OPTIMISING AND FUTURE-PROOFING THE DESIGN OF MAJOR URBAN ROUTES FOR ALL STREET USERS

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1. INTRODUCTION

The paper describes the key elements of the EU Horizon 2020 project **MORE** [**M**ulti-modal **O**ptimisation of **R**oad-space in **E**urope], which involves a partnership between five European cities (Budapest, Constanta, Lisbon, London and Malmo), three universities, five consultancies and five European organisations representing the interests of cities and major street user groups. The primary aim of MORE is to develop a comprehensive and objective approach to the planning, design, management and operation of road-space on major urban routes – to address problems experienced both now and as they might arise in the future - including the development and enhancement of several street design aids.

The urban road network represents the largest public investment in urban infrastructure, and its efficient functioning is vital both to the day-to-day operation of urban society and the local and national economy (carrying by far the bulk of goods and person movements); and the resulting negative externalities (traffic accidents, air pollution, noise, severance, congestion, CO_2 emissions, etc.) can reduce economic efficiency and impact adversely on the health and well-being of people. There is also growing recognition of the importance of physical and operational resilience, both to external events such as adverse weather conditions, and to disruptions on the network itself (e.g. a major road accident or a burst water pipe).

While much road traffic is intra-urban, cities depend economically and socially on wider regional, national and international movements, many carried on the Trans-European road networks; these networks are generally managed by national agencies (e.g. Highways England) and the operational interfaces with the various urban road networks are often poor. How these interfaces might be improved is an important focus of this project.

Cities are beginning to recognise the need to look seriously at how to optimise urban road capacity through the **flexible use of road-space**. This includes an interest in redesigning main roads to encourage a switch from car traffic to public transport, walking and cycling. There is also a greater need to consider the 'Place' functions of streets, improving the servicing of premises, providing a higher quality, less traffic-dominated street environments and supporting the shops and services on high streets that are facing financial challenges. One recent manifestation of this in the UK has been the growing interest in **kerb-space management**.

In the longer term, growing densification, changing retail and employment patterns and emerging new transport modes and services - are all likely to make additional demands on the urban limited road space. New developments such as MaaS (mobility as a service), the electrification of the vehicle fleet and the deployment of automated vehicles, and of drones for deliveries, also call for a rethinking of the functions and design of major urban roads, while ICT and 'big data' afford opportunities for road space management in real time, by providing richer information on patterns of road use and network conditions.

Reducing disruption due to road maintenance and utility works is also part of the challenge that MORE is addressing. Increasing extreme weather events can also disrupt urban mobility and need to be considered in future road design. To help meet this challenge there is a series of technological advances that can be exploited, from SUDS (SUstainable Drainage Systems) to sturdier and adaptive road surface materials, and the repair of sub-surface utilities using burrowing equipment or building multi-functional trenches, plus advances in data that enable road performance to be monitored and managed in real time in all its aspects – from vehicle flows to bus occupancy, parking and loading, and cycling and pedestrian movements.

Meeting these diverse challenges requires a comprehensive approach involving the optimisation of the planning, design, maintenance, operation/management of urban road-space, and has four main dimensions:

- **Spatial**: making best use of the limited road-space, taking into account the needs of all road users (including those who live and work in the area) and all transport modes, by investigating the extent to which space can be simultaneously shared by different street user groups.
- **Temporal**: acknowledging that the balance of user needs varies by time of day, day of week, season, etc. and so there should be flexibility in design and management, to enable variation of space allocation over time – ultimately in a dynamic manner.
- **Material/technological**: developing new materials and technologies to reduce the incidence and impacts of such things as roadworks, flooding, carbon footprint, etc. on multi-modal network operation.
- **Organisational/institutional**: introducing appropriate administrative structures, enforcement procedures, legislation, funding, consultation and decision-making processes to enhance network operation.

But optimisation cannot be purely an 'objective' exercise. There are many interest groups involved and affected, so that significant stakeholder engagement will necessarily form part of the design process; important ethical issues are involved, and some priorities may be largely politically determined (the 'politics of contested space').

2. AIMS AND OBJECTIVES

The primary aim of MORE is to promote the redesign of existing urban main roads and streets to accommodate multi-modal and multi-functional requirements, including the needs of 'Place' users and their associated activities, and address the severe problems of congestion, noise, air pollution, safety etc., in situations where road widening or building new roads is not an option. In such cases the aim is to enable city authorities to make the best use of available road-space by optimally allocating the available capacity, in space and time.

