violence	Improve security (crime and perception of crime), lighting, visibility of all parts of the street section Lively public realm, eyes on the street, overlapping functions day and night	Relative targets compared to reference period	Qualitative assessment by users e.g. with Likert-Scales (for London: more people should feel safe walking by themselves in their local area, fewer people should say they are deterred from travelling by safety concerns) Monitoring of crime Existence of surveillance of public spaces Number of street lights, distance between street lights	(Gehl, 2010; Mayor of London, 2018; Road Task Force, 2013; Transport for London, 2017a, 2017a, 2017c, 2018e, 2019b)
Protection against Unpleasant Sensory Experiences, Opportunities to Enjoy the Positive Aspects of Climate	Protection against wind, rain/ snow, cold/ heat, pollution, dust, noise, glare Arrange place activities so that these have sun/shade, heat/coolness, breeze	Shelters, refuges, separation between the different user groups Greenery, trees	Number of shelters, refuges, distance between sheltered areas Assessment of provided greenery Qualitative assessment of the different aspects	(Gehl, 2010; Transport for London, 2017c, 2019b)

Theme	Objectives	Targets	Indicators	Reference
Positive Sensory Experiences	Good design and detailing, good materials, fine views, trees/ plants/ water Clean surfaces and streets Minimise clutter	Improve overall attractiveness of streets and spaces	Subjective assessment of the different aspects	(Gehl, 2010)
Flexibility of Street Use	Improve flexibility of street use	Increase capacity, prepare for future changed user needs/ transport technologies/ vehicles	Type and number of flexible street use elements	(Mayor of London, 2018; Transport for London, 2019a)
Transport Services				
Multi-Modal Transport Services	Support intermodal trips (> 1 mode per trip) and multimodal travel behaviour (> 1 mode e.g. during 1 week) Provide digital support for routing, ticketing etc.	Provide possibility to transport bicycles on PT vehicles Support for interchange between PT and other modes	Regulation for transporting bicycles in PT vehicles, usage of this service Provision of secure cycling parking close to PT stations Kiss+Ride, Park+Ride facilities Bus/ tram stop accessibility Bus stop connectivity with other public transport services Street-to-station step-free access	(Mayor of London, 2018; Transport for London, 2017a, 2017c, 2019b)
Innovative Transport Services	Provide innovative transport services such as car/ bike/ scooter sharing	Increase usage of shared vehicles, reduce usage of private vehicles	Number of car/ bike/ scooter stations or vehicles (in case of free-floating services)	(Budapest Municipality, 2014, 2017; Mayor of London, 2018; Transport for London, 2019a)

3.3 Performing Evaluations in Vissim, Overview of Output Options

The Vissim Manual provides a detailed description of possibilities for comparing and evaluating different Vissim scenarios, it can be found at:

- Introduction on performing evaluations: https://cgi.ptvgroup.com/vision-help/VISSIM_11_ENG/Content/11_Auswertungen/Ausw_a_ausfuehren.htm?TocPath=Performing%20evaluations|_____0
- Overview of evaluations: https://cgi.ptvgroup.com/vision-help/VISSIM_11_ENG/Content/11_Auswertungen/Ausw_a_Uebersicht.htm

Various supply-side data is produced during Vissim simulations, e.g. information on vehicles, links, areas, nodes, traffic jams, green time distribution or PT waiting times. This data is a valuable input for the evaluation of the different design-solutions for the MORE corridors. The following output options for the result data of each evaluation exist in Vissim:

- OD pair data: Result attributes can be shown that are created from traffic data between the origin zones and destination zones of dynamic assignment, e.g.:
    - Average travel time = Total of travel times / number of vehicles
    - Average delay time = Total of delay times / number of vehicles
    - Average relative delay = Average delay time / average travel time
    - Number of vehicles
    - Total distance travelled / number of vehicles
    - The indicators can be aggregated by departure time or by arrival time

  OD pair data can be only used for the evaluation if dynamic assignment has been used, this will rather not be the case in MORE. OD pair data can be therefore not be used for evaluating MORE-scenarios but belongs instead to the input data.

- Vehicle record: The vehicle record outputs the attribute values for each vehicle as raw data in one row per time step. The evaluation can be restricted to selected vehicle classes and individual vehicles.
- Vehicle network performance: Specific attributes of the entire network can be compiled in lists, e.g.:
    - Total number of vehicles in the network at the end of the simulation
    - Vehicles arrived
    - Average speed [km/h] or [mph], defined as total distance / total travel time
    - Total number of vehicle stops (excluding scheduled stop times of buses and trains at public transport stops, parking times in parking lots)
    - Average number of stops per vehicle defined as total number of stops / (number of veh in network + number of veh that have arrived)
    - Fuel consumption
    - Latent demand: Number of vehicles from meso-origin connector edges, vehicle inputs and parking lots that could not be used, number of vehicles that were not allowed to enter the network from vehicle inputs and parking lots until the end of the simulation.
    - Total travel time: Total travel time of vehicles travelling within the network or that have already left the network.
    - Total delay: Total delay of all vehicles in the network or of those that have already exited it, includes stop times at stop signs, excludes scheduled stop times of buses and trains at public transport stops, passenger service times, parking times in parking lots
    - Latent delay: Total delay of vehicles that cannot be used (immediately)
    - Average delay per vehicle: Total delay / (number of vehicles in the network + number of vehicles that have arrived)
    - Total stopped delay: Total standstill time of all vehicles that are in the network or have already arrived, Standstill time = time in which the vehicle is stationary (speed = 0), excluding scheduled stop times of buses and trains at public transport stops as well as parking times
    - Average stopped delay: Average standstill time per vehicle, Total standstill time / (Number of vehicles in network + number of vehicles that have arrived)
    - Total distance: Total distance of all vehicles in the network or of those that have already exited it
- Vehicle & travel times, vehicle travel times (raw data): A vehicle travel time measurement consists of a From Section and a To Section. The mean travel time from traversing the From Section up to traversing the To Section, including the waiting time and/or holding time, is calculated as well as the distance travelled between the start section and destination section.
- Vehicle input data: Attributes can be assigned to vehicles and pedestrians by defining vehicle types, vehicle data can be reported for all vehicles in the network.
- Areas & ramps: Density and speed of pedestrians can be analysed:
    - Maximum, minimum, average number of pedestrians that were in the area, on ramp or stairs

- Maximum, minimum, average number of pedestrians waiting for a PT vehicle in the area, on the ramp or stairs
  - Number of pedestrians leaving the construction element or walking on it (excluding pedestrians from pedestrian inputs and pedestrians alighting from PT vehicles)
  - Pedestrian density in area, on ramp or stairs
  - Pedestrian density experienced within the perception radius of a pedestrian: Number of other pedestrians within a radius around the pedestrian.
  - Average pedestrian speed, all pedestrian types, calculated as the harmonic mean
  - Vectorial speed differences of all pedestrians within the personal environment radius of their own speed
  - Length and time information on any queues
- Aggregated analysis and visualisation are possible for pedestrian grid cells (density and speed of pedestrians), entire networks, pre-defined areas
- Pedestrian record (only for Viswalk): This record outputs the attribute values for each pedestrian in one row per time step, the evaluation can be restricted to selected pedestrian classes.
- Pedestrian travel times: With the evaluation of the pedestrian travel time, pedestrians are recorded when they are added in the start areas until they enter the associated destination areas.
- Pedestrian travel times (OD data): From a simulation based on a pedestrian origin-destination matrix, the following aggregated data can be generated:
  - Travel time: Average of all travel times of relevant pedestrians per OD relation.
- Delay: Average of all total delay values per OD relation. For each pedestrian, the delay in each simulation step results from: Time step length-(Distance walked during time step)/(Desired speed of pedestrian), Example: The delay is 25% of the length of the time step for a pedestrian at 75% of his desired speed. These values are added up over the entire measured distance of the pedestrian.
  - Relative delay: Average of all relative delays per OD relation, this value is determined separately for each pedestrian as a percentage of the delay in the travel time.
  - Volume: Number of pedestrians on the basis of which the other result attributes were determined.
- Green time distribution: The absolute frequencies of the occurrence of green durations and red durations for each signal group can be evaluated. The evaluation also includes the calculated averages of both.
- Nodes: Data from nodes of microscopic and mesoscopic simulation in the Vissim network can be evaluated.
- Managed lanes: Attribute values of managed lanes, general purpose lanes and other attribute values of managed lane facilities in the Vissim network can be saved, e.g. toll lanes.
- Public transport waiting times: This record contains the duration of each stop, which is not due to boarding and alighting or due to a stop sign, for each PT vehicle.
- Data and collection measurements: At least one data collection point on a link must be defined in the network. The following result attributes refer to all vehicles in the network that have been recorded during data collection measurement:

- Acceleration: Average acceleration of the vehicles
- Distance: Distance covered [m] by the vehicles
- Length: Average length [m] of the vehicles
- Vehicles: Total number of vehicles
- Persons: Total number of occupants of the vehicles
- Queue delay: Total time in [s] that the vehicles have spent so far stuck in a queue, if the queue conditions are met.
- Speed: Average speed of the vehicle at the data collection point
- Speed (arithmetic mean): Arithmetic mean of speed of the vehicles
- Speed (harmonic mean): Harmonic mean of speed of the vehicles
- Occupancy rate: Share of time [0% to 100%] in the last simulation step, during which at least one data collection point of this data collection measurement was busy.

- Signal time table: The current signal states and detector states during a simulation or during interactive tests of signal control logic can be shown in a window. Therein, the green times, yellow times and red times are represented graphically along a horizontal time axis for each selected signal control.
- SSAM: A binary file with trajectories can be saved. Trajectories describe the course of vehicle positions through the network. The file can be uploaded to the Surrogate Safety Assessment Model (SSAM) of the Federal Highway Administration Research and Technology of the U.S. Department of Transportation. SSAM is used to evaluate the road safety of transport routes. [This might be interesting if safety predictions should be done. SSAM can be downloaded and used free of charge. Vissim produces input data for SSAM (vehicle record with specific attributes).]
- Queue counters: Queue characteristics such as queue length and number of queue stops can be analysed.
- Links: Using the Link evaluation, the result attributes of vehicles based on segments or lanes of links and connectors for the defined time interval can be recorded. A link evaluation contains the following data:
  - Volume [veh/h]: In mesoscopic simulation, for link segments outside the sections of microscopic simulation, the average number of vehicles is displayed that have entered and exited the sections on the meso-edge.
  - Vehicle density
  - Average speed
  - Emissions (for add-on module API package only)
  - Delay (relative): Total delay divided by total travel time of all vehicles in this link segment during this time interval
- Delays: In a delay measurement, the average delay is calculated for all observed vehicles compared to a trip without any other vehicles, signal controls or other required stops. A delay measurement may include the following attribute values:
  - Stop Delay: Average stopped delay per vehicle in seconds without stops at PT stops and in parking lots
  - Vehicle delay: Average delay of all vehicles. The delay of a vehicle in leaving a travel time measurement is obtained by subtracting the theoretical (ideal) travel time

from the actual travel time. The theoretical travel time is the travel time which could be achieved if there were no other vehicles and/or no signal controls or other reasons for stops. Delay time does not account for deceleration in reduced speed areas (Using reduced speed areas to modify desired speed). To calculate the loss time caused by a desired speed decision, Vissim calculates a theoretical speed and compares it with the current speed (Using desired speed to modify desired speed decisions). The actual travel time does not include any passenger service times of PT vehicles at stops and no parking time in real parking lots. The delay due to braking before a PT stop and/or the subsequent acceleration after a PT stop are part of the delay.

- Stops: Average number of vehicle stops per vehicle without stops at PT stops and in parking lots
- Number of vehicles
- Person delay: Average delay [s] of all occupants of the vehicles
- Persons: Number of occupants in the vehicles: number of vehicles * average occupancy rate

3.4 Audits and Assessments of Walkability and Public Space

In the following section relevant audit and assessment tools are introduced. References are provided so that the interested reader can easily find more information on each of the tools. Various further tools are provided at the website of Active Living Research Consulting (https://activelivingresearch.org/search/site/content_tools_and_measure?f[0]=bundle%3Acontent_tools_and_measure). In London, pedestrians and place users are considered in urban street design with particular importance. The Mayor of London has adopted the Healthy Streets approach as the core focus of the Mayor’s Transport Strategy (Mayor of London, 2018). Various tools are available or currently developed by TfL to support the efforts of achieving the ambitious goals, these seem to be of special relevance for MORE and are therefore described in particular detail.

3.4.1 Overview of Relevant Audit- and Assessment-Tools

The Pedestrian Environment Review System (PERS) includes a quantitative assessment of design elements such as the width of pavements and steepness of dropped kerbs, as well as qualitative assessments of their general look and feel (Transport for London, 2015). The below Table 5 gives an overview of the PERS review parameters.

Table 5: PERS Review Parameter, Weight Bands and Default Weightings for Each Parameter

Table 2-1: PERS review parameters, weight bands and default weightings for each parameter

Link review			Crossing review			Route review		
Factor	Weight Band	Default weighting	Factor	Weight Band	Default weighting	Factor	Weight Band	Default weighting
Effective width	C	5	Crossing provision	C	5	Directness	C	5
Dropped kerbs	H	3	Deviation from desire line	H	3	Permeability	H	3
Gradient	B	1	Performance	C	5	Road safety	C	5
Obstructions	H	3	Capacity	B	1	Personal security	C	5
Permeability	H	3	Delay	H	3	Legibility	H	3
Legibility	B	1	Legibility	B	1	Rest points	B	1
Lighting	H	3	Legibility for sensory impaired people	H	3	Quality of the environment	B	1
Tactile Information	H	3	Dropped kerbs	H	3	Link Audits and Crossing Audits	C	5
Colour contrast	H	3	Gradient	B	1			
Personal security	C	5	Obstructions	B	1			
Surface quality	H	3	Surface quality	H	3			
User conflict	C	5	Maintenance	B	1			
Quality of the environment	B	1						
Maintenance	B	1						

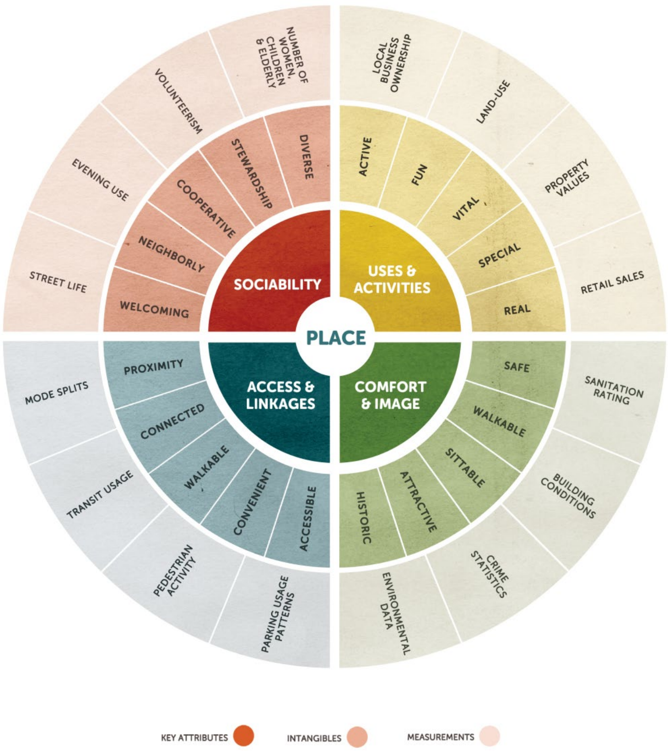
Public transport waiting areas review			Interchange space review			Public space review		
Factor	Weight Band	Default weighting	Factor	Weight Band	Default weighting	Factor	Weight Band	Default weighting
Information to the waiting area	H	3	Moving between modes	C	5	Moving in the space	C	5
Infrastructure to the waiting area	H	3	Identifying where to go	H	3	Interpreting the space	H	3
Boarding public transport	C	5	Personal safety	C	5	Personal safety	C	5
Information at the waiting area	H	3	Feeling comfortable	H	3	Feeling comfortable	H	3
Safety perceptions	C	5	Quality of the environment	B	1	Sense of place	H	3
Security measures	C	5	Maintenance	B	1	Opportunity for activity	B	1
Lighting	H	3	Link Audits and Crossing Audits	C	5	Link Audits and Crossing Audits	C	5
Quality of the environment	B	1	Route Audits	C	5	Route Audits	C	5
Maintenance and Cleanliness	B	1	PT Waiting Area Audits	C	5	PT Waiting Area Audits	C	5
Waiting area comfort	H	3						

Microscale Audit of Pedestrian Streetscapes (MAPS) is a comprehensive assessment of environmental features on microscale, which have influence on physical activity. Three versions of the MAPS tool exist with varying degrees of complexity: 120-item audit survey, 60-item audit survey and MAPS-Mini with 15 items. The items are organised along the following themes: route (land use/destinations, streetscape, aesthetics/social), walkway/sidewalks, crossings. (see https://activelivingresearch.org/blog/2015/09/auditing-pedestrian-environment-brief-tool-practitioners-community-members)

Mehta (2014a) and Mehta (2019) present a Public Space Index (PSI) with 46 variables for the five dimensions inclusiveness, meaningful activities, comfort, safety and pleasurability. For example, criteria for inclusiveness include the presence of people in different ages/ genders, range of activities, opening hours of public spaces, presence of posted signs to exclude certain persons or behaviours etc.

The Project for Public Spaces (PPS) includes four key principles: (1) sociability, (2) uses and activities, (3) access and linkages, (4) comfort and image with each a list of questions. The approach is not as detailed as for example the Public Space Index (PSI) developed by (Mehta, 2014a, 2019) or the twelve quality criteria provided by Gehl (2010)but is a widespread approach used mainly in the U.S. (Project for Public Spaces, 2018)

Figure 2: "The Place Diagram" (Project for Public Spaces, 2018, p. 5)



Moura et al. (2017) present the IAAPE tool (Indicators of Accessibility and Attractiveness of Pedestrian Environments), which is a GIS-based and participative assessment framework for measuring walkability on different scales (city, neighbourhood and street scale) for different pedestrian groups and trip purposes according the 7 C's (Connectivity, Convenience, Comfort, Conviviality, Conspicuousness, Coexistence, Commitment). The replicability of the tool helps urban planners to design more walkable environments in their spatial unit.

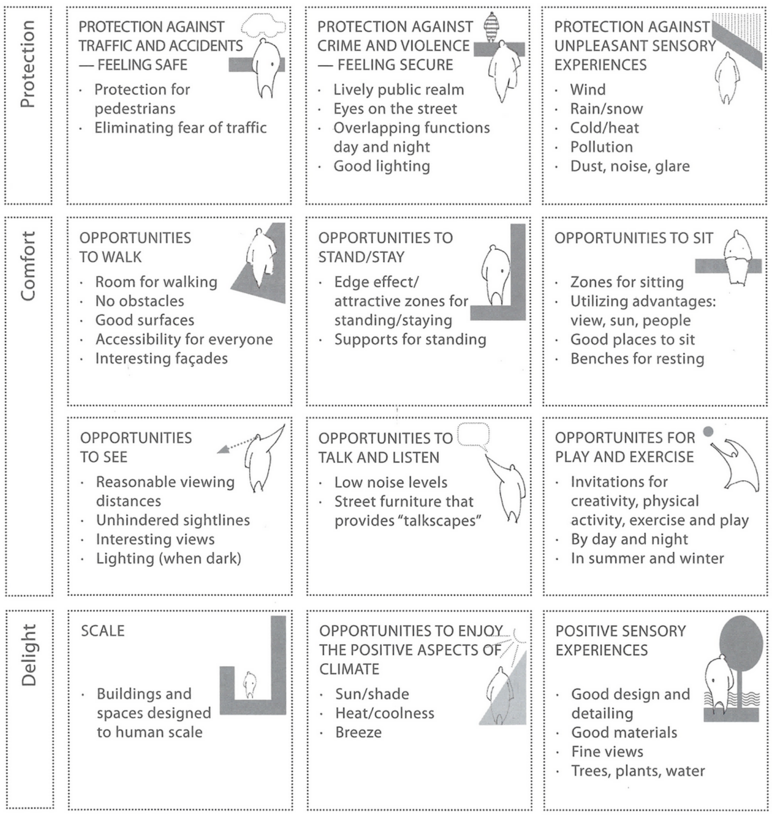
3.4.2 Twelve Quality Criteria, Gehl Institute

Gehl (2010) composed twelve quality criteria for high quality street spaces for pedestrians. The criteria are grouped into to the following categories as shown in Figure 3:

- Protection: Objective and subjective (perceived) safety against traffic and traffic accidents as well as security against crime are prerequisites and motivating factors for walking and for place activities. In addition, "protection against unpleasant sensory experiences" is to be considered.
- Comfort: After taking safety issues into account, the provision of comfortable public spaces has to be ensured in order to invite people into different link-and-place-activities. For pedestrians, sidewalks should offer sufficient space void of obstacles (e.g., a dedicated footway zone) and good surface quality. Providing space for different place-activities invites place users to spend time in public spaces.
- Delight: To ensure quality maintenance and the well-being of pedestrians and place users, the human scale (in regard to adequate street and building dimensions) must be considered. The delight of design with respect to details and materials and green structures promote walking and the enjoyment of public spaces by place users.

Detailed guidance on how to assess the twelve quality criteria and also various further tools are provided at https://gehlpeople.com/tools/twelve-quality-criteria/.

Figure 3: Quality Criteria for High Quality Street Spaces for Pedestrians (Gehl, 2010)



3.4.3 Healthy Street Checks, Transport for London

The London Healthy Street approach puts people and their health at the heart of decision making. It covers movement and place functions and focuses on creating streets that are pleasant, safe and attractive, where noise, air pollution, accessibility and lack of seating and shelter are not barriers that prevent people from getting out and about. This ambition differs substantially from the other identified indicator schemes that often focus on smooth and safe movement of motorised vehicles. The London Healthy Street approach contains indicators that are similar to the ones listed in the above tables (see e.g. Chapter 3.1.1) but their targets differ. For example, a street scores highest in the London Healthy Street Check for Designers when the 85th percentile speed of motorised traffic is less than 32 km/h (Transport for London, 2019b). On the contrary, minimum speed or LOS are required for motorised traffic in many other cities and guidance material as described above. The Healthy Streets Check for Designers is compulsory to use on some TfL schemes (above a certain budget and directly affecting the experience of people using the street), but can be used on any scheme affecting the street environment. TfL provides an Excel spreadsheet to support designers in carrying out the Healthy Street Checks (Transport for London, 2019b).

Ten Healthy Streets Indicators and 31 metrics are defined for scoring healthy street performance of specific street sections (Transport for London, 2019b) with each metric contributing to multiple indicators:

1. Pedestrians from all walks of life: London's streets should be welcoming places for everyone to walk, spend time in and engage in community life.
2. People choose to walk, cycle and use public transport: A successful transport system enables more people to walk and cycle more often.
3. Clean air: Improving air quality delivers benefits for everyone and reduces unfair health inequalities.
4. People feel safe: The whole community should feel comfortable and safe on our streets at all times. People should not feel worried about road danger.
5. Not too noisy: Reducing the noise impacts of traffic will directly benefit health and improve the ambience of our streets.
6. Easy to cross: Making streets easier to cross is important to encourage more walking and to connect communities.
7. Places to stop and rest: A lack of resting places can limit mobility for certain groups of people.
8. Shade and shelter: Providing shade and shelter enables everybody to use our streets, whatever the weather.
9. People feel relaxed: More people will walk or cycle if our streets are not dominated by motor traffic, and if pavements and cycle paths are not overcrowded, dirty or in disrepair.
10. Things to see and do: People are more likely to use our streets when their journey is interesting and stimulating, with attractive views, buildings, planting and street art.

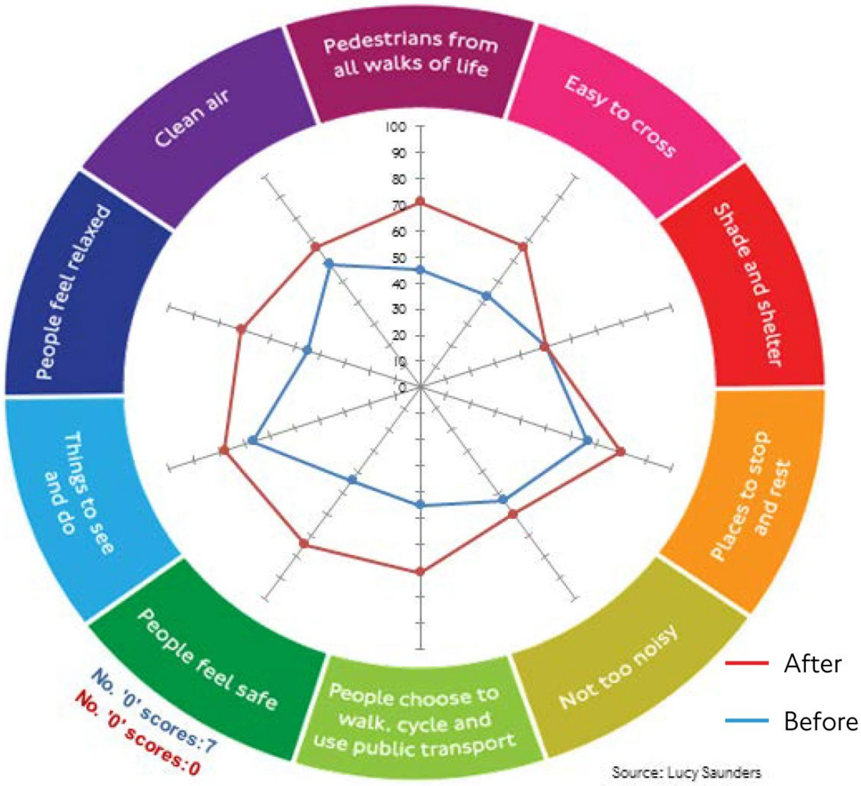
Metrics can be scored from zero or one to three where three is the highest (best) score; ten of the 31 metrics can be scored zero (the lowest score). Overall, the maximum scores of all 31 metrics sum up to 100. However, TfL stresses that the maximum score of 100 will never be reached as compromises and trade-offs need to be made for any one street design. Street designers should seek to increase the score, to have balanced scores in all the ten indicators and to eliminate the zero scores. The below Table 6 list the 10 indicators and the 31 metrics, further detailed information can be found at https://tfl.gov.uk/corporate/about-tfl/how-we-work/planning-for-the-future/healthy-streets. Possible data sources are added in the table by the authors of this document in order to prepare data collection in the MORE-corridors. Figure 4 shows an example output of the Healthy Street Check for Designers.

