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Pedestrian priority in street design - how can it improve sustainable mobility?

Paulo Anciaes[a]*, Peter Jones[a]

[a]*University College London, Centre for Transport Studies, London, United Kingdom*

Abstract

Street design guidelines aimed at pedestrians seldom acknowledge the effects of different design options on other street uses (e.g., cyclists, bus users) or the pathways through which those options contribute to sustainable economic, social, or environmental outcomes. This paper presents a new set of tools for the generation and appraisal of options for reallocating street space to pedestrians in busy urban corridors. Options are generated using two tools that allow planners to specify conditions regarding the street uses that should be prioritized, the uses that should not be made worse off, and the policy objectives that should be achieved. One tool (Policy Interventions tool) presents options that, based on the theory and empirical evidence, fulfil the specified conditions. The other tool (Street Designs tool) presents all possible combinations of street design elements (e.g., footways, cycle lanes, bus stops), in a cross-section view of the street, that fulfil the specified conditions and fit in the available street width. The street design options generated with these methods are then appraised using a third tool that incorporates cost-benefit analysis and multi-criteria procedures. The tools were tested in five European cities and refined based on feedback from practitioners and user group associations. The tools can be used to generate and appraise a comprehensive and balanced set of street design options that improve pedestrian conditions while preserving a balanced distribution of space among other street users and achieving sustainable outcomes.

Keywords: Streets; street planning; street design; pedestrians; street design; option generation; appraisal

* Corresponding author.
E-mail address: p.anciaes@ucl.ac.uk

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1. Introduction

Urban streets have a variety of uses, all requiring space. These uses include the movement of people and goods (by different modes), vehicle-based stationary activities (e.g., car/bicycle parking, loading of goods), people-based stationary activities (e.g., waiting for buses, "window shopping", sitting, socializing), and the provision of space for greenery and for surface water runoff. Fulfilling all these uses allows cities to move towards economic, social, and environmental sustainability. For example, well-designed urban streets facilitate access to jobs and shops, provide opportunities for interaction, and reduce flood risk (NACTO and GDCI 2016, NCSC and SGA 2015).

In many cities, there is now a sustained move towards providing more space for pedestrians, reflecting a new paradigm for transport and urban policy, centred on health, wellbeing, equity, and liveability (Anciaes and Jones 2020). Re-designing streets to give more space to pedestrians has several positive effects, on the local economy (e.g., more expenditure on local businesses), communities (e.g., more social interaction), and environment (e.g., less emissions) (Kang 2016, Mehta 2007, Chiquetto 1997). However, street design guidelines seldom make explicit the pathways through which different street designs contribute to achieve those effects. Guidelines also do not fully acknowledge the effects on other street uses. For example, widening footways may imply reducing space allocated to bus lanes. This may result in a net negative effect on sustainable mobility, if, for example, it leads to the reduction of bus speeds and then to a switch from bus to car use.

These are important gaps, because the new paradigm prioritising walking is developing at the same time that pressure on urban street space is increasing, due to the need to accommodate increased mobility levels, new forms of mobility (e.g., ride-hailing services, micromobility), and increased reliance on home deliveries (ITF 2018, Schocke *et al.* 2020). Street designs that reallocate space to pedestrians should therefore attend to a range of policy objectives and to the effects on other users, especially on other types of sustainable mobility (e.g., cycling, public transport).

This paper presents new tools for generating and appraising interventions for reallocating street space to pedestrians. The goal is to find options that maximize the societal benefits of pedestrian priority while promoting a shift from private cars to sustainable modes. The tools were developed by a consortium of universities, international associations of street user groups (pedestrians, cyclists, and bus users), and the governments of five European cities: London, Lisbon, Budapest, Malmo, and Constanta. The tools are available at www.roadspace.eu.

2. Option generation

The generation of options is a stage that tends to be neglected, not only in street planning and design, but also in transport and urban planning in general (Hull 2009). The usual practice is to present a set of options (or just a single option) to the public for consultation. However, the identification of this set of options is rarely the result of a systematic process. In most cases, it is not clear how the options were identified.

