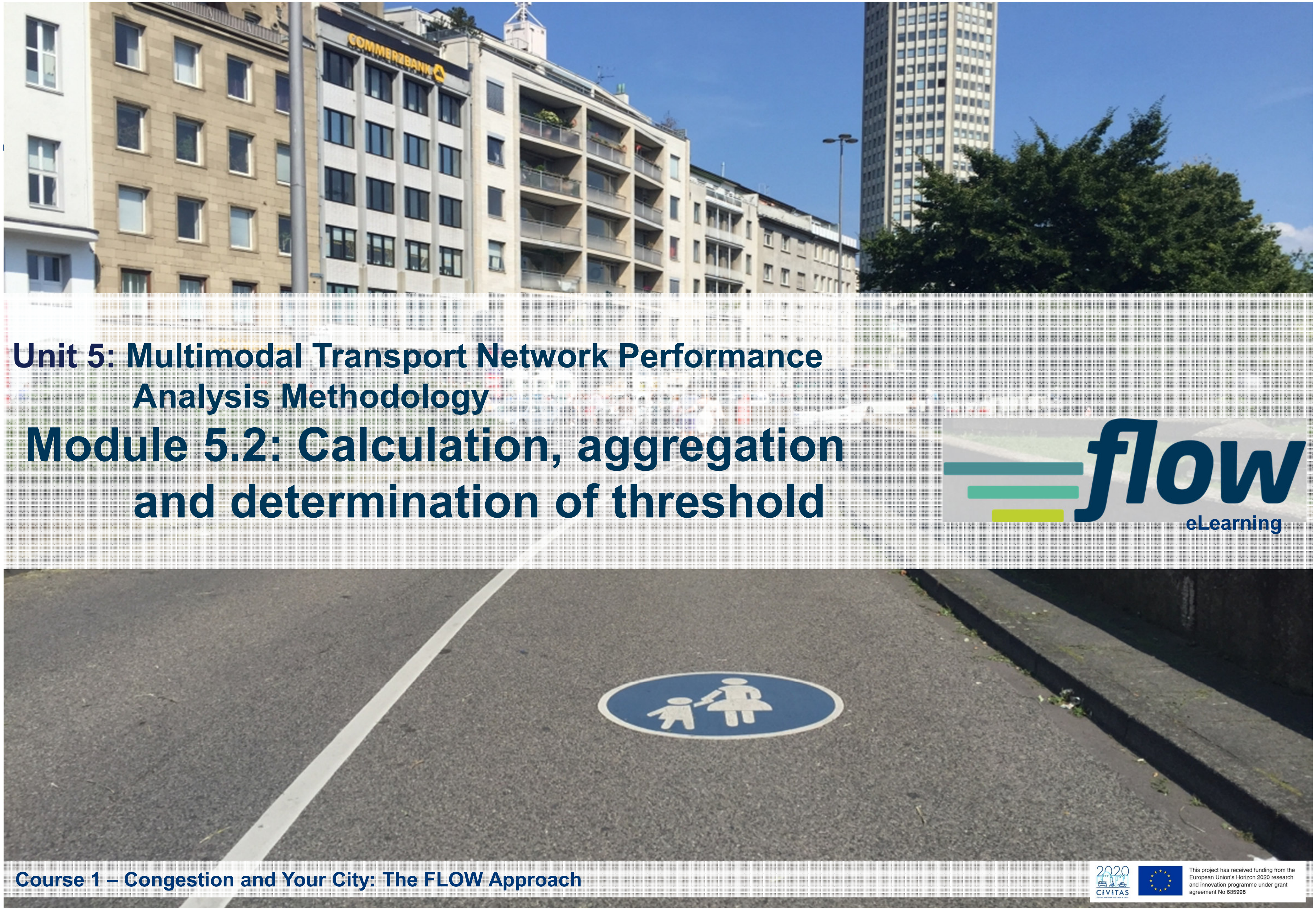


Unit 5: Multimodal Transport Network Performance Analysis Methodology

Module 5.2: Calculation, aggregation and determination of threshold

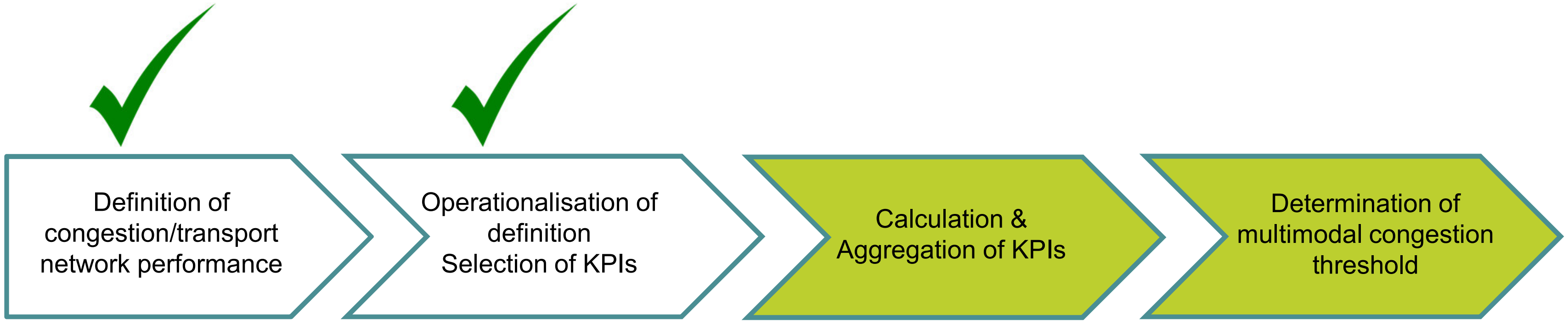
flow eLearning

Course 1 – Congestion and Your City: The FLOW Approach

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 635998

Introduction

This unit explains the calculation and aggregation of the three KPIs: delay, density and level of service (LOS). It also explains how cities can set congestion thresholds cities according to their policy targets.



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Delay and minimum travel time

Delay is commonly defined as the mean time loss per traffic participant along a route – with the general assumption being motor vehicles. Delay is calculated as the difference between the actual travel time and the minimum travel time.

For *car drivers*, FLOW applies the generally accepted definition of minimum travel time as free-flow conditions. This is an established benchmark in traffic engineering practice (ideal travel time).

