

# The transportation system

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Mobility measurement  
method



# A REMINDER FROM LAST WEEK LECTURE TOPIC: APPROACHES IN ACCESSIBILITY MEASUREMENT

Geurs and Van Wee (2004):

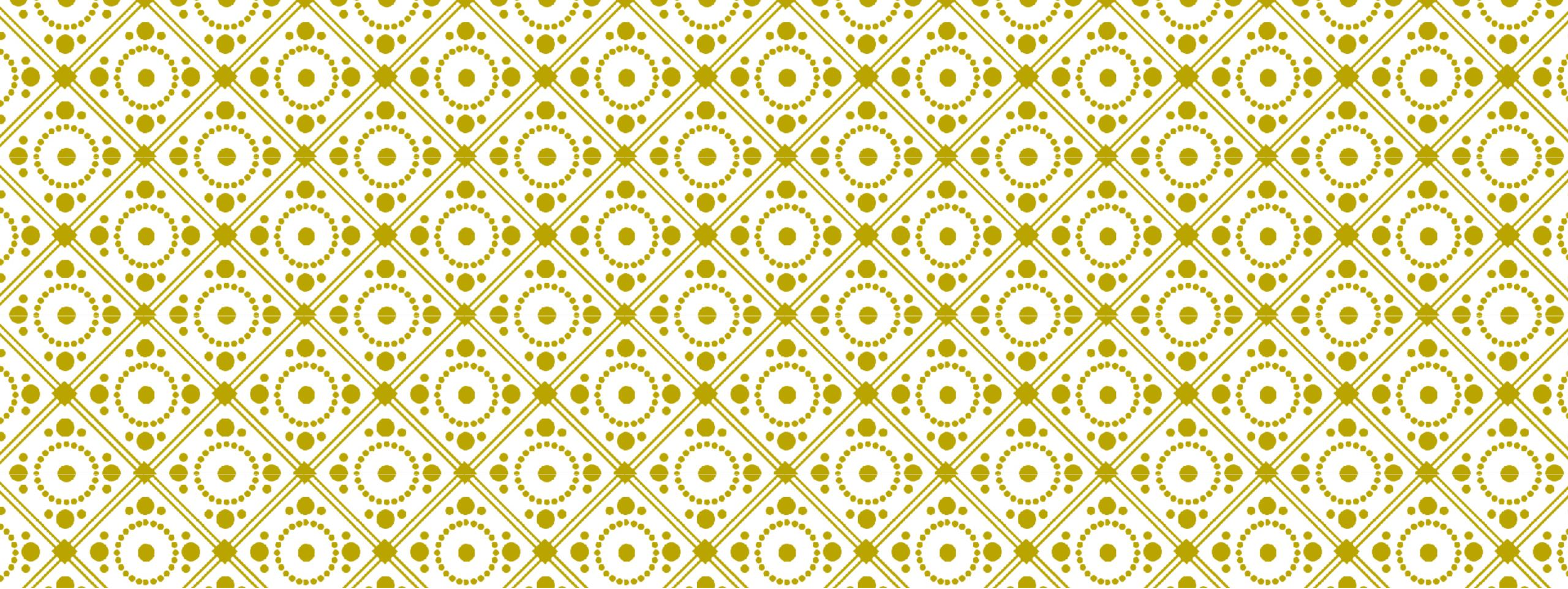
1. Infrastructure based measures
2. Location based measures
3. Person-based measures
4. Utility-based measures

Curtis and Scheurer (2010): Multicriteria analysis accessibility measurement (the SNAMUTS model).