To fill this gap, we have developed two new tools that allow planners to explore feasible solutions for the reallocation of street space among different uses, taking into account the needs of all street users and a range of policy objectives.

2.1. Policy Interventions tool

The Policy Interventions tool generates options for broad types of interventions on urban streets, providing information on how they can address the needs of the different street users and potentially meet policy objectives. The tool requires two inputs: a) the level of priority that should be assigned to each street use: "0" (can be worse off than now, if needed), "1", (should not be worse off than now), or "2" (should be better off than now); and b) the objectives that the intervention aims to achieve (a maximum of 5).

The tool considers 26 street uses (related to the movement and place function of the street) and 28 objectives (related to the street uses or to wider economy, society, and environment effects) (Table 1). These lists were based on literature reviews and input from user group associations and the five partner cities.

Table 1. Street uses and policy objectives considered in the Policy Interventions tool

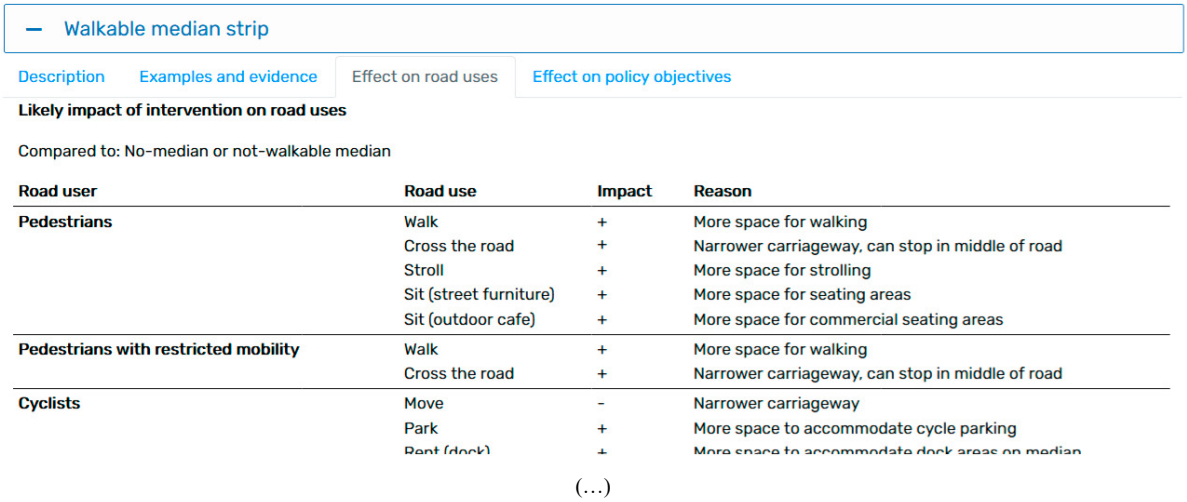
Street uses	walk, cross the street (pedestrians), stroll, sit (street furniture), sit (outdoor cafe), walk (pedestrians with restricted mobility), cross the street (restricted mobility), cycle, park (cycle), rent cycle (dock-based system), rent cycle (dockless), move (micromobility), move (bus), stop (bus), wait (bus passengers), interchange (bus passengers), interchange (rail passengers), move (car), park (car), stop (car), car share, move (motorcyclists), wait (taxi/ride-hailing vehicle), wait (taxi/ride-hailing passenger), move (goods vehicles), stop (goods vehicles), move (emergency vehicles), stop (service vehicles)
Policy objectives	Increase number of trips, reduce travel time, increase travel time reliability, reduce congestion, improve trip quality, achieve a more sustainable modal split, facilitate place activities (e.g. people sitting), facilitate kerbside activities, improve access to local buildings, improve resilience (to weather conditions), increase flexibility (to different street uses), reduce costs of transport, promote local economy, improve traffic safety, reduce community severance, increase personal security, promote physical activity/health, promote social interaction, promote social inclusion, increase wellbeing, increase green space, improve air quality, reduce noise, improve visual environment, protect soil/water and reduce flood risk, improve local climate, reduce energy consumption, improve regional/global environment

The output of the tool is a list of possible interventions for street redesign, selected, based on the tool user input, from a database of 210 interventions. This includes interventions that: a) do not reallocate space among street uses but improve the conditions of some uses; b) reallocate space permanently; c) reallocate space temporarily (i.e., at some times of day or days of week); and d) reallocate space dynamically, based on street conditions at each time. The list was compiled based on a search of academic literature and reports published by public institutions, professional associations, street user group associations, and non-governmental organizations.

