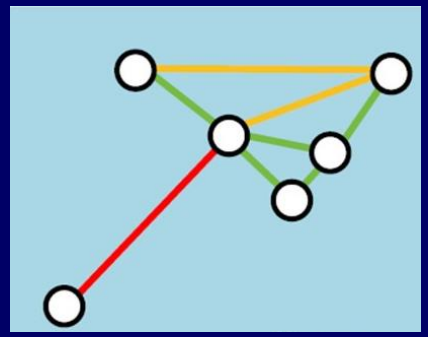
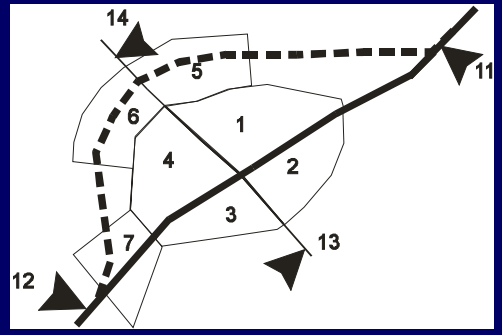
Road network hierarchy, planning of road networks





Transport networks 3.
András Gulyás PhD habil
associate professor

Content

- Road network hierarchy, road categories
- Planning principles of road networks
- Planning input data of road networks
- Modelling of road networks
- Traffic planning of road networks
- Traffic planning – trip generation
- Traffic planning – trip distribution

Road network hierarchy

The road network is connected but it has different functional elements providing a road hierarchy.

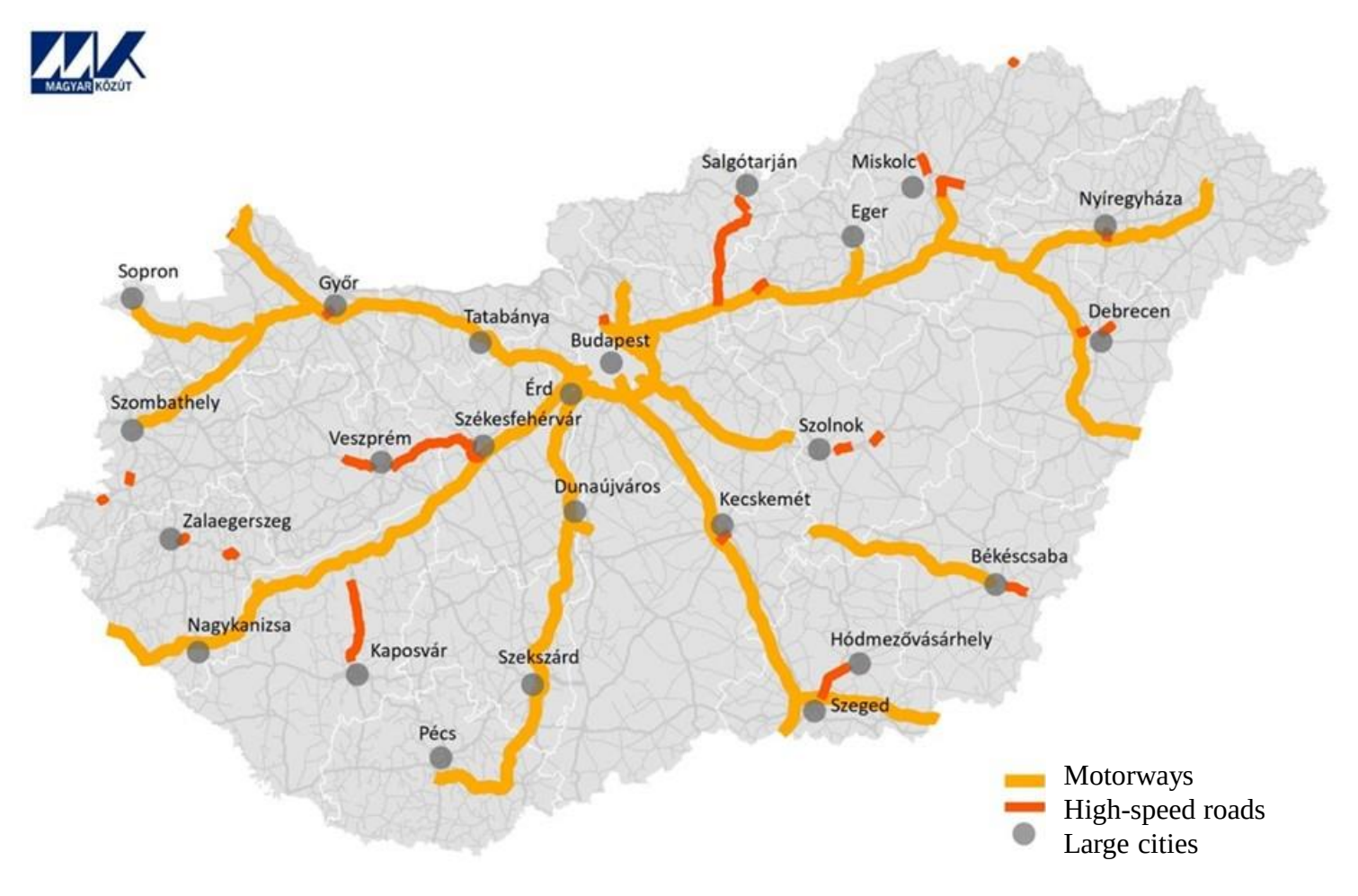
The function and category (class) of a well constructed and maintained road is clearly recognisable by the users.

Roads of different categories differ mainly in their width, number of lanes and alignment as well as service facilities (bus stops, rest areas etc.).

The road hierarchy exists both on national and municipal road networks.

Road network hierarchy

High-speed roads in Hungary: 1738 km



Source: Hungarian Public Roads Co.