Table 6: List of Healthy Street Check Metrics in London (Transport for London, 2019b)

No.	Metric	Scoring System	Possible Data Sources
1	Total Volume of two way Motorised Traffic	Volumes of motorised traffic at peak hour, score 3/2/1/0: <500/ 500-1,000/ >1,000 and dedicated cycling facility/ >1,000 and no dedicated cycling facility	Traffic counts
2	Interaction between Large Vehicles and People Cycling	Volumes of large vehicles, score 3/2/1/0: no / <2 / >5% Score 1/2/3/0: and appropriate cycling facility/ >5% large vehicles and no appropriate cycling facility	Traffic counts
3	Speed of Motorised Traffic	Score 3/2/1/0: 85th percentile speed <32km/h/ 32-40km/h/ 40-48km/h/ >48km/h	Speed measurements
4	Traffic Noise Based on Peak Hour Motorised Traffic Volumes	Score 3/2/1/0: <55vehicles per hour/ 55-450/ >450/ no value	Traffic counts
5	Noise from Large Vehicles	Proportion of large vehicles, score 1/2/3/0: <5%/ 5-10%/ >10%/ no value	Traffic counts
6	NO2 Concentration	NO_2 concentration (if assessing exist), score 3/2/1/0: <32µg/m³/ 32-40 µg/m³/ >40µg/m³/ no value	Roadside NO_2 measurements
7	Reducing Private Car Use	Score 3/2/1/0: no through-movement for motorised traffic (access limited to local residents, public service delivery)/ some time or movement restrictions for motorised traffic/ no access restrictions for motorised traffic	On-site inspection
8	Ease of Crossing Side Roads for People Walking	Score 3/2/1/0: Side roads are one-way out for motor vehicles and have features to encourage drivers to turn cautiously/ side roads are two-way out or one-way without features to encourage drivers to turn cautiously/ side roads have dropped kerbs only/ side roads have no dropped kerbs	On-site inspection
9	Mid-Link Crossing, to Meet Pedestrian Desire Lines	Score 3/2/1/0: All main/ some/ no pedestrian desire lines are provided for with crossings, no value for score 0.	On-site inspection of crossing facilities and ped. behaviour
10	Types and Suitability of Pedestrian Crossings away from Junctions	Score 3/2/1/0: Uncontrolled crossing with <200 motorised vehicles per hour or zebra, parallel, signalised crossing / uncontrolled crossing with 200-1,000 vehicles per hour or signalised crossing with suitable crossing distance and speed of motorised vehicles/ uncontrolled crossing with >1,000 vehicles per hour or signalised crossing with high crossing distances and speed/ not value for zero score	On-site inspection of crossing facilities, traffic counts, speed measurements
11	Technology to Optimise Efficiency of Movement (Pedestrians, Cyclists, Buses, Private/ Shared Motorised Traffic)	Score 3/2/1/0: All/ some/ no detection and optimisation technology has been applied to traffic signals, no value for zero score	On-/off-site inspection of signalling schemes
12	Additional Features to Support People Using Controlled Crossings	Score 3/2/1/0: Controlled crossings have many/ some/ no additional features to enhance their quality, no value for zero score	On-site inspection of crossing facilities

No.	Metric	Scoring System	Possible Data Sources
13	Width of Clear Continuous Walking Space	Score 3: > 2.00 m width for walking in quiet locations with <600 pedestrians per hour or > 2.50 m for 600-1,000 ped/hour or > 3.00 m for > 1,200 ped/hour Score 2/1: 2,00 m-2,50 m/ 1.50 m-2.00 m for 600-1,200 ped/hour or 2.50 m-3.00 m/ 1.50 m-2.00 m for >1,200 ped/hour No value for zero score	On-site inspection, pedestrian counts
14	Sharing of Footway with People Cycling	Score 3/2/1/0: no shared footway/ parts of/ all footway is shared with 3.00 m widths and < 200 ped/hour/ parts of/ all footway is shared with < 3.00 m widths or ≥ 200 ped/hour/ no value for zero score	On-site inspection, pedestrian counts
15	Collision Risk between People Cycling and Turning Motor Vehicles	Score 3/2/1/0: separation of traffic flows or minimal turning movements of motorised vehicles/ low turning movements/ no restrictions on movements/ no separation and high volumes of turning motorised vehicle movements	On-site inspection, traffic counts
16	Effective Width for Cycling	Score 3: Width of cycle lane/track > 2.00 m (one-way) or ≥ 3.50 m (two-way) or lane width for mixed traffic ≥ 4.50 m Score 2: Width of cycle lane/track 1.50 m - 2.20 m (one-way) or 2.50 m -3.50 m (two-way) or lane width for mixed traffic 4.00 m - 4.50 m Score 1: Width of cycle lane/track < 1.50 m (one-way) or < 3.20 m (two-way) or lane width for mixed traffic ≥ 3.20 m Score 0: No cycling facility and lane width for mixed traffic 3.20 m - 3.90 m	On-site inspection of cycling facilities
17	Impact of Kerbside Activity on Cycling	Score 3/2/1/0: No kerbside activity or physical separation of cyclists from parking and loading facilities/ occasional kerbside activity and ≥ 1.00 m clearance/ frequent kerbside activity and ≥ 1.00 m clearance/ cyclists cannot maintain at least 1.00 m clearance from vehicles parked or loading	On-site inspection of facility for cycling and kerbside activities, observation of kerbside activities
18	Quality of Carriageway Surface	Score 3/2/1/0: surface even and smooth/ few minor defects/ many minor defects/ major defects	On-site inspection of surface quality
19	Quality of Footway Surface	Score 3/2/1/0: surface even and smooth/ few minor defects/ many minor defects/ major defects	On-site inspection of surface quality
20	Surveillance of Public Spaces	Score 3/2/1/0: constant/ intermittent/ poor surveillance because of many people, no value for zero score	Pedestrian counts
21	Lighting	Score 3/2/1/0: lighting meets standards fully/ partly/ not at all, no value for zero score	On-site inspection of lighting
22	Provision of Cycle Parking	Score 3/2/1/0: Cycle parking exceeds/ meets/ does not meet existing demand, no value for zero score	On-site inspection of facilities for cycle parking and demand
23	Street Trees	Score 3/2/1/0 depending on number of trees and canopies, no value for zero score	On-site inspection of trees
24	Planting at Footway-Level (Excluding Trees)	Score 3/2/1/0: substantial/ some/ no planting, no value for zero score	On-site inspection of planting
25	Walking Distance between Resting Points (Benches or other Informal Seating)	Score 3/2/1/0: < 50 m/ 50 – 150 m/ > 150 m distance between resting points, no value for zero score	On-site inspection of resting points
26	Walking Distance between Sheltered Areas Protecting from Rain (Including Fixed Awning, Shelter Provided by Buildings/ Infrastructure)	Score 3/2/1/0: < 50 m/ 50 – 150 m/ > 150 m distance between sheltered areas, no value for zero score	On-site inspection of sheltered areas
27	Factors Influencing Bus Passenger Journey Time	Score 3/2/1/0: Priority for busses/ mixed traffic/ negative influences on bus journey time, no value for zero score	On-site inspection of measures for prioritising busses
28	Bus Stop Accessibility	Score 3/2/1/0 depending on wheelchair accessibility of bus stop and kerb height, no value for zero score	On-site inspection of bus stops
29	Bus Stop Connectivity with other Public Transport Services	Score 3/2/1/0: distance between services < 40 m/ 50 – 150 m/ > 150 m, no value for zero score	On-site inspection of bus stops
30	Street-To-Station Step-Free Access	Score 3/2/1/0 depending on the degree of step-free access, no value for zero score	On-site inspection of access to rail/ underground/ bus stations
31	Support for Interchange between Cycling and Underground/ Rail	Score 3/2/1/0 depending on the quantity of cycle parking provided at stations, no value for zero score	On-site inspection of cycle parking facilities at rail/ underground/ bus stations and demand for cycle parking

Figure 4: Example Output of the Healthy Street Check for Designers (Transport for London, 2018b)



3.4.4 Healthy Street Tracker Surveys, Transport for London

Healthy Street Tracker Surveys were piloted at 48 sites in August 2018 (Saunders and Groot, 2019; Transport for London, 2018c). The aim of this new survey is to reliably track the performance of London's streets against the Healthy Streets Indicators capturing qualitative and quantitative data, both at the pan London scale, as well as locally in relation to specific improvements. Trained surveyors complete a questionnaire at selected locations using a tablet device. The questionnaire consists of six key sections relating to nine of the 10 Healthy Streets Indicators. Each item in each of these sections is scored between zero and ten, overall 106 items are to be assessed. Below are the six sections and examples of what is assessed in each:

- Context (date, weather, pavement/road conditions, building or construction works, short pedestrian and cycle count)
- Road features (traffic calming, traffic restrictions, parking, signage, side street features)
- Ambience (street façade, greenery, graffiti, litter, noise, street lighting)
- Crossings and traffic (formal and informal crossings, crossing features, volume and flow of traffic, driver and cyclist behaviour)
- Seating and people (formal and informal seating, seating features, social activity and space, shade and shelter)
- Pavement and cycleway (width and evenness of footway, trip hazards, cycle infrastructure)

Questions are scored to reflect positive and negative factors present on a street, mostly on a scale of 0 to 10 (10 being the highest score). Positive factors on street score well and negative factors lower the scores for each question. Once the weighting is applied (accounting for influence of each factor) this allows TfL to see how well each indicator is scoring. The below example shows how the answer categories from each question are converted into scores:

94	Considering the pavement overall, how far would you agree that the paving material provides an even and level footway for people walking?	Single choice response	Strongly agree	10	Max available score 10
			Agree	8	
			Neither agree nor disagree	6	
			Disagree	4	
			Strongly disagree	2	

Each question has also been assigned a weighting, according to the relative importance of that factor in contributing to a Healthy Street, using evidence from the Healthy Streets documentation (see: https://tfl.gov.uk/corporate/about-tfl/how-we-work/planning-for-the-future/healthy-streets). This allows a weighted percentage score for each indicator to be calculated, which can be stratified by street type or region.

3.4.5 Pedestrian Level of Service Measures

Karatas and Tuydes-Yaman (2018) provide an overview of studies on sidewalk pedestrian level service measures (PLOS) and rating. The authors demonstrate the heterogeneity of the existing concepts and conclude that PLOS ratings should be merged with walkability assessments in order to reduce the variety of the different approaches and to achieve more standardisation and comparability for the assessment of quality of pedestrian facilities.

The Pedestrian Comfort Guidance (PCG) provided by Transport for London is described in more detail as one example approach for PLOS assessments. The PCG particularly compares the volumes of pedestrians and place users with the available space and allows determining a Pedestrian Comfort Level (PCL) grade, based on the density of pedestrians within a given area. PCLs should be determined both for footway comfort and crossing comfort.

In the first step, sites are classified based on site visits as one of the following area types: high street, office and retail, residential, tourist attraction, transport interchange. Activity data should be collected and characteristics of footways and crossing facilities should be mapped in detail in the next step. The following pedestrian activity data is required:

- Pedestrian flow data for footways and crossings.
- A static activity survey to record the reduction in space available for walking from static activity unrelated to street furniture (meeting friends, queuing, taking photographs) is recommended at regional retail centres and tourist attractions as these areas tend to generate a lot of this activity.
- Also note any other relevant activity (e.g. delivery operating times if a loading bay is present).

After all data is entered into the excel spreadsheet, the following criteria is automatically calculated:

- Clear Footway Width - This is the space left for walking after the standard wall and kerb buffers and any street furniture is taken into account
- Crowding - Pedestrian crowding is measured in pedestrians per metre of clear footway width per minute (ppmm) and is calculated using the following formula:
  people per hour ÷ 60 ÷ clear footway width [m]
  This is calculated for average flow, peak hour flow and average of maximum activity
- Pedestrian Comfort Level Categorisation - The crowding level (ppmm) is then categorised according to the Pedestrian Comfort Level scale.
- Clear Footway Width required for PCL B+ - The spreadsheet also calculates the clear footway width required to achieve a PCL of B+. This is to aid decision making, as PCL B+ is the recommended level of comfort for most area types.

Pedestrian densities are provided for all PCLs in Transport for London (2019d) (see Figure 6). For example, PCL B+ on footways and for crossing arms and space to pass on island means 9-11 pedestrians per square metre (ppmm). For queues on crossing islands, the number of rows of waiting pedestrians determines the PCL. Figure 5 summarises which Pedestrian Comfort Level is suitable for different area types for use in the peak hour, and for the average maximum activity level.

Figure 5: Suitable pedestrian comfort levels for different area types (Transport for London, 2019d)

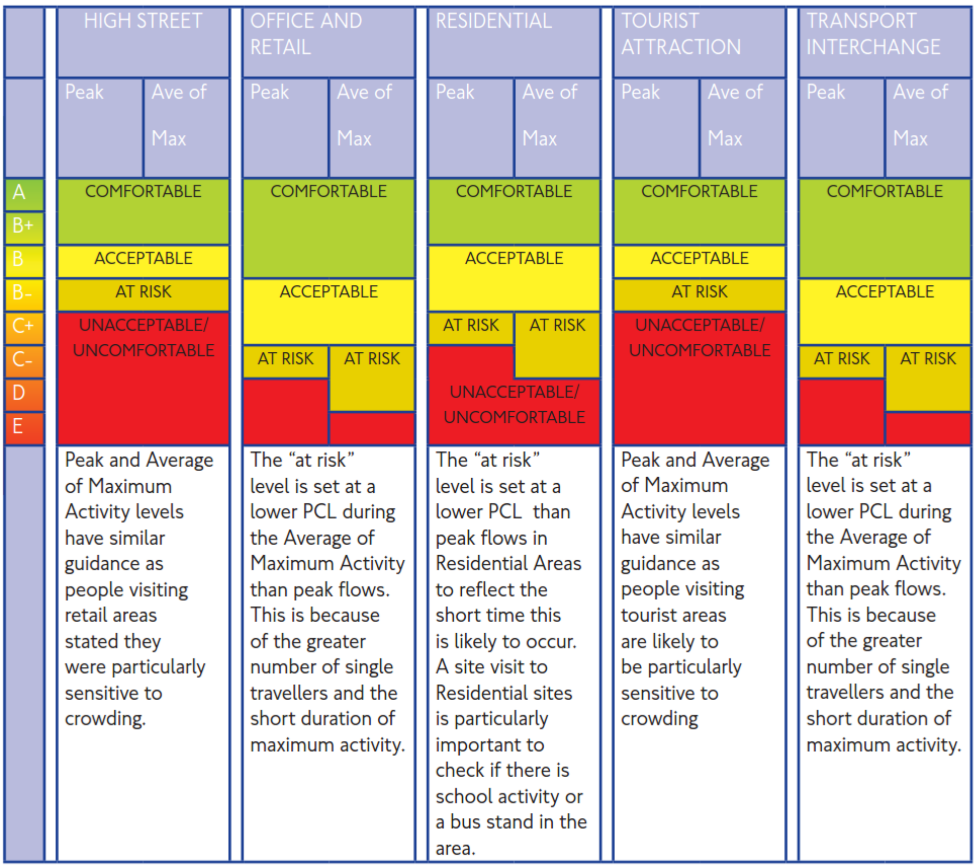


Figure 6: Pedestrian Densities and Comfort Levels (Transport for London, 2019d)

Figure 8 Pedestrian Comfort Levels on Footways

Transport for London (2019d) provides in addition detailed guidance on recommended widths and buffer zones for footways with or without furniture with some examples shown in the below Figures.

Figure 7: Recommended footway width (Transport for London, 2019d)

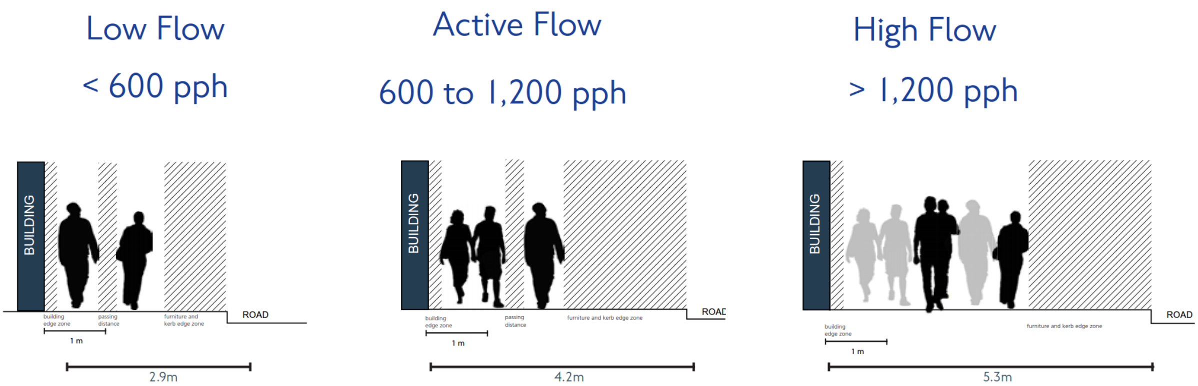


Figure 8: Recommended footway design with bench (Transport for London, 2019d)

Benches

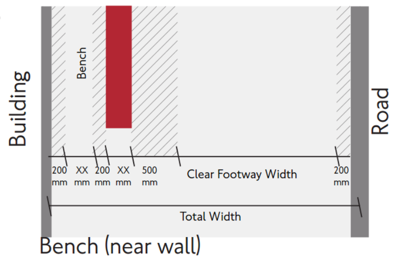
Benches reduce the clear footway width by the bench width, plus an additional 500mm in the direction of seating when in use (legs, bags etc). Note that for the bench to be attractive to people there needs to be room for two people to pass between the bench zone and the kerb or building line (1500mm clear footway width).

If the bench is placed in the middle of the footway, with people able to sit facing one direction only, the reduction is 500mm plus 200mm on the other side.

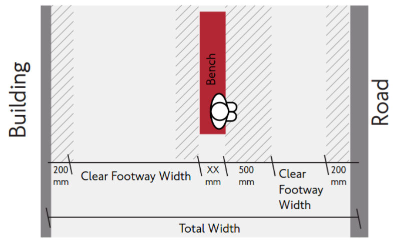
If you can sit facing either way the buffer would be 1,000mm (500mm either side).

500mm from Bench edge for direction of seating, 200mm on non-seating side

If seating is in both directions, 1,000mm (500mm either side)



Bench (near wall)



Bench (middle of footway)

4 Street Performance Assessment Scheme (SPAS) for the MORE Stress Sections

4.1 General Principles and Considerations

Based on the conceptual framework described in Chapter 2 and the lists of objectives, targets and indicators presented in Chapter 3, the *Street Performance Assessment Scheme* (SPAS) is developed in the next step to be applied for the before-after comparisons and also for the cross-site assessments of the existing and the newly developed design solutions for the stress sections in each of the five MORE-cities. For these purposes, the street performance assessment scheme should meet the following requirements:

- It should be sensitive to street design so that different sites can be compared and also before-after studies as planned in WP5 can be evaluated with SPAS.
- It should include supply-side indicators and demand-side indicators. Place functions should have particular weight as their improvement is a common goal in all MORE-stress sections.
- The SPAS should contain standardised indicators and thus allow for comparisons between the MORE-case studies. At the same time, it should be flexible and open for specific indicators that might be suitable only for some of the MORE-case studies.

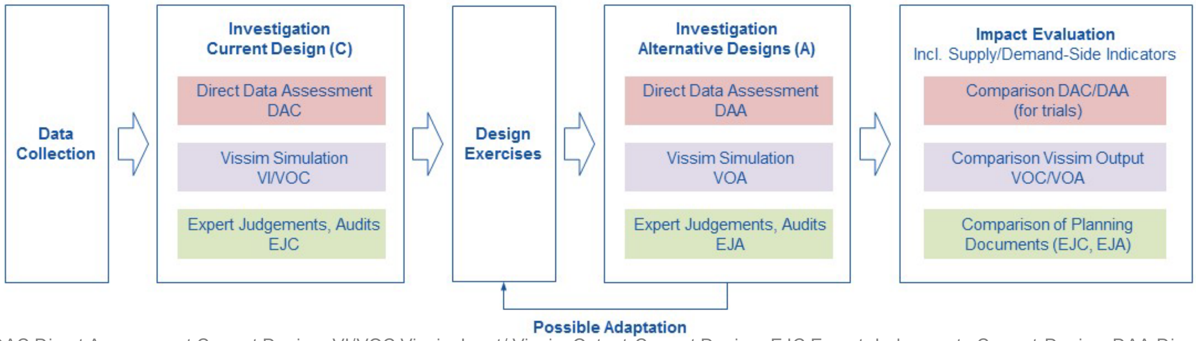
Seeing these requirements, a modular approach is chosen for the SPAS in MORE:

- Key indicators are arranged in the *core module*; this module is ident for all MORE-cities. It ensures comparability across the MORE-cities.
- The *city-specific complementary module* includes individual indicators for each city in order to meet the city-specific requirements and framework conditions. These indicators are not comparable between MORE cities but can be compared for the different possible design solutions within each city.

In this Chapter 4, only the core module is described in detail. City-specific complementary modules and indicators are chosen individually for each MORE-case study based on the overview of possible street design objectives, targets and indicators provided in Chapter 3; these city-specific modules are included in Chapter 5 and 6 on a case-by-case-basis.

The evaluation in MORE relies heavily on the outcomes of the Vissim models as these are the basis for simulating the effects of the different developed design solutions, and as no physical implementation of the developed design solutions was feasible within the lifetime of the MORE-project. Direct assessments would be possible in addition for pilots that might be implemented when e.g. selected lanes will be temporarily blocked or parking spaces are taken out for a limited time period, such pilots have not been implemented in any of the case studies in the MORE-project. Expert judgements are seeked as third pillar of the evaluation approach for complementing and better understanding the collected data and also the outcomes of the modelling exercises. This leads to a multi-data and multi-method approach used for impact evaluation as shown in Figure 9.

Figure 9: Multi-Method and Multi-Data Approach for Impact Evaluation



DAC Direct Assessment Current Design; VI/VOC Vissim Input/ Vissim Output Current Design; EJC Expert Judgements Current Design; DAA Direct Assessment Alternative Design, VOA Vissim Output Alternative Design, EJA Expert Judgements and Audits Alternative Design

In the following, the core module of the SPAS is described. Chapter 4.2.1 gives an overview of the demand-side key performance indicators chosen for the evaluation. The proposed types of data to be collected for computing these indicators and for setting up the Vissim simulation are listed in Chapter 4.2.2. This data is also the basis for developing the alternative design solutions. The supply-side indicators for characterising the streetscape, urban design and land use in the stress sections is introduced in Chapter 4.3.

4.2 Demand-Side Indicators and Wider Impacts

4.2.1 Key Performance Indicators

Table 7 to Table 9 list the demand-side indicators chosen for the core module in SPAS. The performance indicators are grouped along the three dimensions (1) movement functions, (2) place functions and (3) wider impacts. Indicators describing the pure quantity of movement and place activities are the basis of the core module. This might sound simple but was challenging for the MORE partners as volumes of all user groups including pedestrians, place users, and activities for parking and stopping should be quantified. For vehicles, turning movements are necessary for setting up the Vissim models. Changes in the volumes of specific user groups are an important goal for the stress sections that can be monitored based on these indicators; this information allows also computing modal split values specifically for the stress sections, for the current situation and the different design solutions.

Besides the user volumes, key indicators for characterising street users' movement and place activities are considered. This includes e.g. speed, travel times, waiting times, and acceptance of infrastructure and traffic rules (do cyclists accept their facilities or do they actually cycle on different parts of the street, are red lights and crossing facilities accepted, etc.) for the movement functions. Place functions distinguish between (1) stationary activities of place users who use the street as destination and not as conduit for facilitating their movements and (2) kerbside activities (parking, loading/ delivery and drop-off/ pick-up). Similar to the indicators for the movement function, number and characteristics should be measured for the different place activities. Different to movement functions, information on activity duration is needed for place activities.

For the wider impacts, indicators on air pollutant emissions, safety, healthy street performance and security are included into the core module of the street performance assessment scheme. Increasing safety is a key and often mandatory objective in any urban street design; it was included with high priority in all the researched documents. The reduction of air pollutant and also GHG-emissions is another key objective for transport in all MORE cities. Further indicators e.g. for quantifying other environmental or health effects such as noise could be evaluated in the city-specific supplementary modules.

Possible output options in Vissim are presented in an extra column in order clearly show the opportunities for evaluating different proposed scenarios to be simulated in Vissim. The tables thus list not only the performance indicators chosen for the core module in SPAS but also explain whether these indicators can be used for direct assessment and/or for the simulation in Vissim. Direct assessment might mean the comparison of different sites e.g. in the different MORE-cities or before-after studies in case of temporary modifications of the physical environment.

Table 7: Demand-Side Indicators, Movement Functions, Core Module of SPAS

Theme	Indicator (peak-hour, off-peak periods, working days)	Output options in Vissim	Type of assessment	Data basis, unit
Vehicle Volumes Cars, LGV, HGV, Motorcycles, Bicycles, Buses, Trams	• Volumes [veh/h] per cross-section, per turning movement at junctions • Vehicle density at street sections [veh/m]	• Total number of vehicles in the network at the end of the simulation • Number of vehicles arrived in the simulation period • Volume [veh/h] per link/lane segment at each point in time during simulation • Vehicle density [veh/m] • Number of vehicles per OD-relation, PT passengers entering / leaving the area in a PT vehicle • Latent demand: Number of vehicles from meso-origin connector edges, vehicle inputs and parking lots that could not be used, number of vehicles that were not allowed to enter the network from vehicle inputs and parking lots until the end of the simulation.	<u>Direct assessment, before-after</u>: Vehicle volumes might change due to possible temporary modifications of the streetscape (e.g. blocking one lane or parking space) or of traffic regulation (e.g. changes in signalling or speed limit). <u>Vissim simulation, different scenarios</u>: Vehicle volumes change if capacity of a link or a junction are modified.	Counts of vehicle turning movements at junctions [veh./15min]
Pedestrian Volumes Walking along the Footway	• Volumes [ped/h] at street sections between two junctions (by age group, with/ without mobility aid) • Pedestrian density [ped/m²] • Experienced pedestrian density [ped/m²]	• Maximum, minimum, average number of pedestrians (area, ramp, stairs) • Number of pedestrians leaving the construction element or walking on it (excluding pedestrians from pedestrian inputs and pedestrians alighting from PT vehicles) • Pedestrian density (area, ramp, stairs) • Pedestrian density experienced within the perception radius of a pedestrian: Number of other pedestrians within a radius around the pedestrian.	<u>Direct assessment, before-after</u>: pedestrian volumes might change if sidewalk characteristics, street furniture or the characteristics of the adjacent buildings are (temporarily) modified during project lifetime <u>Vissim simulation</u>: pedestrian volumes are defined as input so far	Pedestrian counts [ped./15min]
Pedestrian Crossing Volumes	• Volumes [ped/h] per arm of each junction and at street sections between two junctions (by age group, with/ without mobility aid) • Average pedestrian delay at crossings	• See pedestrian volumes walking along the footway	<u>Direct assessment</u>: only possible for current situation as cities hardly will physically change the street elements with relevance for pedestrian crossing <u>Vissim simulation</u>: overall crossing volumes defined as input but location of crossing activities might change with different crossing facilities provided in the alternative scenarios	Pedestrian counts [ped./15min] Delays [min/ person]

Theme	Indicator (peak-hour, off-peak periods, working days)	Output options in Vissim	Type of assessment	Data basis, unit
Public Transport Passengers	Number of passengers boarding/alighting buses/trams, for each PT stop	• Maximum, minimum, average number of pedestrians who were waiting for a PT vehicle (area, ramp, stairs)	Direct assessment: only possible for current situation as cities hardly will physically change the street elements with relevance for PT demand Vissim simulation: PT passengers defined as input	Data to be provided by PT operator
All Street User Groups	• Total number of people moved within the section [users/h] • Percentage values of vehicle/ pedestrian volumes as modal split [%]	• See Vehicle volumes (cars, LGV, HGV, motorcycles, bicycles, buses, trams) and pedestrian volumes (walking along the footway) plus mean number of persons per vehicle	Direct assessment, before-after: User volumes might change due to possible temporary modifications of the streetscape (e.g. blocking one lane or parking space) or of traffic regulation (e.g. changes in signalling or speed limit). Vissim simulation, different scenarios: Vehicle volumes change if capacity of a link or a junction are modified.	Data basis: counts of vehicle turning movements at junctions, pedestrian counts [persons/ 15min]
Travel Times, Delay, Reliability, Motorised Traffic, Bicycles	• Average travel time/ delay • Travel Time Index = (Actual travel time / travel time at reference speed)-1 as percentage increase of travel time compared to reference speed • Variance / distribution of speed/ delay, percentiles • Waiting times at junctions [s] Cars, LGV, HGV, motorcycles, buses, trams	Output options in Vissim [1]: • Average travel time = Total of travel times / number of vehicles • Average delay time = Total of delay times / number of vehicles • Average speed [km/h] or [mph], defined as total distance / total travel time • Waiting times at junctions and for PT at stops, ratio of waiting time over total travel time including also deviations from desired speed	Direct assessment, before-after: Vehicle travel times might change due to possible temporary modifications of the streetscape (e.g. blocking on lane or parking space) or of traffic regulation (e.g. changes in signalling or speed limit). Vissim simulation: Travel times change with changes in demand or supply	Measurements [s] FCD-data
Travel Times, Delay, Reliability, Pedestrians	• Waiting times at junctions [s] • Average total walking time [s] • Ratio of waiting times over total walking time [%] (within the modelled area, trip could be longer), including also deviations from desired speed	Pedestrian travel times (OD data): From a simulation based on a pre-defined pedestrian origin-destination matrix, the following aggregated data can be generated: • Travel time: Average of all travel times of relevant pedestrians per OD relation. • Delay: Average of all total delay values per OD relation. For each pedestrian, the delay in each simulation step results from: Time step length-(Distance walked during time step)/(Desired speed of pedestrian), Example: The delay is 25% of the length of the time step for a pedestrian at 75% of his desired speed. These values are added up over the entire measured distance of the pedestrian. • Relative delay: Average of all relative delays per OD relation, this value is determined separately for each pedestrian as a percentage of the delay in the travel time. • Ratio of waiting time over total walking/ cycling time Volume: Number of pedestrians on the basis of which the other result attributes were determined.	Direct assessment, before-after: Travel times and waiting times might change due to possible temporary modifications of traffic regulation (e.g. changes in signalling). Vissim simulation: Travel times and waiting times change with changes in demand or supply	Measurements [s]

[1] OD pair data can be only used for the evaluation if dynamic assignment has been used, this will rather not be the case in MORE. OD pair data can therefore probably not be used for evaluating MORE-scenarios but belongs instead to the input data.