The tool user can then explore information about each of the selected interventions. This information is organised into four pages: a) description (see example in Figure 1) - including general guidelines for implementation and types of streets or areas for which the intervention is more suitable; b) examples of applications of the intervention around the world and empirical evidence on the effect on street uses and policy objectives; c) likely effect on each street use (see an example in Figure 2); and d) likely effect on each policy objective.

The effects on street uses and policy objectives are described in the tool output pages as "-" (likely positive), 0 (neutral or uncertain) or "+" (likely positive). This is also the information used to select the options from the tool user input. The tool database includes information on the likely effects of all 210 interventions on all 26 street uses and 28 policy objectives, i.e., a total of 11,340 effects. For many of these effects, there was no empirical evidence available. The assignment of +/0/- values were therefore based on the theory, tracing the likely cause-effects chain that follows the intervention. It was assumed that street redesign lead to immediate effects on the ability of certain users to use the street, which may then lead to changes in behaviour and then to indirect effects on all other street uses and on policy objectives. The process of refining the tool included a review of these hypothesized links by other project partners.

Fig. 1. Example of output of Policy Interventions tool: *Description* page.



— Walkable median strip

Description | Examples and evidence | Effect on road uses | Effect on policy objectives

Likely impact of intervention on road uses

Compared to: No-median or not-walkable median

Road user	Road use	Impact	Reason
Pedestrians	Walk	+	More space for walking
	Cross the road	+	Narrower carriageway, can stop in middle of road
	Stroll	+	More space for strolling
	Sit (street furniture)	+	More space for seating areas
	Sit (outdoor cafe)	+	More space for commercial seating areas
Pedestrians with restricted mobility	Walk	+	More space for walking
	Cross the road	+	Narrower carriageway, can stop in middle of road
Cyclists	Move	-	Narrower carriageway
	Park	+	More space to accommodate cycle parking
	Rent (dock)	+	More space to accommodate dock areas on median

(…)

Fig. 2. Example of output of Policy Interventions tool: *Effect on Street Uses* page.

Table 2 summarizes the results of three applications of the tool in one of the partner cities. All applications assign priorities to pedestrians, differing in the specific street uses that should be better off and should not be worse off, and in the objectives that the intervention should achieve. The generated options include interventions usually aimed at pedestrians (e.g., pedestrianisation, footway extensions) but also interventions aimed at other users (e.g., cycle streets) that nonetheless fulfil all the specified conditions. Some options are common to all three applications. Others are specific to only one of the applications. Several of the generated options (marked with * in the table below) were identified as feasible by the tool users in this city.