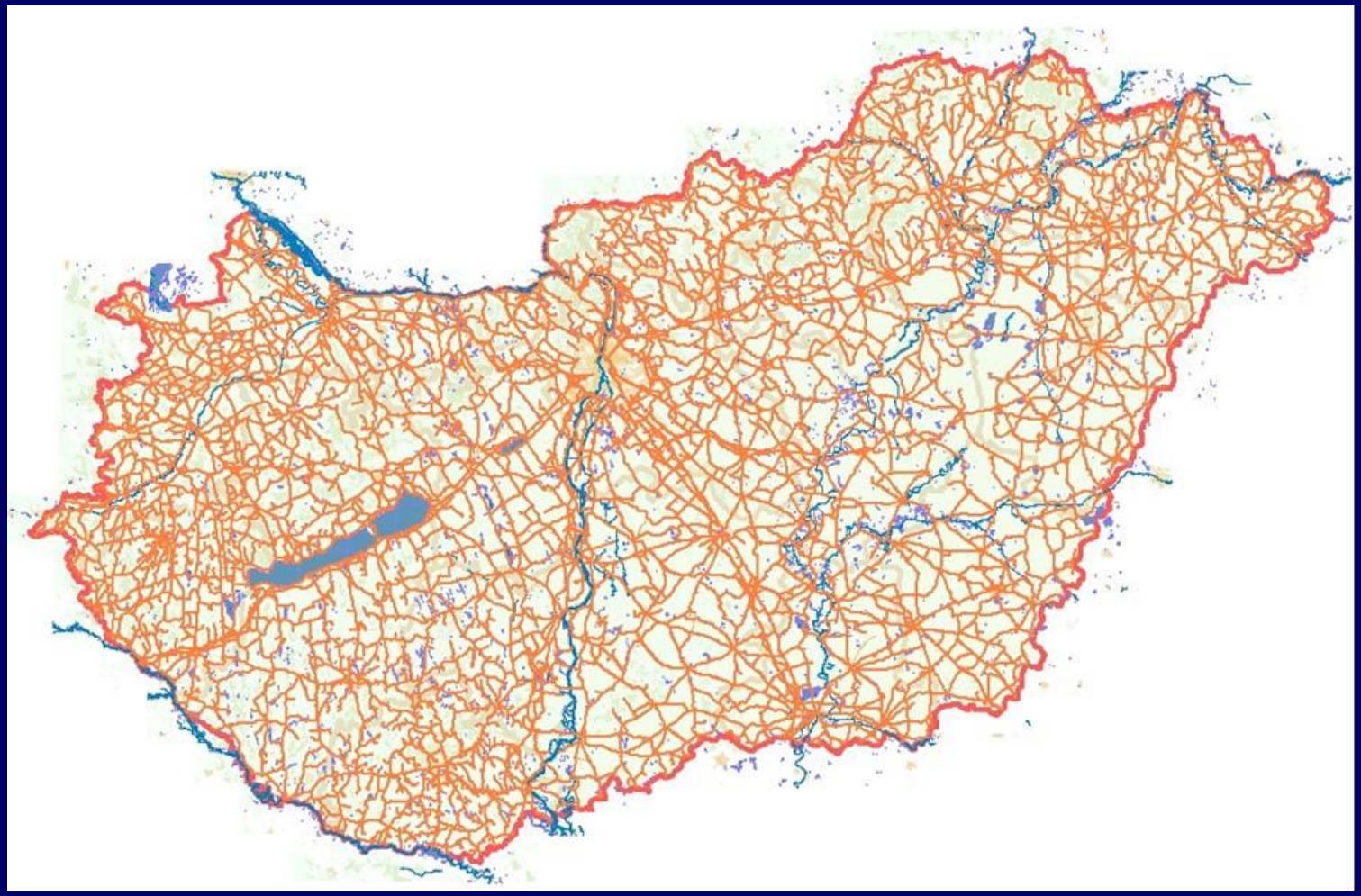
Road network hierarchy

High-speed roads and main roads in Hungary: 9270 km

Source: Hungarian Public Roads Co.

Road network hierarchy

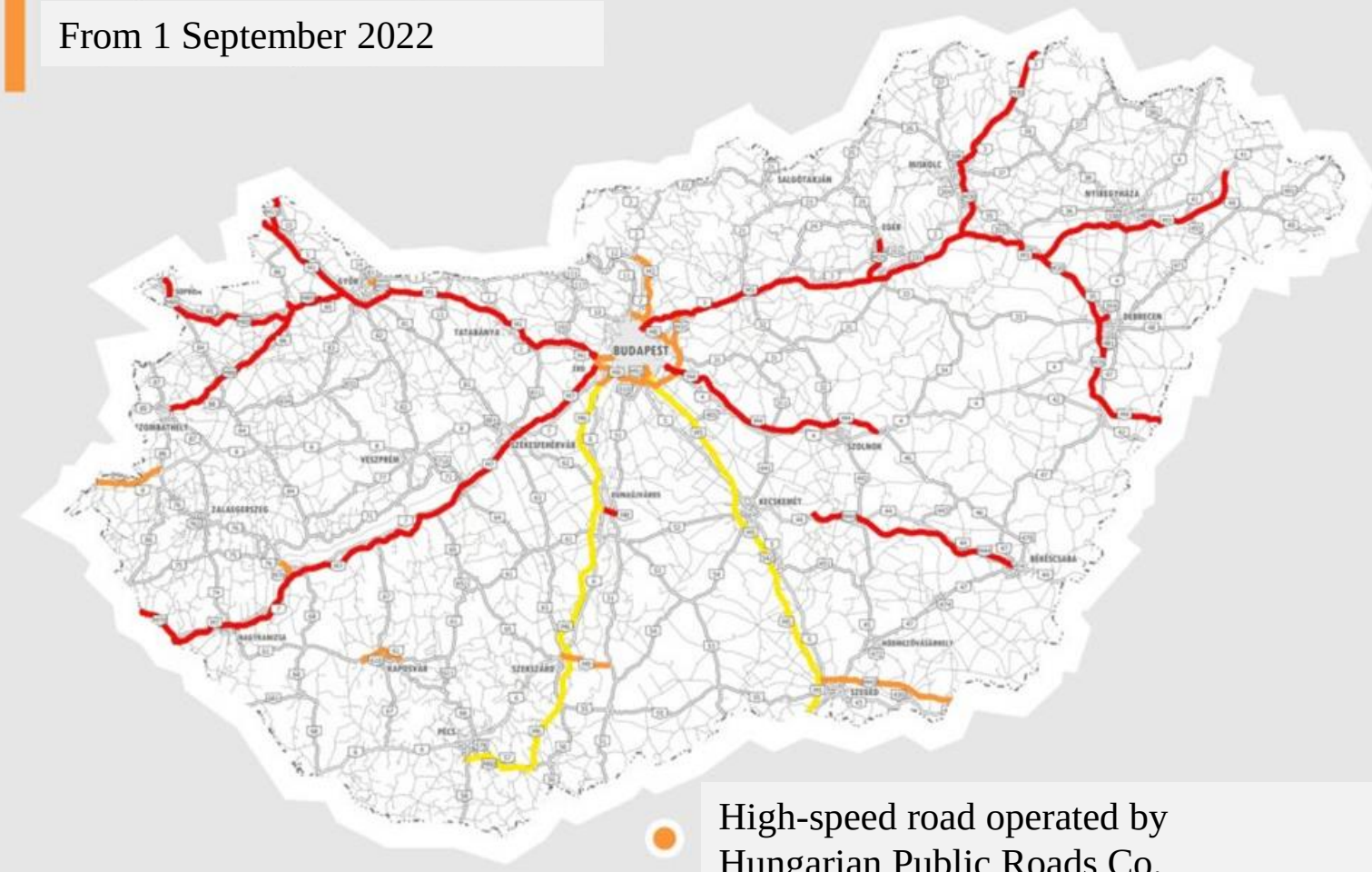
National road network in Hungary: 32395 km



Source: Hungarian Public Roads Co.

Road network hierarchy

From 1 September 2022



High-speed road operated by Hungarian Public Roads Co.

Hungarian Concessionary Infrastructure Development Co. 1237 km

Other existing concessionary companies

MAGYAR KÖZÚT

MKIF MAGYAR KONCESSZIÓS INFRASTRUKTÚRA FEJLESZTŐ ZRT.

Source: Hungarian Public Roads Co.

Road categories – national network

- The 26/2021. (VI. 28.) Ministerial Decree on road administration determines main characteristics of national and municipal road categories and conditions for these road categories
- National road categories:
  1. Motorways (dual carriageway, high-speed, high service level)
  2. Other high-speed roads
  3. Intersection elements of high-speed roads
  4. First class main roads
  5. Second class main roads

Road categories – national network

- National road categories (continued):
  6. Secondary roads
  7. Connector roads
  8. Rest area roads of high-speed roads
  9. Other national roads (intersection elements, rest area roads, rural bicycle roads)

  Municipal road categories:
  - urban high-speed roads
  - first and second class main roads
  - collector roads and service roads

Road categories – national network

High-speed roads

Source: Koren Csaba (szerk.): A közúti infrastruktúra biztonsága. Universitas-Győr, 2012. (in Hungarian) Photos: Iván Gabriella

Road categories – national network

Main roads (up)