Theme	Indicator (peak-hour, off-peak periods, working days)	Output options in Vissim	Type of assessment	Data basis, unit
Spot Speed	• [km/h], at specific locations • in addition to travel times, for vehicles and pedestrians	Output options in Vissim for pedestrians: • Average pedestrian speed, all pedestrian types, calculated as the harmonic mean • Vectorial speed differences of all pedestrians within the personal environment radius of their own speed • Length and time information on any pedestrian queues Mean speed can be also computed for bicycles and motorised vehicles	See travel times, speed of pedestrians might change with changed sidewalk design	Measurements [km/h] FCD-data
Acceptance of Infrastructure (Only if Sufficient Resources are Available)	• Red light running rate at signalised junctions [%] • Utilisation rate of dedicated facilities for cyclists [%] • Utilisation rate of formal crossing facilities for cyclists and pedestrians [%]	None	Direct assessment, before-after: Behaviour might change due to possible temporary modifications of traffic regulation (e.g. changes in signalling, changes in cycle facilities). Vissim simulation: no assessment	Measurements [%]

Table 8: Demand-Side Indicators, Place Functions, Core Module of SPAS

Theme	Indicator (peak-hour, off-peak periods, working days)	Output options in Vissim	Type of assessment	Data basis, unit
Number and Duration of Stationary Activities	Number and duration of stationary activities Liveliness index (number of people times the duration of their stay) By age/ gender/ mobility aids, by type of activity as indicated in the forms	• Suggestion TUD: Number of people and time spent on place activities, by type of activity.	Direct assessment, before-after: number and duration of stationary activities might change if sidewalk characteristics, street furniture or the characteristics of the adjacent buildings are (temporarily) modified during project lifetime Vissim simulation: Pedestrian activities (number, characteristics, type of their activities) are defined as input so far.	Video recording Manual observations
Number and Duration of Kerbside Activities	Number and duration of parking, loading, drop-off/ pick-up events, by location, time, type of event and vehicle, type of parking space (legal vs. illegal, paid vs. unpaid etc.)	• Suggestion PJ: Kerbside supply efficiency: % of time that parking/loading/drop off (etc..) bays are occupied, by time of day, individually or for defined stretches of road • Suggestion PJ: Kerbside demand efficiency: probability of a driver being able to find a space (within X metre) of his/her desired destination • Suggestion PJ: Financial profile: income from payments for parking (and loading, drop off, etc.) • Suggestion TUD: Turnover of parked vehicles (inverse of parking duration, a parking space is better used when more vehicles use it over the day)	Direct assessment, before-after: number and duration of kerbside activities might change if parking supply is (temporarily) modified during project lifetime Vissim simulation: kerbside activities might change if parking supply changes (#or also demand?)	Video recording Manual observations

Table 9: Demand-Side Indicators, Wider Impacts, Core Module of SPAS

Theme	Indicator	Output options in Vissim	Type of assessment	Data basis, Unit
Accidents	Accidents with personal injuries for a 3-year period for the whole stress section should be included: • Location, date, time of accidents, number of injuries (with precise location) [-] • Accident severity [fatality, serious injury, minor injury] • Users involved in the accident (cars, LGV, HGV, motorcycles, cycles, scooters, buses, trams, pedestrians)	None	Direct assessment, before-after: number and severity of accidents might change if infrastructural or regulatory characteristics change or number of users changes, (ATTENTION: no short-term assessment possible) Vissim simulation: no assessment	Police statistics for units see column indicator
Air Quality	Air pollutant concentration on the MORE-corridor: • NO2, • PM10, • PM2.5	A number of results may be generated with COM Interface (see Link)	Direct assessment, before-after: Emissions might change if street design or user behaviour is (temporarily) modified during project lifetime Vissim simulation: Emissions might change if supply /demand changes	Measurements Computation with Vissim
On-Street Crime (Security)	Number of street crimes on the whole section [-]	None	Direct assessment, before-after: number street crimes might change if infrastructural characteristics change Vissim simulation: no assessment	Official statistics

4.2.2 Types of Data to be Collected

The following Table 10 lists the data that needs to be collected for computing the performance indicators as introduced above. The types of data to be collected are in some cases similar to the performance indicators. For example, data on speed can be directly used to quantify the indicator speed. In addition, data on speed is the basis for computing further indicators such as delays or reliability.

Table 10: Proposed Types of Data to be Collected for Demand-Side Indicators

Theme	Type of Data
Link/Movement Function	
Turning Vehicle Movements and Pedestrian Flows at Junctions (Every Single Junction in the Modelled Area)	Turning movements, by direction and arm, by vehicle type and time of day (15-minute intervals): cars, motorcycles, LGV, HGV, cycles, buses, trams
	Pedestrian flows on each footway approaching the junction, walking along the footway and crossing the carriageway, by direction
	Vehicle saturation flows on key approaches to signalised junctions (max. number of vehicles passing at green in over-saturated conditions)
	Vehicle queue lengths on major approaches to junction
Traffic Volumes in between two Junctions	Vehicle flows, by lane and direction; by vehicle type and time of day (15 minute intervals) (to be derived from counts of turning movements at adjacent junctions)
	Pedestrian flows (walking along the sidewalk) by footway, direction and time of day (15-minute intervals), by age group, gender and mobility aids
Pedestrian Crossing Volumes in between two Junctions	Pedestrian flows crossing the carriageway in between two junctions for formal crossing facilities (if possible also informal crossings), by direction, 15-minute intervals, by age group, gender and mobility aids
Public Transport	Total number of people entering the stress section in a public transport vehicle
Travel Times between Junctions	Travel times in both directions along the whole modelled corridor
And/or Spot Speed	Spot speeds at mid-points between junctions
Place Function	
Number and Duration of Stationary Activities	Number and duration of stationary activities, by age, gender, mobility aids, by posture (standing, formal/informal sitting, lying down, multiple movement) and activity type (waiting, consuming etc.)
Kerbside Stopping Activities: Bus/Tram	Frequency of service Number of people boarding and alighting at each bus/tram stop (and railway station entrance), information to be provided for each bus/tram stop
Kerbside Stopping Activities: Parking, Loading, Passenger Drop Off and Pickup, etc.	For each street segment or individual parking space: arrival and departure time for each parking/loading event (to estimate durations), by location, type of event and vehicle type
Wider Impacts	
Accidents	Number, type and severity of accidents Number of injured persons, severity of their injuries By specific location, where possible
Air Quality	Air pollutant concentration on the corridor (e.g. NO2, PM10, PM2.5)
On-Street Crime (Security)	Number of on-street crimes in the stress section (desirable) By specific location, where possible

4.3 Supply-Side Indicators

The careful description of the street layout and its environment is the basis for the evaluation and for understanding changes in the demand-side indicators. The supply-side indicators describe the space provision for each user group in the street, the type of separation between user groups, crossing facilities, inclusive design and the operation of the street (e.g. signalling schemes at traffic lights). Variables for urban design and land use are also included into SPAS even though these will be hardly changed in the process of re-designing the stress sections in the MORE corridors. All researched references show consistently the high importance of urban design and land use for traffic and user behaviour in the street, particularly for the place activities that are of special interest in the MORE project. Their careful documentation is the basis for understanding and purposefully shaping link and place activities in each street section.

Methods for data collection include for all the supply-side indicators mainly GIS-data or on-site inspections, the following Table 11 lists the proposed types of data to be collected for the supply-side indicators for the chosen stress sections.

Table 11: Proposed Types of Data to be Collected for Supply-Side Indicators

Theme	Data and Indicators
Street Network	
Movement and Place Categorisation	Classification of each street segment in the stress section along movement and place functions
Number, Width and Designation of Lanes for Each User Group in the Carriageway	Number and width of lanes in street section between junctions Number and width of lanes/pocket lanes in junction approaches Length of pocket lanes at junctions [m] Turning restrictions at junctions for each user group Allowed user groups on each lane, allowed direction of travel (e.g. for bidirectional cycle facilities)
Gradients of the Street Segment	Gradient [°]
Facilities and Separation of User Groups on Footways	Description of facilities for pedestrians and possible also cyclists, buffer zones if applicable
Signalising Schemes at Junctions	Signal control programs (external controllers if available), Signal control layouts (detector positions if actuated or pre-empted)
Space for Stationary Activities	Extra space beyond standard footway width: location, width [m], space [m²], short description
Opportunities to Sit	Location, width/length [m] of benches and further formal/ informal, commercial/ non-commercial seating facilities Presence of outdoor dining, amount of seating and space [m²]
Opportunities to Play, Exercise	Location, space [m²], width/length [m] of facilities for playing or exercise
Further Street Furniture	Location and characteristics of further street furniture such as street art, drinking fountains, water fountains, public toilets
Trees and Greenery	Location and type of trees and all different possible kinds of greenery
Bus/Tram Stops and Related Facilities	Location, width/length [m] of bus/tram stops and shelters Characteristics of bus/tram stop facilities
Provision for Parking and Stopping (Loading, Delivery, Drop-Off/Pick Up)	Documentation of all parking facilities and restrictions: parking bays, loading bays, prohibited stopping areas, etc. hours of operation and any limits on stopping duration (where appropriate); details of any charges (amount per unit time, hours of operation) Location of bike parking stands; stands for scooters etc. Kiss+Ride, Park+Ride, taxi, shared services facilities
Speed Limit	Speed limit at street section, further legal aspects of traffic regulation
Community Severance, Crossing Facilities	Location of each pedestrian crossing, by type of crossing facility Detection and optimisation technology for active mode users at traffic lights
Inclusive Design	Extent to which each crossing facility is suitable for pedestrians with reduced mobility Quality of footway and crossing surfaces, description and localisation of obstacles at the footway Extent to which each vehicle and PT stop/station is accessible to persons with reduced mobility
Urban Design and Land Use	
Density and Diversity of Land-Use in the Neighbourhood	Number of residents and work places per km² within around 500m radius Proportions of different types of land-use
Usage of Adjacent Buildings, Land Use	Proportions of ground floor usages in adjacent buildings (e.g. residential use or types of non-residential uses such as restaurant, bar, café, supermarket, retail store, bakery, pharmacy and drugstore, bank and ATM, health-related use, educational institution, religious site, public institution, theatre, museum) Estimated types of usage of adjacent buildings for higher-level floors
Scale, Human Dimension, Enclosure	Height of adjacent buildings (number of floors)
Attractive and Active Frontages, Transparency	Proportion of active frontages or soft edges in contrast to inactive walls Qualitative assessment of façade designs

Theme	Data and Indicators
Security, Protection against Crime and Violence	Sufficiency of surveillance and street lighting
Protection Against Unpleasant Sensory Experiences, Opportunities to Enjoy the Positive Aspects of Climate	Location and type of shelters and refuges Cleanliness
Positive Sensory Experiences	Subjective assessment of aspects that positively impact on the quality of street space (might be even scents and smells)

Detailed instructions for data collection and data provision are provided by UCL and TUD in a separate document (Appendix 1). Due to delays related to COVID-19 (e.g., unsuccessful procurement of a consultant), a reduced list of indicators was sent to partners during the last trimester of the MORE-project to ensure the achievement of comparable results within MORE-cities (Appendix 2).

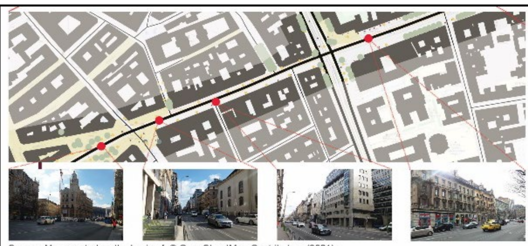
5 Cross-Site Assessment of the Stress Sections

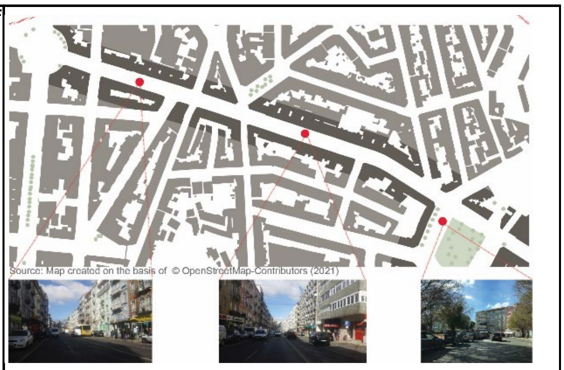
This chapter gives an overview of the stress-sections in their current conditions. Main characteristics of the streets and their usage are presented and compared between the five cities, this is the basis for the subsequent Chapter 6 and for developing the design packages.

5.1 Overview of the Stress Sections

These are all main streets, all have high movement and place functions, with very different street layouts and conditions from the built environment perspective. All stress sections have high motorised traffic volumes (AADT ranges from 6.200 to 35.000 motor vehicles). Public transport is available in all stress sections in the form of bus routes. Both Budapest and London also have underground connections at the stress section. All stress sections are located close to the city centre and thus have a high potential for place activities, this potential is currently not fully exploited mainly due to limited space for place activities, high noise exposure and traffic volumes. All streets are connectors to the TEN-T-network. The length of the sections ranges from 100 metres to two kilometres. Constanta differs mainly because it is not a street section but a roundabout. The Malmö stress section does not exist in its current state, so six reference streets were analysed instead, two of which are presented here. A short verbal description of each stress section, overview plans and photos are presented in Table 12.

Table 12: Overview of the Stress Sections

Budapest	The stress section *Szabad sajtó út/Kossuth Lajos utca* is located in the centre of Budapest between the historic boroughs of Pest and Belváros. It is approximately 800 meters long and is one of Budapest's core axes connecting the city to the TEN-T network. The AADT (annual average daily travel) is about 35.000 motor vehicles, this shows the importance of this section in terms of movement function. During peak hours, up to 200 busses per hour operate in the stress section, which corresponds to almost two buses per minute and direction and up to 40,000 passengers per day.	 Source: Map created on the basis of © OpenStreetMap-Contributors (2021); Photos: MORE-Meeting in Budapest (28.02.2020)
Constanta	The Stress Section *CORA-Junction* is located in Western part of Constanta and connects *Bulevardul I. C. Brătianu* with *Strada Dezrobirii/Pasajul Cumpenei*. The roundabout with a diameter of about 50 meters is an important distributor for traffic between the city and the TEN-T network and thus has a high link function for motorised traffic. The AADT (annual average daily travel) is with 25,000 motor vehicles high for all four arms of the roundabout. With around 13 busses per hour and arm, *CORA-junction* is an important transfer point for public transport. Each arm has three approaching lanes, the junction itself is big so that overall, *CORA-junction* is a major barrier for activities in the neighbourhood.	 Source: Map created on the basis of © OpenStreetMap-Contributors (2021); Photos: City of Constanta

Lisbon	The *Rua Morais Soares* stress section is located north of the centre of Lisbon in the *Penha de França* and *Arroios* districts. The stress section consists of a section about 700 metres long and a square (*Praça Paiva Couceiro*) with a perimeter of about 440 metres. Rua Morais Soares is one of the main roads connecting the Eastern part of the city with the TEN-T network. The average daily traffic volume (AADT) is about 20,000 motor vehicles. There are two lanes in each direction on the section. The square has two to four lanes in cross-section and acts as a distributor into the adjacent streets. Parking is available along the entire section, with one parking lane on each side, but people still park in the second row.	
London	The Stress Section *New Cross Road* is located south-easter London in the borough of Lewisham. The section covers a length of about 2 kilometres; it is part of the A2 corridor which connects the city to the TEN-T network and has thus a high link function for motorised traffic. The AADT (annual average daily travel) is about 30.000 motor vehicles and about 2.500 pedal cycles. In peak hour periods, there are around 100 buses per hour in the stress section, this is almost one bus per minute and direction.	
Malmö	The Reference Streets *Regementsgatan & Mariedalsvägen* are located in the west of Malmö in the Innerstaden district. These streets are two out of six reference streets used to understand the current conditions as input for planning new streets in the Nyhamnen area. Both sections are analysed based on video data over a length of 100 to 150 metres. *Mariedalsvägen (north-south)*, with an AADT (annual average daily travel) of 8,500 motor vehicles, has a higher link function for motorised traffic than *Regementsgatan (east-west),* with an AADT of 6.200 motor vehicles. Both streets have one lane for motorised traffic in each direction with a carriageway width of about 10 metres on *Mariedalsvägen* and 8 metres on *Regementsgatan*. There is one bus route on each of the two roads, with a 10-minute interval during Peak hours on Mariedalsvägen and a 5-minute interval on Regementsgatan, which corresponds to 6 to 12 buses per hour and direction.	

5.2 Land Use

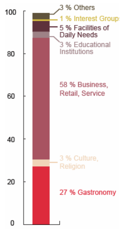
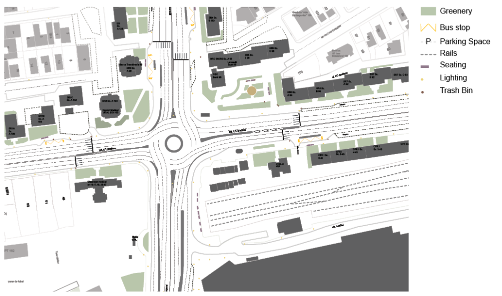
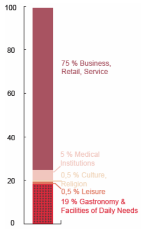
Before having a look on demand-side factors, such as stationary activities and people moved in the following sections, it is important to consider the supply side to understand mobility behaviour. Land use was introduced in Chapter 3.2 as one core supply-side-factor shaping street activities, it determines origins and destinations of trips in their quantity and characteristics, travel times and also the type of travellers. Table 13 gives an overview on the non-residential land uses at ground floor level along the stress sections. All five stress sections generally have a high share of non-residential land uses related to a potentially high number of place activities.

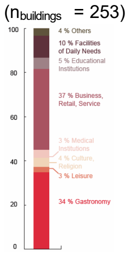
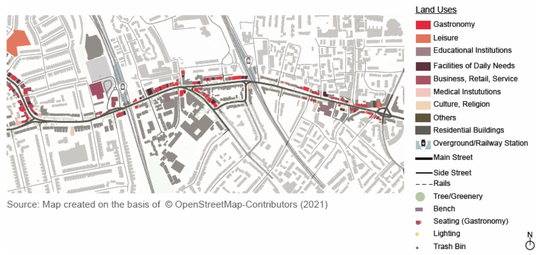
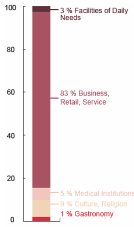
In the case of Budapest and Lisbon the street sections are characterised by compact building structures with numerous building units and diverse land-uses. The category business and retail is the predominant land-use. On the second position is the gastronomy and in the case of Lisbon the combined usages of gastronomy and facilities of daily needs. Also the reference street Regementsgatan in Malmö shows block structures and regarding land use, business and retail as well as gastronomy.

The stress section in London is mainly bordered by rowed houses that align nicely with the street layout. Especially in the middle part of the stress section between the metro stations and in the eastern part the heterogeneity of land uses is high.

The stress section in Constanta is bordered by multilevel apartment houses in rows in the eastern part of the stress section and as solitaires at Cora-junction. Shops and green spaces are placed in the northern part of the stress section. A large shopping mall is located south of the intersection. With Kronprinsen Mall, there is also a large shopping mall located next to the reference street Mariedalsvägen in Malmö, this street is bordered by rowed multilevel apartment buildings.

Table 13: Land Use on the Stress Sections

Budapest	Although the section is located in the tourist centre, the land use is dominated by businesses and retail. Gastronomy tends to be located in smaller streets in the periphery of the stress section.	Non-Residential Land Uses ($n_{buildings}$ = 66)   Source: Map created on the basis of © OpenStreetMap-Contributors (2021) and on data from City of Budapest
Constanta	The areas next to the junction provide some possibilities for place activities, there are shops and other facilities, there is green space and also a playground. The CORA Mall, which is located about 100 m south of the intersection, gives the intersection its name. With its many retail shops, it is a popular destination particularly for car drivers, but also generates demand for public transport and thus pedestrian activities. Other than that, no detailed land use information is available.	 Source: Map created on the basis of © OpenStreetMap-Contributors (2021) and on data from City of Constanta
Lisbon	The section is a very dense commercial zone, with mainly small businesses and retail, but also restaurants	Non-Residential Land Uses ($n_{buildings}$ = 189)   Source: Map created on the basis of © OpenStreetMap-Contributors (2021); and on data from City of Lisbon

London	Land use differs along the stress section from mainly residential buildings in the Western part to mixed land use in the Eastern part and particularly between the two metro stations New Cross Gate and New Cross. Multiple shops, gastronomy and other usages surround the street in this area, particularly around the metro stations themselves.	Non-Residential Land Uses ($n_{buildings}$ = 253)  
Malmö	The ground floor uses in both streets consist mainly of businesses. There is space for outdoor dining. The sidewalks at Mariedalsvägen are slightly narrower. The square in front of Kronprinsen Mall has space for outdoor activities with some green areas and benches.	Non-Residential Land Uses ($n_{buildings}$ = 80)  

5.3 Stationary Activities

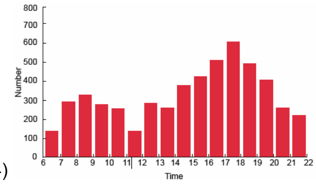
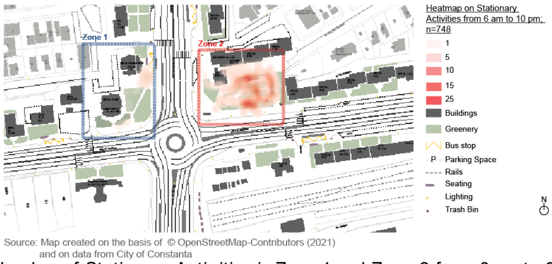
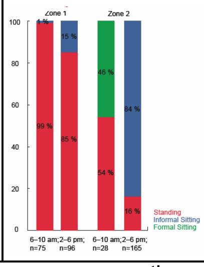
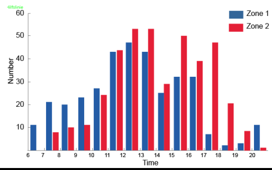
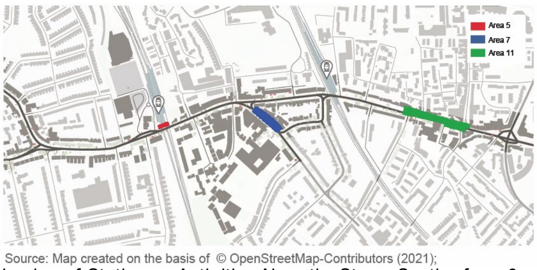
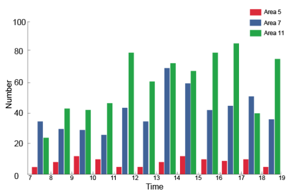
Stationary activities were investigated in the stress sections of Budapest, Constanta, London and in the reference streets of Malmö in order to assess the place function and the extent of stationary activities.

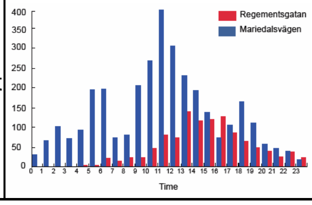
In Budapest, Constanta and in London, most stationary activities occur around public transport stations, where people are standing and waiting. Public transport stops are one main attractor for stationary activities. On the other hand, it is clearly visible, that mixed land uses, such as cafés, multiple shops or shopping centres as well as greenery motivate people to engage in stationary activities, although the conditions and physical quality of the streetscape are not very inviting (e.g. narrow sidewalks or higher vehicle volumes). This indicates the potential for stationary activities in these spaces if the design options of the cities are implemented (see section 6.2). Regarding the distribution of stationary activities over the day, most stationary activities take place around peak hours in all stress sections.

Detailed information on stationary activities along the stress sections are given in the subsequent Table 14.

For Lisbon, there are no data on stationary activities. Instead, a survey on the perceptions of the stress section was conducted (see Del. 5.2).

Table 14: Stationary Activities Along the Stress Sections

Budapest	Stationary activities mostly take place where people are waiting, this is mainly around the entrances of the metro stations Ferenciek tere in the Western part and Astoria in the Eastern part of the stress section. Stationary activities can be also observed in the other parts of the stress section despite the busy street and the narrow sidewalks; this shows the high potential of this street for place activities. Most stationary activities take place around peak hours.	 Number of Stationary Activities Along the Stress Section from 6 am to 10 pm (n=5.234) 
Constanta	High levels of stationary activities can be observed in the Northern periphery of the roundabout, particularly in Zone 2 (n=396). People in Zone 1 (n=352) are mainly waiting at the bus stations or at a bank counter but they also engage in place activities such as informally sitting on the stairs in the afternoon. Zone 2 is obviously very attractive for place activities, thanks to active usages in the buildings bordering Zone 2 in the North and greenery, benches and a playground in the middle part of Zone 2. In the afternoon, most place users sit in Zone 2, which shows the attractiveness of this area.	 Number of Stationary Activities in Zone 1 and Zone 2 from 6 am to 9 pm (n=748)  
Lisbon	No data on stationary activities. Instead a survey on perception of the stress section was conducted. For results, please have a look at Del. 5.2.	
London	A lower level of stationary activities can be assigned to New Cross Gate (red Area 5; n=99) in comparison to Lewisham Road (blue Area 7; n=503) and New Cross Road between Watson's Street and Deptford High Street (green Area 11; n=720). Stationary activities occur to a significantly higher extent where land use diversity is greater and where public transport stops are located. Regarding the activities, most people are standing around or are waiting at the bus stop. Only few stationary activities like chatting or consuming at cafés were observed.	 Number of Stationary Activities Along the Stress Section from 6 am to 8 pm (n=1.322) 

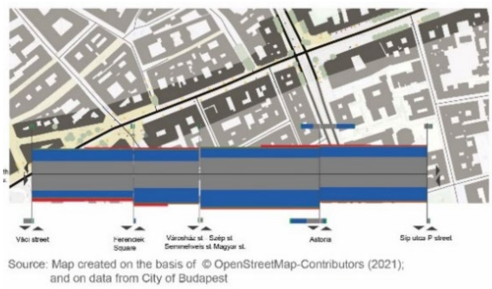
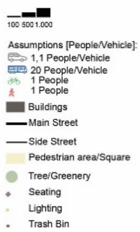
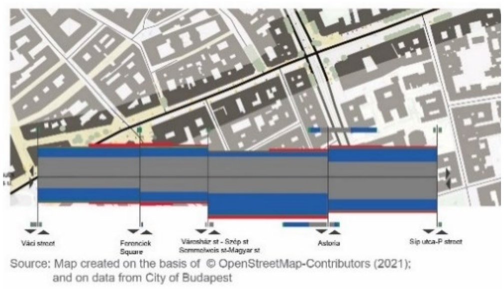
Malmö	Stationary activities take place at both sections. At Mariedalsvägen there is altogether more activity than at Regementsgatan. The square in front of Kronprinsen shopping centre is used throughout the day, with a peak at lunchtime. People might buy their lunch in the surrounding shops and then have lunch in the outside area. But it also seems to be a place to hang out at night. There are almost no place activities observed at other parts of Mariedalsvägen. Regementsgatan is used fairly evenly in the afternoons and throughout the whole length of the observed section. This could mean that people prefer to have a coffee or tea and linger in this street.	 Number of Stationary Activities Along the Reference Streets Mariedalsvägen (n=3.249) and Regementsgatan (n=1.100) from 00:00 am to 23:59 pm 

5.4 People Moved

The high movement function of the stress sections is clearly evident in the People Moved-Figures showing a high number of movement users. Those figures in Table 15 are compiled using vehicle counting and assumptions for occupation levels (people/vehicle) per mode and direction. These assumptions and quantities can be taken from the legend. A summary of the ranges of people moved per mode, time slot and stress section is shown in Table 16

Across all user groups and cities, PM-peak hour volumes (right figure) are equal or higher than AM-peak hour volumes (left figure), with the exception of London. Motorised vehicles are the biggest user group in all cities, again with the exception of London, where public transport is the largest user. However, public transport carries almost as many or more passengers in some segments (e.g. in Lisbon & London). Cyclists are rare on all sections, with the highest usage in London and Malmö. Pedestrian numbers have the highest variance over almost all sections (which shows that some spaces are more frequented by pedestrians, some are less). With some exceptions, pedestrian volumes are highest during the PM peak and near public transport stops. People seem to hurry in the morning to their final destinations and just changing public transport vehicles but seem to spend time in the street in the afternoon, perhaps for errands or shopping activities.