Porta, Crucitti, and Latora (2006): the primal approach (either metric or topological)

Hillier and Hanson (2004): the dual approach or dual graph (topological)





# Mobility concept and definition

# Mobility concept and definition

Mobility measure is used to quantify the overall transport system performance

Urban Mobility assessment requires the application of methodology integrating different metrics (a multi-dimensional approach)

A three layer approach is used:

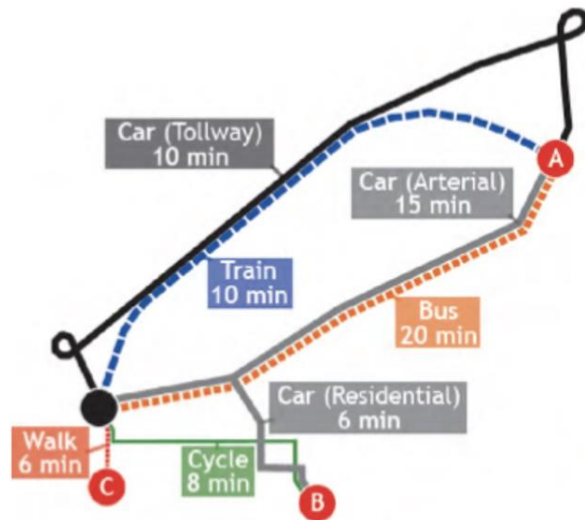
- Urban mobility data
- Indicators
- Indices



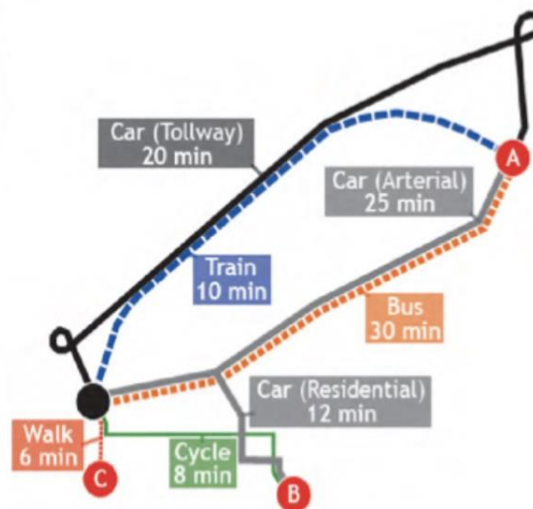
# Mobility definition

Urban mobility represent the movement of persons between various locations within different time frames  
By different transport modes for the purpose of reaching different objectives.

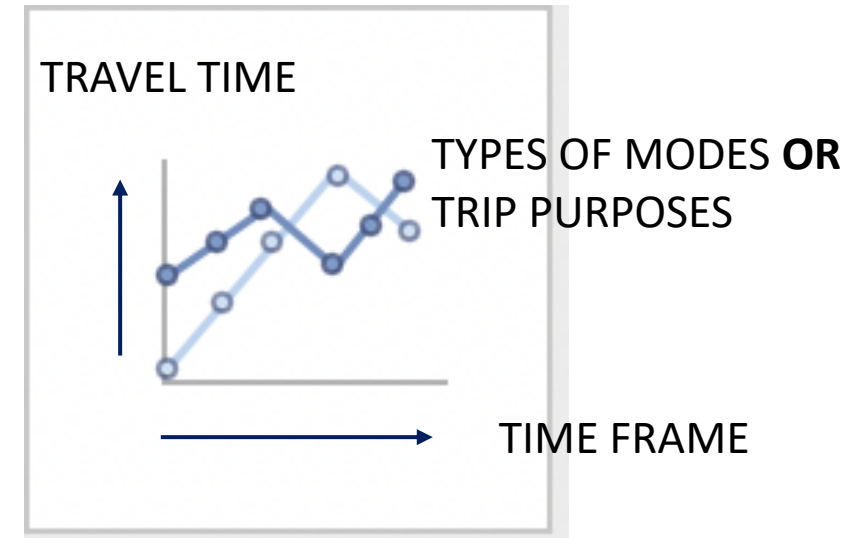
RECALL THE INFRASTRUCTURE BASED ACCESSIBILITY MEASUREMENT FROM THE LAST WEEK:



Travel impediment measures from origin (black dot) to various destinations (A, B, C) using kerb-to-kerb travel time under flow condition (Curtis & Scheurer, 2010, p. 61)



Travel impediment measures from origin (black dot) to various destinations (A, B, C) using kerb-to-kerb travel time during congestion (Curtis & Scheurer, 2010, p. 61)



# THE INFRASTRUCTURE BASED MOBILITY

This measurement has not considered the impact of transportation policies on land use or urban form. For example, how the transport policies influence the level of speed and how does it impact the land use.