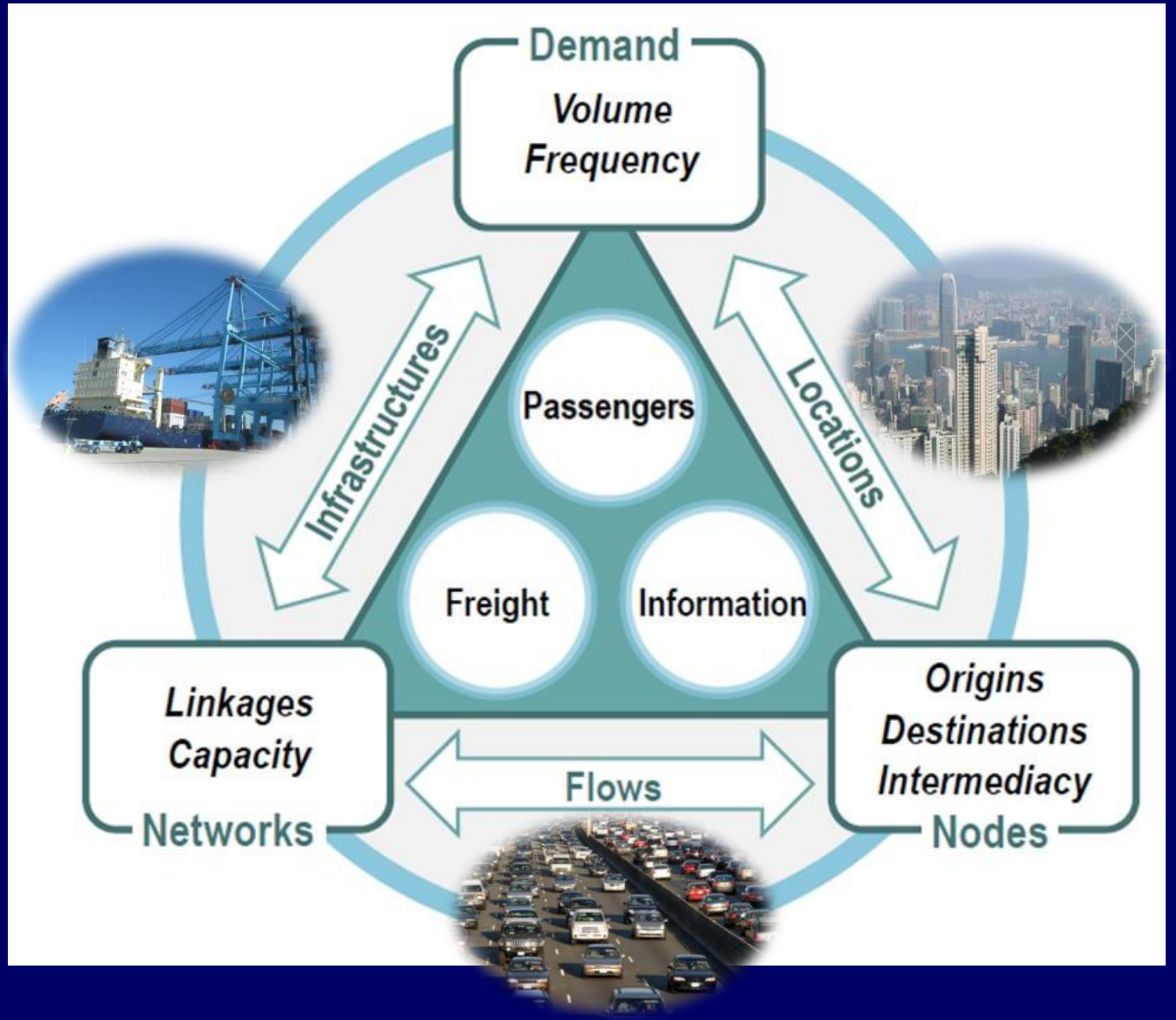
Secondary road (right)

Source: Koren Csaba (szerk.): A közúti infrastruktúra biztonsága. Universitas-Győr, 2012. (in Hungarian) Photos: Iván Gabriella

Source (right, down): Közlekedésépítési Szemle 2009. 11. Photo: : dr. Makula László

Planning principles of road networks

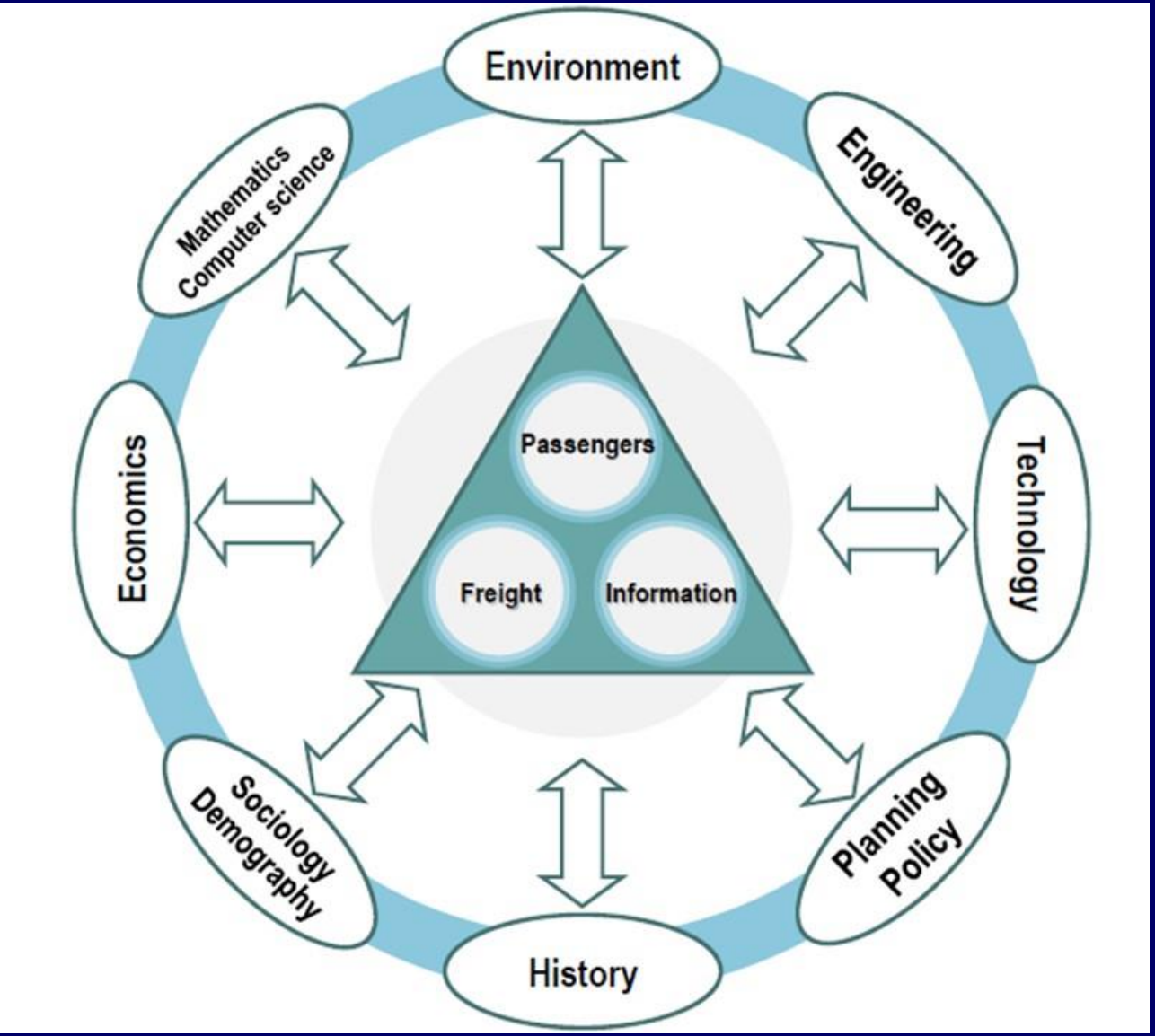
The essence of the transport system



Source: Rodrigue, J-P et al. (2020) The Geography of Transport Systems, Hofstra University, Department of Global Studies & Geography, https://transportgeography.org/