For *cyclists*, minimum travel time is defined as the average cycling speed (15 km/h is commonly assumed) multiplied by the distance over the network from origin to destination. The network can include roadways without cycling facilities.

For *pedestrians*, minimum travel time is defined as the time it would take to walk as the crow flies between two defined points at an average walking speed (1.2-1.4 m/s is commonly used in Europe). This recognises the nature of pedestrian movement and can be applied to the dispersed movements encountered at major junctions and in public spaces as well movement along defined links.

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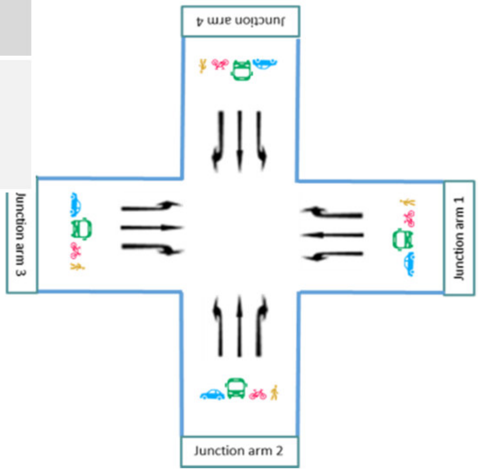
Delay at a junction

FLOW recommends two different network level-related calculation procedures depending on the scope of a walking or cycling measure. For a junction, FLOW assesses the *mean delay for each lane per transport mode (s/pers)*. Control delay (i.e. from traffic signals) is a direct output variable of the microscopic multimodal transport simulation, thus no additional calculation procedure is needed at this level.