This measurement has not considered the impact of land use policies on the accessibility level that furthermore impacted on the spatial distribution of activities. For example, how the development of real estate or apartment near toll access influence the level of accessibility of the area.

This measurement cannot be used in Cost Benefit analysis or economic valuation of accessibility benefit.

# Mobility definition

Mobility is characterized by its side effects such as travel times, costs, and congestion (Amaral 5)

Mobility increases with the shortening of the average travel time, lowering of the travel time deviations  
And travel costs (Casey et al. 6)

The overall mobility is person related and represent the total number of trips within the observed area,  
Regardless of the trip purposes or chosen transportation mode (Brcic et al 2, 8)

A motion of passengers and goods, with the passengers or ton kilometers and the number of undertaken  
rips as the key dimensioning parameters (Litman, 11-13)

Every increase in the number of trips, passengers, or ton kilometers and the transportation speed is a  
positive contribution to mobility (Litman).

# URBAN MOBILITY IN TERMS OF PHYSICAL MOVEMENT

- PUBLIC TRANSPORTATION enabling mobility for all social group represented in a population (the number of passengers transported)
- INDIVIDUAL TRANSPORTATION is any type of movement occurring as a results of personal mobility choice
- FREIGHT TRANSPORTATION is a product of urban population existential needs, with the city usually becomes the production and consumption center.



# Mobility concept

- THE USER PERSPECTIVE: The possibility of moving from one point (origin) to another (destination) by using a certain mode (s).
- THE INFRASTRUCTURE PERSPECTIVE : the capacity of transport system to ensure users reaching destinations with a satisfactory service level.

Mobility is used as a measure of transport system efficiency (Rashidy, 9)

# MOBILITY CONCEPT

Urban mobility data: heterogeneous, collected by using various sources.

According to urban mobility data, urban mobility indicators are defined.

Urban mobility indicators is the value based on data from the segment of the urban mobility.

It describes the phenomena that affect urban mobility or is the result of urban mobility. It represents parameter based on the data form the segment of the mobility system (transport, economy, ecology, society).

To reduce the complexity and scope of data and indicators to be included in the urban mobility Assessment, the urban mobility index is introduced.

Urban mobility index is a single numerical mobility assessment score, as a result of the relational data And/or mobility indicators fusion.

# Mobility data

The list of data sources usable for the purpose of the mobility assessment

Conventional data sources	Information and communication systems of the shareholders	Unconventional data sources
Pneumatic road tube counters	Road tolling system	Public mobile communication networks
Piezoelectric sensors	Parking fee collection system	Satellite photographs
Inductive loops	Public bike sharing system	Social networks
Radar traffic counters	Public car sharing system	Autonomous vehicles
Infrared traffic counters	Car sharing system	Connected vehicles
Magnetic traffic counters	Traffic accidents database	Navigation devices
Ultrasound traffic counters	Registered vehicles database	In-vehicle computers
Video traffic counters	Public passenger transport	
Census	Smart public passenger transport ticketing	
Ecological sensors		
Meteorological sensors		
Manual traffic counting		
Observation		
Surveys		



# Example of urban mobility data and indicators

**Table 1** Transportation Evaluation Perspectives (Litman 2003)

	Vehicle Travel	Mobility	Accessibility
<b>Definition of Transportation</b>	Vehicle travel	Person and goods movement	Ability to obtain goods, services and activities
<b>Measurement units</b>	Vehicle miles	Person-miles and ton-miles	Trips, generalized costs
<b>Modes considered</b>	Automobile and truck	Automobile, truck and transit	Automobile, truck, transit, cycling and walking
<b>Common indicators</b>	Vehicle traffic volumes and speeds, roadway Level of Service, costs per vehicle-mile, parking convenience	Travel distance and speeds, road and transit Level of Service, cost per person-mile, travel convenience	Quality of available transportation choices. Distribution of destinations. Cost per trip
<b>Consumer benefits considered</b>	Maximum motor vehicle travel and speed	Maximum personal travel and goods movement	Maximum transport choice and cost efficiency
<b>Consideration of land use</b>	Treats land use as an input, unaffected by transportation decisions	Recognizes that land use can affect travel choice	Recognizes that land use has major impacts on transportation
<b>Favored transportation improvement strategies</b>	Roadway and parking facility improvements to increase capacity, speed and safety	Transportation system improvements that increase capacity, speeds and safety	Management strategies and improvements that increase transport system efficiency and safety
<b>Transportation Demand Management (TDM)</b>	Generally considers vehicle travel reductions undesirable	Supports TDM strategies that improve personal and freight mobility	Supports TDM whenever it is cost effective