Planning principles of road networks

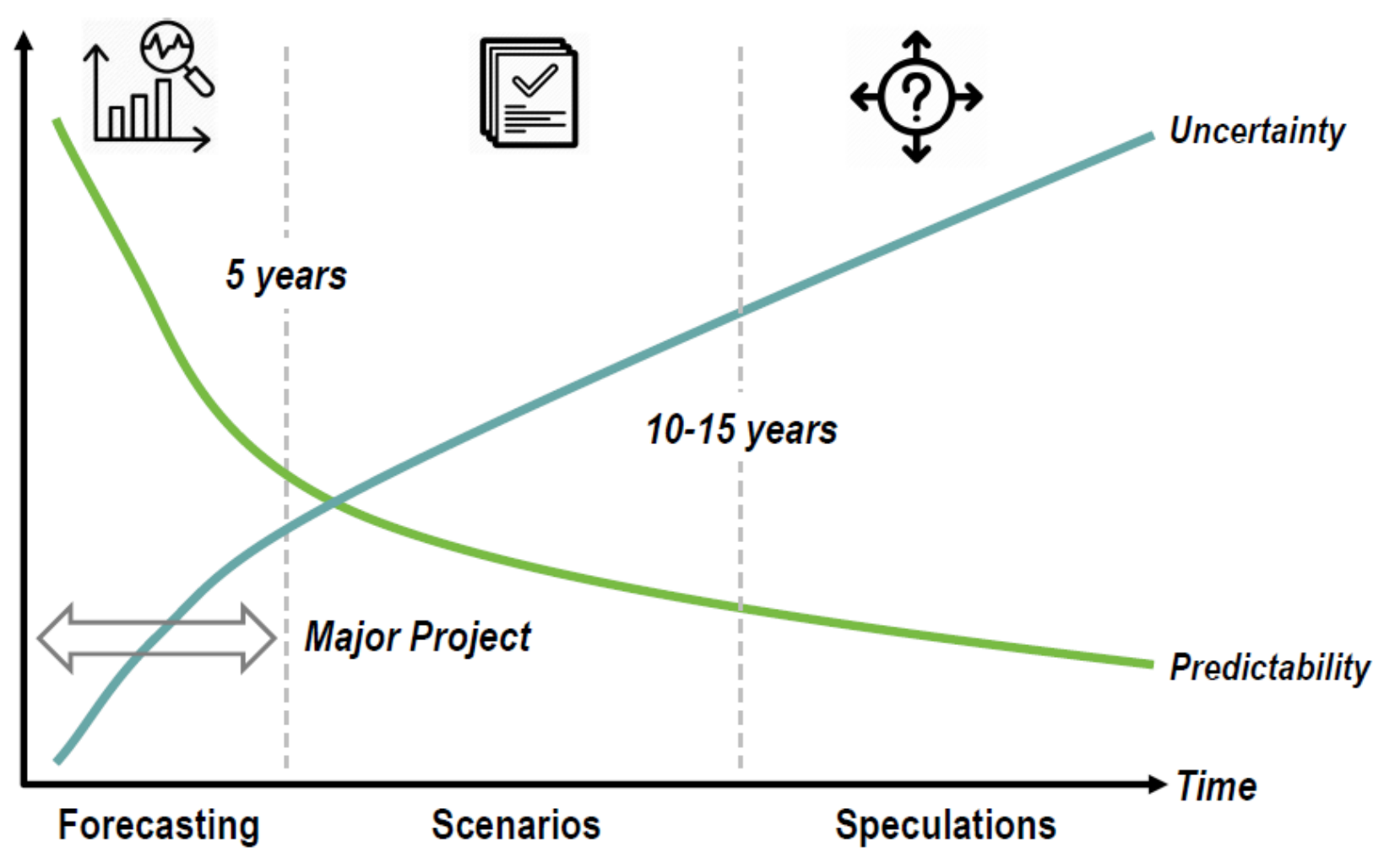
Interdisciplinary connections



Source: Rodrigue, J-P et al. (2020) The Geography of Transport Systems, Hofstra University, Department of Global Studies & Geography, https://transportgeography.org/

Planning principles of road networks

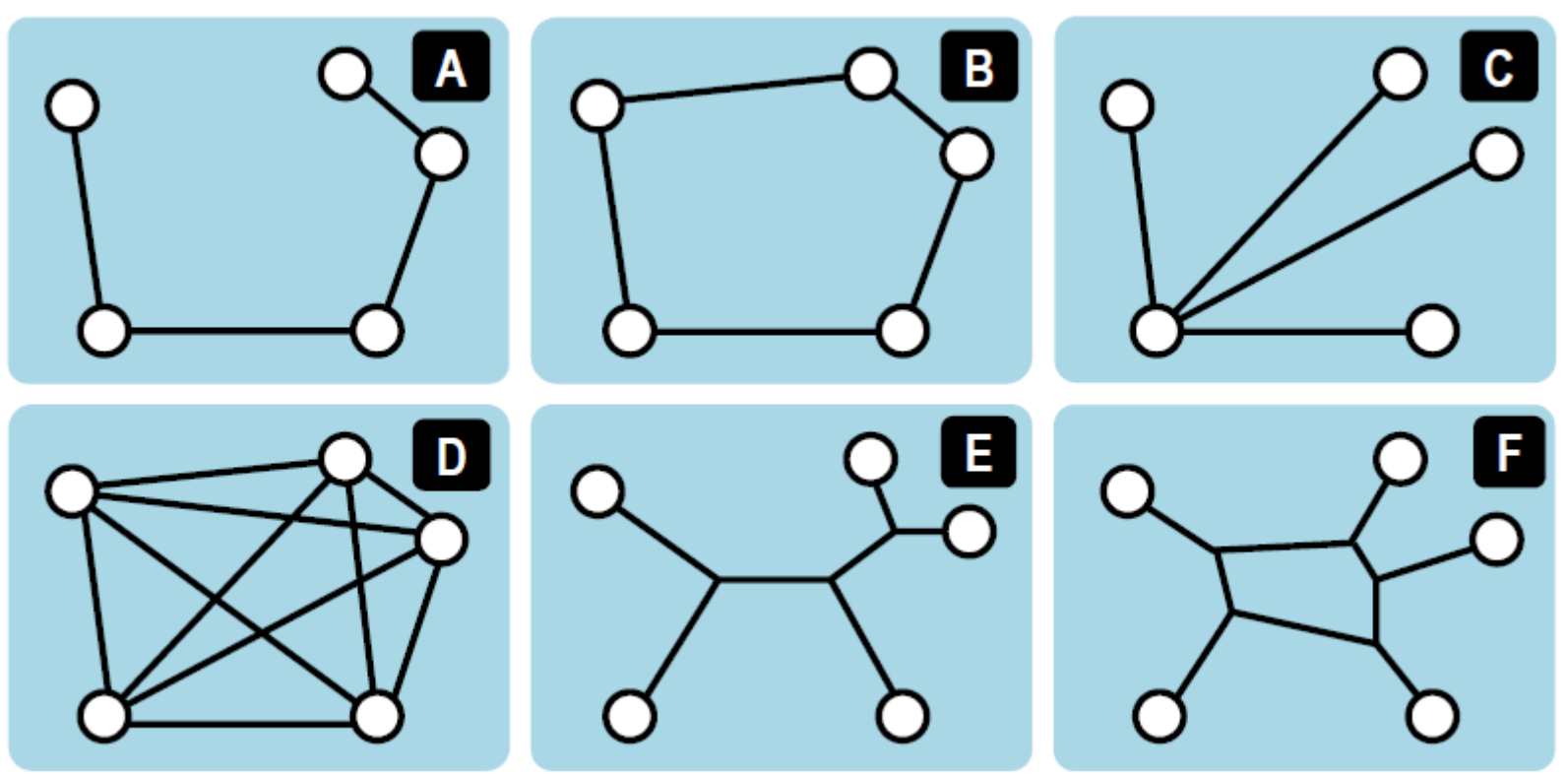
The prediction of future outcomes



Source: Rodrigue, J-P et al. (2020) The Geography of Transport Systems, Hofstra University, Department of Global Studies & Geography, https://transportgeography.org/