This ambitious aim is being achieved through meeting fourteen operational objectives, using a variety of methods:

1. Identifying **'good practice'** in major urban road street planning, design, operation and management, which will be incorporated into a searchable, on-line library data base (met through objective 8).
2. Developing a **conceptual framework** for identifying requirements along a particular route, including the mobility needs of road users, other street user activities, those working and living adjacent to the road, and wider policy considerations (e.g. climate change, energy efficiency, community cohesion, road safety, personal security, etc.).
3. Developing a comprehensive set of cross-modal and cross-sector **performance indicators**, drawing on the conceptual framework (Objective 2), against which the performance of existing roads and new design options can be judged using new appraisal tools (objective 10).
4. Investigating the **organisational/institutional** arrangements (including the regulatory background, administrative processes and funding), which can facilitate or act as barriers to the introduction of comprehensive road-space allocation strategies, recognising cultural and political differences.
5. Identifying **opportunities and threats** arising from new transport and non-transport **technologies and emerging digital eco-systems**, including fleet electrification, automated vehicles, drones, new logistics concepts, 'mobility as a service', dynamic LED street signs and road markings, and digital communications
6. Developing **future scenarios** as inputs to design briefs, reflecting potential changes in demographics, working practices, new transport products, etc.
7. Developing interactive tools for **stakeholder engagement**, to contribute to the design brief and to the co-creation of design options, using both physical 'planning for real' and web-based tools.
8. Developing web-based tools to assist in the **generation of design options,** drawing on existing case study experience and using combinatorial algorithms to develop new whole-street design options.
9. Developing an **enhanced simulation tool** (based on VISSIM) capable of simulating the actions of all street users and providing outputs in the form of the agreed performance indicators (Objective 3).
10. Developing a set of **comprehensive appraisal tools** for assessing the road-space design options, using the simulation outputs from objective 9.
11. Applying the developed concepts and tools on **radial case study corridors** in five European cities, to demonstrate their applicability and to derive optimal design solutions.
12. Conducting an overall **assessment of the case study corridor exercises**, to assess their effectiveness and derive findings that would be applicable to other European cities.

13. Developing **guidelines** for optimal road-space allocation on major urban corridors that can be applied by cities across Europe and beyond, describing processes and introducing the Application Tools.
14. **Disseminating** results widely through European-level and national organisations, and exploiting internationally the commercial products developed in MORE, through the preparation of a business plan and effective legacy planning.

The corridor analysis will include the development of new strategies for optimising traffic signal control at junctions (and any intermediate pedestrian crossings) and will require some consideration of potential spill-over network effects that extend beyond the major roads. It will also consider the scope in individual cases for taking some pressure off the main corridor routes in the future by upgrading any adjacent railway services in the same corridors, or using water transport to carry more freight and passenger traffic – plus the potential for using air-borne drones.

3. CONCEPTS

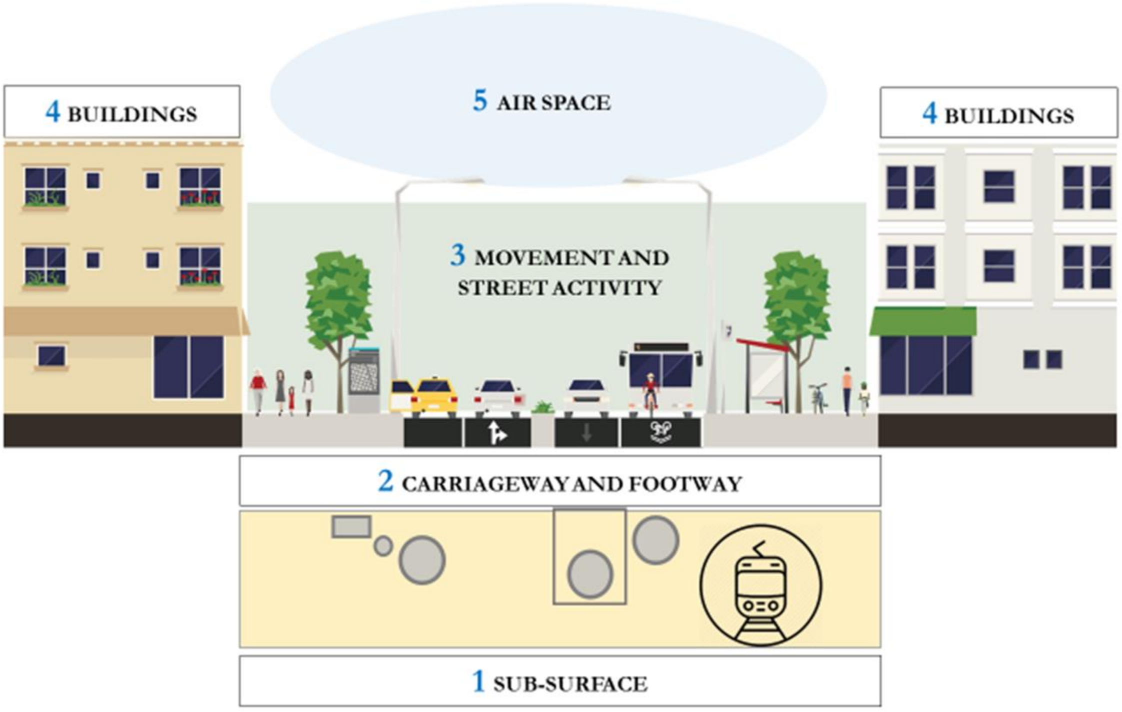
In tackling this broad and challenging agenda, MORE is developing a number of core concepts and definitions.