Which one is data

Which one is indicators

*This table compares three common perspectives used to measure transportation.*

# Mobility indicator dimension

It describes the phenomena that affect urban mobility or is the result of urban mobility

THE TRANSPORT  
RELATED CATEGORIES  
(travel time, speed, trip  
matrices)

THE ECONOMIC  
INDICATORS (fuel price,  
parking fee, household  
income)

THE SOCIAL INDICATORS  
(social acceptancy: the  
number of accidents  
and fatalities)

THE ENVIRONMENTAL  
INDICATOR (pollution  
emissions, noise)

# Mobility Indicator

An overview of transport indicators

Transport indicators	Unit	Transport indicators	Unit
Average distance covered by daily trips	km	Quantity of trips	vehicle/h
Average daily trip duration per person	h	Number of trips	number
Average trip duration per kilometre	h	Travel time	h
Average trip duration per vehicle	h	Travel purpose	%
Total number of passenger and ton kilometres	pkm/tkm	Average travel time using public transport system to the desired point of interest	h
Reliability factor	0-1	Capacity/supply of public passenger transport system	number of passenger seats
Average travel time using road network to the desired point of interest	h	Time required to switch between transport modes	h
Average vehicle speed	km/h	Average distance between transport modes	km
Average freight transport speed	km/h	Station access time	h
Road network length	km	Public transport services per inhabitant	trips per inhabitant
Length of the transport network intended for non-motorised trips.	km	Modal split	%
Coverage of the road network with ITS services	%	Average duration of a search for a parking place	h
Traffic volume (Passenger Car Equivalent)	PCE	Congestions in the transport system	h
Road capacity	vehicle/h	Delays in the transport system	h
Quantity of trips vehicle/kilometres	vehicle/km		



# Mobility Indicator

An overview of social and economic indicators

Social indicators	Unit
Number of accidents	number
Number of persons injured	number
Number of persons killed	number
Adjustment of the transport system to the specific user groups	%
Overall satisfaction with the transport system	%
Adjustment to persons with special needs	%
Share of persons walking or cycling longer than 15 minutes a day	%
Share of children walking or cycling to school	%
Communication cohesion	%
Perception of security	%
The share of users feeling safe considering the traffic incidents	%
Satisfaction with the transport – related public space	%
Access to mobility services	%
Number of traffic accidents in the transport system per inhabitant/kilometre	no/inhabitant/km

Economic indicators	Unit
Public transport single ticket price	HRK
Fuel price (per litre)	HRK
Price of the daily parking ticket	HRK
Cost of resident parking	HRK
Cost of parking for the employees of the companies	HRK
Cost of public bike sharing system usage	HRK
Cost of public car sharing system usage	HRK
Fixed costs of a car (allocated to the urban mobility)	HRK
Pollution costs per inhabitant	HRK
Total transport costs per inhabitant	HRK
The number of public services and work opportunities within a 10-minute reach by walking or 20 minutes by transportation	number
Total household expenditure	HRK
Household income per unit of consumption	HRK
Average mobility – related expenditure of households, companies and city management	HRK
The share of companies and public institutions satisfied with the financial aspects of mobility	%
Annual investments to the freight and passenger transport	HRK
Annual infrastructure investments	HRK
Total costs generated by transport	HRK
GDP	HRK