Planning principles of road networks

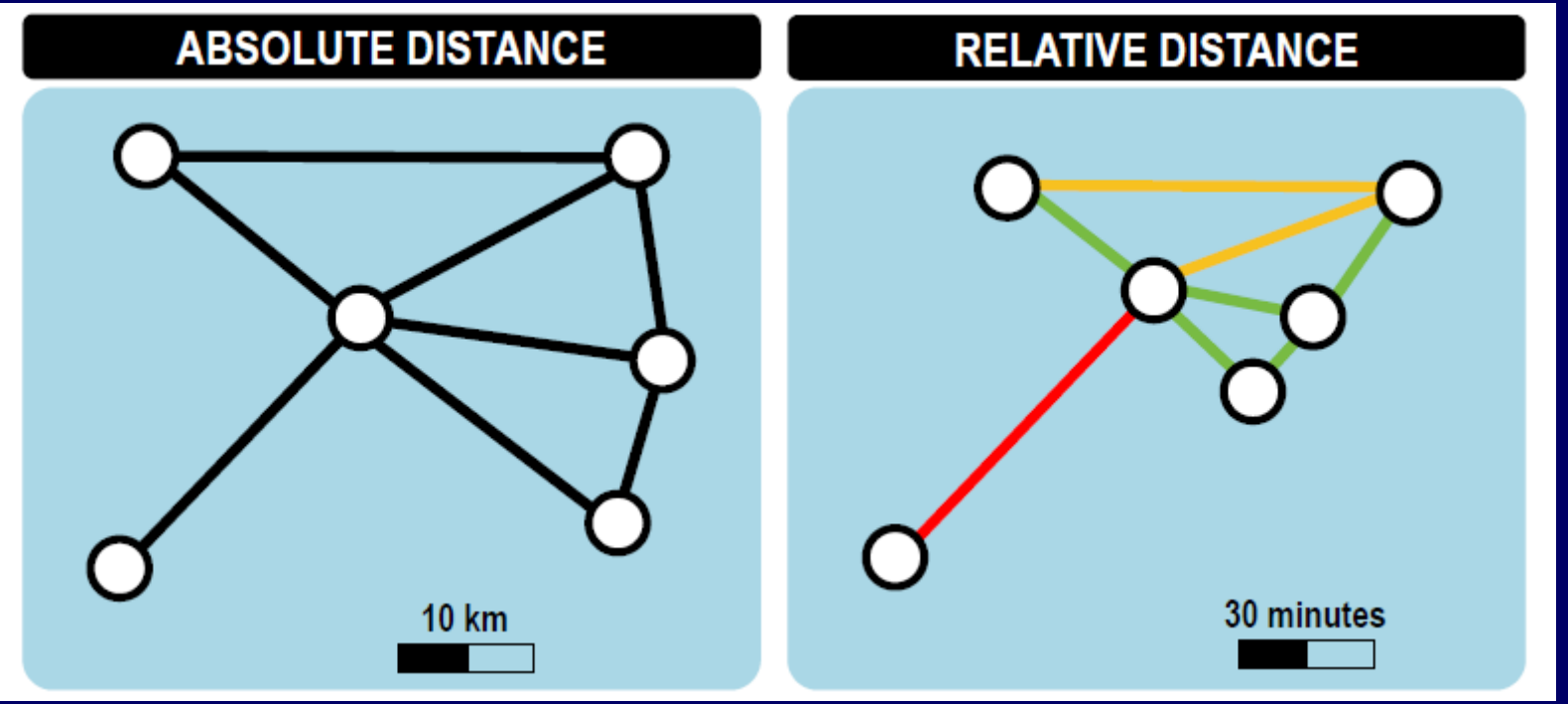
Network strategies to service a set of locations



Source: Rodrigue, J-P et al. (2020) The Geography of Transport Systems, Hofstra University, Department of Global Studies & Geography, https://transportgeography.org/

Planning principles of road networks

Absolute and relative distance in a network

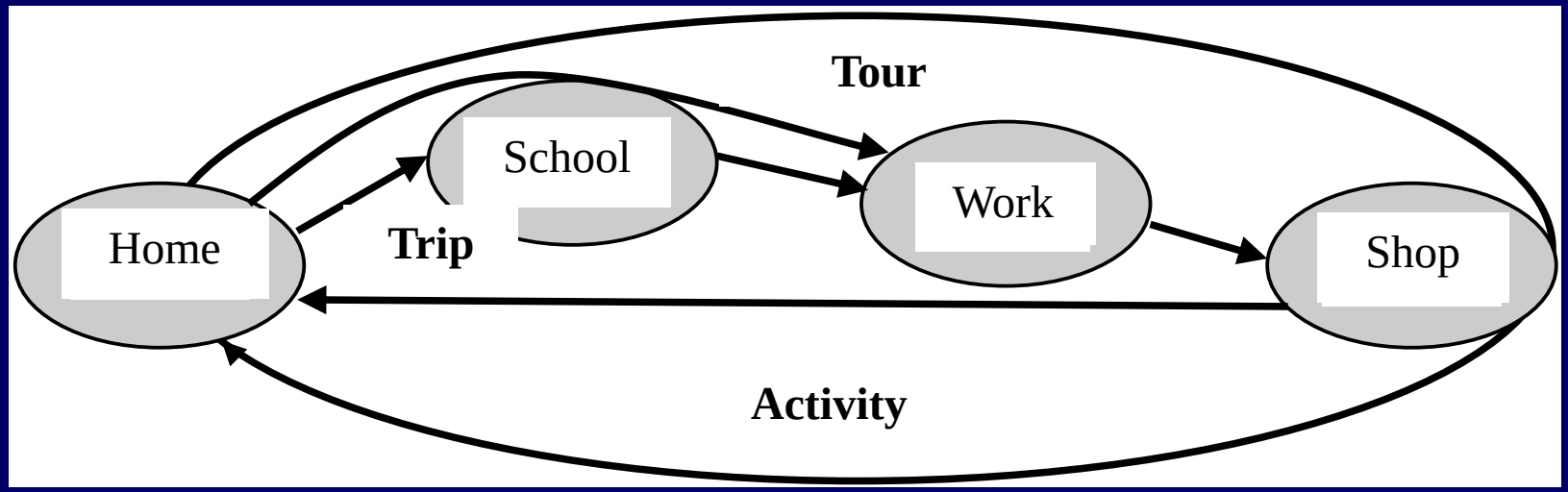


Source: Rodrigue, J-P et al. (2020) The Geography of Transport Systems, Hofstra University, Department of Global Studies & Geography, https://transportgeography.org/

Planning principles of road networks

- A motion is changing place, moving to a geographically different point, satisfying a travel demand originated from an activity demand. Motion includes walking as well.
- Trip or travel are motorised motion or movement. The specific value of trip/person/day is always less than the specific value of motion/person/day.
- The highest number of personal movements by mode in cities occurs in the elevator.

Planning principles of road networks



- A trip or a motion has always an origin and a destination including only traffic-related stops. A trip chain or tour consists of two or more trips one after the other in time successively, i.e., to work stopping at school.
- In case of activity based planning, besides travel time the time spent at various locations is taken into account as well.

Planning input data of road networks

- **Population and demographics**
- **In general, the greater the population of an urban area, the more complex are the transportation issues, and thus the planning and modelling efforts. However, population size is not the only issue; in fact, other demographic indicators such as income, race, gender and household size all have potential impacts on aspects of travel considered in the forecasting process.**
- **The aging of the population has significant effects on travel behaviour including the percentage of work-related travel, auto mode share, and time of day of travel.**

Source: Transportation Research Board: Travel Demand Forecasting: Parameters and Techniques. National Cooperative Highway Research Program Report 716. Washington, D.C. 2012.