Assessment Level		Measure Example	Applied indicator
Local	junction:	Reallocation of green times in favour of pedestrians and/or cyclists	Delay, LOS
	segment:	Traffic calming - Introduction of Tempo 30 road sections	Density, LOS
Network	corridor (network segment):	Introduction of new cycle path Public bike sharing scheme	Delay, LOS



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Delay along a corridor

flow eLearning

For a corridor, FLOW calculates the mean delay per transport mode as the *difference between actual and minimum travel time (s/pers)*. A fundamental component of the FLOW methodology is considering delay per person (as opposed to per vehicle) to provide a common basis for comparison amongst different transport modes. The mean delay per lane per vehicle on both levels needs to be scaled by the number of persons.

Assessment Level		Measure Example	Applied indicator
Local	junction:	Reallocation of green times in favour of pedestrians and/or cyclists	Delay, LOS
Local	segment:	Traffic calming - Introduction of Tempo 30 road sections	Density, LOS
Network	corridor (network segment):	Introduction of new cycle path Public bike sharing scheme	Delay, LOS

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Density

FLOW has adopted the commonly accepted definition of density (TRB 2010, FGSV 2015), which is based on the proximity of vehicles or persons to one another. Density is defined as *the number of vehicles (cars, public transport or bicycles) and persons occupying a given length of roadway lane*, usually specified as one kilometre.

photo: M. Schneider & C. Aistleitner

photo: Urda Eichhorst

photo: James Cridland

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Density on a road segment

eLearning

Density on a road segment between two adjacent junctions (outside of the junction areas) is calculated for each lane individually. Single *density values are calculated for each lane separately* using the recommended units of veh/km for vehicles and pers/m^2 for pedestrians (assuming that each lane is used by a single mode of transport).

A transformation of pedestrian area-based density into lane-based density must be carried out in order to have the same units for comparison (pers/m^2 → pers/km).

Assessment Level		Measure Example	Applied indicator
Local	junction:	Reallocation of green times in favour of pedestrians and/or cyclists	Delay, LOS
Local	segment:	Traffic calming - Introduction of Tempo 30 road sections	Density, LOS
Network	corridor (network segment):	Introduction of new cycle path Public bike sharing scheme	Delay, LOS

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Level of service

Level of service is a concept used to classify the continuum of traffic states into a limited number of levels (usually six) rated from A to F, where LOS A stands for the best service quality and LOS F the worst. The LOS level thresholds are determined based on the freedom to choose desired speed, the ability to pass slow moving vehicles or pedestrians and the freedom to change lanes or to ease cross- or reverse-flow movements of pedestrians.

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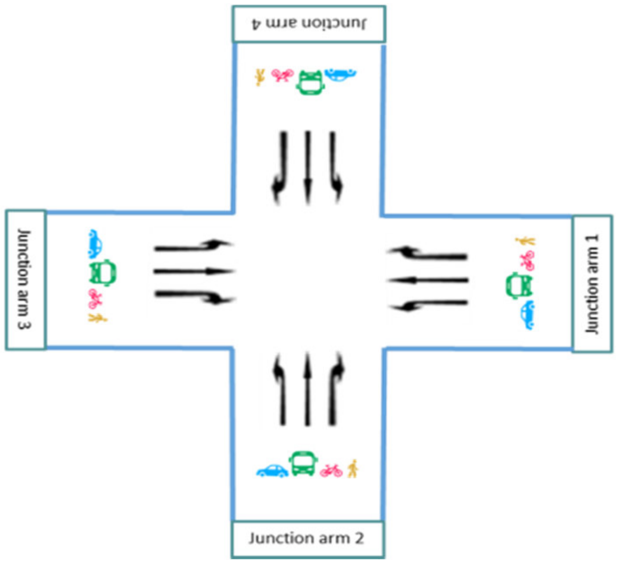
Level of service at a junction