Table 2. Results of three applications of the Policy Interventions tool

Inputs			Generated options
Should be better off	**Should not be worse off**	**Policy objectives**	(*: identified as feasible by city)
walk; cross the street	walk (pedestrians with restricted mobility); stop (service vehicles)	improve traffic safety	greenways; de-clutter footway; footway extensions*; inclusive design; cycle street (shared with car); cycle parking/hire on side street; narrow the street carriageway*; reduce number of traffic lanes; decrease width of traffic lanes; high-occupancy vehicle lanes; area-wide traffic restriction; vehicle-based restrictions; license plate number traffic restrictions; dynamic traffic restriction; road pricing; cordon and area-wide charges; dynamic pricing; high-occupancy toll lanes; reduce speed limit; low speed zones; corner extensions of footway*; park & ride; kiss & ride; parking/loading space on side streets; consolidated freight distribution*; part-time parking/loading space*
stroll; sit (outdoor café); cross the street (pedestrians with restricted mobility)	cross the street; sit (street furniture)	facilitate place activities; promote local economy; promote social interaction	pedestrianisation*; part-time pedestrianisation*; de-clutter footway*; greenways; add/improve street lights; footway extensions; narrow the street carriageway; reduce number of traffic lanes; decrease width of traffic lanes; point closures/traffic cells; area-wide traffic restriction; regular road closure; vehicle-based restrictions; road pricing; cordon and area-wide charges; high-occupancy toll lanes; kiss & ride; parking/loading space on side streets; enforcement of parking/loading regulations; part-time parking/loading space; consolidated freight distribution; add/improve courtyards, squares, plazas*
walk; cross the street; sit (street furniture)		reduce community severance; increase personal security; promote social inclusion	part-time pedestrianisation*; add/improve street lights*; de-clutter footway; narrow the street carriageway; reduce number of traffic lanes; decrease width of traffic lanes; point closure/traffic cells; regular road closure*

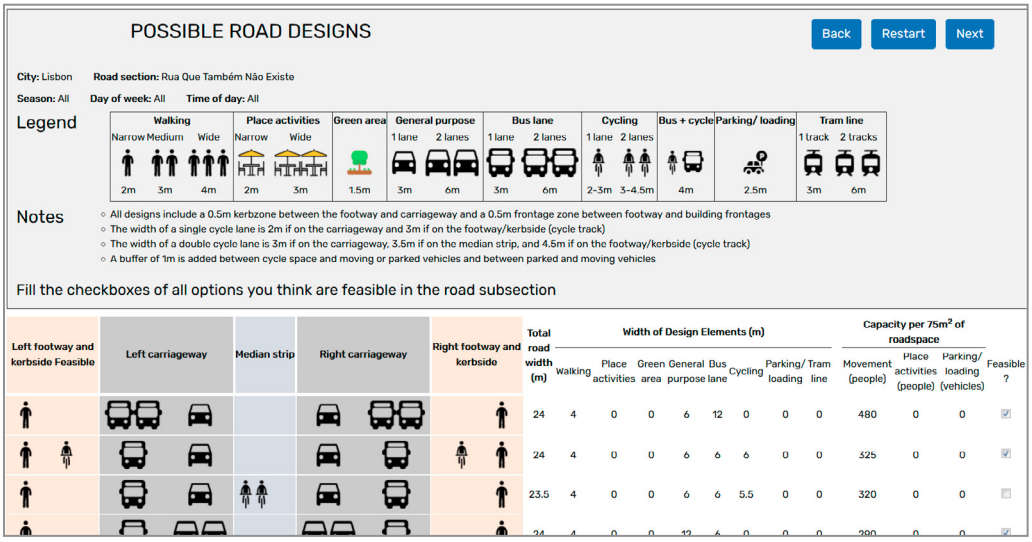
2.2. Street Designs tool

The Street Designs tool generates street space allocation options that are technically feasible and address the needs for space of different street uses. The designs combine nine possible street design elements: space for walking, space for place activities (e.g., stalls, benches, outdoor cafés), green area, lane for general traffic, bus lane, space for cycling (cycle lane or cycle track), mixed bus and cycle lane, space for parking and loading, and tram line.

The construction of the tool used the Morphological Box method, which generates all combinations of all possible characteristics of each option (Zwicky 1947). In this case, the method generates all possible positions that a design element can occupy in a cross-section view of the street. Each element has two possible widths: the minimum standards and a more comfortable space provision. The assignment of these widths was based on street design guidelines in the five partner cities. In some cases, we assumed that the width of an element depends on its location across the street and on the adjacent elements. For example, cycling infrastructure requires more space if it is located in the middle strip of the street, surrounded by moving motorised traffic. The total width occupied by the elements in each combination was then calculated by summing the width of each element. Only total widths in the range 15-35m were considered. Further constraints were imposed regarding the placement of design elements across the street. For example, lanes for the movement of motorised traffic cannot be placed at the edge of the street, next to buildings.