Planning input data of road networks

- **Employment and housing and other land uses**
- **The types, location, and concentration of housing and employment are key factors in an urban area's travel patterns. For work travel, a significant number of trips flow from home to work in the morning and the reverse in the evening.**
- **But as work hours change based on economic and travel conditions and the types of jobs in an area, and as both work and home locations become more dispersed, the travel flows become less temporally and geographically regular.**
- **This, in turn, affects nonwork travel traditionally made during off-peak periods.**

Source: Transportation Research Board: Travel Demand Forecasting: Parameters and Techniques. National Cooperative Highway Research Program Report 716. Washington, D.C. 2012.

Planning input data of road networks

- **Development density, diversity, design, and destinations**
- **Development can have many different effects on planning and modelling. Population (through housing) and employment density are indicators of land use intensity and, in many urban areas, are accompanied by improved pedestrian amenities, such as sidewalks, and transit options.**
- **Land use mix, or diversity, can affect motorized trip making; areas with greater mix often permit a wider variety of needs to be satisfied without needing to drive.**
- **Accessibility to a variety of destinations can affect mode shares, trip lengths, and trip chaining.**

Source: Transportation Research Board: Travel Demand Forecasting: Parameters and Techniques. National Cooperative Highway Research Program Report 716. Washington, D.C. 2012.

Planning input data of road networks

- **Geographic features**
- **As with population size, increases in the geographic size of an urban area usually mean more complex planning and modeling issues. But it is also dependent on the land use and the density associated with the geography.**
- **Any natural feature that creates a travel barrier from mountain passes to water crossings to buildable versus unbuildable land affects planning and modelling.**
- **Such barriers create good locations for screenlines to be used in model validation and must be key targets for practitioners to model accurately**,

Source: Transportation Research Board: Travel Demand Forecasting: Parameters and Techniques. National Cooperative Highway Research Program Report 716. Washington, D.C. 2012.

Planning input data of road networks

- **Climate change**
- **Prolonged periods of extreme temperatures, either hot or cold, can have an impact on planning and modelling, particularly if the climate results in degradation of or limitations to the transportation system.**
- **Global climate change and its impacts (such as rising sea levels) are now also a consideration in the planning and modelling process.**
- **However, these still-developing environmental models are considering time horizons beyond the current capabilities of travel forecasting models, so caution should be exercised when selecting analysis tools.**

Source: Transportation Research Board: Travel Demand Forecasting: Parameters and Techniques. National Cooperative Highway Research Program Report 716. Washington, D.C. 2012.

Planning input data of road networks

- **Land use control and governance**
- **The ability to regulate land uses, and at what level of geography, can have an impact on planning and the type of modelling required to test future changes.**
- **An urban area with a regional government and an urban growth boundary may have different travel characteristics than an urban area with weak counties and home-rule, with local land use control in the hands of hundreds of small municipal civil divisions, such as boroughs, townships, and other municipalities. The latter case is likely to make realization of aggressive shifts in future land use difficult to achieve even if they are modelled well, so planners should consider an appropriate level of land use sensitivity/modelling.**

Source: Transportation Research Board: Travel Demand Forecasting: Parameters and Techniques. National Cooperative Highway Research Program Report 716. Washington, D.C. 2012.

Planning input data of road networks

- **Presence of special generators**
- **Resort areas that experience a significant number of visitors may have different travel characteristics than areas with fewer visitors. Whether the visitors to the area stay for a single day or multiple days is also an issue.**
- **Small- and medium-sized urbanized areas that include a major university typically have different travel patterns than similar sized cities without a large campus. Presence of a large university indicates a potentially a larger share of bicycle, walking, and transit trips than other similar sized areas.**
- **The presence of a county centre can also potentially impact travel patterns when compared against a similar sized city with a higher proportion of manufacturing employment.**

Source: Transportation Research Board: Travel Demand Forecasting: Parameters and Techniques. National Cooperative Highway Research Program Report 716. Washington, D.C. 2012.

Planning input data of road networks

- **Presence of alternative transportation modes**
- **The presence of (or desire for) modes other than single occupant vehicles means an urban area should consider mode choice modelling.**
- **The complexity and specifications are dependent on the type of mode and type of analysis.**
- **The introduction of new fixed-guideway transit into an area has been a frequent application of transferable parameters for use in mode choice estimation, calibration, and validation.**

Source: Transportation Research Board: Travel Demand Forecasting: Parameters and Techniques. National Cooperative Highway Research Program Report 716. Washington, D.C. 2012.

Planning input data of road networks

- **Highway network and travel conditions**
- **Highway mileage and area travel conditions may lead to different requirements for planning and modelling. Areas with significant congestion will likely need to employ travel time feedback in their models to ensure that they are accurately reflecting the effects of congestion on travel behaviour. Less congested areas, where more travel is on arterials rather than freeways, will have different considerations when developing volume-delay functions for their models.**
- **The level of external and through travel for an urban area can affect travel conditions and may be a consideration in planning and modelling. Areas with significant through travel may be especially concerned with ways to explore diverting that through travel away from the region.**

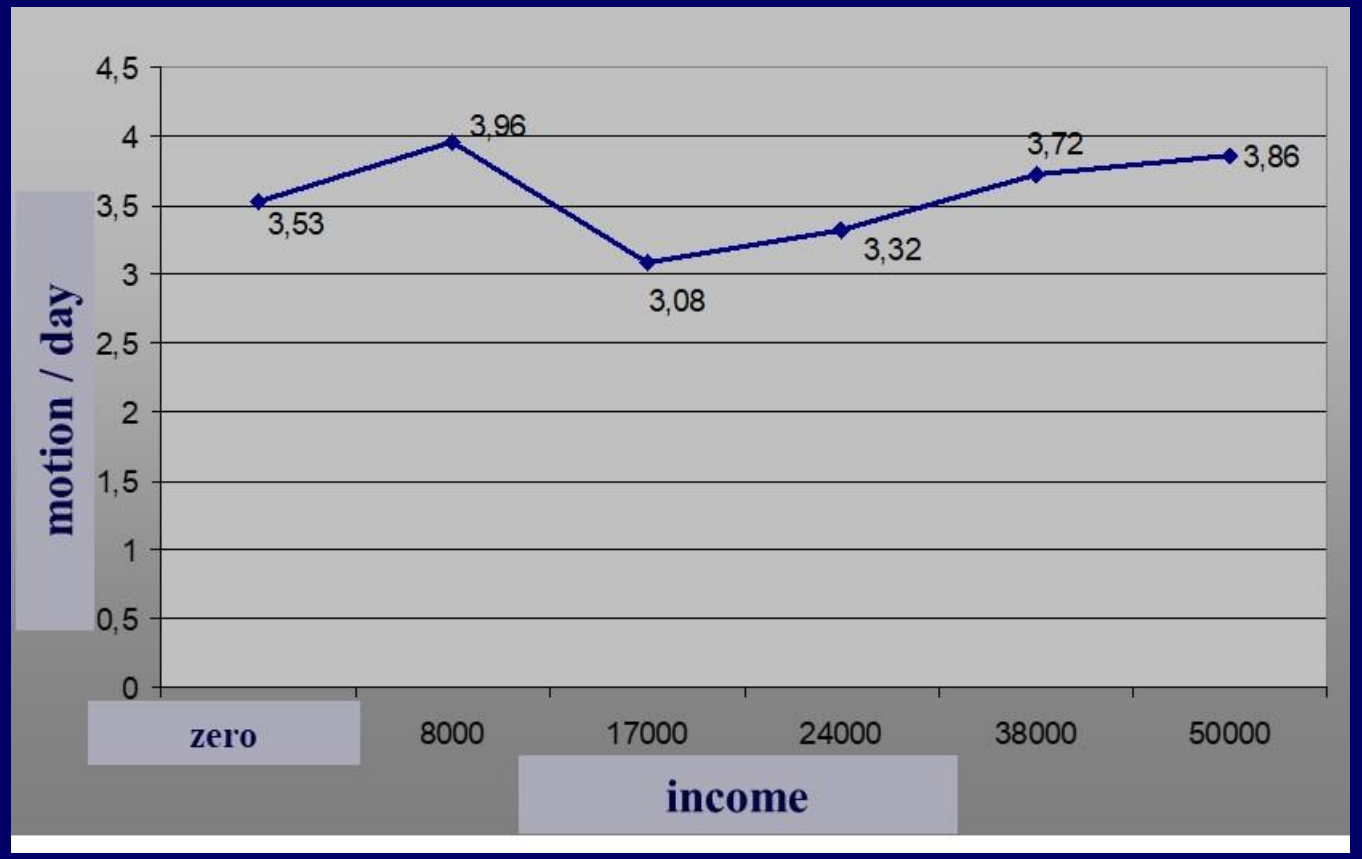
Source: Transportation Research Board: Travel Demand Forecasting: Parameters and Techniques. National Cooperative Highway Research Program Report 716. Washington, D.C. 2012.