# Mobility Indicator

An overview of environment indicators

Environmental indicators	Unit	Environmental indicators	Unit
Noise	dB	Waste generated by transport activities	t
Greenhouse gas emission	g/km	Transport-related land consumption per inhabitant	%
Polluting emission	g/km	Consumption of public space for mobility needs	%
Energy consumption	kWh	Consumption of public space for parking needs	%
Utilisation of the sustainable energy sources	%	Consumption of public space by transport infrastructure	%
Share of the renewable energy in the total energy consumed by the transport system	%	Land fragmentation	%
Energy consumption per capita by different modes	kWh	Average exposure to transport – related pollutants	%
Energy consumption per ton – kilometre	kWh/tkm	Average exposure to overall pollutants	%
Number of days with air pollutants exceeding the limitations	number of days	Impact of car usage	value (1-5)
Environmental investments	HRK	Average duration of exposure to pollutants	h
Share of population unsatisfied with the transport-related emission and noise levels	%	Meteorological conditions	value (1-5)
Share of population that considers the transport – related consumption of land to be appropriate	%	Energy efficiency of supporting buildings and facilities in the transport system	value (1-5)
Share of population that considers the sustainable energy sources available	%		

# Mobility indicators

Measure a change of status or a parameter; to indicate progress in line with the predefined objectives. The indicator enables an efficient and simple monitoring of changes during a certain time period.

Indicators	Definition
The mobility of inhabitants	A number of trips per inhabitant within the observed time period (a year, a month, a day, thus observing daily, monthly, or annual mobility)
Total mobility rate	A daily number of trips per person
Total mobility length	The number of achieved passenger kilometers per person in a unit of time; The number of vehicle kilometers
Total mobility time	A number of hours spent on travelling per person in a unit of time
?	The average travel time needed to reach the destination (expressed by time units), normalized by distance and weighted by factors depending on the objective of the mobility assessment.



# MOBILITY INDICES

A result of the relational data and/or mobility indicators fusion, with an aim to assess mobility.

The indices is used to reduce the complexity and scope of data and indicators to be included in mobility assessment.

The index represents a synthesize measurement that containing a significant amount of information in a single scalar.

Index is used for the status assessment of the complex system as a whole, not on the level of the individual components.

# Mobility index: a sampling mobility index

Measure the status assessment of the complex system as a whole.

Indicators	Definition
A sampling mobility index (Frei 54)	A set of indicators and indices intended for the measurement of mobility in medium and small size urban surroundings.

The mobility indicators are defined through the following criteria: the sidewalk width, the free walking pass, the vertical and horizontal signalling, the safety belt use, the respect for traffic lights, the pedestrian traffic lights, the more than one person per vehicle criterion and the cycling lane availability. For each of the criteria, an indicator was defined and then synthesized into seven indices, one for every criterion. This approach enables the normalisation of different parameters i.e. the reduction of all criteria to a single dimension. These seven indices are integrated in one index called the sampling mobility index. The data used in the calculation are obtained by the field analysis or through surveys. The index represents a sum of values of the seven included indices:

$$SMI = \sum(SWI + FWPI + VHSl + SBUI + RTLI + PTLI + MOPVI + IC) \quad (1)$$

where: *SWI* is Sidewalk Width Index, *FWPI* is Free Walking Pass Index, *VHSl* is Vertical and Horizontal Signalling Index, *SBUI* is Safety Belt Use Index, *RTLI* is Respect for Traffic Lights Index, *PTLI* is Pedestrian Traffic Lights Index, *MOPVI* is More than One Person per Vehicle Index, *IC* is Cycling lane availability Index.

The highest possible value of the index is 700 points and the lowest is zero. The total span is divided into five categories, where the first one, from 0-140 points, denotes the worst result (red) and from 560 to 700 points the best one (green) [43].

# Mobility index: travel time index

Indicators	Definition
Travel time index	measuring the congestion differences between metropolitan areas and is related to the traffic flow speed. The Travel Time Index is calculated as a quotient of the time required for travelling during the congestion (Congested Travel Time) and the time needed to pass the same section without congestion (Free Flow Travel Time).