The tool requires two inputs: a) the width that is currently allocated to each type of design element; and b) the priorities that should be assigned to each street use: "0" (Not relevant in this street - no space provided), "1" (Relevant, but not priority - will have some space but not more than now), or "2" (Relevant and priority - will have at least the same space but more, if possible).

The output of the tool is a list of cross-section street designs, selected, based on the tool user input, from the set of all possible combinations of design elements. The street designs shown fulfil two conditions: a) have a total width equal or slightly smaller (<1m) than the available street width (i.e., the sum of the widths currently assigned to the different elements), and b) are consistent with the priorities specified by the user regarding the desired changes in the allocated width. Figure 3 shows an example of the output page. Each design is identified with icons representing the type and size of the design elements. Information is also shown on the total street width assigned to each type of design element, and the capacity (per 75m^2 of street space) assigned to movement, to people-based place activities, and to parking and loading. Capacity is calculated based on the width assigned to each design element and information on space used by each type of street use, collected from NACTO and GDCI (2016). The tool users are then asked to select which of the combinations shown are feasible in their own context.



(…)

Fig. 3. Example of output of Street Designs tool

Table 3 summarizes the results of three applications of the tool in one of the partner cities. All applications assign priority to walking, differing in the degree of priority and in the set of other design elements that also have priority. The number of generated options is large, although it differs considerably across the three applications. Within each application, the total capacity of the street for movement, place activities, and parking/loading also varies, which shows that the set of generated options provide an ample set of possibilities for the user to choose from. However, only a few options were identified as feasible by the tool users in this city.

Table 3. Results of three applications of Street Designs tool

Should have at least the same space but more, if possible	Should have some space (but not more than now)	Number of options generated	Capacity range (per 75m^2)		
			Movement	Place activities	Parking/ loading
Space for walking; space for place activities; green area; space for parking/loading	Lanes for general traffic; space for cycling	30 (feasible: 2)	155-225 people	65-80 people	0-11 vehicles
Space for walking; space for place activities; green area; space for cycling;	Lanes for general traffic	70 (feasible: 1)	175-255 people	65-80 people	0 vehicles
Space for place activities; green area; space for cycling; space for parking/loading	Space for walking; lanes for general traffic	80 (feasible: 5)	125-195 people	65-80 people	0-5 vehicles

3. Option appraisal

Appraisal is the comparative assessment of the positive and negative forecasted impacts of different options for a project. Appraisal is a standard practice in the case of large projects to build new transport infrastructure (e.g., new motorways, railways, or bridges), but less common in the case of smaller projects to modify small parts of the urban transport network. There are currently no tools for the appraisal of the reallocation of space in urban streets. The usual practice is to use microsimulation to produce indicators of the performance of the different options in terms of movement by different modes. The set of indicators usually includes speeds, travel time, and/or delays. In some cases, local environmental impacts, such as air pollution, are also estimated. A decision is then taken based on political priorities, the performance indicators, and the results of public consultation. There is no established procedure to objectively compare the merits of the different street design options.

The main aim of appraisal is to judge the efficiency of an option versus another, i.e., how the positive impacts balance against the negative impacts, for each option. However, projects also have an equity dimension, because positive and negative impacts may affect different people. This is particularly important in the case of interventions to reallocate street space, because, by definition, they make some street users better off at the expense of other users.

We have developed a new tool to appraise options for reallocating street space, taking into account the effects of the options on all street uses and on a range of policy objectives. The inputs of the tool are, for each option: a) the estimated implementation and maintenance cost; b) the space allocated to each design element; and c) the value of performance indicators.

Three sets of performance indicators are considered: a) movement, per travel mode (volume, speed/travel time, delays, reliability of travel time, trip quality); b) people-based and vehicle-based place activities (number, duration, and quality of activities); and c) wider impacts (property values, visits to local businesses, expenditure in local businesses, traffic safety, physical activity, community severance, personal security, equity, visual impacts, energy consumption, air pollution, CO2 emissions, noise, local climate, land use, and nature). Many of these aspects can be measured with more than one type of indicator. For example, (poor) quality of parking activities can be measured as the average number of illegal activities per day or as the percentage of satisfied users. For this reason, the tool user is given the possibility to choose an indicator to measure those aspects (and then insert the respective value). Only the performance indicators for which there is data need to be filled - the tool can run with minimal input data.