Table 15: People Moved on the Stress Sections

	AM Peak	Legend	PM Peak
Budapest			

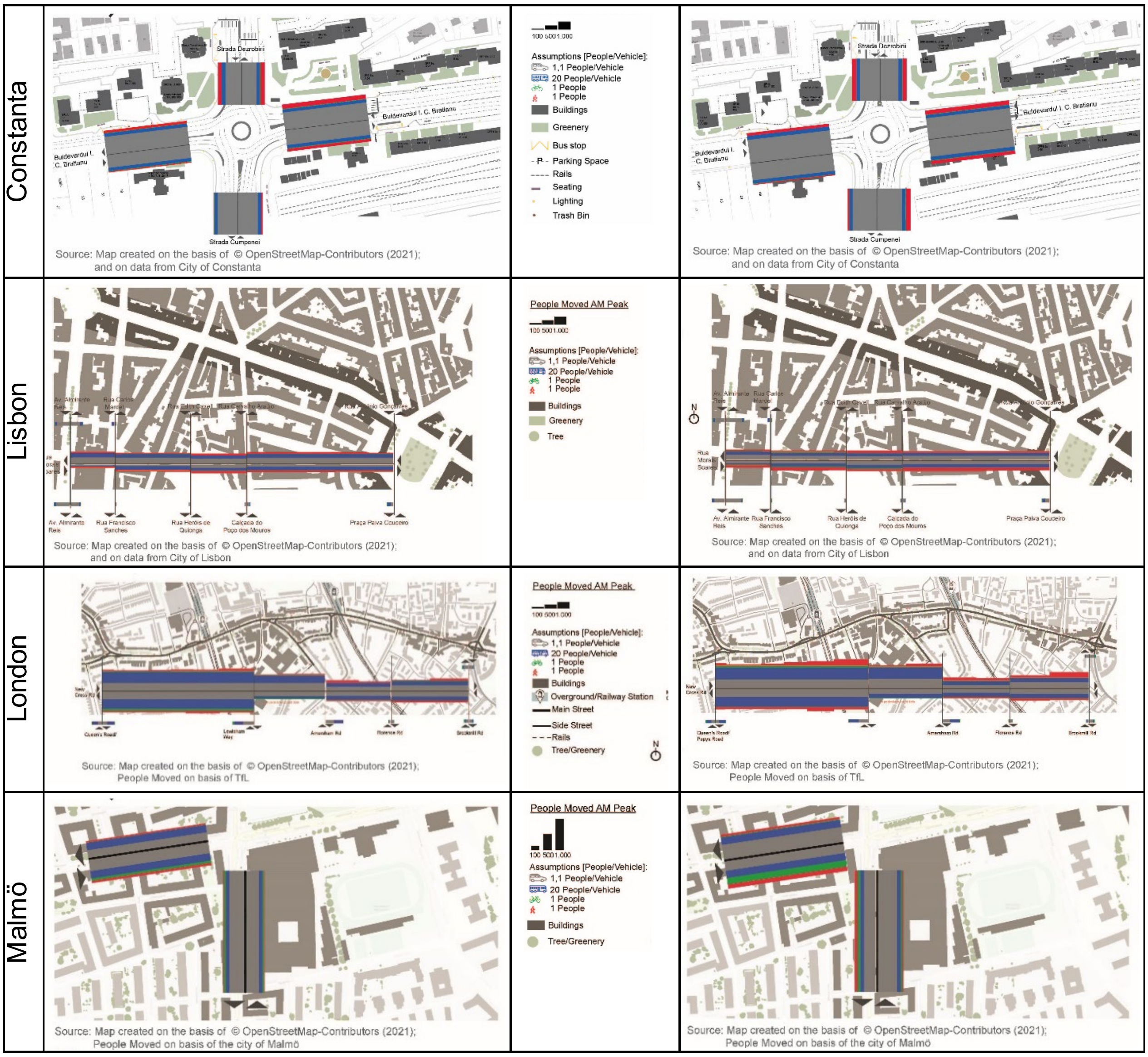


Table 16: Ranges of People Moved per Mode on the Stress Sections

	Budapest		Constanta		Lisbon		London		Malmö	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
Vehicles	3000–3700	3100–5050	2300–3000	2850–3700	1000–1050	650–1000	1500–3050	1200–2950	650–900	850–1050
Public Transport	2000–3600	2150–4050	500– 500	500–500	700–1000	650–1000	550–4250	720–4150	250–500	250–500
Cycling	10–70	10–70	2–4	1–2	3–7	1–9	50–400	50–350	70–100	150–250
Pedestri-ans	250–550	400–1550	150–650	300–700	350–550	500–750	450–850	550–1450	50–100	150–200

5.5 Public Transport

For public transport, loadings (users in bus lines shown on the segments) and boarders/alighters at bus stops were analysed as shown in Table 17.

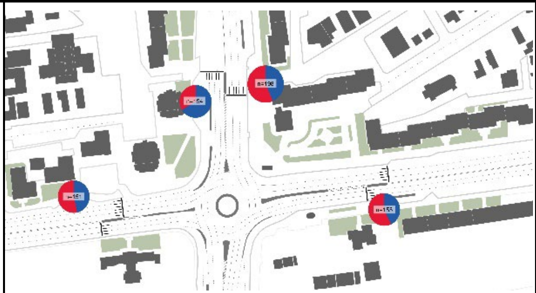
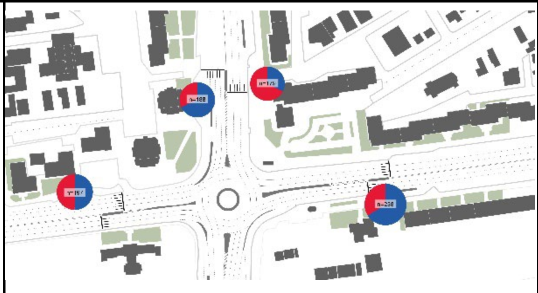
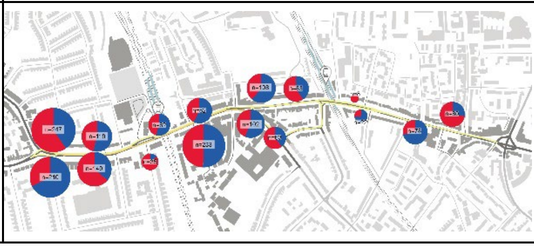
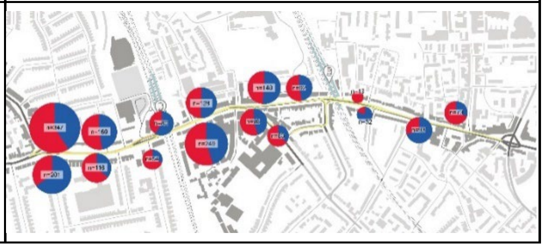
In Budapest, there are only boarder/alighter counts for the four biggest transport stops. More people get off buses in the eastbound direction during the morning peak. The loadings are higher in westbound direction in AM peak and in eastbound direction in PM peak. There are overall more public transport users in PM peak.

In Constanta, some interesting pattern can be observed. For example, more people come and leave the bus from South to North over the whole day, more people board the bus from North to South over the whole day. There is no information available about the loadings.

The number of bus passengers and also boarders and alighters in public transport vehicles in London is high along the whole stress section but again specifically at the metro stations. It tends to be higher in the afternoon compared to the morning and shows clear temporal commuting pattern with different shares of boarders and alighters in the morning and in the afternoon.

There is no comparable public transport data for Lisbon and Malmö.

Table 17: Public Transport Boarders, Alighters and Loadings on the Stress Sections

	AM Peak	Legend	PM Peak
Budapest		Loadings 1.000–1.500 1.500–1.750 1.750–2.000 2.000–2.250 2.250–2.500 Boarders Alighters	
Constanta		Boarders Alighters	
London		Bus Loadings 0–500 1.000–1.500 Boarders Alighters	

5.6 Kerbside Activities

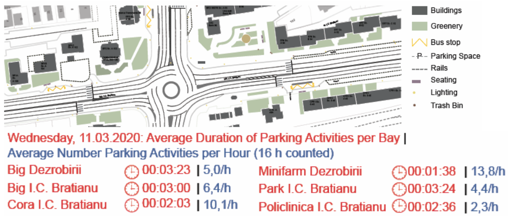
The following Table 18 shows the key facts on kerbside activities along the stress section, in particular the share of legal and illegal parking activities, the average duration of parking activities and if available, data on different activity types.

Kerbside activities vary from city to city, no general conclusions can be drawn. Parking duration is highest in Lisbon with 02:28 h in average per parking activity. Particularly noteworthy is the high share and duration of parking in the second lane. 51 percent (n = 76) of all illegal kerbside activities are parking in average 01:41 h in second lane, what affects traffic flow negatively. London also shows high rates in illegal parking (37 %; n = 203), but in comparison to Lisbon the average parking duration per parking activity is around four times lower (00:23 h). Constanta shows the shortest parking durations with two minutes in average (n = 672), which could be explained by the high share of pick up- and drop off-activities (74 %). Almost no illegal kerbside activities were observed in Malmö.

In Budapest, no kerbside activities were observed along the stress section

Table 18: Kerbside Activities on the Stress Sections

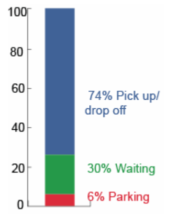
<table>
<tr>
<td>Constanta</td>
<td>The parking bays around the Cora intersection are mainly used for short-term parking. The average parking time is 2:23 minutes across all bays and a maximum of 3:24 minutes. Most cars are just picking up or dropping off something or someone there, which explains the short duration.</td>
<td>



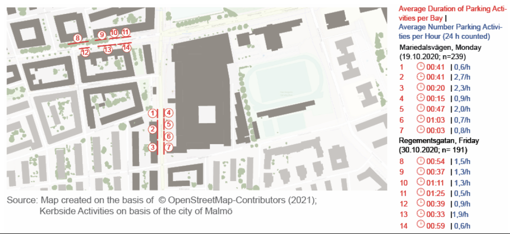
Key Characteristics

<table>
<tr><td colspan="2">Wednesday, 11.03.2020</td></tr>
<tr><td>Total Activities:</td><td>672</td></tr>
<tr><td colspan="2">Average Duration:</td></tr>
<tr><td>All Parking Activities:</td><td>0:02:23</td></tr>
</table>

Share by Activity Type



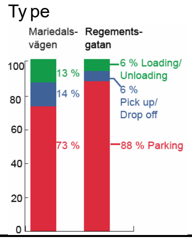
</td>
</tr>
<tr>
<td>Malmö</td>
<td>The parking time at Mariedalsvägen is shorter compared to Regementsgatan. Users tend to park on Regementsgatan and pick up/drop off and load on Mariedalsvägen, which could be due to the fact that there are more shops on Mariedalsvägen.</td>
<td>



Key Characteristics

<table>
<tr><td></td><td>Mariedalsvägen</td><td>Regementsgatan</td></tr>
<tr><td>Total Activities:</td><td>239</td><td>191</td></tr>
<tr><td>Illegal Parking [%]:</td><td>4 %</td><td>6 %</td></tr>
<tr><td colspan="3">Average Duration:</td></tr>
<tr><td>All Parking Activities:</td><td>00:34</td><td>00:50</td></tr>
<tr><td>Legal Parking:</td><td>00:35</td><td>00:52</td></tr>
<tr><td>Illegal Parking:</td><td>00:02</td><td>00:08</td></tr>
</table>

Share by Activity Type



</td>
</tr>
</table>

Lisbon

The parking bays on the stress section are well utilised on weekdays. The highest demand for parking is in the middle of the section (bay 4, bay 12) with the highest number of legal and illegal parking activities (second row). More illegal parking activities were found at crossings that normally should be kept clear of parking for safety reasons. The average parking duration was 2:28 hours, which is far longer than a short visit to a shop or restaurant. Illegal parking was shorter on average, but still longer than one hour.

Thursday 12.12.2019: Number of Legal Parking Activities per Bay* | Number of Second Lane Parking Activities per Bay (11 h counted)*

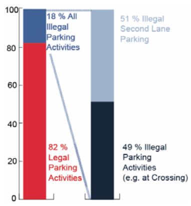
Bay 2	64	4	Bay 10	22	-	Bay 15	41	4
Bay 4	136	24	Bay 11.1	13	-	Bay P1	63	-
Bay 6	30	1	Bay 11.2	33	1	Bay P2	17	-
Bay 7	9	4	Bay 12	108	24	Bay P3	19	-
Bay 9	47	11	Bay 13	22	2	Bay P4	44	1

*Bicyles and Motorcycles are excluded.

Key Characteristics

Thursday, 12.12.2019	
Total Legal and Illegal Parking Activities:	817
Legal Parking Activities	668
Illegal Parking Activities [%]:	18 %
Thereof Second Lane Parking	51 % n=76
Average Duration:	
All Parking Activities:	02:28 h
Legal Parking Activities:	02:34 h
Illegal Parking Activities: Second Lane Parking:	01:25 h 01:41 h

Share of Legal and Illegal Parking Activities (n=817)



London

About 20 parking spaces exist in the stress section. These are very well used; the share of illegal parking is with 37 percent high. Parking duration is low, this shows that the limited number of parking bays is efficiently used for short-term activities related to the adjacent buildings.

Wednesday 07.03.2018: Average Duration of Parking Activities per Bay | Average Number Parking Activities per Hour (14 h counted)

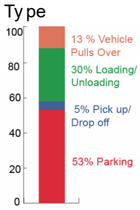
Bay 1	00:13:40	Bay 6	00:22:03	Bay 11	00:09:44	Bay 16	00:09:41	Bay 21	00:02:55
	4,4/h		3,1/h		2,4/h		1,1/h		0,6/h
Bay 2	00:22:36	Bay 7	00:34:54	Bay 12	00:07:43	Bay 17	00:18:47	Bay 22	00:10:25
	0,5/h		1,0/h		1,0/h		4,5/h		2,2/h
Bay 3	00:14:34	Bay 8	00:23:37	Bay 13	00:09:17	Bay 18	00:06:36		
	0,1/h		4,9/h		0,8/h		0,7/h		
Bay 4	00:10:24	Bay 9	00:04:05	Bay 14	00:15:09	Bay 19	00:11:20		
	0,3/h		1,4/h		1,9/h		0,7/h		
Bay 5	01:01:15	Bay 10	00:14:47	Bay 15	00:25:51	Bay 20	00:10:05		
	0,6/h		5,0/h		1,4/h		0,4/h		

Source: Map created on the basis of © OpenStreetMap-Contributors (2021); Kerbside Activities on basis of TfL

Key Characteristics

Wednesday, 07.03.2018	
Total Activities:	549
Illegal Parking [%]:	37 %
Average Duration:	
All Parking Activities:	00:15:12
Legal Parking:	00:10:19
Illegal Parking:	00:23:37

Share by Activity Type



6 Cross-Site Assessment of Case Study Design Packages

6.1 Design Process

The design process included at least three different stages across all MORE-cities:

- Preparation of design days: Internal work on the organisation of design days (e.g. setting dates for workshops/public events, inviting participants, develop possible workshop formats under COVID-19-pandemic conditions) as well as on content and inputs for design days (e.g. preparation of maps, information for participants)
- Implementation of design days: Formal design workshops with stakeholders (Budapest, Constanta, Lisbon, London, Malmö) and/or on-site visits for public design exercise (Constanta, Lisbon, Malmö)
- Decision making on final design options: Follow-up discussions to the design days in small expert groups mainly from city administration and the MORE-project teams in each partner city, final choice of design packages for Vissim simulation

During this design process, the MORE-cities engaged with different stakeholders and applied the MORE-tools and further methods to gather various design options for the stress sections and finally to decide on design options to be modelled in Vissim (see sections 6.2 and 0). In the following, the design process across the MORE-cities is summarised. For more detailed information on the outcomes of the city-specific usage of the tools and how they were used, see Del. 5.3.

6.1.1 Stakeholder Groups Engaged in the Design Process

Due to the growing complexity of urban street planning regarding different user needs and competing street functions (movement- and place-function), participation is one key component for successful planning processes, to ensure quality and acceptance of designs. During the different stages of the design process, various stakeholders were engaged in the MORE-cities:

- Internal experts: In the context of the MORE-project, internal experts are in most cases urban planners, transport planners, traffic engineers as well as architects from the municipal authority.
- External experts: In the context of the MORE-project, external experts are for example consultant companies, NGOs or local public transport providers, which are not part of the municipal authority.
- Interested citizens, local residents and shop owners, especially engaged during on-site design exercises.

Role of Dialogues with Internal and External Experts

Dialogues with internal and external experts can be summarised as a key instrument during the different stages of the design process.

In Constanta, Lisbon, London and Malmö dialogues were conducted before the design days to define key issues and/or priorities for the stress sections. In some cases, the results of the Road Space Design Tool and the Policy Intervention Tools were used as a basis for discussions with experts to get an impression of feasible interventions and designs before the design days (e.g. London, Constanta). Furthermore, experts were involved during or after the stakeholder design days to get reflections on the designs, for design evaluation as well as for the decision on the final design options for the Vissim modelling exercises (Budapest, Constanta, London, Malmö).

Participation of Interested Citizens, Local Residents and Shop Owners

In the cities of Constanta, Lisbon and Malmö, public design days were made on-site. Particularly due to COVID-19, planned public indoor participation exercises had to be shifted into on-site visits. The purpose was to inform and to involve interested citizens, local residents and shop owners into the MORE-design process, to get into dialogue with these person groups and share impressions and experiences regarding the stress sections.

Therefore, the cities prepared maps of the street sections and used the MORE-physical toolkit “Blocks and Acetates” to create new possible designs together with the citizens and to build the communication-bridge between the perspectives of planners and citizens.

6.1.2 Overall Used Tools/Methods During Design Process

During the design process, the MORE-cities had the opportunity to test several MORE-tools for the generation of multiple design options, before the cities decided on the final designs to be modelled in Vissim. The usage of the methods and tools is summarised in the following.

Traffweb and Surveys

Traffweb was applied as a participation tool for citizens and experts to share their perspectives on the stress sections. This tool was used to collect information on issues and problems, and on strengths and weaknesses of the individual stress sections as a basis for the design process in all cities. Malmö also conducted a survey on the perception of the reference streets via Traffweb, while the cities of Constanta and Lisbon preferred an on-site visit.

Physical Toolkit: Blocks and Acetates

In Constanta, Lisbon and in Malmö, on-site visits were organized, in order to involve the public into the MORE-design process (see also 6.1.1). Especially in Lisbon, this method was used to reach, inform and engage different person groups during two time periods and to reach elderly persons, who often tend to be an “info-excluded” person group. Five different design suggestions were generated in Lisbon by applying this method. In Budapest the

MORE-physical toolkit “Blocks and Acetates” was used as a participation and design tool during the stakeholder design exercises.

Policy Intervention Tool and Road Space Design Tool

The MORE-Policy Intervention Tool is a kind of library of structured street interventions, developed to provide feasible measures for the sections under stress on predefined priorities and to show impacts of interventions. The second MORE-Road Space Design Tool creates multiple suggestions for new space allocations for street users at cross-sections on basis of the input of desired street elements. Both tools were used by Budapest, Constanta, Lisbon and London during the design process to get various suggestions on reasonable measures and options for cross-sections created by objective tools. These results were the basis for further discussions with stakeholders.

Linemap

While the MORE-Road Space Design Tool generates multiple options for selected cross-sections in a “block design”, with Linemap detailed possible designs can be generated on the map for the whole section under stress. Almost all MORE-cities have transferred the design options for the stress sections into Linemap.

Other Tools (e.g. Streetmix, Microsoft Programs)

The usage of the developed MORE-tools and especially the physical toolkit “Blocks and Acetates” was intended in presence as they were developed in pre-pandemic times. Due to COVID-19, the MORE-cities had to be flexible and partly switch their indoor planned participation and design activities into online sessions or to on-site activities. Thereby they had to be creative and adapted the functions of the physical toolkit into other digital formats, which were appropriate. Hence, the MORE-cities used in addition to the developed tools common formats (e.g. Streetmix, Microsoft Programs) to enable participation.

Overall, the MORE-cities have applied almost all recommended and developed MORE-tools and methods to generate multiple design packages. On the basis of the various discussions on different street design layouts, design priorities, and the amount of design options to be modelled for different time-periods with Vissim, the MORE-city partners finally agreed on few selected design options. These finally chosen design-options for the subsequent modelling exercises in Vissim across the cities are summarised in section 6.2.

The following Table 19 gives a synthesised overview on key aspects of the design process across all MORE-cities. It contains information on engaged stakeholders, on the format of activities (online, presence) and on the tools and methods used during the whole design process.

Table 19 Overview on the Design Process of the MORE-Cities

	Engaged Stakeholders During Design Process						Formats Used During Design Process		Used Tools and Methods During Design Process								Number of Used Tools/ Methods
	Experts from Municipality/ Authority	Local PT Provider	External Experts	NGOs	Citizens/ Residents	Shop Owners	Online	Presence	Blocks and Acetates	Linemap	Other Tools (e.g. Streetmix, Microsoft Whiteboard, PPT)	Road Space Design Tool	Policy Intervention Tool	Dialogues with Experts	TraffWeb	Further Activities (e.g. Surveys)	
Budapest	x	x	x		x	x		x	x		x	x	x	x	x		6
Constanta	x	x	x		x	x	x	x	x	x		x	x	x	x	x	7
Lisbon	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	8
London	x	x			x	x	x			x	x	x	x	x	x		6
Malmö	x		x		x	x	x	x	x	x	x			x	x	x	6

6.2 Design Packages

In total, the MORE-cities have generated 29 design options to be modelled in Vissim:

- Budapest: 3 design options
- Constanta: 10 design options
- Lisbon: 5 design options
- London: 8 design options
- Malmö: 3 design options

These generated design options cover a range of different layouts, addressing different topics and the following key priorities:

- Designs with focus on public transport
- Designs with focus on cycling
- Designs with focus on pedestrians and place users
- Designs with focus on general traffic (individual motorized modes including two-wheelers, cars, vans, heavy goods vehicles)
- Designs as mixed options: These designs include cover than one key priority

The key priorities were derived from the design titles given by the cities or from the descriptions of the designs (see Del. 5.3). Table 20 gives an overview about the number of the chosen design options per key priority for each MORE-city as well as the share of designs per key priority over all cities. Mixed design options were used most frequently by the MORE-cities to obtain designs that consider the needs of multiple street user groups (28 %). The designs with focus on cycling are represented with 10 percent. Designs with the key priority on pedestrians (21 %) and on public transport were chosen more often (24 %). The MORE-cities Budapest, Constanta and Malmö additionally generated designs with the focus on general traffic to obtain a better comparison to the designs with the focus on the environmentally friendly transport modes. The final number of design packages, including modelling for different time periods is shown in Table 23.

Table 20 Key Priorities of Design Options and Number of Designs per MORE-City

Key Priorities	Buda-pest	Con-stanta	Lisbon	London	Malmö	Sum of Designs	Share of Designs
Focus on Public Transport	-	2	1	4	-	7	24 %
Focus on Cycling	-	1	1	-	1	3	10 %
Focus on Pedestrians/Place Users	-	-	1	4	1	6	21 %
Focus on General Traffic (Individual motorized modes)	1	3	-	-	1	5	17 %
Mixed Options	2	4	2	-	-	8	28 %
Sum of Designs	3	10	5	8	3	29	100 %

To provide a comprehensive overview of all generated designs, the single elements of the design options in comparison to the current condition were summarised in Table 21. The comparison of designs with the current condition is possible in all MORE-cities, except of Malmö. In Malmö, designs cannot be compared to current condition, due to the fact that the street in Nyhamnen does not exist yet. To get an impression of the different designs of Malmö, the comparison is done between the designs (see Table 22).

Having a closer look on the single components of the designs in Table 21, each city has generated options with improved conditions for pedestrians. Sidewalks were extended continuously along the whole stress section or at least in some parts, to provide more space for walking or for place activities. Some cities have installed additional crossing facilities for pedestrians to improve traffic safety while crossing and to reduce detours for pedestrians (Budapest, Lisbon, London). In terms of improving the quality of space, all cities provide at least one design with additional green structures and/or street furniture such as parklets. Especially in mixed designs and in designs with the focus on place activities and pedestrian facilities, improved conditions for pedestrians can be identified.

Regarding bicycle facilities, Budapest, Constanta and Lisbon include new bicycle lanes in some of the designs – mostly in those designs which focus on cycling or in mixed designs. Similar to these cycling measures, extra bus lanes can be found in the design options with focus on public transport and in mixed designs.

An overlap of the three above mentioned types of infrastructures appears within the mixed designs, which include in most cases the highest number of measures for changing the street layout (range: 5–8 measures; see Table 21) and are thus the most ambitious designs.

In the case of London, the whole stress section was divided into three segments, thereof the central section includes two different layouts – gyratory and two-way-running street. Consequently, in London, one design covers four options. London has created two different designs, one focusses on the key priority with improvements on pedestrians and place-based features, the second on as improvements on public transport. Finally, eight design options enter into the modelling exercises with different time periods (see chapter 6.3).In Table 21 the measures for all eight options are presented in summarised form for the two key priorities. In those designs bus and cycle lanes as well as improvements on pedestrian infrastructures are included in their designs. Both designs cover a wide range of measures.

In terms of parking, cities reduce the supply and/or the width of parking lanes. Only Budapest and Lisbon increase their parking infrastructure. Regarding the current condition, kerbside activities played no important role in Budapest. In their design “Transport Approach” temporary loading zones (at night time) are planned, to meet the requirements of delivery of the stores within the areas with mixed land use structures. Also small mobility points are included to accommodate kerbside activities, such as bicycle parking. In contrary to Budapest, Lisbon faces in the current situation high parking pressure and second-lane parking, which has a negative impact on traffic flow. Therefore, one design is dedicated to parking improvements in Lisbon.

The number of vehicle lanes is reduced in all finally chosen design options in all cities with the exception of Constanta. Constanta generated the highest number of designs with a variety of distinctive key foci and priorities for different user groups. Three designs focus on general traffic measures. In those designs, there is no reduction of vehicle lanes in comparison to the current condition. The main differences lie either in the transformation of the roundabout into a signalised junction or in the installation of an additional fly-over (level +1), for motorized traffic or for pedestrians. In contrary to those general traffic designs, Constanta created other designs with the focus on cycling or public transport.

Regulatory measures, such as the reduction of speed limit were implemented in Budapest and Constanta. In Lisbon and London streets are closed for motorised vehicles for the benefit of bicycle and bus transport or traffic directions/routing was changed, so that new spaces for liveable urban environments can be created. To improve traffic safety, some city-designs consider additional traffic lights or speed limit reductions as a regulatory measure (e.g. Budapest, Constanta, Lisbon).