eLearning

As mentioned earlier, the mean delay at a junction is calculated per lane and transport mode. The German Highway Capacity Manual suggests how to transform mode-specific delay values to LOS. It provides delay thresholds for junctions with or without traffic signals and for all modes. The table illustrates LOS thresholds for different modes at a signalised junction. The values used to determine LOS can be modified by cities to meet their own priorities.



LOS	car	public transit	cycle	pedestrian	utility points	range of utility points
	car mean delay (s/veh)	PT mean delay (s/veh)	cycle max.delay (s/veh)	pedestrian max. delay (s/ped)		
A	≤20	≤5	≤30	≤30	110	101-120
B	≤35	≤15	≤40	≤40	90	81-100
C	≤50	≤25	≤55	≤55	70	61-80
D	≤70	≤40	≤70	≤70	50	41-60
E	>70	≤60	≤85	≤85	30	21-40
F	-	>60	>85	>85	10	1-20

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Level of service on a segment

flow eLearning

Density is used to assign LOS thresholds for cars and pedestrians. For public transport and cycling LOS is not based on density but rather on other empirical values. For public transport on travel speed indices (see table). For cyclists, the German Highway Capacity Manual bases LOS on disturbance rates. The disturbance rate for bicycles is calculated based on the width of the facility and the number of encounters along the cycling facility.

LOS	car	public transport	cycle	pedestrian	utility points	range of utility points
	car density (veh/km)	PuT travel speed index (-)	cycle disturbance rate DR unidirect. traffic (D/cycle/km)	pedestrian density (pers/m^2)		
A	≤7	≥2,00	<1	≤0,10	110	101-120
B	≤14	≥1,50	<3	≤0,25	90	81-100
C	≤23	≥1,25	<5	≤0,60	70	61-80
D	≤34	≥1,00	<10	≤1,30	50	41-60
E	≤45	≥0,75	>10	≤1,90	30	21-40
F	>45	<0,75	-	>1,90	10	1-20

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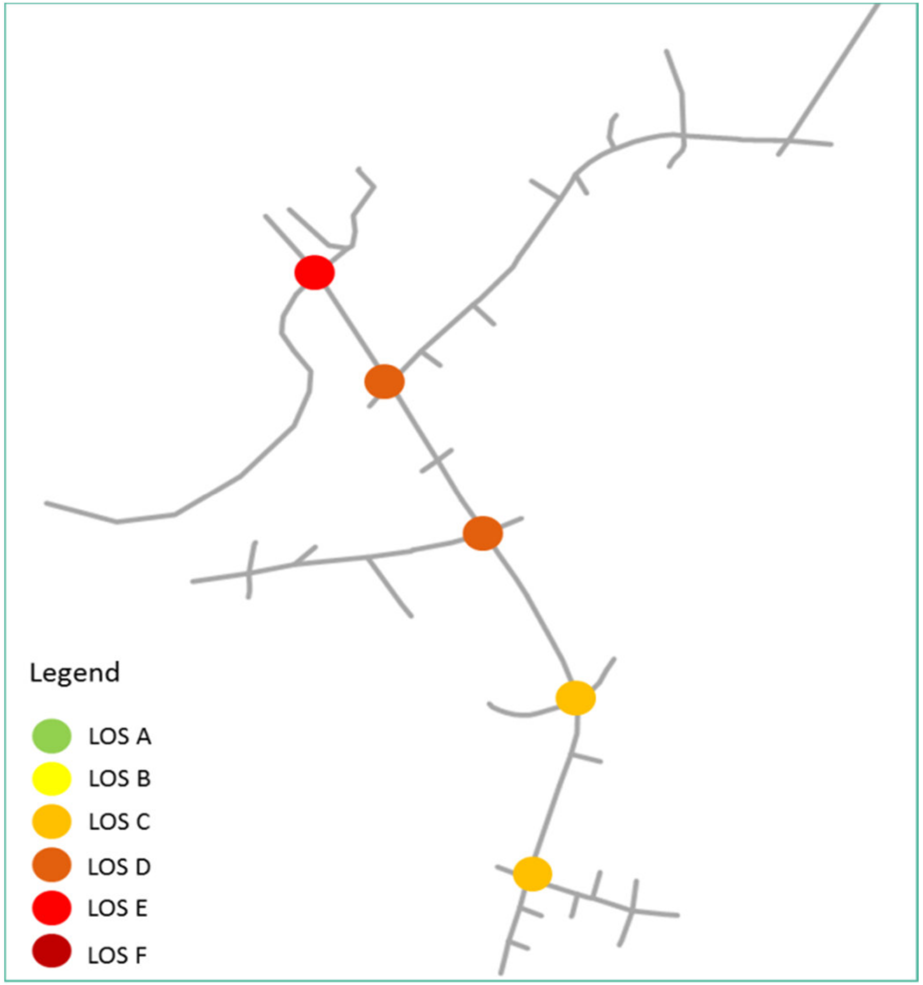
Level of service along a corridor