3.1 Roads vs Streets

MORE critically distinguishes between urban 'roads' – expressways for use only by motorised vehicles and with restrictions on stopping – and 'streets', with pedestrian and cycling traffic, street-level crossings, plus parking and loading, building frontages and street activities, as illustrated below. These have very different functions and hence different priorities and design options, as illustrated below.

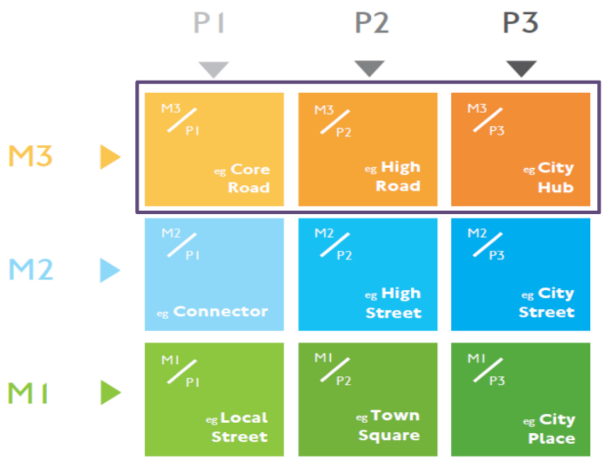
2.2 Streets as 'eco-systems'

Most street design manuals only deal with an individual travel mode, or at best look at the overall use of the carriageway and footway, with no explicit consideration of competing kerbside activities. And none consider the urban street in the wider context of the local environment in which it operates. MORE goes beyond previous studies and treats the street as a complete 'eco-system', as illustrated below.



Here we consider the carriageway and footway and the various activities that these support, but also the activities in the adjoining buildings, and infrastructure and activity above and below the street, and the ways in which these interact with each other. This also provides the opportunity to consider system inputs and outputs, and various types of flows, such as energy flows and financial flows.

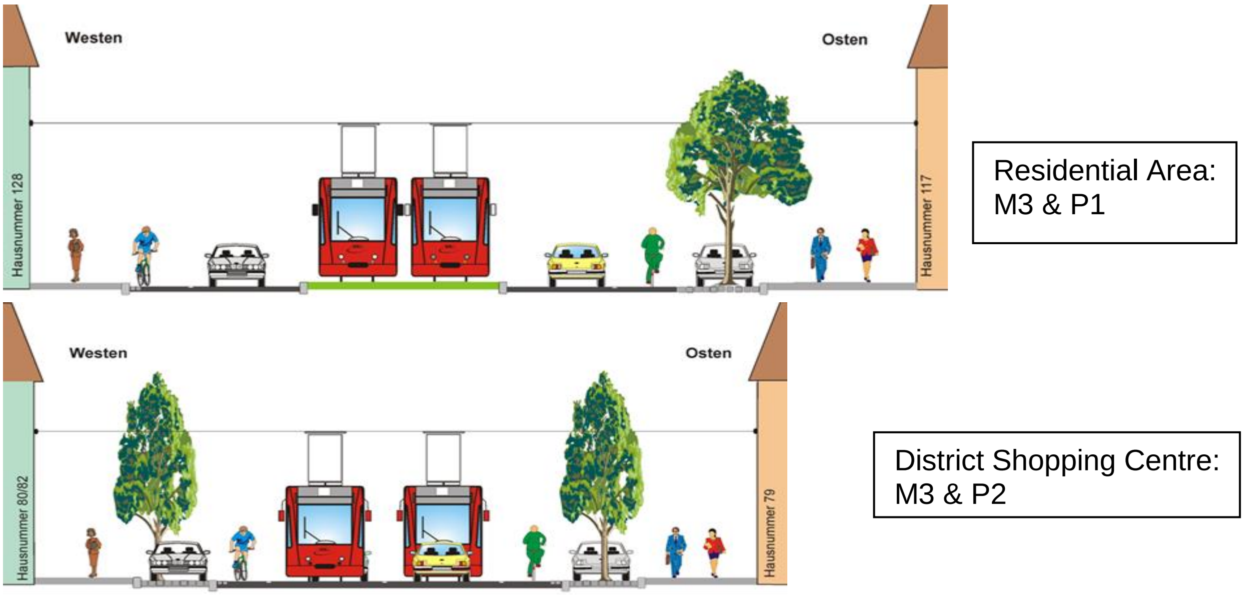
2.3 Explicit recognition of 'Movement' and 'Place' function of urban streets