O	▼	D	Start_X	Start_Y	End_X	End_Y	Average of 8AM2	Average of 12PM2	Average of 5PM2
1		2	125,5352	-8,53834	125,5361	-8,54547	0,266666667	0,266666667	0,266666667
1		5	125,5352	-8,53834	125,5428	-8,54118	0,033333333	0,033333333	0,033333333
2		3	125,5361	-8,54547	125,541	-8,54634	0,033333333	0,033333333	0,033333333
2		29	125,5361	-8,54547	125,5352	-8,56093	0,066666667	0,066666667	0,066666667
3		4	125,541	-8,54634	125,544	-8,54678	0,033333333	0,033333333	0,033333333
3		5	125,541	-8,54634	125,5428	-8,54118	0,033333333	0,033333333	0,033333333
3		37	125,541	-8,54634	125,5398	-8,55439	0,066666667	0,066666667	0,066666667

Link_ID	O	D	Start_X	Start_Y	End_X	End_Y	8AM	12PM	5PM	Length	8AM	12PM	5PM	Speed8AM	Speed12PM	Speed5PM
1	1	2	125,53517	-8,5383389	125,53608	-8,545472	16	16	16	5,4	0,266667	0,266667	0,266667	20,25	20,25	20,25
2	1	5	125,53517	-8,5383389	125,54281	-8,5411806	2	2	2	0,9	0,033333	0,033333	0,033333	27	27	27
3	2	3	125,53608	-8,545472	125,54102	-8,5463433	2	2	2	0,55	0,033333	0,033333	0,033333	16,5	16,5	16,5
4	2	29	125,53608	-8,545472	125,53519	-8,5609308	4	4	4	1,8	0,066667	0,066667	0,066667	27	27	27
6	3	5	125,54102	-8,5463433	125,54281	-8,5411806	2	2	2	0,65	0,033333	0,033333	0,033333	19,5	19,5	19,5
7	3	4	125,54102	-8,5463433	125,54401	-8,5467755	2	2	2	0,35	0,033333	0,033333	0,033333	10,5	10,5	10,5
8	3	37	125,54102	-8,5463433	125,53979	-8,5543941	4	4	4	0,9	0,066667	0,066667	0,066667	13,5	13,5	13,5



# Mobility index: the smartness index

To benchmark transport cities, a composite scoring system was developed to measure the Smartness index of a city's transportation system.

$$SI = \frac{\sum_{j=1}^J \sum_{i=1}^{I_j} S_{ij}}{\sum_{j=1}^J I_j} \cdot 100\%$$

Indicators	Definition
$SI$	The smartness index
$S_{ij}$	The smartness score for indicator $i$ in each sub-system $j$
$J$	The total number of sub-systems
$I_j$	The total number of indicators in each subsystem

# Mobility index: shared mobility index

Shared mobility index assessing the three categories: general information and demographics, mobility, vision and objectives.

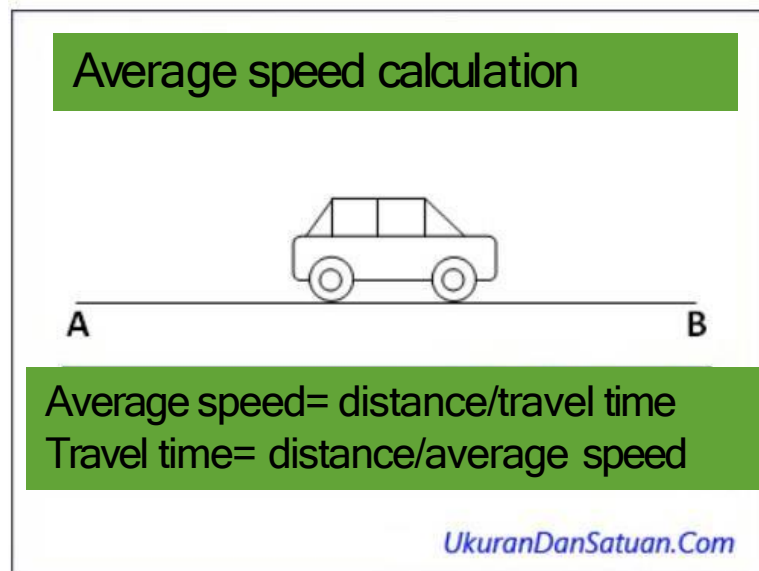
The index is intended for the decision makers on the level of the city administration when the new mobility related services are being introduced. Example: the index can measure the needs and readiness of a certain environment to implement public vehicle sharing system (a car sharing system)