The calculation of mode-specific and/or multimodal LOS on a corridor is complex and does not necessarily provide representative results. It is more useful to develop a graphic representation of LOS on a mode-specific basis and use this to inform decision-making.

For example, the figure presents automobile LOS at junctions along a corridor. By presenting corridor LOS in this way, the calculation and assignment of LOS values by mode can be displayed for each transport mode separately, based on the specific values used to calculate LOS for that particular mode.



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Aggregation from KPI to multimodal performance index

eLearning

The figure on the right provides an overview of the aggregation procedure from separate mode-specific indicators to a single multimodal performance index (MPI).

Density cannot be aggregated as the measurement loses significance

1. Calculation of mode-specific variables in their own units
   - density: veh/km; pers/m^2
   - delay: s/veh, s/pers
   - LOS: A-F

2. Transformation of mode-specific variables into the same unit
   - delay: s/pers
   - LOS: utility points

3. Aggregation of transformed values into one multimodal index (priority factor, set by the city, see previous module 5.1)

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Two ways to aggregate

eLearning

There are two different ways to aggregate the values from the different modes. The table below presents two different aggregation options:

1. a *mean delay of all modes* measured in seconds/person
2. a *mean LOS of all modes* measured in utility points

The use of utility points (LOS) may be more appropriate as it better illustrates the perception of different traffic participants, e.g. the LOS as perceived by a car driver compared to that perceived by a cyclist.

<table>
<tr><th rowspan="2">KPI</th><th colspan="2">Input variable after transformation depending on scale of measure</th><th rowspan="2">Weighting factor based on city strategy</th></tr>
<tr><th>local</th><th>network</th></tr>
<tr><td>delay
[s/person]</td><td>$t_{d,i,j}$ = mean delay on lane i for transport mode j</td><td>$t_{d,j}$ = transport mode specific delay along the whole corridor for transport mode j</td><td rowspan="2">prioritised transport mode:
$q_{i,j}$ (pers/h); p_j (-)
no priority, only single weighting:
$q_{i,j}$ (pers/h); $p_j = 1$
all transport modes are treated equally:
$q_{i,j} = 1$ $p_j = 1$</td></tr>
<tr><td>LOS
[A-F]</td><td>$UP_{i,j}$ = utility point on lane i for transport mode j</td><td>Only graphical display of single values</td></tr>
</table>

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Multimodal LOS: aggregation

FLOW endorses a single multimodal measure of transport network service quality achieved by aggregating individual mode-specific measurements. In order to provide a common basis for the aggregation, the six LOS classes are converted into utility points using a discrete utility function that ranges from 0 to 120.