Table 21: Measures of Designs Options in Comparison to the Current Condition of the Stress Section

	Design Options and Assignment to Key Priority	Measures of Design Options in Comparison to the Current Condition: Pedestrian Infrastructure			Place-Based Features	Cycling Infrastructure	Public Transport		Parking		Infrastructure for Motorised Vehicles		Regulatory Measures			Reorganisation	Nr. of Measures
		Extension of Sidewalk in Parts	Continuous Extension of Sidewalks	New Crossings	Greenery / Furniture	Cycle Lanes	Bus Lanes	Increased Frequency	Reduced Supply / Width	Increased Supply / Width	Reduction of Lanes	Additional Lanes	Reduced Speed Limit	Close of Street for User Groups	Traffic Lights	Level +1	
Budapest	1. Minor Modification			x											x		1
Budapest	2. Urbanistic Approach		x (at least at one or both sides)	x	x	x				x (bicycle)	x		x		x		8
Budapest	3. Transport Approach		x (at least at one or both sides)	x	x	x				x (bicycle + loading at night)	x		x		x		8
Constanta	1. Bus Lane (Instead Parking)						x		x								2
Constanta	2. Increased Bus Frequency						x	x	x								3
Constanta	3. Dedicated Cycle Lanes					x					x						2
Constanta	4. Wider Sidewalks + Speed Limit 30 km/h		x		x				x		x		x				5
Constanta	5. Signalized Junction														x		1
Constanta	6. Overground Passage for Vehicles											x				x	2
Constanta	7. Overground Passage for People															x	1
Constanta	8. Combined Option 1	x				x	x	x	x		x				x		7
Constanta	9. Combined Option 2	x			x	x			x		x				x		6
Constanta	10. Combined Option 3					x	x					x			x	x	5
Lisbon	1. Priority Parking		x							x	x						3
Lisbon	2. Priority of Public Transport						x				x						2
Lisbon	3. Priority of Cycle Lanes		x	x	x	x											4
Lisbon	4. Priority of Pedestrians, Bus and Greenery		x		x		x		x		x						5
Lisbon	5. Scenario Paiva Couceiro	x			x				x		x		x	x	x		7
London	1. Place Based - Pedestrian Priority	x		x	x	x (with bus)	x		x					x			7
London	2. Priority Public Transport	x		x		x (with bus)	x		x					x			6

Key Priorities: Focus on public transport | Focus on cycling | Focus on pedestrians/place users | Focus on general traffic (Individual motorized modes) | Designs as mixed options

Table 22: Description of Measures of Design Options from Malmö - Comparison Between Designs

		Description of Measures of Design Options (Comparison Between Designs)											
Design Options and Assignment to Key Priority		Pedestrian Infrastructure		Place-Based Features	Cycling Infrastruc-ture	Public Transport	Parking	Infrastructure for Motorised Vehicles	Regulatory Measures			Reor-ganisa-tion	Nr. of Measures
Malmö	1. Liveability	Widened Sidewalks and Implementation of Public Squares	7 Pedestrian Refuges	x	Unidirec-tional Cycle lanes on each side		Loading	One Lane per Direction	Reduced Speed Limit				7
	2. Sustainability	Continuous Sidewalks	5 Pedestrian Refuges + Middle Strip		Bidirec-tional cycle lanes on each side	Bus Lane	Moderate Supply and Load-ing	One Lane per Direction	Reduced Speed Limit				7
	3, Mobility	Continuous Sidewalks	4 Pedestrian Refuges			Bus Lane	Higher Supply and Loading	2 Lanes per Direction					5

Key Priorities: Focus on public transport | Focus on cycling | Focus on pedestrians/place users | Focus on general traffic (Individual motorized modes) | Designs as mixed options

In Table 22 the measures of the design options especially for Malmö are described. In the case of Malmö, the designs are compared with each other, since it is a new street design project and there is no existing street to compare with. The city of Malmö developed three designs for Nyhamnen:

1. Liveability with focus on pedestrians/place based measures
2. Sustainability with focus on cycling
3. Mobility with focus on general traffic

The first design shows a range of changes for improving the conditions for pedestrians and for creating new liveable urban environments that invite walking and place activities. Continuous and wide sidewalks, seven pedestrian refuges, new public squares and new greenery and street furniture are example measures in this first design. The supply for motorised vehicle is reduced. Only loading zones are considered to be implemented, no space is provided for parking activities. One lane for motorised vehicles for each direction should support traffic calming.

The second design is more ambitious in the provision for cycling. In comparison to the first design with one-directional cycle lanes, the second design contains bidirectional cycle lanes on each side. For the installation of those cycling lanes, the sidewalks are wide, but in comparison to the first design with a reduced sidewalk width. Bus lanes and a moderate supply of parking lanes are included into this second design.

The first pedestrian-focussed and the second cycling-focussed designs cover seven measures each.

The third design supports general traffic. In comparison to the before introduced designs, it includes two lanes for vehicle traffic, one bus lane and a significant higher supply of parking spaces for kerbside activities. Regular speed limit is planned with 40 km/h. Continuous sidewalks with a reduced width in comparison to the first design and no cycling infrastructure are considered.

In comparison to the liveability and sustainability layouts, the mobility design is less ambitious regarding the number of measures (five measures).

The generated design options (see Table 20) are analysed under different temporal traffic demand which results in the design packages. Constanta, Lisbon and London tested the introduced designs in each case for two time periods. Budapest decided to test four timeslots per scenario.

Malmö tested each of the three designs in up to three different demand scenarios and up to three different time periods. The demand scenarios include a “Business as Usual”-scenario with current demand pattern, a COVID-19-indicated “Working from home” scenario and changed demand according to the Malmö 2040 SUMP. Additional infrastructure such the introduction of a new bridge (reducing the need for through traffic along the Nyhamnen stress section), as well as a new mobility hub and the regulation of lowering the speed limit from 40 kilometres per hour to 30 kilometres per hour were tested. The mobility scenario using the current demand pattern without changes in traffic regulation or demand patterns can be interpreted as a base scenario.

The overview of the modelled design packages in Table 23 results from the design options plus one base scenario per city (besides Malmö) multiplied by the number of chosen time period. This means that in total there are 12 up to 22 design packages.

Table 23: Overview of modelled Design Packages per City and Time Slot

Time Period	Budapest	Con-stanta	Lisbon	London	Malmo
AM Peak	4	11	6	9	8
Inter Peak	4			9	7
PM Peak	4	11	6		7
Evening	4				
Total Design Packages	**16**	**22**	**12**	**18**	**22**

Overall, the cities have generated a range of different and city-specific designs for their stress sections. The design packages address distinctive user groups and needs of different transport modes under different demand patterns.

6.3 Modelling exercises

The modelling exercises help to understand the street performances with current or future demand patterns for the different design options. All city-partners modelled the set of design packages with PTV micro simulation tool Vissim. This chapter presents the methodology and results of these modelling exercises for Budapest, Constanta, Lisbon, London and Malmö.

All the models use the design packages (see chapter 6.2) and the user demands as an input but with different approaches: Budapest, Constanta, Lisbon and London started with a calibrated base scenario of the current street design. Budapest set up the Vissim model using traffic data for vehicles and pedestrians as well as public transport stop passenger data. The model was calibrated using floating car measures. Overall, eight vehicle categories (car, three types of lorries; motorcycle, bicycle, other micro mobility devices) were considered.

Constanta set up the base scenario with data related to the geometrical details of the junction, desired speed distribution, vehicle volumes and pedestrian volumes without information on calibration.

Lisbon modelled the network using nodes and sections. The traffic demand (from counting, see chapter 5.4) was fed into the model and used for calibration. Calibration was tested for AM peak and all user groups (car, light truck, heavy truck, motorcycle and bicycle) – besides of pedestrians – with good results. London had already calibrated and validated a 2019 Vissim model for the AM and PM peaks for the stress section. Modelled vehicles are cars/light goods vehicles, taxis, medium goods vehicles, heavy goods vehicles, motorcycles, and pedal cycles. Pedestrians were added to the model for specific areas.

Malmö did not have a base model for current street design because the stress section Nyhamnen does not exist so far. Therefore, the Malmö team set up the Vissim model with the different designs and traffic volumes, taken from forecasts.

Malmö as well as London have models capturing a larger area than the stress section. Whilst London did only cover the stress section in modelling exercises, Malmö chose a mesoscopic approach with modelling Nyhamnen (stress section) within the Malmö city-wide model. In this case, network and design in the wider area are kept for all simulations regardless of the design within the stress section.

For each model, MORE-cities collected data and computed performance indicators as an output to compare street design impacts. Table 24 shows the considered indicators for each city[2]. Each indicator was computed for each scenario either at one or more locations of the stress section or on network or stress section level. The overview shows, that overall more indicators were used for (motorised) vehicles than for any other user group. The reduced indicator list provided by TUD with its focus on motorised transport is most likely one reason for this (see Appendix 2).

Table 24: Modelling Indicators Collected per City

User Group	Indicator	Budapest	Constanta	Lisbon	London	Malmo	Total per Indicator/User Group	
Pedestrians	Volume	x		x			2	7
	Pedestrian LOS/Density (ped/m²)	x		x	x		3	
	Pedestrian Speed	x		x			2	
Cyclists	Cyclists Average Speed	x*			x		2	4
	Cyclists Average Delay	x*			x		2	
Buses	Average Travel Time [s]			x			1	2
	Average delay [s/veh]			x			1	
Others	Emissions			x	x	x	3	3
Vehicles	Volume	x		x	x		3	27
	Nr. of stops	x		x			2	
	Vehicle Density	x			x		2	
	Vehicle Average Speed	x	x		x	x	4	
	Average Travel Time	x	x	x		x	4	
	Average queue length (m)			x			1	
	Average delay [s/veh]	x	x	x	x	x	5	
	Average delay stopped [s/veh]	x	x			x	3	
	Vehicles' level of service	x		x	x		3	

x* Budapest considered indicators over all user groups

[2] This overview is not complete: indicators that are equal to other ones are not displayed here as well as indicators that have only been mentioned but not discussed by the city reports in D5.3.

The following paragraphs contain descriptions of modelling results per city with focus on pedestrian/place oriented design impacts and a summary of modelling exercises assessment.

The Budapest results for pedestrians show that speed of pedestrian is not affected by the design (average speed ranges from 2,9–3,1 kilometres per hour with the lowest speed in evening hours and the highest speeds in AM Peak even though the pedestrian flows are the highest in PM Peak).

Regarding motorists and all other user groups performance, users average delay and speed were in focus of the study. The highest speeds and lowest delays are reached with the base scenario over all time periods. Advantages and disadvantages for the different user groups are not considered, thus e.g. the impact of the implemented bicycle lanes in the mixed approach on bicycle speed and delay cannot be analysed.

Interesting observations for the Budapest results are:

- The scenario of motorists results in very high delays and low speeds even if the design has only minor modifications compared to the base scenario which could be caused by changes in junction signalling schemes.
- The mixed scenario (transport approach) has in (besides the base scenario) the best results for all user groups even though width of motorist lanes is reduced to gain space for place activities.

Constanta only analysed performance indicators for motorised vehicles. The results show the biggest effect in motorised traffic quality when traffic regulation is changed from the current roundabout to a signalised junction. With traffic lights, vehicle delay increases by 250 percent (PM) up to 350 percent (AM) and average speeds decreases by 35 percent (PM) up to 40 percent (AM). This indicates that the signalised junction is more effective with higher volumes (PM) but still results in lower performance compared to the current roundabout and is therefore not recommended as a proposed design.

The overall best results for motorised vehicles in terms of traffic quality are achieved with the overfly bridge for vehicles, where vehicles do not have to interact or yield to other users. This measure is a massive intervention and a barrier for pedestrians and for place activities underneath the passage, this solution should therefore not be considered further in the context of the MORE-project with its clear focus on the environmentally friendly modes and high quality street spaces inviting place activities.

For the remaining scenarios, there is no clear evidence for the best design. The scenario with an increased bus frequency and additional bus lanes (Key Priority: Focus on Public Transport Measures) and also the bike lane scenario (Key Priority: Focus on Cycling Measures) show good results.

Three interesting observations for the Constanta results are:

- The reduction of lanes for motorised vehicles per direction from 3 to 2 in the arms does not affect speeds and delays as much as expected and as much as other measures.
- The reduction of speed limits from 50 to 30 kilometres per hour does only change average speeds slightly. Speeds are slow over all designs and especially in PM peak when the junction is busy. Thus a speed limit reduction at least in the afternoon would not affect traffic significantly but make the area around CORA-Junction less noisy, safer and more attractive for place users.
- The implementation of a passage for pedestrians does not increase the performance of motorised users. Pedestrians should be kept crossing on carriageway level.

The Lisbon results give information on pedestrian and vehicle performance. For pedestrians the following findings appeal: the largest widening of the sidewalk (Mixed Option) has the best pedestrian LOS results, but also small widening can increase LOS for pedestrians. Considering air quality as an indicator for quality for pedestrians and place activities, the best results come with the PT priority scenario.

Regarding performance indicators for motorised vehicles, travel time and delays for buses and individual vehicles were analysed. For vehicles, the design has only slight impacts on travel time at large parts of the stress section with low volumes (direction east). With higher volumes (direction west), it shows that travel time and vehicle delays are highest with reduced number of lanes without additional bus lanes. The best results were identified in the PT oriented and mixed scenarios (reduction of traffic lanes and addition of bus lanes in either one or two directions). The impact of those designs on the performance of buses is present but small. Also regarding queue length, the PT oriented and mixed scenarios show the best results.

Interesting observations for the Lisbon results are:

- The reduction of lanes per direction for motorised vehicles increases travel times and vehicle delays without additional bus lanes but not when additional bus lanes are introduced.
- The Square Scenario (Key Priority: Focus on Measures for Pedestrians/Place Users; Praça Paiva Couceiro converted from a “roundabout” distributing traffic from main street to the neighbourhood to an attractive square for place usages) shows negative impacts in terms of delays and queue length at the streets surrounding the square but not at the square itself. Redesigning the square seems to be a good option for encouraging place activities when traffic can be shifted to other streets.
- The mixed scenario (designation of one general traffic lane into a bus lane in one direction, widening the sidewalk, adding greenery) which is the most attractive for pedestrians and place users on stress section level, shows good results for motorised vehicles as well.

In London, similar to Lisbon, pedestrian density and pedestrian LOS were analysed: Pedestrian LOS shows good performance levels (Level A) over almost the whole stress section for each scenario. Poor LOS are found at and next to public transport stops with different effects at different parts of the stress section and within the design options, thus a clear ranking of pedestrian friendly designs is not feasible.

The emission analysis shows the best results with the current design for each indicator. The public transport priority design shows overall better results than the pedestrian/place oriented design.

Vehicle density is already high in the current situation but even higher with both considered alternative designs. The assessment of the designs in terms of their impacts on average speed and delay is difficult (see below). Average speed of buses is comparable to general traffic speed and can partly be increased with the PT-Scenario (Key Priority: Focus on Public Transport Measures).

Interesting observations for the London results are:

- The appraisal shows different results for the two hours modelled in PM Peak: The public transport as well as pedestrian priority designs lead to higher average speeds and lower delays for all users and motorists with low demand (Hour 1) but contrary effects with higher demand (Hour 2). This indicates that the adaption of street designs with priority for pedestrians is feasible if overall network demand is not exceeded.

- Cyclists' speed is generally the highest, thus also higher than motorises speed (and delays are consequently lower) in each design and simulation option – cyclists are the less disturbed user group in the stress section even when they do not have a dedicated facility (Base Scenario)

- As London design options rather contain punctual than linear modifications for pedestrians, pedestrian density is not changed significantly in any of the investigated scenarios.

The Malmö results, on the one hand, compare different design options and, on the other hand, compare different demand patterns. In Malmö as well as in Constanta, only indicators for motorised vehicles were analysed. The mobility scenario shows the highest average travel time and highest delays with lowest average speed for motorised vehicles at AM peak which is unexpected because this design should particularly support traffic quality for motorised users. At PM peak, the mobility scenarios show good results. The best results for both time periods and demand patterns are achieved with the liveability scenario in combination with a speed limit reduction to 30 kilometres per hour and working from home demand pattern. The environmental impact analysis supports this result: the liveability scenario leads to the lowest emissions.

The impact of design is the lowest at interpeak when traffic demand is generally low: the performance indicators are almost equal overall design options and simulations for this time period.

This section should focus on the design option appraisal which is difficult in Malmö because demand patterns are chosen individually for each design option. It is assumed, that the good results for the sustainability scenario are based on reduced commuter volumes and thus also reduced overall demand. Nevertheless, the modelling results show that sustainable or liveable scenarios are preferable solutions especially for place-focused designs if there is a change in vehicle demand.

Interesting observations for the Malmö results are:

- The implementation of a bridge close to the stress section (in order to reduce the need to through traffic along the stress section) reduces average travel times and delays on the stress section but only with the mobility scenario. The bridge does not change performance indicators for motorised vehicles if traffic demand is low (sustainability scenario).
- The sustainability scenario is rated almost as good as the liveability scenario under the same conditions (speed limit 30 km/h; no additional bridge).
- Most of the differences between the studied scenarios result from changes in street network capacity outside the stress section and from the varying overall traffic volumes; this is a consequence of the mesoscopic modelling approach.

In general, it turned out that the analysis of the different design packages via micro-simulation is tough especially for pedestrian and place user needs because the simulation tools are traditionally focused on the assessment of traffic quality for motorised vehicles, measured for example as LOS. This can be seen, for example, in Constanta, where the best rated solutions are unattractive for place users. In contrast, Lisbon and Malmö identified designs that perform well for all user groups. In summary, modelling exercises show:

- MORE-cities used different approaches to set up and run the Vissim models – some built and calibrated a model in the MORE-project from scratch, some used an existing model; Malmö used a mesoscopic model, all the other cities applied only microscopic models.
- Four of the MORE-cities decided to model rather a few number of design options (with complex changes) under different conditions and one MORE-city modelled a high number of designs (with few changes) but the effect sizes of the observed indicators is hardly related to the number of changes.
- MORE-cities modelled at least two timeslots with the higher demand timeslot showing stronger effects in the performance indicators for motorised vehicles. This indicates that vehicle volumes (and speed) are two parameters of highest relevance for urban street design. The model results show that many (also place activity friendly) designs are possible if volumes of motorised vehicles are moderate.
- Indicators used to assess modelling results focus on motorised vehicles – bicycle and pedestrian indicators were only tested in one respectively two cities, thus the best rated designs are basically the best designs for motorists.

- Environmental impact was analysed by three of the MORE-cities but mostly the best results came out for the scenarios with priority for motorised traffic. This is logical, since an increased number of stops, for example, has a negative impact on the environment. However, there are also methodological limitations to be mentioned here, since additional trees in the design options have a positive influence on the environment, which cannot be represented in Vissim. Also the effects of changes in demand resulting from changes in street design have hardly been considered.
- Regarding measures that improve place quality, speed limit reduction (to 30 km/h) was tested in two cities with reasonable results for motorists: no significant deterioration of traffic quality was found because speeds are low anyway.
- Also the reduction of general traffic lanes or narrowing traffic lane width was tested in four cities (to give space either to public transport, bicycles or pedestrians/place activities). The modelling results show that traffic quality for motorised vehicles is partly very sensitive to this measure but taking out one lane for general traffic for the benefit of other groups is mostly feasible.

6.4 Results from Appraisal Tool

The MORE appraisal tool compares the positive and negative forecasted impacts of different options for road design and roadspace allocation. The tool performs three types of appraisal:

- Political and Technical Assessment - Impacts are measured in terms of how they conform to political priorities, legal standards, and best practice.
- Cost-Benefit Analysis - Impacts are monetised, where possible
- Multi-Criteria Analysis - Different assessors assign different priorities to different impacts. The options are then ranked.

The three types of appraisal are separate. In practice, tool users will perform only the types for which they have sufficient data. The table below shows the appraisal work done by the MORE cities. Budapest has not performed any appraisal work. The other four cities completed at least one type of appraisal. Constanta and Malmö completed the Political and Technical Assessment. Lisbon and London completed the Political and Technical Assessment and Multi-Criteria Analysis. None of the cities completed the Cost-Benefit Analysis. This was because data on implementation and maintenance costs of the options (a required input) was not available (Constanta), unit monetary values of performance indicators (another required input) were not available in national-level government publications (Constanta, Lisbon), or because values were only available for movement activities (not place activities), which would render the results biased towards the options that prioritize movement of cars, yielding large negative net benefits for those options (London, Malmö).

Table 25 Appraisal work done by MORE cities

	Budapest	Constanta	Lisbon	London	Malmö
Number of options included in appraisal (including „do nothing“)	0	3	5	2	3
Political and Technical Assessment		Yes	Yes	Yes	Yes
Cost-Benefit Analysis					
Multi-Criteria Analysis			Yes	Yes	

The tool requires basic inputs about each of the options appraised. This includes implementation and maintenance cost, the allocation of road space (how much width is allocated to each design element), and other characteristics of the road design (e.g. pedestrian crossings, type of cycle infrastructure, parking spaces, cycle parking, bus stops, loading bays, micromobility regulations, provision for pedestrians with disabilities). As shown below, all the information was supplied by the cities, except, in the case of Constanta, the options implementation/maintenance costs. This means none of the results of the Constanta appraisal considers cost.

Table 26 Basic information on options

	Constanta	Lisbon	London	Malmö
Implementation and maintenance cost		Yes	Yes	Yes
Roadspace allocation	Yes	Yes	Yes	Yes
Other elements of road design	Yes	Yes	Yes	Yes

The appraisal tool was designed to support a wide range of performance indicators. In practice only some of those indicators will be measured by the tool users. Table 27 shows the movement performance indicators used by the MORE cities in the appraisal. The first column shows the performance indicators. The other columns show the mode of transport for which the indicator was estimated by cities and inputted into the appraisal tool. The set of indicators collected is biased towards motorised modes. Indicators for pedestrians were used by Lisbon only (although Constanta also estimated volume of pedestrians). Indicators for cyclists were only used by Lisbon and London. None of the cities estimated any indicator for micromobility vehicles.

Apart from the indicators below, the tool calculated automatically, from the basic information supplied about the options (that in Table 26), indicators of provision of space for the various modes of transport.

Table 27 Performance indicators used by cities in appraisal (Movement)

Performance indicator	Constanta	Lisbon	London	Malmö	Not used by any city
Volume	Pedestrians; cyclists; buses; cars/taxis	Pedestrians; cyclists; buses; cars/taxi; motorcyclists; goods vehicles	Cyclists; buses; cars/taxis; goods vehicles	Buses; cars/taxis; goods vehicles	Micromobility
Speed	Cars/taxis	Pedestrians; cyclists buses; cars/taxi; motorcyclists; goods vehicles	Cyclists; buses; cars/taxis; goods vehicles	Buses; cars/taxis; goods vehicles	Micromobility
Travel time	Cars/taxis	Pedestrians; cyclists buses; cars/taxi; motorcyclists; goods vehicles	Cyclists; buses; cars/taxis; goods vehicles	Buses; cars/taxis; goods vehicles	Micromobility
Delays	Cars/taxis	Pedestrians; cyclists buses; cars/taxi; motorcyclists; goods vehicles	Cyclists; buses; cars/taxis; goods vehicles	Buses; cars/taxis; goods vehicles	Micromobility
Reliability			Cyclists; buses; cars/taxis; goods vehicles	Buses; cars/taxis; goods vehicles	Pedestrians; micromobility; motorcyclists
Trip quality		Pedestrians			Cyclists; Micromobility; buses; cars/taxis; motorcyclists; goods vehicles

Table 28 shows the place performance indicators used by the MORE cities in the appraisal. The first column shows the performance indicators. The other columns show the type of place activity for which the indicator was estimated by cities and inputted into the appraisal tool. Again, the set of indicators collected is biased towards motorised modes, especially car parking and bus stopping. Malmö used an indicator of number of cycling parking activities. Lisbon and London also considered some indicators of people-based activities. None of the cities considered parking of shared cycling, or car share parking.

Apart from the indicators above, the tool calculated automatically, from the basic information supplied about the options (that in Table 26), indicators of provision of space for the various types of placce activities.

Table 28 Performance indicators used by cities in appraisal (Place activities)

Indicator	Constanta	Lisbon	London	Malmö	Not used by any city
Number	Bus stopping	Car parking; bus stopping; strolling; sitting (street furniture)	Car parking; all people-based activities	Cycle parking; car parking; car/taxi stopping; bus stopping; loading	Cycle parking (dock); cycle parking (dockless); car share; sitting (café)
Duration		Car parking; bus stopping	Car parking; all people-based activities		Cycle parking; Cycle parking (dock); cycle parking (dockless); Car/taxi stopping; car share; loading; sitting (street furniture); sit (café)
Quality		Car parking			Cycle parking; Cycle parking (dock); cycle parking (dockless); Car/taxi stopping; ; car share; bus stopping; loading; sitting (street furniture); sit (café)

Table 29 shows the performance indicators related to wider policy objectives used in the appraisal. The first column shows the type of performance indicators. The other columns show individual indicators estimated by cities and inputted into the appraisal tool. Few indicators were used. Lisbon used two economic indicators. None of the cities used any social indicator. Lisbon, London, and Malmö used indicators on air pollution and/or energy consumption.

Apart from the indicators above, the tool calculated automatically, from the basic information supplied about the options (that in Table 26), indicators of green space; inclusion of pedestrians with disabilities and community severance (which is based on number and type of pedestrian crossing facilities and traffic volume and/or speed)

Table 29 Performance indicators used by cities in appraisal (Wider policy objectives)

Type of indicator	Constanta	Lisbon	London	Malmö	Not used by any city
Economic		Transport costs; visits to local businesses			Property values; expenditure in local businesses
Social					Traffic safety; personal security; physical activity; social interaction; wellbeing
Environment		PM10, No2; energy	No2	Energy	PM2.5; noise; soil and water; local climate; CO2 emissions

The table below shows the results of Political and Technical Assessment. In general, and as expected, designs giving priority to a given mode performed best for performance indicators related to that mode. In all cities, some violations of political priorities and/or of technical standards were observed, for all options, all options except the "do nothing" one, and some of the options only.

Table 30 Results of Political and Technical Assessment

	Constanta	Lisbon	London	Malmö
Best options	• The two options to redesign the road were better than the "do nothing" option for the movement of cyclists and buses and better for the movement of private motorised modes	• The option giving prioriry to pedestrians and green areas was the best for all indicators of movement by pedestrians • The option giving priority to public transport was the best for all indicators of movement by bus • The option giving priority to parking/loadign was best for space provided and number of parking activities, but not best for duration and quality of those activities • The "do nothing" option was the best for all indicators of movement by car, motorcycle, and goods vehicles	• The "do nothing" option was the best for all movement indicators. • Of all place indicators included in the assessment, the only instances of options being preferred to others was for the place-oriented option, which was best for: "duration of car parking", width available for bus stops, and duration of people-based activities • Air pollution was much worse in the "do nothing" option than in other options	• The "liveability scenario" was the best for pedestrians, place activities, and community severance • The "sustainable scenario" was the best for bus movement, cycle movement and parking, car/taxi stopping, loading, and energy consumption • The "mobility scenario" was the best for the movement of car/motorcycle/goods vehicles, and car parking
Violations of political criteria	• All options to redesign the road increased community severance, violating the political priority to pedestrians crossing the road (inputted by the city in the tool) • All options to redesign the road did not provide more space for people-based activities, violating the political priority to these activities	The option prioritizing buses violated technical standards for the width of lanes for the movement of general traffic	All options to redesign the road provided no space for cyclists, violating the political priority to cyclists (inputted by the city in the tool)	• The "mobility scenario" and "sustainability scenario" did not increase space for people-based place activities, violating the priority for those activities (inputted by the city in the tool). • All options to redesign the road provided no extra space for buses, violating the political priority to bus movement (inputted by the city in the tool) • All options to redesign the road provided no space for shared cycle parking, violating the political priority to this mode
Violations of technical standards	All options (including the "do nothing") violated principles of inclusive design (no provision made for pedestrians with disabilities)	All options except the one prioritizing pedestrians violated principles of inclusive design (no full provision made for pedestrians with disabilities)	All options (including the "do nothing") violated principles of inclusive design (no provision made for pedestrians with disabilities)	

Table 31 shows the results of the multi-criteria analysis. In Lisbon, the assessment was conducted by three assessors. The option that gave priority to buses was better for movement and environment aspects. The option that gave priority to parking/loading was better for place activities and economic aspects

In London, the assessment was conducted by one assessor only, so the results have a higher degree of implicit subjectivity than in Lisbon. The "do nothing" was ranked first. This is explained by the fact that the vast majority of performance indicators collected were for movement (which is consistently better in the "do nothing" option, which does not give priority to public transport and place activities).

Table 31 Results of Multi-Criteria Analysis

	Lisbon	London
Number of assessors	3	1
Results	• The option that gave priority to buses was better for movement and environment aspects • The option that gave priority to parking/loading was better for place activities and economic aspects	The "do nothing" option was ranked first, followed by the options that give priority to public transport and the options that give priority to place activities

Overall, the use of the appraisal tool highlighted differences in the merits of the different options for road redesign. Some bias was observed for options that emphasize private car traffic (i.e. the "do nothing" options. This is explained by the fact that more indicators of movement were collected and inputted in the tool than indicators of place activities or wider economic, social, and environmental objectives.