Streets perform a broad range of competing strategic and local multi-modal and multi-activity functions, including interchange. Transport for London and the London Boroughs have reclassified all roads in Greater London to take into account their importance for 'Movement' (by all modes of transport) and 'Place'. This has used the '3 by 3' classification shown alongside (from M/P 3 'Strategic' to M/P 1 'Local' significance), and is a radical departure from the conventional classification of urban roads based purely on their role in the vehicle movement hierarchy (e.g. using terms such as 'district distributor' or 'collector') – and encourages a more holistic approach to road-space design that enable engineers to much better engage with the wide range of road user groups.

2.4 Context-sensitive design

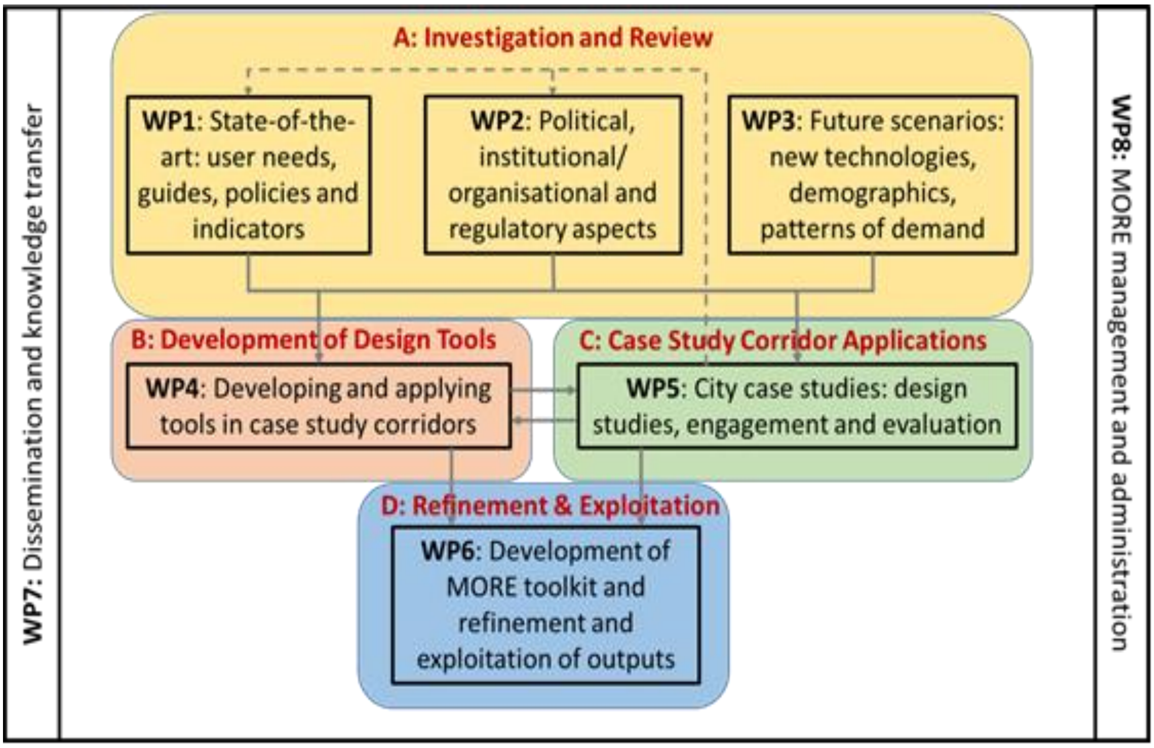
Different design solutions may be appropriate along a major feeder route (row 'M3' above). This notion is illustrated in the figures below, taken from a study on two sections of a major feeder route in Freiburg in the EU project 'ARTISTS' (Arterial Streets Towards Sustainability), drawn to the same scale.