LOS	utility points	range of utility points
A	110	101-120
B	90	81-100
C	70	61-80
D	50	41-60
E	30	21-40
F	10	1-20

In this approach, utility points are set as a mean of the corresponding quality classes, since values for the six LOS classes vary among the different modes.

In order to aggregate the utility points, which are computed by mode, into a single aggregated utility value, a mean utility point is computed as a weighted average (centre column). These mean utility points can then be converted into an integrated level of service (for all modes) by associating the results with the corresponding range of utility points (column 3).

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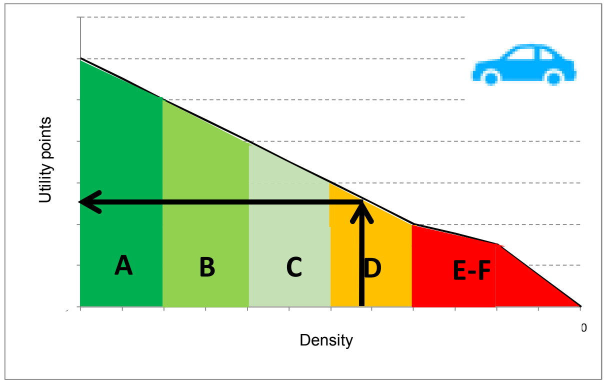
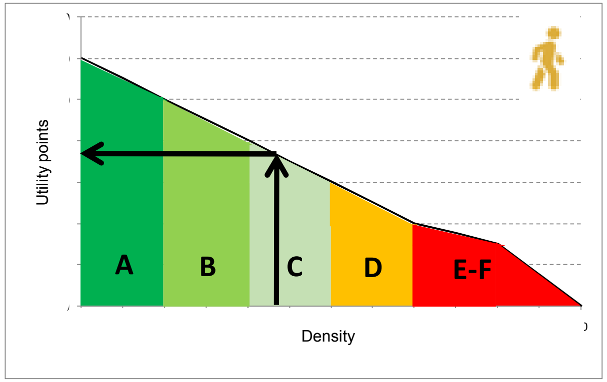
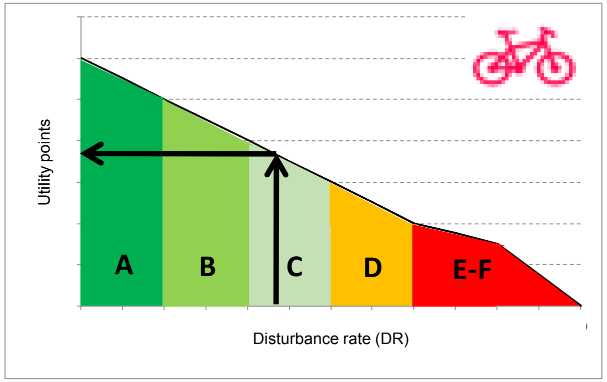
Multimodal LOS: aggregation example

The diagram illustrates a hypothetical aggregation procedure for density, aggregating mode-specific, single indicators into one multimodal performance index (MPI). The resulting MPI is LOS D based on the utility point range (see previous page).







Car	Pedestrian	Bicycle	
Utility points = 50	Utility points = 70	Utility points = 70	
Weighting = 1	Weighting = 1	Weighting = 3	MPI = 60 (D)
Traffic volume (pers/h) = 2000	Traffic volume (pers/h) = 1000	Traffic volume (pers/h) = 300	

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Determining a congestion threshold

eLearning

As a last step, a city can set a threshold, beyond which it considers the performance of its transport network unacceptable (i.e. congested). The determination of a congestion threshold is possible for the mode-specific KPIs and for the multimodal (aggregated) MPI. Moreover, the determination of a congestion threshold is possible in two ways:

1. Delay, as measured in seconds, or density, as measured in persons per kilometre, exceeds a specified value
2. A decision that discrete LOS classes are considered unacceptable in your city (e.g. LOS E or F)

Cities must determine their own congestion threshold, which is a political decision

Density cannot be aggregated as the measurement loses significance

LOS E and F are usually considered undesirable (i.e. congested)

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Achievements

FLOW's proposed methodology consists of:

- *calculating the performance and capacity of each transport mode independently.* The formulas for these mode-specific calculations come from recent guidelines in order to ensure technical consistency. In addition, the KPI delay is evaluated on a person basis rather than a vehicle basis (i.e. moving people rather than vehicles).
- *offering an aggregation procedure to create a multimodal performance index.* The MPI provides a single value to represent the transport system as a whole at the selected assessment level. This aggregation emphasises the importance of a multimodal transport system and the aggregation of mode-specific KPIs shows that implementing a given measure does not necessarily lead to more congestion if all traffic participants are taken into account.
- *providing the option to apply a weighting in the aggregation process* so that the index can be adjusted to reflect the strategic priorities of a city.
- *taking into account the user perspective*.

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Where work is still needed

The interaction of different transport modes within the same space is highly complex. At this point, the following interactions cannot be evaluated:

- interactions between different modes within a shared lane (e.g. cars and bikes share a lane). The volume of each varies depending on a range of factors.
- situations where mutual disturbance is caused by lateral movement of vehicles, cyclists or pedestrians from their own designated space into the neighbouring space due to crowding in their space (e.g. a cyclist leaves the cycle lane while overtaking and disturbs motorised traffic in the adjacent lane or pedestrians spill out onto a roadway when the sidewalk is extremely crowded)

While FLOW aims to address user perceptions of transport network performance, the operationalised KPIs cannot fully reflect the spatial, temporal and individual variations in user perception described in the FLOW definition of multimodal transport network performance. FLOW has introduced “minimum travel time” as a simplified measure for “acceptable travel time”. Further empirical research is needed to replace “minimum” by “acceptable” travel time.

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Playing with the numbers: Heart of Budapest project

eLearning

Following is an example from the city of Budapest, where a road segment was reshaped to improve the conditions for walking and cycling.

The heart of Budapest project was completed in September 2011. Its aims were to:

- reduce traffic volume
- create better conditions for pedestrians and cyclists
- improve quality of life in the city centre increase attractiveness for tourists

Measures included:

- An enlarged green area
- reconstruction of a tram line
- widened walkways
- bicycle lanes

Heart of Budapest project area before

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Heart of Budapest description

The sub-goals of the Heart of Budapest project were:

- To improve the urban environment;
- To refurbish degraded historic buildings;
- To regain attractiveness for local residents and establish commercial activities;
- To substantively decrease the amount of traffic;
- To create space and rest for pedestrians and cyclists;
- To decrease air pollution.