The tool then performs a cost-benefit analysis. The tool user can choose, from dropdown menus, the data source of monetary unit values of each performance indicator, where available in the tool's database. The tool will indicate the source of the value, country, year, original currency and value, and value converted to €2021. The tool user can also specify their own unit and respective unit value, which will override the values in the tool's database.

The tool will then return: a) the total monetary value of each performance indicator (where available), for each option; b) the overall net benefit and benefit-cost ratio of each option; and c) the options that violate design or legal standards (for example noise standards).

Figure 4 shows an example of the output, for a street with 6 traffic lanes and three options for reallocating the space of some lanes: wider pedestrian pavements, green median strip, or cycle lane. Cells highlighted in grey identify cases where the performance indicator was not estimated or no monetary unit value was available in the tool's database or inputted by the user. Green highlights identify the best option for each performance indicator. Red highlights identify options for which the indicator violates standards.

COST-BENEFIT ANALYSIS: OUTPUT

Synthesis of Cost-Benefit Analysis

		Net benefit (over 5 years)	Benefit-cost ratio	Acceptable	violations
Option 0	*6 traffic lanes*	€ 0	0.0	No	Noise standards
Option 1	*Widen pavements*	-€ 3,409,872	0.3	No	Noise standards
Option 2	*Add green median*	-€ 3,911,205	0.2	Yes	
Option 3	*Add cycle lane*	-€ 5,673,467	0.2	No	Noise standards

Detailed Cost-Benefit Analysis

Performance indicator	Unit	Now (do nothing)	Option 1 *Widen pavements*	Option 2 *Add green median*	Option 3 *Add cycle lane*	Monetised changes Option 1 *Widen pavements*	Monetised changes Option 2 *Add green median*	Monetised changes Option 3 *Add cycle lane*
Implementation cost	1 €	0 €	-€ 135,700	-€ 90,500	-€ 81,300	-€ 135,700	-€ 90,500	-€ 81,300
Maintenance cost	1 €	0 €	-€ 122,130	-€ 81,450	-€ 73,170	-€ 122,130	-€ 81,450	-€ 73,170
Link function								
Private cars								
Level of service	Space per vehicle (m2/vehicles/day)	0.08	0.07	0.09	0.07			
Travel time	Travel time (minutes)	0.02	0.03	0.03	0.03	-€ 1,269,155	-€ 1,269,155	-€ 1,208,322
Delays	Average delay (minutes/km)	0.4	0.6	0.6	0.6			
Reliability								
Trip quality	% of satisfied users	0.06	0.14	0.6	0.12			
Taxis								
Level of service	Space per vehicle (m2/vehicles/day)	0.08	0.07	0.09	0.07			
Travel time	Travel time (minutes)	0.02	0.03	0.03	0.03	-€ 254,182	-€ 254,182	-€ 507,603
…								
Wider impacts								
Economic								
Property values								
Visits to local businesses	Number of visits to local shops per day	1,018	2,463	2,463	2,463			
Expenditure in local businesses		8.2	€ 11.1	€ 11.1	€ 11.1			
Total expenditure	Total expenditure per year (1000 €)	€ 3,046.87	€ 9,979	€ 9,979	€ 9,979			
Social								
Safety	Number of fatalities per year	0.98	0.88	0.95	1.31	€ 870,461	€ 261,138	-€ 2,872,522
Health (physical activity only)								
Community severance	UCL index	0.08	0.08	0.08	0.08	-€ 964,102	-€ 964,102	€ 520,425
Personal security	% users feeling safe (from crime)	0.6	0.81	0.51	0.61			
Equity (inclusive design)								
Visual impacts								
Environmental								
Energy consumption								
Air pollution								
Co2 emissions								
Noise	LAeq16h (dB(A))	71	69	65	65	€ 510,397	€ 692,651	€ 633,378
Local climate								
Land use								
Nature								

Fig. 4. Example of output of Appraisal tool

As an alternative, the tool contains a multi-criteria analysis module. This requires further inputs: the scale of each indicator (i.e., the best and worst value) and the priorities assigned by each stakeholder to each indicator. The tool then returns, for each stakeholder, the overall score of each option and the ranking of the options.