# MOBILITY INDICES MEASUREMENT: congestion index

1. main indicator= travel time

See the manual MKJI, 1997 (chapter 5, page 5-17):

Illustration:



To calculate vehicle speed in free flow condition, the manual assigned this formula:

$$FV = (FV_0 + FV_w) \times FFV_{SF} \times FFV_{CS}$$

dimana:

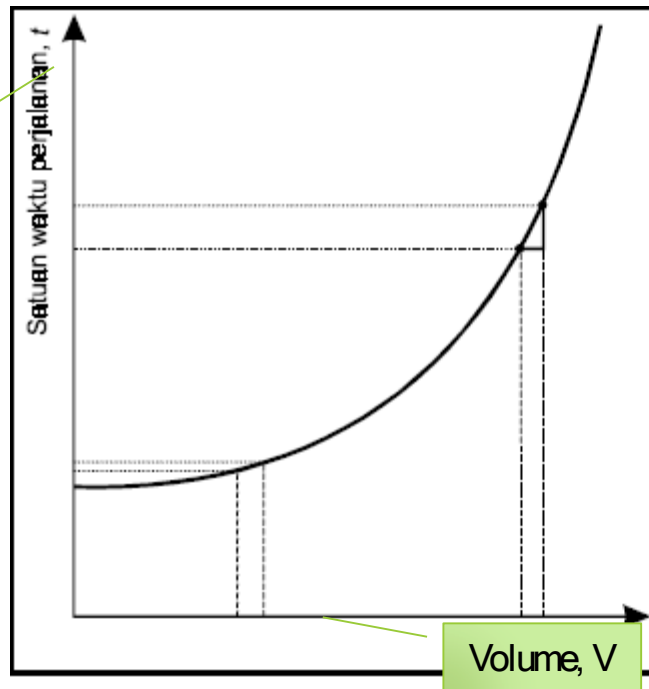
Free flow speed	Basic speed	Adjustment factor for road wide	Adjustment factor for kerb or shoulder or road side constraint	Adjustment factor for city size
FV	=	Kecepatan arus bebas kendaraan ringan pada kondisi lapangan (km/jam)		
FV <sub>0</sub>	=	Kecepatan arus bebas dasar kendaraan ringan pada jalan yang diamati (lihat Bagian 2.4 di bawah)		
FV <sub>w</sub>	=	Penyesuaian kecepatan untuk lebar jalan (km/jam)		
FFV <sub>SF</sub>	=	Faktor penyesuaian untuk hambatan samping dan lebar bahu atau jarak kerb penghalang		
FFV <sub>CS</sub>	=	Faktor penyesuaian kecepatan untuk ukuran kota		

We can calculate travel time once we know the distance, the average speed (on free flow and peak hour). Travel time can also be measured in Google map or other application.

# INFRASTRUCTURE BASED MEASURE = MOBILITY INDICES MEASUREMENT

## 2. Indicator based on congestion level

- The longer travel distance and the longer travel time, the more the contribution on road congestion (Tamin, 2010).