In the residential section (M3 & P1), there is sufficient space to accommodate all road users with dedicated provision (for pedestrians/street activities, cycling, parking/loading, general traffic and trams); but as the feeder route passes through a district shopping centre (M3 & P2), the road width is narrower and the road user demands are greater. Given the greater Place importance, footway widths are retained, and more kerbside space is provided for parking and loading. Separate space is also retained for cycle lanes, and this allocation is achieved by using the same part of the carriageway for trams and general traffic, BUT by giving priority to trams through upstream and downstream signalised priority, to encourage sustainable mobility and maximise personal rather than vehicle capacity. This is a significantly different design solution to that found in conventional UK road engineering design thinking – where general traffic and tram lanes would be maintained, by taking out the cycle lanes and reducing kerbside parking and loading provision.

3. METHODS

The project is being implemented in six technical work packages (WPs 1-6), plus WP7 covering dissemination and knowledge transfer, and WP8 management and administration. The project involves four methodological 'stages', within which a variety of specific methods and tools are being employed and developed. These four stages are shown below (A to D), overlaid on a diagram illustrating the full work package structure.



Stage A: Investigation and review

The first three work packages draw on existing data and information, to synthesise and exploit that knowledge, in order to identify: (WP1) user needs, existing policies and guidance on road space allocation, and key performance indicators; (WP2) institutional and organisational arrangements and barriers; and (WP3) future demographic pressures and technological options, and potential scenarios.

A variety of methods is being combined in order to fulfil the tasks identified in WPs 1-3, and to achieve Objectives 1 to 6:

- Synthesis and evaluation of existing products, information and data. This draws on our partners' knowledge (particularly in the case study cities), plus international academic, industry and policy/practice literatures, using search engines, requests to European road user and city networks, and professional bodies.
- Interviews with road user groups, institutions and other stakeholders, both nationally and internationally, and with the case study cities. This includes interviews with officials of professional organisations, city partners, representative stakeholder groups, road user groups and citizens (via face-to-face or group interview techniques, e.g., focus groups).
- Scenario planning methods, to develop demand/supply options to input into the corridor design exercises in the five cities. This draws on partners' knowledge and builds on recent work undertaken on future city mobilities as part of the EU CREATE project.

Stage B: Development of design tools

Four design Application Tools are being developed within MORE to aid the process of dynamic road-space allocation on feeder routes (Objectives 7 to 10); this includes the training and support during Stage C:

1. Web-based tool to assist stakeholders in generating potential design options, comprising a searchable library of existing street designs, and a facility to develop completely new design options by generating new combinations of design components.
2. Physical and web-based tools to promote meaningful stakeholder engagement in the co-creation of design options, using a GIS platform and building on the Buchanan Computing TraffWeb and LineMap products, and previous work at UCL.
3. Expansion of the PTV VISSIM software, to capture the full range of 'Movement' and 'Place' activities, and to provide enhanced outputs covering a broader range of urban performance indicators.
4. A road design appraisal tool to enable design options to be assessed against the design brief, for their impact on different groups and design objectives. Different techniques will be used, including outputs achievement, benefit-cost analysis (involving the monetarisation of performance indicators) and a multi-criteria analysis. This will draw, in part, on the enhanced appraisal tool currently being developed as part of the FLOW project.

Stage C: Case study feeder route corridor applications

Each city is developing and implementing a common set of procedures for determining the optimal dynamic allocation of road-space, in different time periods, using the tools developed in Stage B. This involves active stakeholder engagement, and the designs will be captured in sets of detailed design drawings and graphical representations for each time period. These will be subject to testing, through micro-simulation, with preferred designs being determined by user acceptability and by applying the new appraisal tool.

Detailed road user data will be required for the case study routes. This will draw together existing data streams, based on vehicle-based GPS, embedded road sensors, parking sensors and mobile phone data. While there have been major advances in data collection and consolidation, it is not yet possible to fully monitor all aspects of street activity– although this could change during the life of the project. To cover the gaps in information we will use video surveys (with cameras on posts or housed in drones) and use this information to simulate the information that would have been obtained from sensors, which may not yet be available on that street, or widely in vehicles.

One key feature of this process of dynamic management of road-space is to determine how to provide information to road users about the function of each part of the road at different times of day. Conventionally, this has been done through traffic signs and road markings. Our city partners believe that physical signing and lining will be needed for several decades, for regulatory/enforcement reasons and until all road users can make use of direct digital feeds. But the advance in MORE will be to investigate the use of LED signs and road markings on ordinary urban roads (not motorways), to convey changes in regulations at different times of day.

The first step in gaining official approval for such signs will be to carry out laboratory and off-road trials, to show technical feasibility and public comprehension and acceptability, initially with mock-ups using large computer monitor screens. A central challenge here will be how to manage and sign the transition from one road-space layout to another, taking into account vehicles currently parking and loading, and the visual impacts of changing signs and road markings. We will also explore the growing opportunities to provide real-time information to drivers in their vehicles (e.g. dynamically changing and allocating parking and loading availability), to increase the efficiency of system operations.