7 Summary and Generic Conclusions

This deliverable presents the cross-site assessment of the design exercises in the five MORE-partner cities for each individual stress section. It is based on the work done by each city individually as presented in D5.3 and in D5.4. All city partners were highly engaged in developing design solutions for their stress sections. They all succeeded in organising stakeholder engagement activities despite COVID19-restrictions with some great innovations such as online or on-site formats for stakeholder engagement. The developed design packages span a wide range of proposed design changes with different priorities. The designs that focus on pedestrians and place activities give an idea of what is possible for these streets with limited available space and with high levels of movement and place functions.

All cities set up Vissim models for simulating the effects of the different design packages in terms of performance indicators for the movement and the place functions including also wider impacts. The final indicators chosen by the cities for the assessment focus on traffic quality for motorised vehicles including also air pollutant emissions. This is consistent with the focus of the used simulation tool Vissim which is most advanced and sensitive for motorised vehicles. Future further functionalities particularly for pedestrian activities and place activities would support designers' ambitions in prioritising these user groups and in demonstrating positive effects for scenarios that re-allocate street space towards these user groups.

The results of the modelling exercises are encouraging. They show that it is possible to assign more space to the environmentally friendly modes and also to place activities. Volumes and speed of motorised vehicles are key factors to be considered, their reduction is related to various positive side effects e.g. in terms of safety particularly for the vulnerable street user groups.

The *Street Performance Assessment Scheme* (SPAS) and its implementation in the appraisal tool proved suitable for the appraisal of the design options but sophisticated. None of the MORE-cities computed all of the SPAS-indicators for comparing the different design options. The main reason for this is that none of the MORE-cities actually implemented changes in the physical design of their stress sections on-site. The whole appraisal relies on the Vissim modelling exercises and so does the choice of the indicators. Even though the SPAS was only applied in parts for the comparison of the different design options, it was helpful for the empirical analysis of the current conditions in the stress sections. This analysis covered all parts of SPAS comprehensively as shown in Chapter 5 of this deliverable and particularly the insights gained on pedestrian and place activities in the current conditions were a valuable input for developing the alternative design packages.

The whole SPAS focusses on the impacts of street use in the different scenarios. In the analysis, the missing consideration of the complete streetscape with all its components turned out to be a missing piece. Therefore, a new task was created to widen the scope of the cross-site assessment. The objective of this new task was to derive and apply indicative values to the individual components of a typical streetscape, and to illustrate their individual and combined contribution to carbon emissions and energy consumption (see Appendix 3). Application of these values to a typical existing and a future streetscape (both virtual) provided an indication of the carbon savings achievable using interventions and investments already available, in addition to the savings to be had from changes to physical mobility. Elements considered included road surfacing, capital carbon of the vehicles on that road, bus stops, vegetation, underground utilities etc. An attempt was made to conclude a carbon footprint value for the lifecycle of each streetscape element (from cradle to grave), however data to this effect was not always available. The results of this work are presented in the Appendixes to this deliverable, they are a valuable complement to the various impacts of street use that are covered by SPAS and the MORE appraisal tool.

We do hope that the work done in the five MORE-cities encourages stakeholders in other cities to dare to take on ambitious street designs. It is worth the effort, cities all over the world convincingly demonstrate the gains from giving street space back to the environmentally friendly transport modes and particularly to place activities. Successful cities are liveable cities and liveable cities are cities with attractive streets and public spaces.

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Appendixes

Appendix 1: Instructions for Data Provision sent in February 2021

MORE
Multimodal Optimisation of Roadspace in Europe

Evaluation of Alternative Design Solutions in the MORE Stress Sections

Instructions for Data Provision (February 2021)

Start date of project:	1st September 2018	Duration:	36 months
		Version:	2
		Prepared by:	Regine Gerike, Caroline Koszowski, Bettina Schröter (TUD), Peter Jones, Paulo Anciaes (UCL)
		Checked by:	x
		Verified by:	x
		Status:	x
		Dissemination level:	PU/CO

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769276

1 Introduction

This document provides guidance for MORE partners on the data that will need to be recorded about the exploration of potential street design elements, the generated street design options for the MORE stress sections and, for the ones that are taken forward for modelling and appraisal, subsequent information on how each design option performs.

The document will be used:

a) By the city itself in preparing reports D5.3 and D5.4 (design options for the current and future conditions on the stress section); and

b) By TUD in the cross-city evaluation of the options (Task 5.5 and report D5.5).

The data mainly comprises the inputs and outputs of the four sets of MORE tools, as specified in the following sections. Most of this data will be automatically generated by the tools, as indicated below.

Rows highlighted in green identify data that needs to be collected manually by the cities (in spreadsheets). Rows not highlighted identify data that is automatically produced and saved when using the tools (upon request, in the case of the Appraisal tools).

The data listed in the tables below might be collected and presented at different spatial levels (e.g. whole modelled network or major junctions in Vissim, or the full stress section in the Appraisal tools).

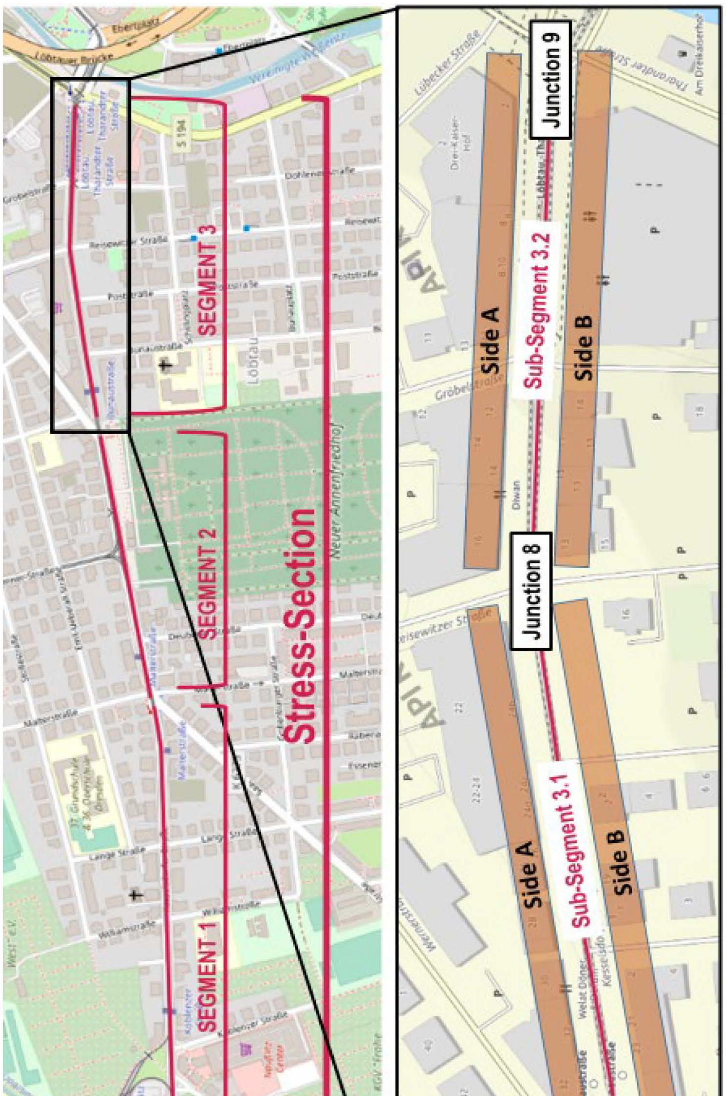
There are five potential spatial levels that might be appropriate in different contexts:

1. **Network level** (only applicable to some Vissim outputs)
2. **Stress section**: basic level for most Vissim variables and the appraisal outputs
3. **Segment**: basic level for stakeholder engagement (as in most cases the whole stress section is too long to be examined in one go)
4. **Sub-segment**: a finer spatial resolution within a segment, used for defining the location of cross-section design optioneering (in the second option generation tool) and maybe for looking at things such as kerbside efficiency.
5. **Major junctions** – which might be critical points along the stress section and generally define the boundaries between segments and sub-segments.

Please include a figure with an overview of the whole stress section, its segments and sub-segments and any key junctions (see an example in Figure 1). Please number each Segment from left to right (or top to bottom) as S1 to Sn, Sub-segments within the appropriate segment (e.g. S1.1. S1.2...S1.n) and Junctions from J1 to Jn.

In addition, for some types of analysis it will be necessary to know which side of the street the data applies to; so please define **'Side A' and 'Side B'**, as shown below. Should it be necessary to identify individual street design elements, such as bus stops or pedestrian crossings, then please add to your map with a unique identifier (e.g. BS1 = bus stop 1).

Figure 1: The spatial components within the stress section



2 Option Generation using web tools

The input and output data from the option generation web tools (i.e. Policy Interventions tool and Road Designs tool) will be automatically saved when using the tools and sent to the Buchanan Computing server, then forwarded to UCL. No action is required by the cities.

Table 1: Policy Interventions (P) using web tools: input data

Code	Data
OGP_in1	Name of city
OGP_in2	Segment number (e.g. S1)
OGP_in3	Priorities given to the different road uses
OGP_in4	Selection of policy objectives

Table 2: Policy interventions (P) using web tools: output and application data

Code	Data
OGP_out1	List of Policy Interventions generated
OGP_out2	List of options investigated
OGP_out3	Extent to which each option investigated (whether Description, Road Uses, Objectives, and Evidence tabs were open)
OGP_out4	Interventions that were selected, from the list provided by the tool, as being potentially feasible options
OGP_out5	Interventions that the city is planning to use as part of a specific design option exercise

Table 3: Road designs (D) using web tools: input data

Code	Data
OGD_in1	Name of city
OGD_in2	Sub-segment number (e.g. S1.1)
OGD_in3	Space currently allocated to each design element, in a cross-section view of the road
OGD_in4	Priorities given to the different design elements

Table 4: Road designs (D) using web tools: output and application data

Code	Data
OGD_out1	List of options generated for the cross-section allocation of design elements
OGD_out2	Cross-section options that were selected, from the list provided by the tool, as potentially feasible options.
OGD_out3	Ranking of the five best options among the ones selected as feasible (1-5)
OGD_out4	Cross-section options that the city is planning to use as part of a specific design option exercise

3 Stakeholder engagement

This includes both the preparations for the design exercises and the input and outputs of the design exercises themselves - using the physical toolkit and Line Map, and the web consultation using TraffWeb.

Table 5: Stakeholder engagement preparations (P): input data for each event

Code	Data
SEP_in1	Name of city
SEP_in2	Details of method used to select/recruit stakeholders
SEP_in3	List of affiliations and characteristics of participants taking part in the in-house and 'design days' events

The template for Table 5 will be provided by UCL (*MORE Data provision Table 5 - Stakeholder engagement preparations inputs.docx*).

Table 6: Stakeholder engagement exercises (E): Unique Identifier for each design option

Code	Data
SEE_uid1	Name of city (first three letters)
SEE_uid2	Segment (e.g. S1)
SEE_uid3	Season (Spring, Summer, Autumn, Winter, all)
SEE_uid4	Day of week (Weekday, Saturday, Sunday, all)
SEE_uid5	Time of day (Morning peak, Evening peak, Off-peak, all)
SEE_uid6	Specific design conditions (weather, emergency, etc)
SEE_uid7	Street use priorities (allowing for a maximum of 8 use priorities)

A Unique Identifier is required to ensure that the same design can be tracked through the whole design process (i.e. physical toolkit, Line Map, TraffWeb, Vissim, appraisal tool). The unique identifier is derived from combining the variables in Table 6.

If you start the design process in Line Map, you will be asked to complete this table at the start of your session.

If you start by using the physical toolkit (blocks and acetates), then you need to fill a spreadsheet provided by UCL (*MORE_UniqueIDGenerator.xlsx*).

The unique identifier code will identify the option in all stages that follow (stakeholder engagement, option modelling, and option appraisal). The code will have the following format:

ABC_Sijklmn_opqrstuv

Where:

- 'ABC' are the first 3 letters of the city
- 'Si' identifies the road segment (within the stress section) ("S" plus an integral number starting from 1)
- 'j' is the season (0=all, 1=spring, 2=summer, 3=autumn, 4=winter)
- 'k' is the day of week (0 for all days, and 1-7 for other days)
- 'l' is the time of day (0=all times, 1=morning peak, 2=evening peak, 3=off-peak)

- ‘m’ is for any specific conditions (0=no specific conditions, 1=special events, 2=extreme weather conditions, 3=emergencies)
- ‘n’ is for the year to which the design relates (4-digit code)
- ‘o’ to ‘v’ are letters identifying up to 8 street use priorities (if less than 8 uses have priority, the remaining components are identified as "0").

Table 7: Stakeholder engagement exercises (E): output data - for each design option

Code	Data
SEE_out1	Unique Identifier for option
SEE_out2	Whether design option was based on option previously generated with the ‘policy interventions’ tool
SEE_out3	Whether design option was based on option previously generated with the ‘road designs’ tool
SEE_out4	Whether design option is to be taken forward for modelling and appraisal
SEE_out5	Map showing the characteristics of the design option with the location of the design elements
SEE_out6	Number and lengths assigned to each footway and kerbside design element
SEE_out7	Number and average road widths assigned to each carriageway design element
SEE_out8	Advantages of each option, as reported by stakeholders
SEE_out9	Disadvantages of each option, as reported by stakeholders

If you carry out the design option exercises in LineMap, you will be asked to complete Table 7 at the end of your session. Instructions on filling in this data are provided in the LineMap Training Guide.

If you carry out the design option exercises using the physical tool kit (blocks and acetates) and the resulting designs are transferred into LineMap, then the table can be completed in LineMap.

If you carry out the design option exercises using the physical tool kit (blocks and acetates) but the resulting designs are not transferred into LineMap, then Table 7 needs to be input into a spreadsheet. UCL will provide a data input sheet for this purpose (*MORE_physicaltoolkit_information_template.xlsx*).

Table 8: TraffWeb (T): ‘Issues’ application

Code	Data
SET_iss1	Name of city
SET_iss2	Segment
SET_iss3	Dashboard outputs

Table 9: TraffWeb (T): Design options consultation - for each design option

Code	Data
SET_do1	Unique Identifier for option
SET_do2	Opinion about effects on street uses
SET_do3	Opinion about space allocated to design elements
SET_do4	What respondent likes about the design option
SET_do5	What respondent dislikes about the design option
SET_do6	Rating of the option (1-10)
SET_do7	Suggests for improving the option
SET_do8	Respondent interest
SET_do9	Mode of transport
SET_do10	Age group
SET_do11	Gender
SET_do12	Contact information (optional)

4 Option Modelling

Input and output data is needed for the appraisal of the design options. Most of the outputs of the modelling stage will come directly from Vissim. Each option will be identified by its unique reference number.

Information will be provided on how to extract this information from Vissim.

Table 10: Option modelling: input data - for each design option

Code	Data
OM_in1	Unique Identifier for option
OM_in2	Screenshot of the modelled network (including all network objects and scale bar)
OM_in3	Desired speed distribution (name of standard distribution or values of individual distributions)
OM_in4	Entering vehicle input volumes
OM_in5	Pedestrian input volumes
OM_in6	Pedestrian distancing values (modelling parameters e.g. due to COVID-19 social distancing)

Table 11: Option modelling: output data - for each design option

Code	Data
OM_out1	Unique Identifier for option
OM_out2	Volume [veh/h] - per **segment** - for each type of vehicle - average across simulation runs
OM_out3	Vehicle density [veh/m] - per **segment** - for motorised vehicles and bicycles - average across simulation runs: as plot with colour scheme according to Table 12
OM_out4	Pedestrian density [ped/m^2] (measurement based on grids) - per **sub-segment and side of road** (A & B) - for typical simulation runs: as plot with colour scheme according to Table 12
OM_out5	Number of simulation runs where threshold F (see Table 12) of Pedestrian density is exceeded - for at least one **sub-segment and side of road**
OM_out6	Pedestrian density experienced [ped/m^2] (measurement based on grids) - per **sub-segment and side of road** (A & B) - for typical simulation runs: as plot with colour scheme according to Table 12
OM_out7	Number of simulation runs where threshold F (see Table 12) of Pedestrian density experienced is exceeded - for at least one **sub-segment and side of road** (A & B)
OM_out8	Maximum, minimum, and average number of pedestrians who were waiting for a public transport vehicle - per **segment** - average across simulation runs
OM_out9	Average travel time [s/veh] = Total of travel times / number of vehicles - at **network level** - for motorised vehicles and bicycles - average across simulation runs
OM_out10	Variance and 95% percentile of average travel times across simulation runs - at **network level** - for motorised vehicles and bicycles
OM_out11	Average travel time [s/veh] = Total of travel times / number of vehicles [for the **stress section**] - for motorised vehicles and bicycles - average across simulation runs
OM_out12	Variance and 95% percentile of average travel times across simulation runs [for the **stress section**] - for motorised vehicles and bicycles
OM_out13	Average delay [s/veh] = Total of delay / number of vehicles - at **network level** - for motorised vehicles and bicycles - average across simulation runs
OM_out14	Variance and 95% percentile of average delay across simulation runs - at **network level** - for motorised vehicles and bicycles
OM_out15	Average delay [s/veh] = Total of delay / number of vehicles [for the **stress section**] - for motorised vehicles and bicycles - average across simulation runs
OM_out16	Variance and 95% percentile of average delay across simulation runs [for the **stress section**] - for motorised vehicles and bicycles
OM_out17	Average delay stopped [s] - at **network level** - for motorised vehicles and bicycles - average across simulation runs
OM_out18	Variance and 95% percentile of delay stopped across simulation runs - at **network level** - for motorised vehicles and bicycles
OM_out19	Average delay stopped [s] [for the **stress section**] - for motorised vehicles and bicycles - average across simulation runs
OM_out20	Variance and 95% percentile of delay stopped across simulation runs [for the **stress section**] - for motorised vehicles and bicycles
OM_out21	Average speed [km/h] or [mph] = total distance / total travel time - at **network level** - for motorised vehicles and bicycles - average across simulation runs
OM_out22	Variance and 85% percentile of average travel speeds across simulation runs - at **network level** - for motorised vehicles and bicycles
OM_out23	Average speed [km/h] or [mph] = total distance / total travel time [for the **stress section**] - for motorised vehicles and bicycles - average across simulation runs
OM_out24	Variance and 85% percentile of average travel speeds across simulation runs [for the **stress section**] - for motorised vehicles and bicycles
OM_out25	Average number of stops per pedestrian [-] - per **segment** - pedestrians - average across simulation runs
OM_out26	Variance and 95% percentile of number of stops per pedestrian across simulation runs - per **segment**
OM_out27	Average time of stops per pedestrian [s] - per **segment** - pedestrians - average across simulation runs
OM_out28	Variance and 95% percentile of time of stops per pedestrian across simulation runs - per **segment**
OM_out29	Average total walking time [s] [for the **stress section**] - pedestrians - average across simulation runs
OM_out30	Variance and 95% percentile of average total walking time across simulation runs [for the **stress section**]

OM_out31	Share of time [0-100%] that the parking space was occupied by stopped vehicles - by **sub-segment and side of road** - vehicle/purpose type - average across simulation runs
OM_out32	Total number of stopped vehicles [-] [for the **stress section**] - by vehicle/purpose type - average across simulation runs
OM_out33	Total value of parking fees [for the **stress section**] - average across simulation runs
OM_out34	Number of vehicles that could not be parked [-] [for the **stress section**] - for all vehicle and purpose types - average across simulation runs
OM_out35	Variance and 95% percentile of number of vehicles that could not be parked across simulation runs [for the **stress section**] **for all vehicle and purpose types**
OM_out36	Environmental impact (CO, NOx; VOC, Fuel Consumption by node evaluation) - on **network level** - average across simulation runs

Table 12: Colour Scheme Instructions:

Level of Service	Colour Code	Vehicle Density [veh/lane] To be used for OM_out4 in Table 11	Pedestrian Density [ped/m²] To be used for OM_out5 and OM_out6 in Table 11
A	(255, 0, 0, 255)	≤7	≤0,178571
B	(255, 0, 255, 255)	8-14	0.178572 -≤0,270270
C	(255, 0, 255, 0)	15-23	0.270271- ≤0,454545
D	(255, 255, 255, 0)	24-34	0.454546- ≤0,714286
E	(255, 255, 128, 0)	35-45	0.714286- ≤1,333333
F	(255, 255, 0, 0)	>45	>1,333333

The following data (Table 13) will be derived from the Vissim Output data:

Table 13: Option modelling: derived output data - for each design option

Code	Data
OM_calc1	Unique Identifier for option
OM_calc2	Spatial output level (**network, stress section, segment**)
OM_calc3	Total number of people moved within the **network** [users/h] - for all road user groups (average across simulation runs) Computed based as follows: $\mathrm{OM_{calc2}} = \sum_{segments}\left(\frac{\sum_{vehicle\ types}(Volume_{vehicle\ type} \times \text{ mean number of persons per vehicle}_{vehicle\ type} \times segment\ length)}{\sum segment\ length}\right)$
OM_calc4	Percentage values of vehicle/ pedestrian densities as modal split [%], at **stress section** and **segment** levels
OM_calc5	Average waiting times – pedestrians, at **stress section** and **segment** levels
OM_calc6	Ratio of waiting times over total walking time - pedestrians [%], at **stress section** and **segment** levels (average across simulation runs)
OM_calc7	Proportion of vehicles that could not be parked, for all vehicle and purpose types, at **stress section** and **segment** levels (average across simulation runs)
OM_calc8	Variance and 95% percentile of proportion of vehicles that could not be parked, across simulation runs, at **stress section** and **segment** levels for all vehicle and purpose types

The outputs below (Table 14) cannot be produced by Vissim (unless we can input relationships between design features and pedestrian volumes) and will need to come from other sources, if available. This includes: other models (linked to Vissim outputs or not); evidence in the literature; studies from similar road sections in the city. If available, the information needs to cover the current situation (measured values) and at least one of the design options (model forecasts).

Table 14: Other possible information on impacts of road design options - for each design option

OM_oth1	Unique Identifier for option
OM_oth2	Spatial output level (**network, stress section, segment**)
OM_oth3	Number and duration of stationary activities (e.g. sitting, window-shopping)
OM_oth4	Accidents with personal injuries for the whole stress section
OM_oth5	CO^2 outputs
OM_oth6	Number of street crimes
OM_oth7	Property prices or rents
OM_oth8	Number of visits to local businesses
OM_oth9	Expenditure in local businesses
OM_oth10	Amount of physical activity and other health indicators
OM_oth11	Energy consumption
OM_oth12	Noise levels

5 Option appraisal

The input and output data from the option appraisal tool will be automatically produced when cities use the tool. **You need to save this data**; after using the tool, the user will be prompted to click a button that will start a macro recording all the inputs and outputs and saving the file with a new name. The cities will then forward this file to UCL. Each option will be identified by its unique identifier.

Table 15: Option Appraisal: input data [all at Stress Section level] - for each set of design options to be compared

Code	Data
	Note: variable numbers refer to Table 11
OA_in1	Number of options to be jointly appraised
OA_in2	Set of Unique Identifier for options to be compared
OA_in3	Allocated road width to each design element, in each option
OA_in4	Number and types of pedestrian crossing facilities, in each option
OA_in5	Estimated implementation and maintenance cost of each design option
OA_in6	Impacts on traffic volumes, by mode (from VISSIM) [OM_out2, OM_out3, OM_out4, OM_out5, OM_out 6, OM_out 7, OM_out 8, OM_calc3, OM_calc4]
OA_in7	Impacts on speeds or travel times, by mode (from VISSIM) [OM_out9, OM_out 11, OM_out21, OM_out23, OM_out29]
OA_in8	Impacts on delays, by mode (from VISSIM) [OM_out13, OM_out15, OM_out17, OM_out19, OM_out25, OM_out27, OM_calc5 OM_calc6]
OA_in9	Impacts on travel time reliability, by mode (from VISSIM) [OM_out 10, OM_out12, OM_out 14, OM_out 16, OM_out18, OM_out20, OM_out22, OM_out24, OM_out26, OM_out28, OM_out30]
OA_in10	Impacts on trip quality, by mode (from other sources, if available)
OA_in11	Impacts on parking and loading [OM_out31, OM_out32, OM_out33, OM_out34, OM_out35, OM_calc7, OM_calc8]
OA_in12	Impacts on people-based activities (OM_out7 and from other sources, if available [OM_oth3])
OA_in13	Impacts on property values (from other sources, if available) [OM_oth7]
OA_in14	Impacts on visits to local businesses (from other sources, if available [OM_oth8]
OA_in15	Impacts on expenditure in local businesses (from other sources, if available [OM_oth9]
OA_in16	Impacts on traffic safety (from other sources, if available) [OM_oth4]
OA_in17	Impacts on health/physical activity [OM_oth10]
OA_in18	Impacts on crime (from other sources, if available) [OM_oth6]
OA_in19	Impacts on energy consumption (from other sources, if available) [OM_oth11]
OA_in20	Impacts on air pollution (from VISSIM) [OM_out36]
OA_in21	Impacts on CO2 emissions (from other sources, if available) [OM_oth5]
OA_in22	Impacts on noise levels [OM_oth12]
	POLITICAL AND TECHNICAL ASSESSMENT
OA_in23	Priorities to road uses
OA_in24	Priorities to objectives
	COST BENEFIT ANALYSIS
OA_in25	Choice of unit monetary value, from the list provided in the tool, or inputted new value
	MULTI CRITERIA ANALYSIS
OA_in26	Worst and best possible values per indicator
OA_in27	Weights for priorities of different assessors/stakeholders

Table 16: Option Appraisal: output data [all at Stress Section level] - for each set of design options to be compared

Code	Data
OA_out1	Unique Identifier
OA_out2	Quantified impacts for each option
OA_out3	Options identified as politically or technically unacceptable
OA_out4	Monetised impacts for each option
OA_out5	Net benefit and benefit/cost ratio of each option
OA_out6	Standardized scores for each option, for each assessor
OA_out7	Ranking of options, for each assessor

Appendix 2: Short Indicator List sent in October 2021

MORE
Multimodal Optimisation of Roadspace in Europe

D5.5 Cross-Site Assessment of Case Study Design Packages

Reduced indicator list for describing the case study design packages for cross-site assessment in D5.5
29 October 2021

Start date of project:	1st September 2018	Duration:	36 months
		Version:	1
		Prepared by:	Regine Gerike Caroline Koszowski Bettina Schröter Rico Wittwer Peter Jones
		Checked by:	x
		Verified by:	X
		Status:	x
		Dissemination level:	CO

This project has received funding from the European Union's Horizon 2020 research

1 The Purpose of this Document

The instructions for data provision for the evaluation of alternative design solutions from February 2021 are the basis for this document ("MORE WP5 Data Provision Instructions FINAL - for D5.3and D5.4.docx").

This document provides a reduced list of indicators for describing the case study design packages as the basis cross-site assessment in D5.5. This reduced indicator list is hopefully feasible for city partners even though not much time is left. This reduced indicator list is focused on motorised vehicles. This is not perfectly in line with the MORE focus which is rather on pedestrians, place activities, qualities of streetspace. TUD even though suggests to go for the indicators on motorised traffic with first priority for cross-site analysis as these are feasible, we think that these are the only ones that we can really compare.

TUD very much welcomes Vissim Output also on pedestrians, place activities, kerbside activities, bicycles in addition to the below indicators. We will be pleased to integrate those into D5.5 whenever this is feasible in the remaining time and even if these will be not available for all cities.

TUD would appreciate city partners input as soon as possible as we are supposed to deliver our report and information for the toolkit asap.