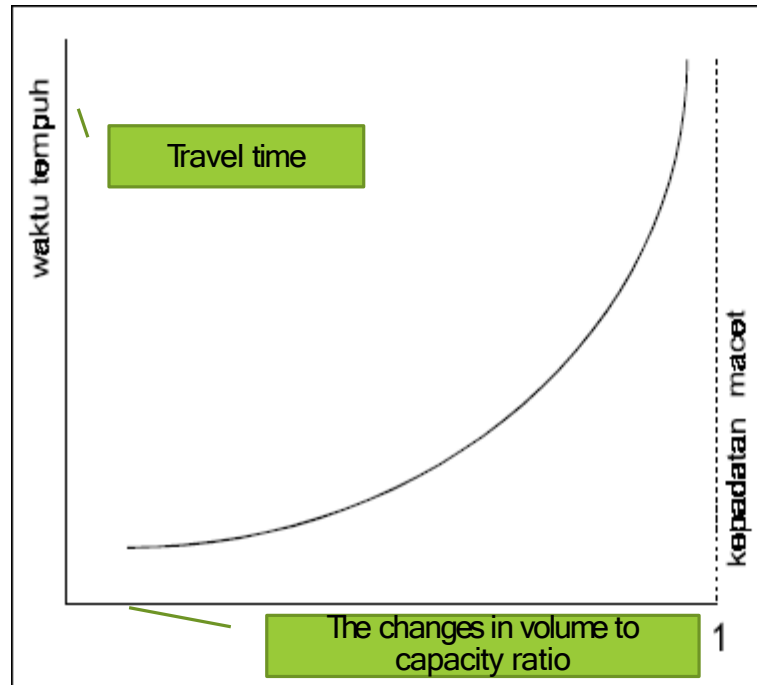
Speed is the general indicator of pelayanan (*Level of Service=LOS*)

See the manual MKJI for LOS calculation for urban street  
(chapter V section 2.2.3 page. 5-18)

**Gambar 1.1**  
Kemacetan dan beberapa efek  
eksternalnya  
Sumber: Ortuzar and Willumsen (1994)



# LOS CALCULATION PRINCIPLES



Road capacity is named as SMP or EMP (equivalent passenger vehicle) (atau dalam Satuan Mobil Penumpang/SMP) per hour. The relationship between speed and volume is not linear. The number of vehicle added during low volume increase travel time slightly but the added vehicle during high volume during increase travel time dramatically. The curve is shown as in the figure (**Black, 1981 in Tamin, 2010**).

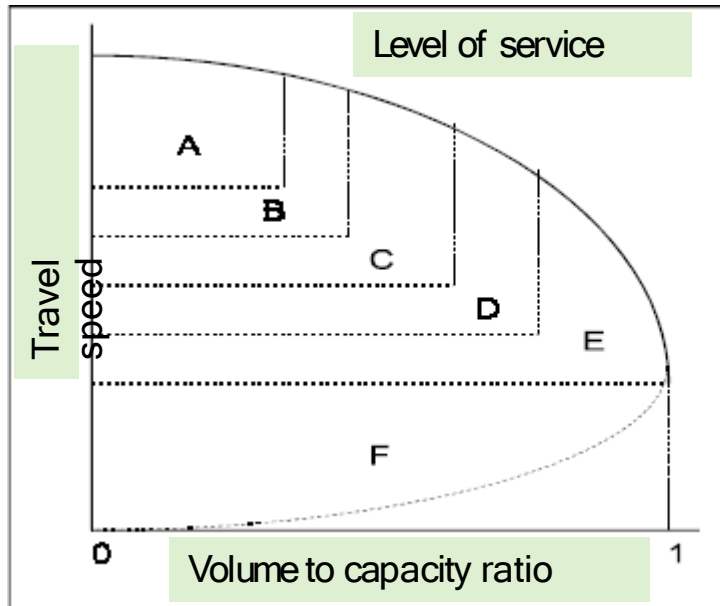
**Gambar 2.7**

Hubungan antara nilai nisbah volume per kapasitas dengan waktu tempuh

From: Tamin (2010)

See the manual MKJI for LOS calculation for urban street (chapter V section 2.2.3 page. 5-18)

# LOS CALCULATION PRINCIPLES



Gambar 2.8  
Tingkat pelayanan



A  
Free flow



B  
Stable (for  
inter-urban  
roads)



C  
stable (for urban  
roads)



D  
Not stable  
traffic flow



E  
Traffic flow  
faltered



F  
Congestion  
condition

Tamin, 2010

See the manual MKJI for LOS calculation for urban street  
(chapter V section 2.2.3 page. 5-18)

# Attachment

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Example from a published paper

The end



Q & A Session