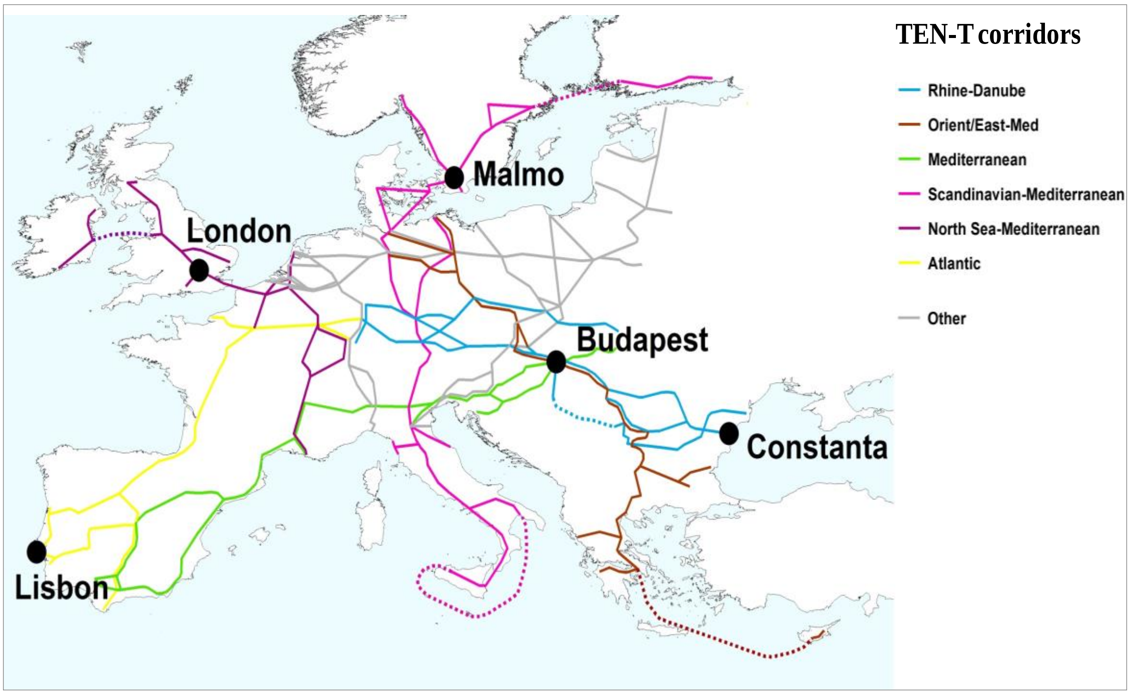
The four Application Tools will be jointly applied on each case study route as part of the design process and be adapted to local conditions (e.g. translated into the local language, developed and calibrated for local conditions, etc.) and trialled in each case study city, as part of the local road-space design exercise (Objective 11).

Designs are being developed to address both current conditions and potential future conditions 20-25 years ahead (in the latter case, looking multi-modally and at a wider corridor impact area). Future conditions will be influenced both by changes in demographics and employment patterns, and by the development of new products and services, aided by advances in technologies. Here aspects that will be considered by MORE, using a scenario planning approach, will include:

- Electrification of the vehicle fleet
- Autonomous vehicles: road, rail water, air
- Advances in traffic control systems
- Advances in parking and loading management
- Implications of employing new types of sensors
- Self-healing roads
- Trenchless technologies underground logistics

Broad strategies will be prepared for the whole feeder routes (from TEN-T interface into central city areas), but ‘sections under stress’ or ‘pinch points’ have been identified where more detailed design exercises and simulations will be carried out. In general, cities have chosen to focus their efforts on different locations along the feeder route to examine in depth the current and future conditions.

The TEN-T corridors and cities covered by MORE are shown geographically below. The cities range in size from around 300,000 inhabitants to over 8 million, and together interact with six of the nine TEN-T European road corridors (i.e. Atlantic, North Sea-Mediterranean, Scandinavian-Mediterranean, Mediterranean, Orient East-Med, & Rhine-Danube).



In London, the study is focussing on the A2 corridor, between the Inner Ring Road and the M25. Two of the other case study corridors are illustrated below.

BUDAPEST

Budapest lies at the convergence of three TEN-T networks, causing many challenges since the Rákóczi corridor is often used by passenger and freight traffic as a connecting route with the different TEN-T corridors. As a result, there are many competing demands on this urban space which suffers from congestion and could benefit from road space reallocation solutions. This could lead to improvements in competitiveness of Budapest and its region and contribute to a sustainable, liveable, attractive and healthy urban environment.