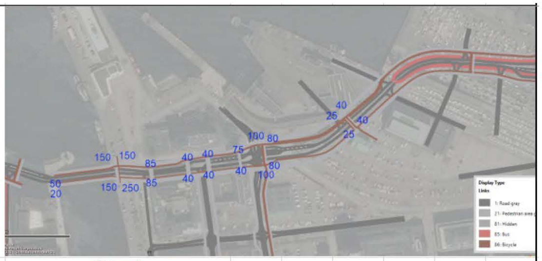
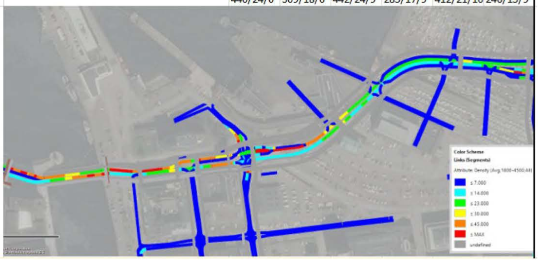
2 General Simplifications

- Only the design packages for current conditions
- Only motorised traffic, AM and PM (inter-peak and PM for London)
- Only sections, no nodes

3 How to Provide the Data to TUD

You might provide the data in excel files with each one tab per scenario, these might be appendices to D5.4. This is how Malmö provided their results, this is perfect as the basis for D5.5:

CODE	Description	Data	Segment 1		Segment 2		Segment 3	
			West	East	West	East	West	East
	Scenarionamn i VISSIM	59 Liveability - Utan åtgärder - Hemarbete LT						
OM_in1	**Uniqe Identifier**	MAL_S1_0030_2021_B_0_ABCD0000						
OM_in2	**Screenshot of modelled network**							
OM_in3	**Desired Speed decision**	40km/h (Standard)						
OM_in4	**Entering Vehicle input volumes**							

OM_in5	**Pedestrian input volumes**							
OM_in6	**Pedestrian distancing values**	Not used						
OM_out1	**Uniqe Identifier**	MAL_S1_0030_2021_B_0_ABCD0000						
OM_out2	**Volume v/h (Car/HGV/Bus)**		440/24/0	309/18/0	442/24/9	285/17/9	412/21/10	246/15/9
OM_out3	**Vehicle density**							

CODE	Description	Data	Segment 1		Segment 2		Segment 3	
			West	East	West	East	West	East
OM_out4	**Pedestrian density [ped/m^2]**	Not applicable						
OM_out5	**Number of runs exceeding threshold F**	Not applicable						
OM_out6	**Pedestrian density experienced [ped/m2]**	Not applicable						
OM_out7	**Number of runs exceeding threshold F (exp)**	Not applicable						
OM_out8	**Max, min and avg number of waiting ped at stop**	Not applicable						
OM_out9	**Average travel time (Network level)**	167,23						
OM_out10	**Variance and 95%perc avg TT (Network level)**	0,5929 / 168,36						
OM_out11	**Average travel time (Stress section)**							
OM_out12	**Variance and 95%perc avg TT (Stress section)**							
OM_out13	**Average delay [s/veh] (Network level)**	40,66						
OM_out14	**Variance and 95%perc avg Delay (Network level)**	0,1764 / 41,34						
OM_out15	**Average delay [s/veh] (Stress section)**	39,85						
OM_out16	**Variance and 95%perc avg Delay (Stress section)**	4,1616 / 42,91						
OM_out17	**Average delay stopped [s/veh] (Network level)**	30,33						
OM_out18	**Variance and 95%perc avg Delay S (Network level)**	0,09 / 30,77						
OM_out19	**Average delay stopped [s/veh] (Stress section)**	25,67						
OM_out20	**Variance and 95%perc avg Delay S (Stress section)**	1,7424 / 27,72						
OM_out21	**Average speed [km/h] (Network level)**	25,83						
OM_out22	**Variance and 85%perc avg speed (Network level)**	0,04 / 26,03						
OM_out23	**Average speed [km/h] (Stress section)**							
OM_out24	**Variance and 85%perc avg speed (Stress section)**							
OM_out25	**Average number of stops per pedestrian (Segment)**	Not applicable						
OM_out26	**Variance and 95%perc nu stops (Segment)**	Not applicable						
OM_out27	**Average time of stops per pedestrian (Segment)**	Not applicable						
OM_out28	**Variance and 95%perc time of stops (Segment)**	Not applicable						
OM_out29	**Average total walking time (Segment)**	Not applicable						
OM_out30	**Variance and 95%perc avg total WT (Segment)**	Not applicable						
OM_out31	**Share of time parking is occupied (Sub-segment)**	Not applicable						
OM_out32	**Total number of stopped vehicles (Stress section)**	Not applicable						
OM_out33	**Total value of parking fees (Stress section)**	Not applicable						
OM_out34	**Num veh that could not be parked (Stress section)**	Not applicable						
OM_out35	**Variance and 95%perc of cars not parked (Stress section)**	Not applicable						
OM_out36	**Environmental impact (CO/Nox/VOC/Fuel) (Network level)**	35799 / 6965 / 8297 / 512						

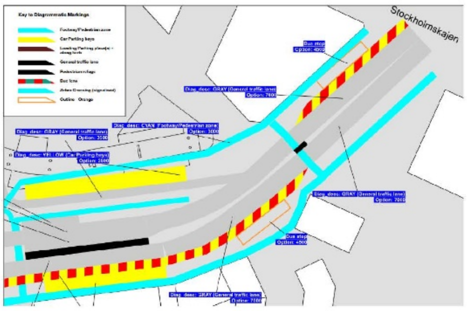
4 Information to be provided to TUD

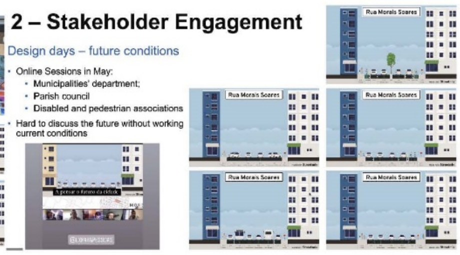
4.1 Description of the Street Layouts for the Design Packages

Please describe the Street Layouts for each scenario. The screenshots from linemap are suitable, please provide a complete legend explaining all colors that you use in each figure. Please provide in addition examplary cross-sections that actually show with precise widths at selected locations how the streetspace is allocated. TUD needs these cross-sections for really understanding the allocation of streetspace, the screenshots from Linemap do not contain any widths and are not precise; they give an excellent overview of the whole section but do not show in detail how streetspace is allocated.

Please also provide us key numbers, this is particularly the desired speed and the vehicle/pedestrian input volumes.

These are best practice examples for both the linemap screenshot and the precise description of cross-sections at selected locations:





D5.5 Cross-Site Assessment of Case Study Design Packages
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Reduced indicator list for describing the case study design packages for cross-site assessment in D5.5 29 October 2021
Version: 1
Page 5 of 6

4.2 Vissim outputs

Please provide the following list of indicators for each scenario. You might provide this information in excel files with each on tab per scenario including the following indicators:

Code	Data
OM_out1	Unique Identifier for option
OM_out9	Average travel time [s/veh] = Total of travel times / number of vehicles - at **network level** - for motorised vehicles and bicycles - average across simulation runs
OM_out10	Variance and 95% percentile of average travel times across simulation runs - at **network level** - for motorised vehicles
OM_out11	Average travel time [s/veh] = Total of travel times / number of vehicles [for the **stress section**] - for motorised vehicles - average across simulation runs
OM_out12	Variance and 95% percentile of average travel times across simulation runs [for the **stress section**] - for motorised vehicles
OM_out13	Average delay [s/veh] = Total of delay / number of vehicles - at **network level** - for motorised vehicles - average across simulation runs
OM_out14	Variance and 95% percentile of average delay across simulation runs - at **network level** - for motorised vehicles
OM_out15	Average delay [s/veh] = Total of delay / number of vehicles [for the **stress section**] - for motorised vehicles - average across simulation runs
OM_out16	Variance and 95% percentile of average delay across simulation runs [for the **stress section**] - for motorised vehicles
OM_out17	Average delay stopped [s] - at **network level** - for motorised vehicles - average across simulation runs
OM_out18	Variance and 95% percentile of delay stopped across simulation runs - at **network level** - for motorised vehicles
OM_out19	Average delay stopped [s] [for the **stress section**] - for motorised vehicles - average across simulation runs
OM_out20	Variance and 95% percentile of delay stopped across simulation runs [for the **stress section**] - for motorised vehicles
OM_out21	Average speed [km/h] or [mph] = total distance / total travel time - at **network level** - for motorised vehicles - average across simulation runs
OM_out22	Variance and 85% percentile of average travel speeds across simulation runs - at **network level** - for motorised vehicles and bicycles
OM_out23	Average speed [km/h] or [mph] = total distance / total travel time [for the **stress section**] - for motorised vehicles - average across simulation runs
OM_out24	Variance and 85% percentile of average travel speeds across simulation runs [for the **stress section**] - for motorised vehicles
OM_out36	Environmental impact (CO, NOx; VOC, Fuel Consumption by node evaluation) - on **network level** - average across simulation runs

If still time is left, TUD would appreciate the following derived indicators as a "nice-to-have":

Code	Data
OM_calc1	Unique Identifier for option
OM_calc2	Spatial output level (**network, stress section, segment**)
OM_calc3	Total number of people moved within the **network** [users/h] - for all road user groups (average across simulation runs) Computed based as follows: $\mathrm{OM_{calc2}} = \sum_{segments} \left(\frac{\sum_{vehicle\ types}(Volume_{vehicle\ type} \times \text{ mean number of persons per vehicle}_{vehicle\ type} \times segment\ length)}{\sum segment\ length} \right)$
OM_calc4	Percentage values of vehicle/ pedestrian densities as modal split [%], at **stress section** and **segment** levels
OM_calc5	Average waiting times – pedestrians, at **stress section** and **segment** levels
OM_calc6	Ratio of waiting times over total walking time - pedestrians [%], at **stress section** and **segment** levels (average across simulation runs)
OM_calc7	Proportion of vehicles that could not be parked, for all vehicle and purpose types, at **stress section** and **segment** levels (average across simulation runs)
OM_calc8	Variance and 95% percentile of proportion of vehicles that could not be parked, across simulation runs, at **stress section** and **segment** levels for all vehicle and purpose types

If then still time is left, we would particularly welcome data on pedestrians, place activities, kerbside activities, cycling.

Appendix 3: Carbon Values in the Complete Streetscape

MORE
Multimodal Optimisation of Roadspace in Europe

Carbon Values in the Complete Streetscape

Start date of project:	1st September 2018	Duration:	36 month
		Version:	1
		Prepared by:	Ellen Hill (Vectos-G)
		Checked by:	Paul Curtis (Vectos-G)
		Verified by:	Paul Curtis (Vectos-G)
		Status:	Final
		Dissemination level:	Public

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769276

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1 Introduction

The objective of this additional task is to derive and apply indicative values to the individual components of a typical streetscape, to illustrate their individual and combined contribution to carbon emissions and energy consumption. Application of these values to a typical existing and a future streetscape (both virtual) provides an indication of the carbon savings achievable using interventions and investments already available, in addition to the savings to be had from changes to physical mobility. In order to reach an estimation of carbon savings from a typical streetscape (present day) to a future streetscape, a 1km linear stretch of street is considered.

Elements considered include road surfacing, capital carbon of the vehicles on that road, bus stops, vegetation, underground utilities etc. There is a degree of overlap between many of these elements such as electrical power supply (underground utility) serving bus stops as well as electric vehicle charging points. However, each have been addressed individually with an aim to provide a simplistic representation of the carbon savings to be had between a typical situation now, and a potential future situation, rather than comparison between each element themselves.

Capital and operational carbon values have been obtained through desk-top research focussing on case studies in the English language. Gaps in research and potential further workstreams have been identified and are explained in Section 6.

Capital carbon is also referred to as embodied or embedded carbon, and describes the carbon dioxide (CO2) output of the manufacture of an element. In some cases only the material carbon footprint of an element is presented in research, which excludes factors such as carbon cost of delivery etc, and in other cases this is factored in to the capital carbon figure presented. In some instances the operational carbon is included to provide context such as emission values for motor vehicles. An attempt is made to conclude a carbon footprint value for the lifecycle of each streetscape element (from cradle to grave), however data to this effect was not always available.

Carbon dioxide (CO2) and carbon dioxide equivalent (CO2e) are both used in this report to refer to the carbon production in its various forms. CO2e is commonly used in the reference material and is defined as a 'unit comparing radiative forcing of a GHG (greenhouse gas) to carbon dioxide. The carbon dioxide equivalent is calculated using the mass of a given GHG multiplied by its global warming potential'[1].

[1] Kärnä, P, 2012. Carbon footprint of the raw materials of an urban transit bus: case study: diesel, hybrid, electric and converted electric bus.

2 The Typical Street

The 'typical street' is defined as a streetscape comprising elements typically found on the majority of urban streets today. The example used here depicts each element but may not be exhaustive in reflecting every streetscape. The 'typical street' is deliberately conservative so as to more clearly understand the overall change in carbon use from the situation now and in the future.

The 'typical street' is illustrated in Figure 1.

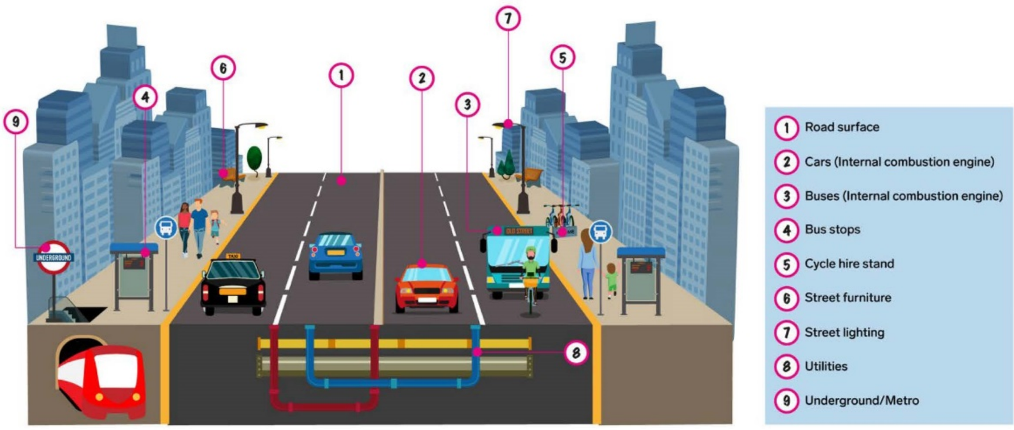


Figure 1 – The Typical Street

The individual streetscape components for which research material is available are demonstrated in Figure 1.

It is acknowledged that a wide array of vehicle types use a typical urban street frequently and that it is not just cars and buses, however this range is vast and for simplicity in this example only these two examples have been analysed. All vehicles in the 'typical street' scenario are internal combustion engine (petrol or diesel) as, whist this is rapidly changing, this represents the traditional composition of engine types on the roads currently. For instance, in the UK in 2021, whilst newly registered low emission vehicles (Battery Electric (BEVs), Hybrid Electric (HEVs) and Plug in Hybrid Electric (PHEVs) reached 27.5% of all car sales[2], the proportion of ICE vehicles on the road was still as high as 97.6%[3].

---

[2] Errity, S., 2022. Electric car sales UK: More EVs registered in 2021 than previous five years combined.
[3] Innovate UK, 2021. UK Transport Vision 2050: investing in the future of mobility.

The capital carbon and operational carbon emissions over a specific period are considered for each streetscape element where information is available, recognising that there are interdependencies and that the derived figures are indicative averages. Due to limiting research to the English language many of the case studies and research material are UK based.

2.1 The Streetscape

2.1.1 Road Surface

Research demonstrates that in the UK asphalt (or tarmac) is the most popular surfacing material and is used to construct over 95% of roads, with the remaining 5% being constructed of concrete.

Capital CO2e within asphalt derives from the aggregate and binder which together comprise 44% of the total volume of carbon, 42% is emitted through the heating and drying stage, and the remaining 14% derives from the mixing and delivery. This culminates in a capital carbon value of approximately 50 kg of CO2e per tonne of asphalt[4].

It is estimated that getting the asphalt required to resurface a mile of single lane carriageway (excluding transport to the site) can produce up to 26.5 tonnes of CO2[5], this equates to approximately **16.5 tonnes of CO2e per km of road**. This will vary depending on road width, depth, and any curves etc.

In England it is estimated that major roads need to be resurfaced every 10-12 years due to the effects of water, sun, and air, as well as the weight of traffic[6]. The surface will also be disrupted to maintain or install utilities over this time.

2.1.2 Cars

In the production stage it is reported than an average ICE (internal combustion engine) vehicle generates 720kg of carbon per £1,000 spent. This means that for example, a medium sized car worth £24,000 is approximated to generate more than 17 tonnes of CO2e before it drives its first mile.[7] However other sources have calculated a mid-sized ICE vehicle to generate around 5.6 tonnes of CO2e in its production phase alone[8], excluding the additional elements of manufacture such as travel. This second figure is widely cited in research pertaining to electric vehicle manufacture and use in the UK and is more applicable to other values stated (i.e. relates to the production in isolation) therefore it is used in further assessment for comparison purposes in this report.

---

[4] Loveday, C., 2011. Driving Down Carbon on Recycled Roads.
[5] Cozier, M., 2021. New road surface is set to cut emissions.
[6] Highways England. 2021. Anti-ageing roads could keep roadworks at bay.
[7] Berners-Lee, M., 2020. How bad are bananas.
[8] Patterson, J., Alexander, M. and Gurr, A., 2011. Preparing for a Life Cycle CO2 Measure.

Over the lifetime of a car (on average 13.9 years and 154,859.9km driven) this medium sized car is estimated to produce a further 27 tonnes of CO2e[9].

The theoretical capacity of a typical urban street in the UK, as a single carriageway (6.1m width) with a 30mph speed limit, is 900 vehicles per hour in one direction[10]. Assuming a 60:40 split in directional flow this is 1,500 vehicles on the road within an hour. As a worst case therefore the road could see up to 36,000 vehicles in one day (24 hours), and 13,140,000 vehicles in a year (365 days). This equates to a maximum potential capital carbon impact of **8,400 tonnes of CO2e** counting cars across an hour, and 73.58 million tonnes of CO2e counting cars in a year on the 'typical street'.

2.1.3 Buses

The CO2e produced in materials for a standard diesel bus at 12m is between 45.5 to 54 tonnes, made up of the metals (steel and aluminium chassis respectively), devices and batteries, plastics, lubricants, and other materials (such a plywood, double glass, bitumen).

Metals are reported to make up around 1/3rd of the capital CO2e (despite being circa 60-80% of the weight), followed by the electrical components and double glass. The materials ultimately form approximately 1/3rd of the emissions of the entire manufacture of a bus where transport and manufacture process costs are not accounted for. [11]

Whilst the material carbon footprint is notable, the majority of carbon emissions of a standard single decker bus results from its operational lifetime, this being an average of 822g of CO2e per km driven[12]. The average age of a bus in London in 2018/19 was 5.9 years old, and in non-metropolitan areas of England was 8.4 years. The average distance driven by London buses in 2018/19 was approximately 707,500 km per bus[13] in the year. Indicatively therefore, the lifetime carbon emissions (excluding capital carbon) are in the region of 3,431 tonnes of CO2e per bus.

The 1 km 'typical street' could see multiple buses at any one time and many buses across a typical day, this being dependent on number and frequency of services. Using a judgement of four buses being on the 'typical street' at any one time would therefore result in a maximum potential cost of **216 tonnes of CO2e per km of road**. As with cars, this figure would in actuality be higher as more buses route along the road across the day.

---

[9] G., 2019. Carbon emissions in the lifetime of cars.
[10] Design Manual for Roads and Bridges (DMRB). Determination of Urban Road Capacity. TAA= 79/99. Volume 5: Section 1.
[11] Kärnä, P, 2012. Carbon footprint of the raw materials of an urban transit bus: case study: diesel, hybrid, electric and converted electric bus.
[12] DEFRA, 2007. Passenger transport emissions factors: Methodology paper.
[13] Transport for London, 2022. Buses performance data.

2.1.4 Bus Stops

CO2 data for bus stops has been obtained for Transport for London (TfL) bus stops, which are reported to each contribute an average of 7.9 tonnes (8.7 tons) from their production phase[14].

Assuming a bus stop is located every 400m on any given bus route in an urban area, four bus stops would be expected to be on a 1km stretch of street. This is **31.6 tonnes of CO2** in total for the 'typical street'.

2.1.5 Cycle Hire Stand

Whilst bicycles are more or less carbon neutral in use (not accounting for additional food to fuel the rider or heat produced), the material carbon footprint of the bicycles themselves is a consideration as is the maintenance of a hire scheme.

The maintenance of a bike hire scheme involves vehicles and trailers to rebalance the bikes around the scheme area, thus producing standard vehicle carbon emissions. Information on the typical distance driven to fulfil the rebalancing is not readily available.

Research of a scheme in Edinburgh demonstrates that over 5 years, one bike in the scheme will release 195 kg of CO2e (based on 1,000 bikes), or 4.7g of CO2e/km. Of this, 33.3% comprises the manufacturing stage and therefore represents the capital carbon, with transport making up 14.1% and usage of the bikes 49.9%, the remaining 2.7% considers the waste disposal. [15] As such it is estimated that the embodied carbon value (being 33.3%) is circa 65kg of CO2e per bike.

Extrapolating these results and applying them to a different timeframe is difficult as the CO2e values will adjust with the number of bikes included in the scheme and depending on the nature of the rebalancing. On the basis however of one cycle hire hub on the 'typical street' with 10 bikes docked, this would theoretically contribute just under 2 tonnes of CO2e in 5 years, or 400 kg of CO2e in 1 year. This research does not posit how the carbon value will change with increased years nor to the standard lifecycle of the elements of a bike sharing scheme. Applying just the capital value of 65kg of CO2e to 10 bikes docked on the 'typical street' results in **650 kg of CO2e**.

2.1.6 Street Furniture

Street furniture naturally varies enormously from decorative artwork to public benches to bins, and there is little research on the environmental impact of a typical steel bench for example. However there is data available for household furniture for which the average piece

[14] Natural Shelter, 2022. Natural Shelters Are Innovative.
[15] D'Almeida, L., Rye T., and Pomponi, F., 2021. Emissions assessment of bike sharing schemes: The case of Just Eat Cycles in Edinburgh, UK.

produces 47 kg of CO_2e[16], and hence this has been used as a proxy in the place of more applicable data.

Assuming a bench is provided on average every 100m[17] on the 'typical street' a total of 20 benches would be available, resulting in **940 kg of capital CO_2e**.

2.1.7 Street Lighting

LED (light emitting diode) bulbs have already begun to replace traditional bulbs (55% LED in 2020 in the UK[18]) in many places and savings in energy and cost are being made with about 90% of an incandescent bulb's energy being released as heat[19].

A non-street specific LED bulb is reported to emit between 167 and 264 kg of CO_2e over a 20-year lifespan (European and USA studies respectively). Of this value 98% is the operational CO_2e and 2% the embodied carbon equivalent meaning that each light produces around 3.34 to 5.3 kg of capital CO_2e.[20] This does not include the lighting column.

The embodied carbon footprint of LEDs however are reportedly far higher than traditional bulbs[21], however it is understood that the operational emission savings outweigh the disbenefits of the embodied carbon figure.

In the UK the standard distance of street lights in an urban area is between 30 and 50m apart. Based on 30m spacing on one side of the road therefore the 'typical street' would have 33 street lights, equating to a maximum potential of **174.9 kg of capital CO_2e**. The actual embodied carbon figure would be higher to account for the street column etc.

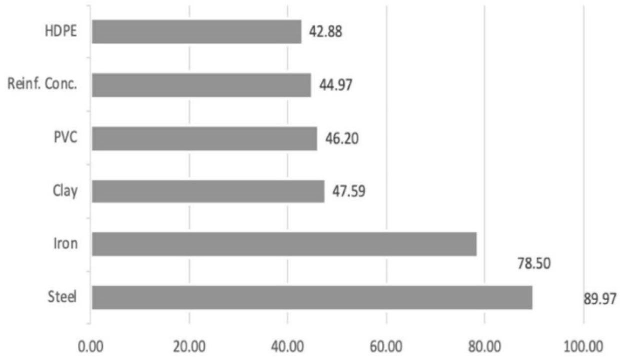
2.1.8 Utilities

This covers a wide range of different services including gas lines, electricity supply, broadband cables and housing, as well as drainage pipes etc. The exact composition of utilities under a typical street is difficult to estimate, however data is available on the capital carbon footprint of materials normally used for many of these purposes.

Graph 1 demonstrates the CO_2e values based on a 12" diameter pipe and weight per linear foot used as a starting point for understanding the carbon impact. HDPE stands for high density polyethylene.

---

[16] MyToolShed, 2019. Furniture's Carbon Footprint and the Importance of Upcycling.
[17] Department for Transport, 2007. Manual for Streets.
[18] Ward, J., 2021. Saving costs and carbon by investing in street lighting.
[19] FSG, 2020. How Street Lighting Upgrades Can Have a Positive Impact on Our Climate.
[20] Finnegan, S., Jones, C. and Sharples S., 2018. The embodied CO2e of sustainable energy technologies used in buildings: A review article.
[21] Gray, A., 2020. Lighting's Dark Secret: Embodied Carbon in the LED Industry.



Graph 1 – Utility Materials Capital Carbon Equivalent per linear foot[22]

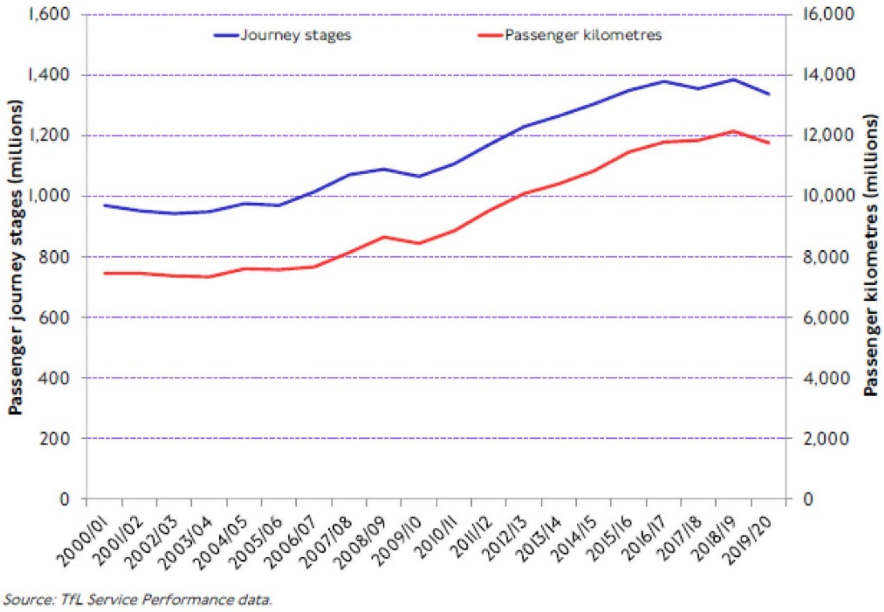
This graph demonstrates that an HDPE pipe will have the least CO2e impact whilst steel will have the maximum, however there are limitations in material choice dependent on the service itself, but also on the soil in which the pipes will sit[23].

Without any further information on average length of pipes, cables etc forming the suite of underground utilities, it is not possible to posit a capital carbon value for the 'typical street'. Nevertheless it is clear that where material changes can be made to encasement material there is a hierarchy of carbon savings to be had.

2.1.9 Underground/Metro

The underground figures are based on the London Underground, for which TfL reports uses more electricity than anything else in the city[24]. In 2008 the average tube journey was reported to generate 48g of CO2e with the total footprint for the underground being 754,437 tonnes of CO2e in 2007/8[25]. Graph 2 shows passenger km on the London Underground, and using 2007/8 as appropriate it is evident that just under 8,000 passenger kms were undertaken[26]. Applying the 8,000 passenger kms to the total CO2e emissions from this year indicates a value of 94 tonnes of CO2e per km in a year. This is the operational CO2e and no information has been found on the embodied carbon of the London Underground.

[22] Mosier, R, Adhikari, S., and Mohanty, S., 2020. A comparison of the carbon footprint of pavement infrastructure and associated materials in Indiana and Oklahoma.
[23] Mosier, R, Adhikari, S., and Mohanty, S., 2020. A comparison of the carbon footprint of pavement infrastructure and associated materials in Indiana and Oklahoma.
[24] Katwala, A., 2018. London's wild plan to make the Tube carbon neutral by 2050.
[25] Transport for London, 2008. LU Carbon footprint report 2008.
[26] Transport for London, 2020. Travel in London Report 13.



Graph 2 – Passenger km and journey stages by London Underground, 2000/01-2019/20[27]

2.2 The Typical Street – Total Capital Carbon

Street Element	Capital Carbon	Operational Carbon (10 years)
Road Surface	16.5 tonnes	-
Cars	8,400 tonnes	3,547,800,000 tonnes
Buses	216 tonnes	686,200 tonnes
Bus Stops	31.6 tonnes	-
Cycle Hire Stand	650 kg	3.9 tonnes
Street Furniture	940 kg	-
Street Lighting	174.9 kg	-
Utilities	-	-
Underground	-	-
Estimated Total	**8,666 tonnes**	**3.5 billion tonnes**

Each component has been considered independently and estimated CO_2 or CO_2e values have been applied accordingly. Based on the aforementioned judgements on the likely

[27] Transport for London, 2020. Travel in London Report 13.

provision of each element on a 1km linear ‘typical street’, the total capital carbon figure attributed is approximately **8,666 tonnes of CO2e**, or **266 tonnes of CO2e excluding cars**. This excludes utilities or any operational carbon.