Planning input data of road networks

Specific values of trips and motions, and their tendencies

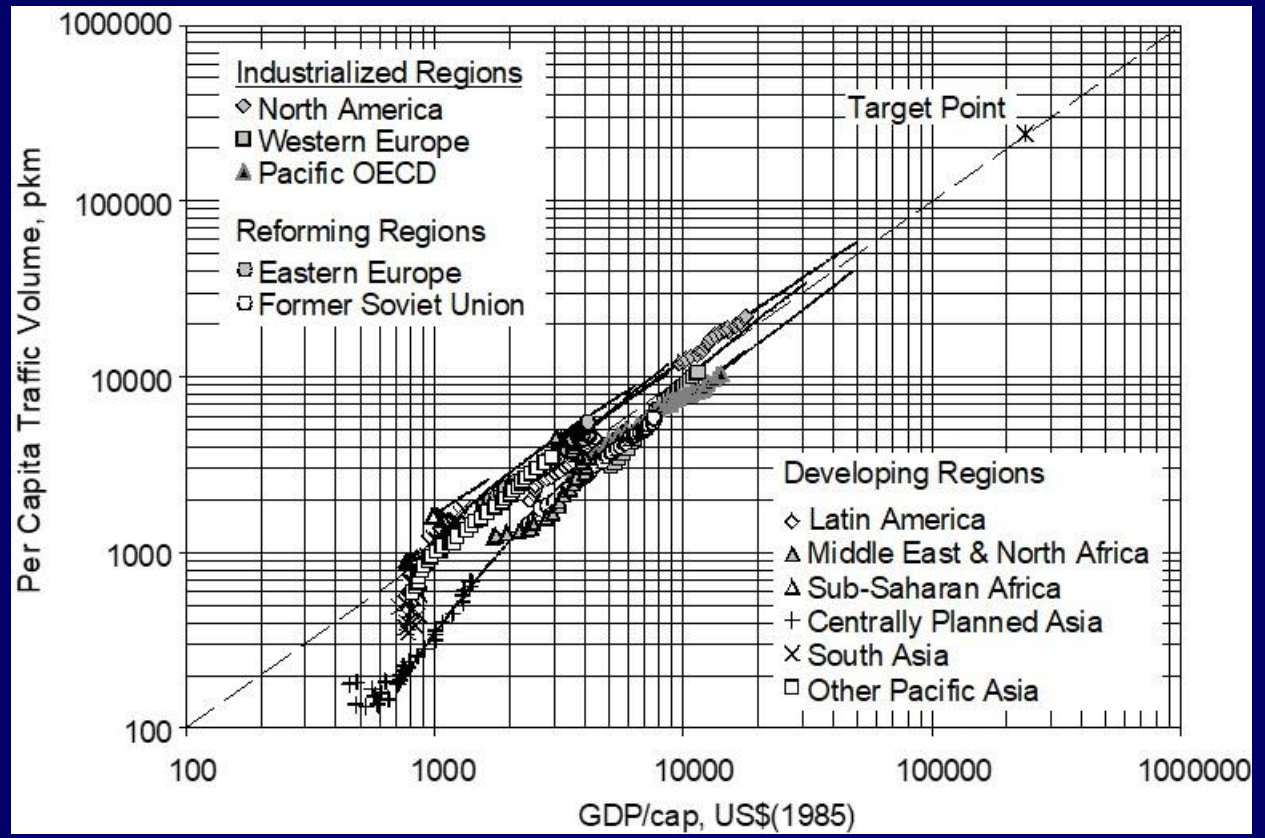
specific value	*tendency*
motion / person / day	constant
trip / person / day	increasing
km travelled / person / day	increasing
time of travel / person / day	constant

Planning input data of road networks



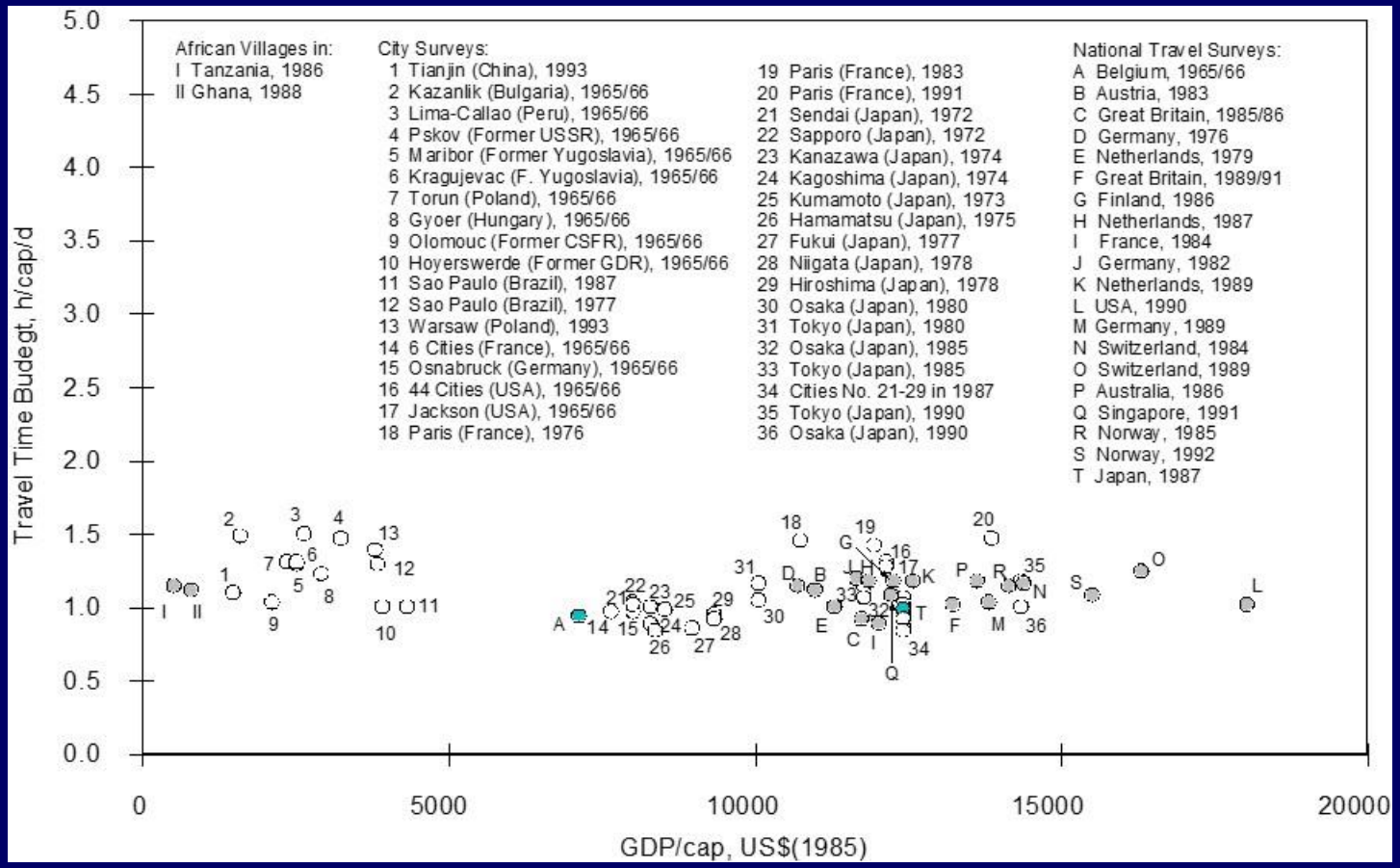
Number of motions depending on income rate (The Netherlands, 1990)

Planning input data of road networks



Kms travelled (km/person/year) depending on gross domestic product (GDP, USD/person/year)

Planning input data of road networks



Time of travel (hour/person/day) depending on gross domestic product (GDP, USD/person/year)

Modelling of road networks

- The objective of network modelling and traffic planning is to create a network suitable for the satisfaction of travel demands, choosing an appropriate transport mode. Main tasks are the determination of traffic flows, volumes and loads as well as the analysis of capacity utilisation.
- Traffic planning and network modelling characteristically deals with a future situation, analysing and assessing traffic on a developed network version, using alternatives. For a successful model calibration there is a need for getting acquainted with the current network and its traffic flows.