Heart of Budapest project area before

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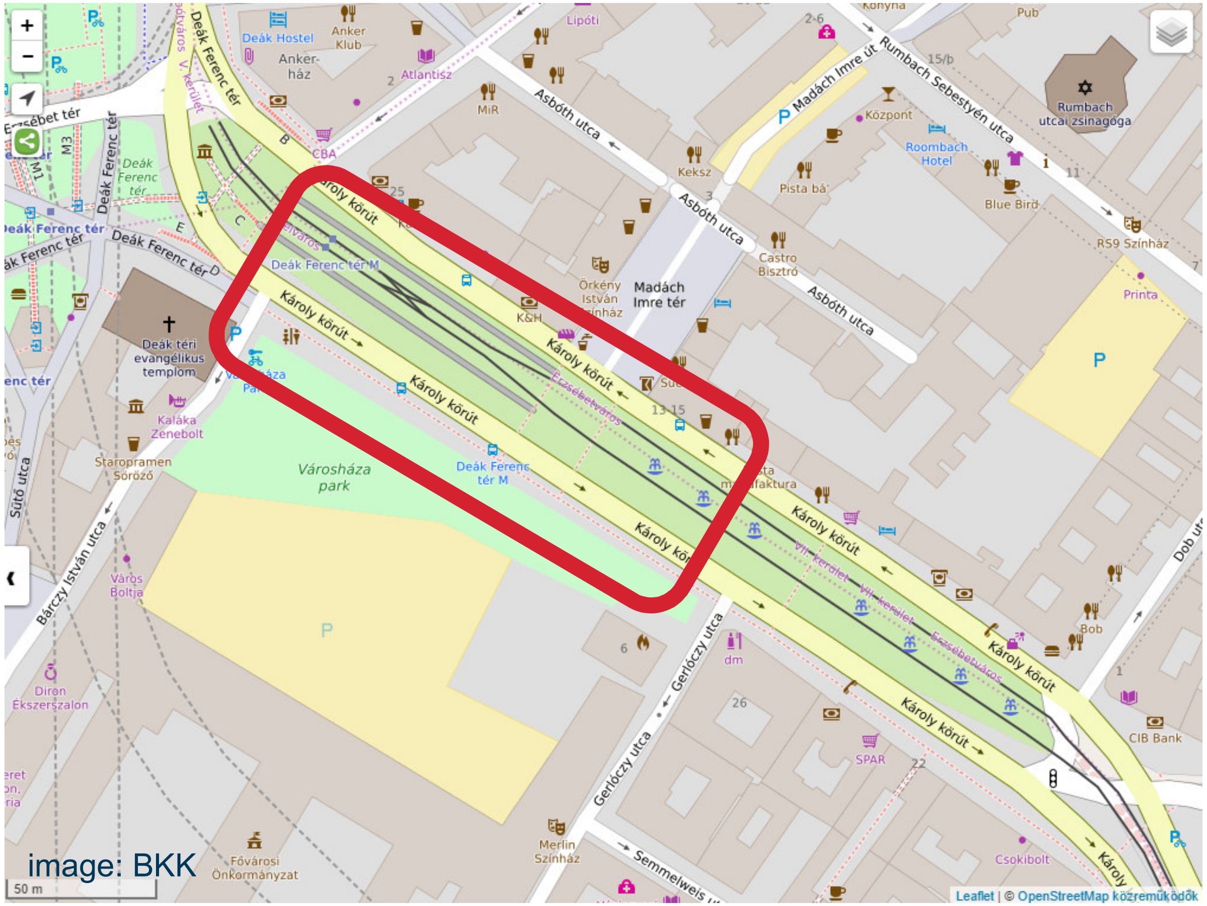
Heart of Budapest: your task

On the following page is a set of before and after data on the segment that was changed in the context of the Heart of Budapest project.

Your task this time is a calculation. Your job is to *review the contents of module 5.2 and, using the data provided on the next page, calculate the MPI for the Heart of Budapest segment* using the density-based LOS values (no priority factor).



Heart of Budapest project area

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Before and after in numbers

	Before	After
General information	250 m length	250 m length
	2x3 lanes for motorised traffic	2x2 lanes for motorised traffic
	No bike facility	Dedicate cycle lane, both directions
	20 m wide pedestrian surface	25 m wide pedestrian surface
Traffic volumes	285 motor vehicle / lane / hour	375 motor vehicle / lane / hour
	1710 motor vehicle / hour	1500 motor vehicle / hour
	20 cyclist / hour	300 cyclist / hour
	1300 pedestrian / hour	1500 pedestrian / hour
LOS indicators	Car density: 19	Car density: 25
	Bike disturbance rate: 4	Bike disturbance rate: 3
	Pedestrian density: 0,26	Pedestrian density: 0,24

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Heart of Budapest after

flow eLearning

Please share your results – as well as any comments and questions – with others on the forum.

Return to course overview

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