Furthermore, over a 10 year period the complete carbon emissions are generally estimated to be in the order of 3.5 billion tonnes of carbon based on the research obtained and presented in this report (and assuming a worst case whereby all cars visiting the typical street have not been counted before). This figure will be higher again due to the method of calculating cars and buses using the ‘typical street’, and due to hidden carbon costs such as lighting columns, the embodied carbon of the cycle hire docking furniture, electricity source etc. As such this should be used as an indication of impact for comparison with the ‘future street’ only.

3 The Future Street

The ‘future street’ is defined as a streetscape that improves upon the ‘typical street’ using a variety of interventions that are either already available and happening now, or are readily gaining traction. The purpose of presenting a ‘future street’ is to demonstrate the extent of decarbonisation that is feasible now or in the near future in just the streetscape itself. The ‘future street’ is therefore illustrated in Figure 2.

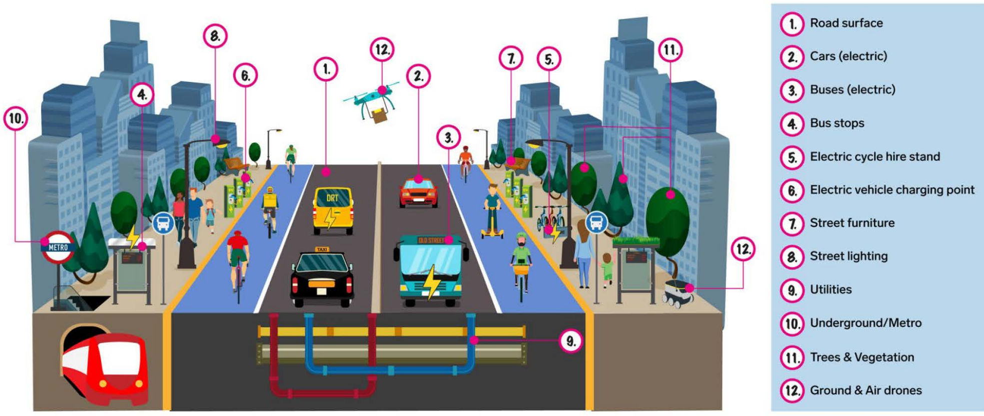


Figure 2 – The Future Street

The individual streetscape components for which research material is available are demonstrated in Figure 2. Some of these components are duplicated from the ‘typical street’, however many represent improved facilities in terms of carbon savings and additional elements have been added.

The capital and operational carbon emissions over a specific period are considered for each streetscape element, recognising that there are interdependencies and that the derived figures are indicative averages. Due to limiting research to the English language many of the case studies and research material are UK based but are anticipated to be applicable elsewhere.

3.1 The Streetscape

3.1.1 Road Surface

As noted for the 'typical street', asphalt is the most commonly used road surfacing material used in the UK. Asphalt is also recyclable with 100% of its materials suitable for reuse into new asphalt at the end of its lifespan. Following its initial creation, recycling of asphalt materials cuts 44% of carbon emissions compared to new asphalt due to this proportion of its total carbon contribution consisting of the aggregate and binder themselves.

The average asphalt road lasts for 18 years and after this new roads can be created using the original material[28], and based on 56% of the capital carbon relating to the processing (44% being recyclable materials), the recycled asphalt produces a capital cost of **9.24 tonnes of CO2e per km of road.**

Considering the carbon footprint of asphalt over its lifecycle, evidently its footprint is better the longer it remains in use. Thus it is important to future proof its production to extend its life. An example of this is an asphalt road with 50kg CO2e per tonne lasting for 20 years its footprint is effectively 2.5kg of CO2e per tonne per year. Using best practice however to extend its life to 40 years reduces this to 1.25kg CO2e per tonne per year. If this same asphalt is then recycled at the end of its lifespan the footprint reduces further to 0.7kg CO2e per tonne per year. [29]

Whilst asphalt is currently the most popular choice in the UK for road surfacing, research suggests that the colour of light concrete can help to reduce carbon impacts. Changing 1m^2 of black asphalt into a light concreate prevents the emission of 22.5 kg of CO2. This offsets 30 – 60% of the CO2 emitted during the manufacturing process of the cement used in the concrete. This also aids in saving on street lighting through higher levels of reflected light, allowing reductions of up to 35% in lighting.[30]

3.1.2 Cars

Comparison of the CO2 emitted during production is reported with a wide range, ranging from double of a medium-sized ICE vehicle, to less than an ICE vehicle. The battery is widely accepted to be CO2 intensive in production in a way that elements of an ICE vehicle are not.

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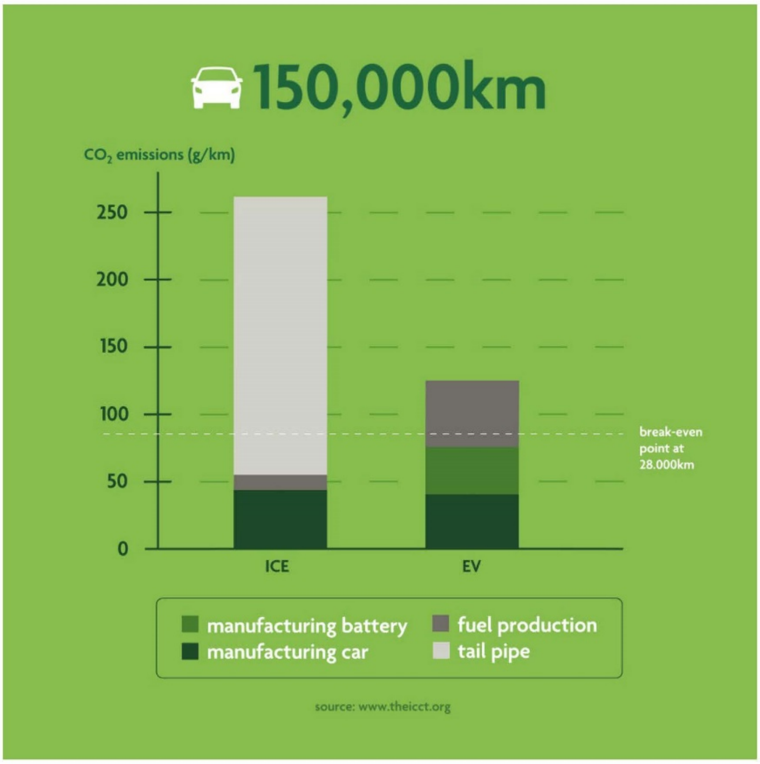
[28] Loveday, C., 2011. Driving Down Carbon on Recycled Roads.
[29] Loveday, C., 2011. Driving Down Carbon on Recycled Roads.
[30] European Concrete Paving Associating, 2020. Concrete roads can strongly contribute to reduction of CO2 emissions from road transport.

An indicative value for Electric vehicles (EV) in production has been derived at approximately 8.8 tonnes of CO2e[31], however once they are in use 28,000 km (achieved after an average 2 years of driving) is the average 'breakeven point' whereby after this stage, driving an EV has a positive carbon impact. This is dependent on the type of energy production used which is factored into the carbon emissions.

On this basis, with the average lifecycle of a vehicle in the UK being 8.5 years, for the final 6.5 years of driving an EV would have a positive impact over an ICE vehicle.[32] This is illustrated in Graph albeit this shows a slightly different capital carbon CO2 value than stated above.



Graph 3 – Breakeven point and CO2 emissions over 150,000 km[33]

This graph demonstrates that the carbon savings are in the order of 20.5 tonnes based on the lifecycle of a modern car. Although this is dependent on the source of electricity, it is

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[31] Patterson, J., Alexander, M. and Gurr, A., 2011. Preparing for a Life Cycle CO2 Measure.
[32] Allegro, 2019. At what point is your EV truly more sustainable than a fossil fuel car?
[33] Allegro, 2019. At what point is your EV truly more sustainable than a fossil fuel car?

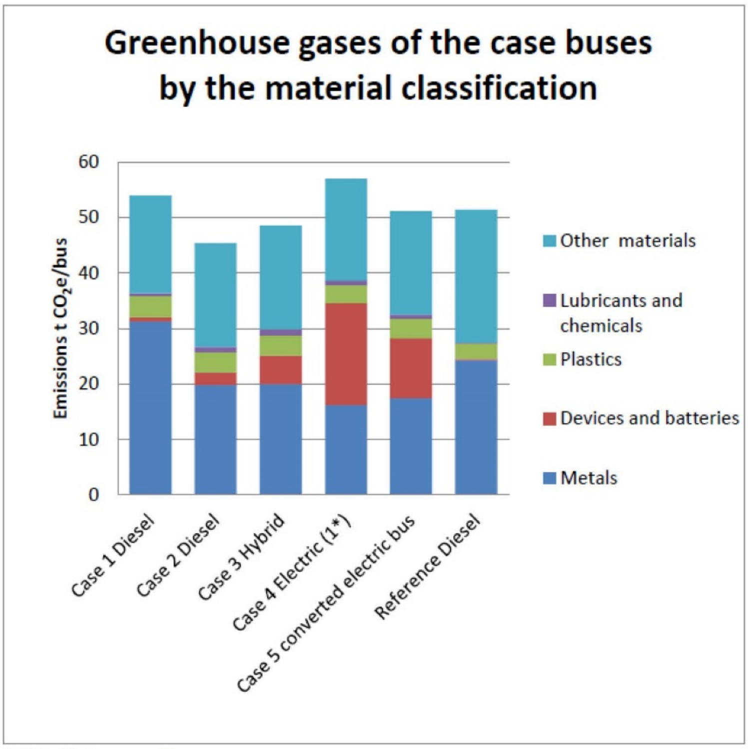
suggested that in 95% of the world, driving an EV is better than an ICE vehicle[34], and the carbon impact of driving an EV will continue to reduce as grid electricity production becomes cleaner[35].

Applying the same methodology as to the 'typical street' and assuming a maximum of 1,500 vehicles on the road within an hour (which is a worst case assessment), the total capital value would be **13,200 tonnes of CO2** counting cars across an hour. This equates to 115.63 million tonnes of CO2 counting cars in a year on the 'future street'.

3.1.3 Buses

Research indicates that the material carbon footprint of a hybrid bus is 49 tonnes of CO2e, and for a fully converted electric bus is 51 tonnes of CO2e. An electric bus is calculated to produce 57 tonnes of CO2e. These refer to standard 12 metre buses as considered for the 'typical street'. Graph 4 illustrates the composition of materials in relation to their CO23 emissions. [36]

[34] Knobloch, F. et al., 2020. Net emission reductions from electric cars and heat pumps in 59 world regions over time.
[35] Staffell, I. et al., 2019. April to June 2020 Electric Insights Quarterly.
[36] Kärnä, P, 2012. Carbon footprint of the raw materials of an urban transit bus: case study: diesel, hybrid, electric and converted electric bus.



(1*) Preliminary results

Graph 4 – Material carbon footprints of the case buses by the material classification[37]

Whilst the material carbon footprint is higher for electric buses due to the increased amount of electrical components, the majority of carbon emissions of a standard single decker bus result from its operational lifetime, these emissions being vastly reduced for an electric bus.

The operational phase of an electric bus is in theory carbon neutral, as are hydrogen buses both of which are already in operation in London. The average age of buses in London in 2018/19 was 5.9 years old, and the average distance driven by London buses in 2018/19 was approximately 707,500 km per bus[38] in the year. Lifetime carbon emissions are therefore cut from the 'typical street' by 3,431 tonnes of CO2e per bus, with CO2e production involved only in the renewal of the fleet. There is no data at this time to suggest that the lifecycle of an electric or indeed hydrogen bus will differ from a diesel bus, however it is reasonable to assume that there will be a variation.

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[37] Kärnä, P, 2012. Carbon footprint of the raw materials of an urban transit bus: case study: diesel, hybrid, electric and converted electric bus
[38] Transport for London, 2022. Buses performance data.

Based on the capital carbon production of a fully electric bus, and using the same methodology as for the 'typical street' by judging that four buses are present at any one time, the maximum potential cost is **228 tonnes of CO2e per km of road**. This is higher than for the 'typical street'.

3.1.4 Bus Stops

Negative carbon shelters are being developed for TfL which have a net gain of sequestered carbon amounting to 166kg per shelter, making it carbon negative.[39]

More carbon savings could potentially be made by combining this engineering with simple changes such as 'green roofs' of shelters, where sedum plants are grown. This type of initiative is being installed in Milton Keynes in the UK where existing bus shelters are being upgraded with green roofs. No CO2 saving has been quantified for this scheme but it will undoubtedly improve urban greening and does not require a new bus stop.[40]

On the basis of a bus stop located every 400m, four bus stops would be present on the 1km length of 'future street'. This is a net carbon **negative impact of 664 kg of CO2**.

3.1.5 Electric Cycle Hire Stand

Electric bike hire schemes operate in the same way as non-electric schemes, but with electric bikes. Therefore, the primary difference in capital carbon is the production of the electrical components of an e-bike and the power source to the docking station. Given the additional weight of an e-bike it is reasonable to judge that the rebalancing of bikes would use more fuel however research is limited on this.

A push bike is understood to produce around 4.7g of CO2e per km where an e-bike produces about 31.2g of CO2e per km over its operational lifetime including production[41]. In its production alone a standard commuting e-bike is reported to produce approximately 165 kg of CO2e[42].

Whilst it is clear that e-bikes produce more CO2e in their production (battery manufacture) and operational phases (recharge of the battery), they are more likely to replace car trips over public transport or other active travel trips given the extended range available over a push bike, as well as convenience and attractiveness. Therefore, the case can be made that in the context of the 'future street' they increase the CO2e value and yet have a wider positive impact on carbon savings. The watt-hours requited to travel 1 km is shown in Graph 5 to compare between modes.

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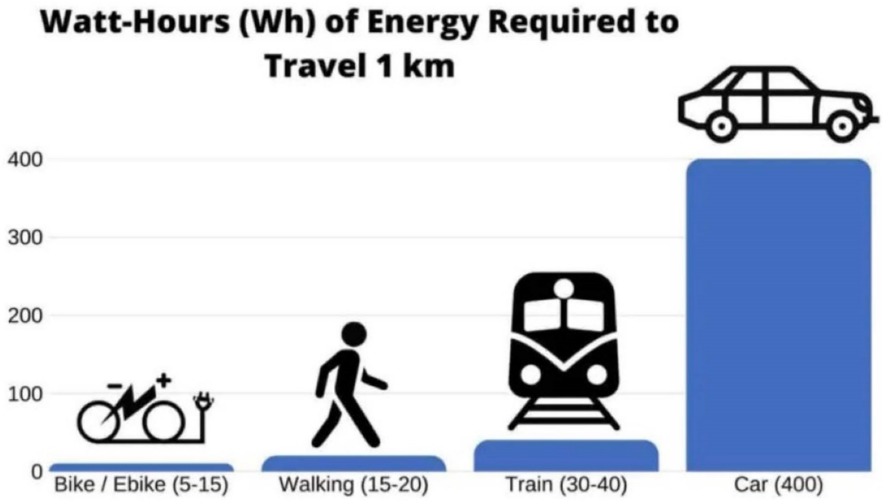
[39] Natural Shelter, 2022. Natural Shelters Are Innovative.
[40] Milton Keynes Council, 2021. Carbon reducing green bus shelters to be installed in Milton Keynes.
[41] D'Almeida, L., Rye T., and Pomponi, F., 2021. Emissions assessment of bike sharing schemes: The case of Just Eat Cycles in Edinburgh, UK.
[42] TREK, 2021. Sustainability Report and Corporate Commitment 2021.



Graph 5 – Watt Hours of Energy Required to Travel 1km[43]

Using a figure of 165 kg of embodied CO2e per e-bike results in in **1.65 tonnes of CO2e.**

3.1.6 Electric Vehicle Charging Point

Electric vehicle charging points add an element to the streetscape from the 'typical street', and therefore will add capital and operational carbon values to the street. However their benefit is clear, which is to facilitate the use of EVs within the street environment and these have already been demonstrated to have a medium to long term positive impact on emissions.

Data is not readily available on the capital carbon of the charging points themselves, and electrical power supply will contribute to this, however the footprint of the energy used itself depends entirely on how energy is made for the national grid. An EV charged using renewable energy is carbon neutral (in this respect), whereas using standard grid electricity results in around 40g of CO2 per km[44].

3.1.7 Street Furniture

Again considering benches as a standard item of street furniture, research demonstrates that wooden benches are carbon neutral, and can result in an average net gain of carbon

[43] eBikesHQ.com, 2022. Electric Bikes and the Environment? Carbon Footprint, Energy, Battery Disposal.
[44] Carbon Footprint, 2022. ELECTRIC VEHICLES Why Make the Move to Full Electric now?

amounting to 66.5kg per bench. This would equate to a saving of 113.5kg of carbon per bench. Carbon can be stored in wood furniture for about 30 years[45].

Assuming there are 20 benches on the 'future street' results in a **negative impact of 1.33 tonnes of capital CO2e.**

3.1.8 Street Lighting

LED bulbs are already becoming a popular choice for street lighting, where 1 LED bulb is reported to use 1/6th of the power of a traditional halogen lightbulb. The UK and many other countries are already in the process of switching to LED lighting, therefore the carbon value for street lighting remains the same as for the 'typical street' at **174 kg of capital CO2e**.

As with any element powered from the electrical grid, the operational carbon footprint of street lighting will depend on the source. As the grid decarbonises therefore operational carbon will become carbon neutral.

3.1.9 Utilities

The materials choice for utilities are very much restricted to the functional technical capabilities of each service.

As broadband technology evolves so do the materials used, where a shift from copper wiring to fibre optic wiring is almost commonplace. One of the benefits of doing this is to enable a reduction in exchanges as fibre optic networks can travel further than copper without losing performance. Fibre technology also produces less heat consequently requiring less cooling, thus using less energy. Additionally, the extraction of 2kg of copper required to produce a 200 foot length of wire produces around 1 tonne of CO2e. Production of the equivalent length of fibre optic cable produces 0.06kg of CO2e. This is a significant carbon saving.[46]

Without any further information on the number of underground utilities it is not possible to speculate as to the carbon impact to the 'future street', however research demonstrates that this sector is moving in the right direction to reduce carbon emissions.

3.1.10 Underground/Metro

Many schemes are in place to neutralise the carbon emissions of underground networks. In London one of the interventions is to use the tube to heat London homes as it is estimated that there is enough heat wasted in London to meet 38% of the city's heating demands.[47] This would work towards carbon neutrality although is not directly appliable to the 'future street' in isolation.

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[45] CINARK, The Royal Danish Academy and Vandkunsten Archtects, 2019. The construction material pyramid.
[46] TalkTalk, 2021. Making the 'climate case' for Full Fibre.
[47] TheCivilEngineer.org, 2019. Heat produced by an underground line to warm houses in London.

Another strategy to reducing energy use on the London Underground is reducing the need to use the trains' brakes, which are one of the main causes of the underground's heat. The plan is to do this through more use of coasting as well as regenerative braking systems that harvest some of the energy lost in braking and supply it back to the train.

Solar panels are also planned to be introduced alongside railway tracks, as well as building in battery storage on the network. This could allow energy to be bought at times when renewable energy is freely available (windy or sunny days for example) for use at peak times, rather than buying from the grid. Private wind farms are also being investigated.[48]

Whilst exact carbon savings could not be obtained, the intention in London is to make the underground carbon neutral by 2050. Assuming that this aspiration will succeed then the operational carbon impact applied to the 'future street' is **neutral**.

3.1.11 Trees & Vegetation

Many streets already have trees and grass verges, but in many cases more can be done to create carbon sinks within the streetscape.

Trees are a good carbon sink however, they only sequester a meaningful amount of carbon once fully grown. A typical tree over its lifecycle (approximately 100 years) is estimated to sequester approximately 1 tonne of CO2[49].

Assuming trees can be positioned evenly every 5m on the virtual street, this is 400 trees on the 'future street', equating to sequestration of around **400 tonnes of CO2**.

3.1.12 Ground & Air Drones

Ground and air drones are a relatively new innovation but are rapidly gaining in popularity for deliveries, replacing car and van trips. A study undertaken in the USA found that an air drone was at least 26 times more efficient than the alternative mode, Graph 5 illustrates this.[50]

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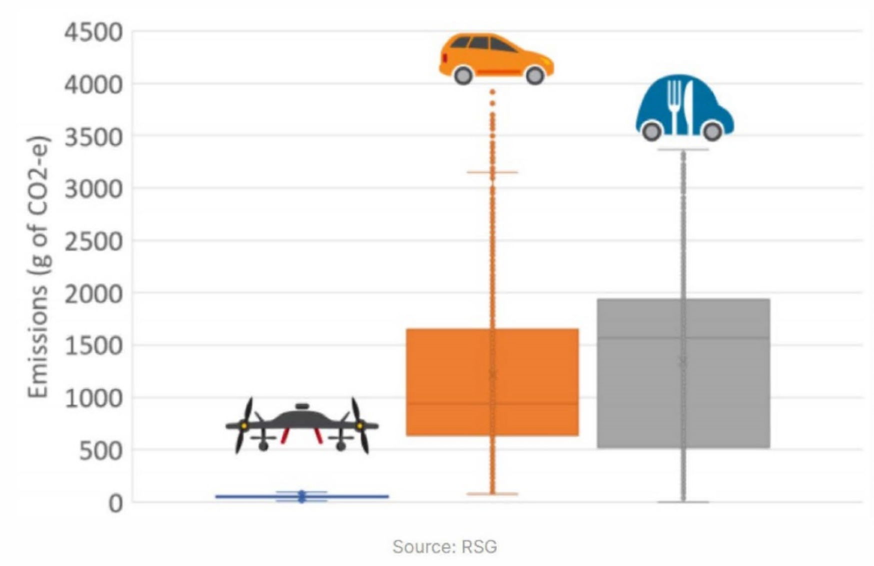
[48] Katwala, A., 2018. London's wild plan to make the Tube carbon neutral by 2050.
[49] Grantham Institute. 2015, How much CO2 can trees take up?
[50] Wygonik, E., 2020. Calculating the Climate Cost of Drone Delivery.



Graph 5 – Air drone compared to car delivery[51]

Being a fairly new innovation, there is little informal available on the embodied carbon of ground or air drones, but it is anticipated that the operational savings would offset this somewhat.

3.2 The Future Street – Total Capital Carbon

Street Element	Capital Carbon	Operational Carbon (10 years)
Road Surface	9.24 tonnes	-
Cars	13,200 tonnes	Neutral
Buses	228 tonnes	Neutral
Bus Stops	negative 664 kg	-
Cycle Hire Stand	1.65 tonnes	Neutral
EV Charging Point	-	-
Street Furniture	negative 1.33 tonnes	-
Street Lighting	174 kg	Neutral
Utilities	-	-
Underground	-	Neutral
Trees & Vegetation	negative 400 tonnes	-
Ground & Air Drones	-	-
Estimated Total	**13,037 tonnes**	**Neutral**

[51] Wygonik, E., 2020. Calculating the Climate Cost of Drone Delivery.

Each component has been considered independently and estimated CO_2 or CO_2e values have been applied accordingly. Based on the aforementioned judgements on the likely provision of each element on a 1km linear 'future street', the total capital carbon figure attributed is approximately **13,037 tonnes of CO_2e**. This excludes some elements where there was limited data or any operational carbon.

Furthermore, based on a future year where it is assumed the electrical grid supply will be carbon neutral, the operational carbon emissions will also be vastly carbon neutral. This is a simplistic figure that assumes aspirations and net zero targets will succeed. As such this should be used as an indication of impact for comparison with the 'typical street' only.

4 Carbon Savings in the Streetscape

Street Element	Capital Carbon	Operational Carbon (10 years)
Road Surface	-7.26 tonnes	-
Cars	4,800 tonnes	-3.5 billion tonnes
Buses	12 tonnes	-686,200 tonnes
Bus Stops	-32.3 tonnes	-
Cycle Hire Stand	1 tonne	-3.9 tonnes
EV Charging Point	-	-
Street Furniture	-1.5 tonnes	-
Street Lighting	-900 g	-
Utilities	-	-
Underground	-	-
Trees & Vegetation	-400 tonnes	-
Ground & Air Drones	-	-
Estimated Total	**4,371 tonnes**	**-3.5 billion tonnes**

Based on the data extracted and presented in the previous sections the total indicative capital carbon savings (excluding cars) from the 'typical street' to the 'future street' are **429 tonnes of CO_2e per km of road**. EVs have a higher capital carbon value than ICE vehicles and therefore the embodied carbon for the 'future street' could be in the order of 4,371 tonnes more than the 'typical street'

The estimated carbon savings including operational emissions are in the order of **3.5 billion tonnes of CO_2e per km of road** over a 10-year period on the basis of fully decarbonising the electrical grid. Capital carbon costs are not included in this figure. Over 20 years this is expected to decrease further and exponentially when capital carbon is factored in.

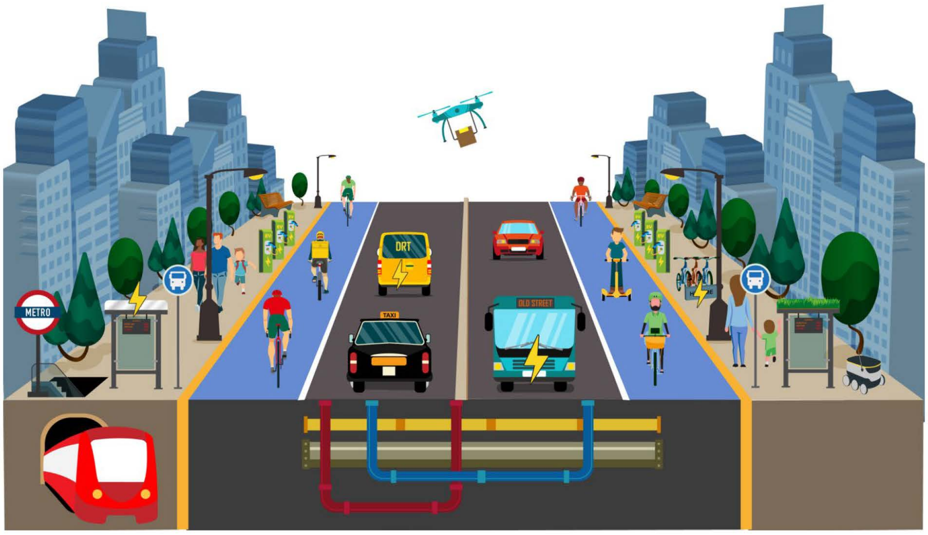


Figure 3 – The Future Street – Carbon Savings

5 Limitations & Future Research Needs

Specific limitations in the data available have been discussed where relevant with the primary points of note being the use of difference source material (each employing different methods of CO2/CO2e calculation), and different units of measurement over differing timeframes reported. The values reported are approximations and are intended to build an indicative picture of the virtual streets for comparison only. Average values have been used meaning that for some components there will be a wider range of values available.

From this desk-top assessment alone, gaps in research are apparent for a number of the elements considered; for street lighting there is a wealth of evidence relating to the benefits of LED when operational, but limited information on the embodied carbon related to the lighting (including lighting column etc).

The capital carbon make-up including both materials and manufacture of buses is an interesting topic of which further study would be beneficial, particularly how this might change with the increase carbon values of batteries over diesel vehicles.

As noted previously, there is little information on the embodied carbon of street furniture, however there is a clear path to decarbonisation in material use which is the use of wood over metals and plastics.

For the underground no data has been identified that considers the capital embedded carbon including train carriages, tracks, ventilation, manufacture, delivery, and fitting of new items and frequency of replacements etc. This therefore does not allow for a comparison to other modes of travel in terms of the lifecycle carbon emissions, where the underground has been demonstrated to have a far lesser impact on emissions than other non-active modes of travel, but with an unknown ongoing embodied carbon cost.

Ground and air drones are perhaps the newest technology discussed in this analysis and it is not evident through desk-top research that information is available on the capital carbon of drones.

As working from home or remotely becomes more popular it will mean a reduction in regular trips within the streetscape, whether that be car, bus, or active travel trips for example. This will have an impact on the carbon footprint of the streetscape however it would need to be offset against the higher energy spending within the home, as well as the extra elements of a journey to work such as food shopping and leisure trips.

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