4. Implications for policy and practice

The new tools provide an objective and systematic approach for the reallocation of street space, an issue that is usually contentious, as the gains for one user often come at the expense of losses for other users, or produce unintended economic, social, or environmental effects. This is relevant for interventions that prioritise walking in urban streets, given the increased need to accommodate new forms of mobility and home deliveries. The main intended users of the tools are planners in local governments or consultancy companies. However, the tools are freely available and can be used by researchers, non-governmental organisations, businesses, or the public.

The Policy Interventions tool fills a gap in existing methods, as the information on possible interventions is currently scattered in academic studies and reports, each focusing on specific case studies and usually looking at a single street use or policy objective. The tool brings together the existing information and classifies it in a systematic way, providing practitioners with a better understanding of the characteristics of each intervention in comparison with alternatives, using standardized information about the likely effect on street uses and policy objectives.

The Street Designs tool provides detailed information of how options for street space reallocation translate into a complete allocation of street space, in cross section, among different uses. There is a large number of feasible combinations of design elements that can be incorporated in a street design. Furthermore, these elements can have different widths. It is important that practitioners consider the full range of feasible combinations, including less obvious ones, as each combination addresses the needs of street users and policy objectives in a different way.

The Appraisal tool provides an objective method to combine the various performance indicators of different options, considering not only the usual indicators of movement, but also indicators of people and vehicle-based place activities and wider economic, social, and environmental effects. This gives practitioners a balanced view of the wide range of effects that street space reallocation can have, reducing the implicit bias that occurs when only movement indicators are considered.

Overall, the tools help practitioners to identify and assess options that address user needs and policy objectives, while considering the local conditions and technical constraints. This allows practitioners to present a comprehensive and balanced set of options for public consultation, which not only increases the probability of finding effective interventions but can also increase the political acceptability of the options that are eventually chosen.

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References

Anciaes, P., Jones, P. 2020. Transport policy for liveability – valuing the impacts on movement, place, and society. Transportation Research Part A: Policy and Practice 132, 157-173.

Chiquetto, S. 1997 The environmental impacts from the implementation of a pedestrianization scheme. Transportation Research Part D: Transport and Environment 2, 133-146.

Hull, A. 2009. Implementing Innovatory Transport Measures: What Local Authorities in the UK Say About Their Problems and Requirements. European Journal of Transport and Infrastructure Research 9, 202-218.

ITF (International Transport Forum). 2018. The Shared-Use City: Managing the Curb, https://www.itf-oecd.org/shared-use-city-managing-curb-0

Kang, C-D. 2016. Spatial access to pedestrians and retail sales in Seoul, Korea. Habitat International 57, 110-120.

Mehta, V. 2007. Lively streets determining environmental characteristics to support social behavior. Journal of Planning Education and Research 27, 165-187.

NACTO (National Association of City Transportation Officials) and GDCI (Global Designing Cities Initiative) (2016) Global Street Design Guide. Island Press, Washington., https://globaldesigningcities.org/publication/global-street-design-guide

NCSC (National Complete Streets Coalition) and SGA (Smart Growth America) (2015) Evaluating Complete Streets Projects: A Guide for Practitioners., https://smartgrowthamerica.org/resources/evaluating-complete-streets-projects-a-guide-for-practitioners-2

Schocke, K-O., Höhl, S., Quitta, A., Schäfer, P. 2020. Commercial traffic 2.0 - Analysis and recommendations of delivery strategies for the package delivery industry in urban areas., In R Elbert, C Friedrich, M Boltze, and H C Pfohl (Eds.) Urban Freight Transportation Systems, Elsevier, Amsterdam, pp. 79-100.

Zwicky, F. 1969. Discovery, Invention, Research - Through the Morphological Approach. Macmillan, Toronto.