Map: The MORE Feeder Route connects the Mediterranean, Orient/East-Med, and Rheine-Danube TEN-T corridors with the Budapest city centre and main train station

Picture: The Elizabeth Bridge, part of the MORE corridor, caters primarily for motorised modes - largely ignoring the place function.

LISBON

The main challenge on the case study corridor is the intense commuting traffic and congestion at peak-hours, as it connects the northern suburbs - and the northern part of Portugal - with the major employment centres in Lisbon. An additional pressure is the increasing road traffic associated with the port of Lisbon (both freight transport and cruise passengers). The southern part of the corridor has multiple interchanges (inter-urban buses, metro, rail, ferry), freight, tour buses, and, the new Lisbon bike share system and a new large-scale underground car parking area. New housing and employment developments plan along the corridor add to this challenge.

Map: The MORE Feeder Route lies in the east of the city, connecting the Atlantic TEN-T corridor with the city centre and main train station and ferry terminal

Photo: Stress point where high-volume motorised environment conflicts with needs of residents and local business

Stage D: Refinement and exploitation

Once the case study corridor scheme exercises have been substantially completed, MORE will carry out an assessment of the design exercises (addressing Objective 12), looking at:

- (i) the effectiveness of the new design process and its outcomes overall;
- (ii) the performance of the four Application Tools developed in Stage B;
- (iii) cross-site comparisons; and (iv) identification of general findings relevant to other cities in Europe.

This will lead to the development of the MORE toolkit (Objective 13), which sets out and illustrates the recommended process for designing the dynamic management of road-space on major urban corridors and introduces the four Application Tools developed to aid this process. This Stage will also review the four tools, and refinements will be made to them, to ensure that they are in a form that is suitable for exploitation. There will be an active and targeted process of dissemination and exploitation (Objective 14).

5. FUTURE-PROOFING STREETS – SOME POLICY CHALLENGES

To date, road-space allocation in cities has been carried out on a rather ad hoc basis, with demands for individual modes being the driver of change at different points in time (e.g. installation of bus priority networks, or segregated cycle networks); on the whole this has often been at the expense of the allocation of space for kerbside activities. The introduction of the Red Route network in London set out to take a more comprehensive approach in the 1990s, although it gave a stronger priority to the needs over Movement over Place than would be the case in London today (e.g. acceptance of reduction in network capacity required to deliver the Elephant and Castle regeneration scheme), and there has been no systematic review over the whole network of changes in user needs and political priorities since then – although the recent plans for selective introduction of 20mph sections is an indication of a recent rebalancing of demands.

Potentially there are many parts of the street that could have specific space allocation policies, designed to meet the specific needs of different street user groups:

BUILDINGS	Footway			Carriageway							Footway			BUILDINGS
	Curtilage	Movement	Street Furniture	Footway kerbside	Running lanes	Median kerbside	Median strip	Median kerbside	Running lanes	Footway kerbside	Street Furniture	Movement	Curtilage	

Probably the area that has adopted the most sophisticated and comprehensive approach to space allocation – although in a rather piecemeal way, over time – is that of kerbside parking controls. Here three strategies have been adopted, often in combination:

- **Physical restrictions:** pro-actively limiting the number of parking spaces available in an area
- **Regulation**: controlling who can park in a space (e.g. resident, or general public), during which hours and for how long; and
- **Pricing**: charging per unit time

More generally, current regulations (e.g. access controls) often differentiate between street user types, on one of three bases:

- The type of **person**: resident, disabled person, etc
- The type of **activity**: access, drop-off, parking, loading; and
- The **mode** being used: bus, cycle, etc.

If a more strategic approach is to be taken to overall street-space allocation, the question arises as to on what basis this should be done. In MORE we ae exploring three approaches to 'optimising' space allocation:

- **Policy-based**, by reviewing city documents relating to any stated road user hierarchy, and the city objectives relevant to street planning and design as set out in SUMPs (Sustainable Urban Mobility Plans) and other policy documents.
- **Stakeholder-based**, by identifying the full range of user groups affected by the particular street, and developing a multi-criteria analysis approach to exploring options and impacts – with weightings developed through stakeholder engagement; and
- **Pricing-based**, looking at the relative economic value of different street activities; in some cases, this is relatively straightforward and has been done previously (e.g. bus lane and parking provision), but where provision is currently uncharged (e.g. loading), this becomes more challenging.

One of the biggest challenges facing our MORE city partners – and cities more generally – is how to deal with the plethora of new mobility-related produces and services that are appearing across the world. National and city governments find themselves in 'catch-up' mode, trying to moderate the potential negative impacts of large-scale take-up of new initiatives – from Uber to electric scooters – while not wanting to stifle innovation that could improve mobility options for residents and assist in meeting high-level city goals (e.g. reduced air pollution, traffic congestion and CO2 emissions).

Regulation is traditionally approached by considering whether to authorise the use of a new mode once it has been proven and, if so, under what conditions. This can be a slow and cumbersome process – the commercial introduction of the hovercraft in the UK was seriously delayed as it could not be decided whether land, air or sea regulations should apply. More currently, we observe a large increase in electric scooter sales, but with no legal basis to use them on the public highway.

In MORE we are exploring a different approach to regulation, which is inherently more flexible and could help to shape new product development, rather than seek to control it retrospectively. This involves looking at the attributes of the street rather than the mode and deciding what types of modal performance should be allowed on different parts of the highway. For example, a new set of regulations might be framed as follows:

- **Footways:** limited to non-motorised modes and electric motorised modes with a maximum capable speed of 8mph (????), and with audible warning if wheel-based; no protective gear required.
- **Cycle lanes:** designed for wheeled modes travelling at between 8mph and 20mph (????), both motorised and non-motorised. Some protective gear recommended, depending on the vulnerability of the vehicle's construction, plus night-time lighting.

- **Main carriageway:** limited to motorised vehicles capable of travelling in excess of 20mph (????). All such vehicles should be registered, with some recognisable form of identification, an accurate speed indicator and with night-time lighting. Some protective gear required, depending on the characteristics of the vehicle.

Where cycle lanes are not provided, it might be necessary to define the footway/ carriageway boundary in a different manner. Clearly, where there is no footway adjacent to an all-purpose road, as in many rural areas, then all modes could potentially be found on the carriageway - although possibly with additional hazard warning requirements.

Finally, adopting the notion and capability of applying **dynamic street space allocation** builds in a much higher degree of flexibility than is possible with fixed physical signs and road markings, but traffic regulations need to adapt to sanction such developments.

There are some tricky issues to be addressed here, such as:

- Allowing for different uses of the same physical space (e.g. kerbside) at undefined times of day – not pre-specified. In some extreme cases, part of a footway might become part of the carriageway at certain times.
- Ensuring that the electronic signs and road markings are correctly operating and are fully visible at all times.
- Determining how to record the traffic regulations in operation at any particular point in time, in a way that is reliable and enforceable.
- Determining how to handle transition periods, from one set of regulations to another; for parking this is unlikely to be a problem, as the switchover period would need to be set at the maximum allowed parking duration; but for the temporary introduction, say, of a bus lane might find a driver in the 'wrong' lane for a short period of time.

It may also be appropriate to think differently about the carriageway/kerbside balance. For example, a half bus boarder might be a good compromise between the needs of buses to stop against a kerb, while taking up less kerb-space than a normal bus stop, at the expense of delays to larger vehicles too wide to pass around the bus. Similarly, cyclists in lanes adjacent to the kerb can experience potential conflicts with vehicles accessing/egressing kerbside spaces – in some cases might a cycle lane on the off-side of a vehicle running lane be safer?

Issues such as these would benefit from a constructive debate among government and professionals, and the full range of street user group representatives – of both Movement and Place. The MORE project plans to hold a number of European events to debate these issues, led by POLIS. during the remainder of the project (completion August 2021).

6. CONCLUSIONS

Urban street planning, design, operation and management is entering a time of rapid change and challenge, but with exciting opportunities to take full advantage of new data sources and transport-related technologies, in order to improve the user experience and better achieve urban transport objectives – both Movement and Place-related. Indicative of this change is the growing interest in the UK and US, among both the public and private sectors, in 'kerbside management' – a term which has not yet become established in mainland Europe.

The paper outlines work that is on-going in a European project, to explore these issues, and develop frameworks and tools to enhance future streets. MORE is investigating both current and likely future conditions on busy urban streets, using scenarios and taking a comprehensive 'eco-system' approach. The project argues that the key to getting more out of street-space is to adopt a comprehensive approach that explores the possibilities of allocating space/capacity dynamically – as is already common practice at traffic signalised junctions. A new regulatory framework, and public acceptance, will key to implementing such changes.

A great deal of interest has been expressed in this work by public and private sector bodies in several countries in Europe and beyond. To facilitate on-going communication and exchanges of ideas, MORE has set up an Exchange Forum, to share new ideas and tools with cities, consultants and industry partners across the world, and would welcome greater UK involvement. If you would like to join the Forum, please email: Francesco Ripa at POLIS: FRipa@polisnetwork.eu.

Acknowledgement

The materials reproduced in this paper are taken from MORE reports that remain the property of the consortium partners.

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