Modelling of road networks

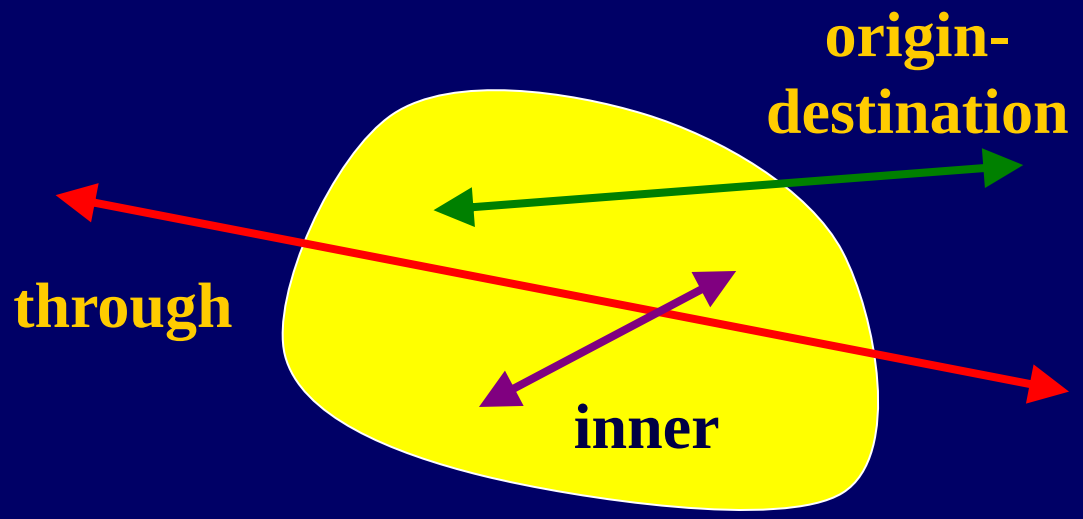
- **Transport development plans usually consist of**
  - **analysis of the current situation,**
  - **forecast of the expected traffic in the future,**
  - **establishment of development objectives, forming a strategy,**
  - **planning the future network alternatives and an assessment of these,**
  - **creation of a feasible project list and ranking of these projects.**
- **Traffic modelling is performed usually in traffic layers, differentiating at least between personal and freight traffic, moreover, within personal traffic, between the car usage and the public transport usage.**

Modelling of road networks

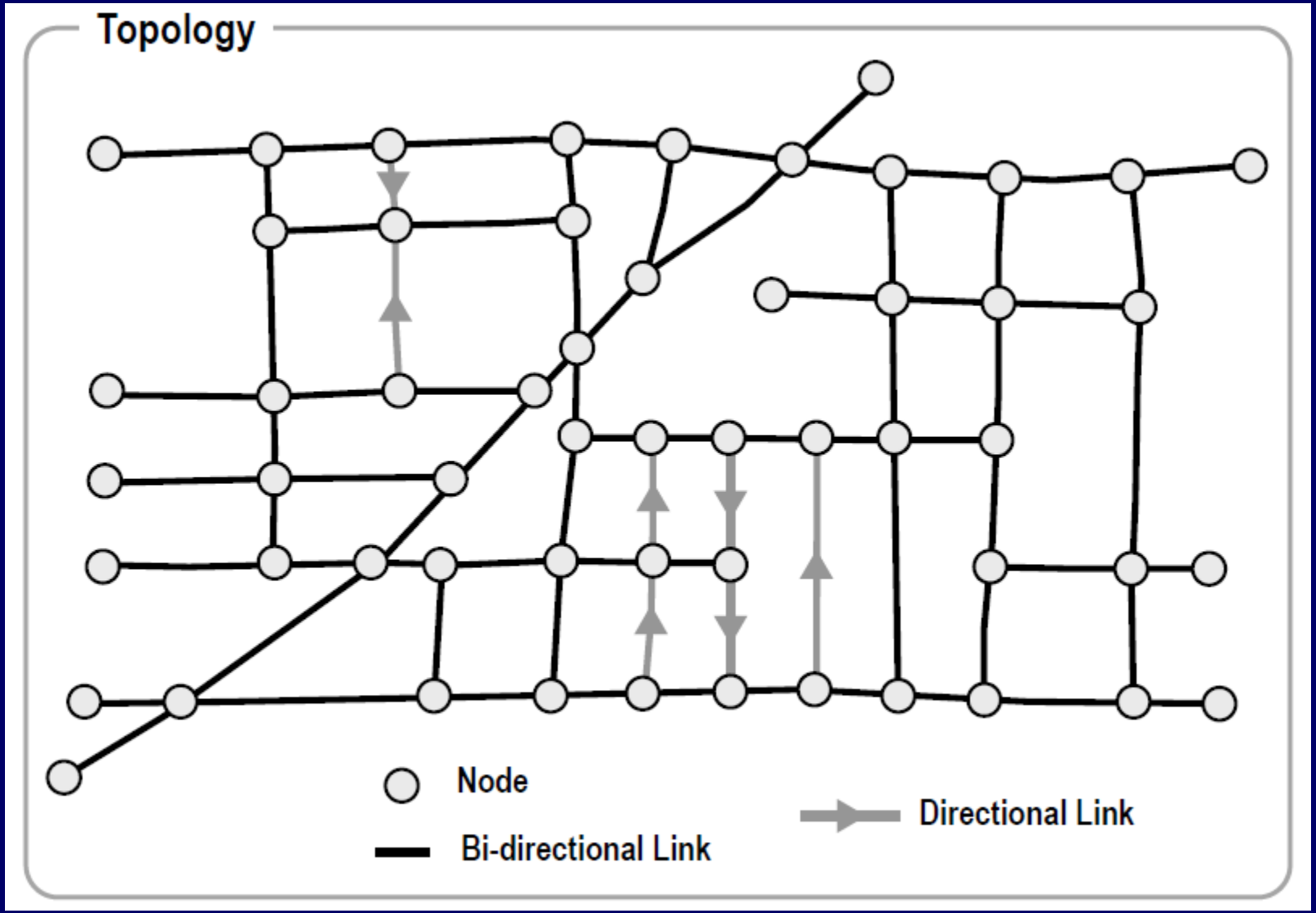
- **Relations of settlement and traffic:**
  - **through traffic has both its origin and destination outside the settlement, but it moves through the settlement, crossing its border two times – volume of through traffic is important for the planning of a bypass road**
  - **origin-destination traffic has a starting or ending point within the settlement while its other ending or staring point is outside the settlement, crossing its border one time**
  - **inner traffic remains within the settlement border – volume of inner traffic is important for the planning of road network elements inside the settlement**

Modelling of road networks

Relations of settlement and traffic: through traffic, origin – destination traffic, inner traffic.

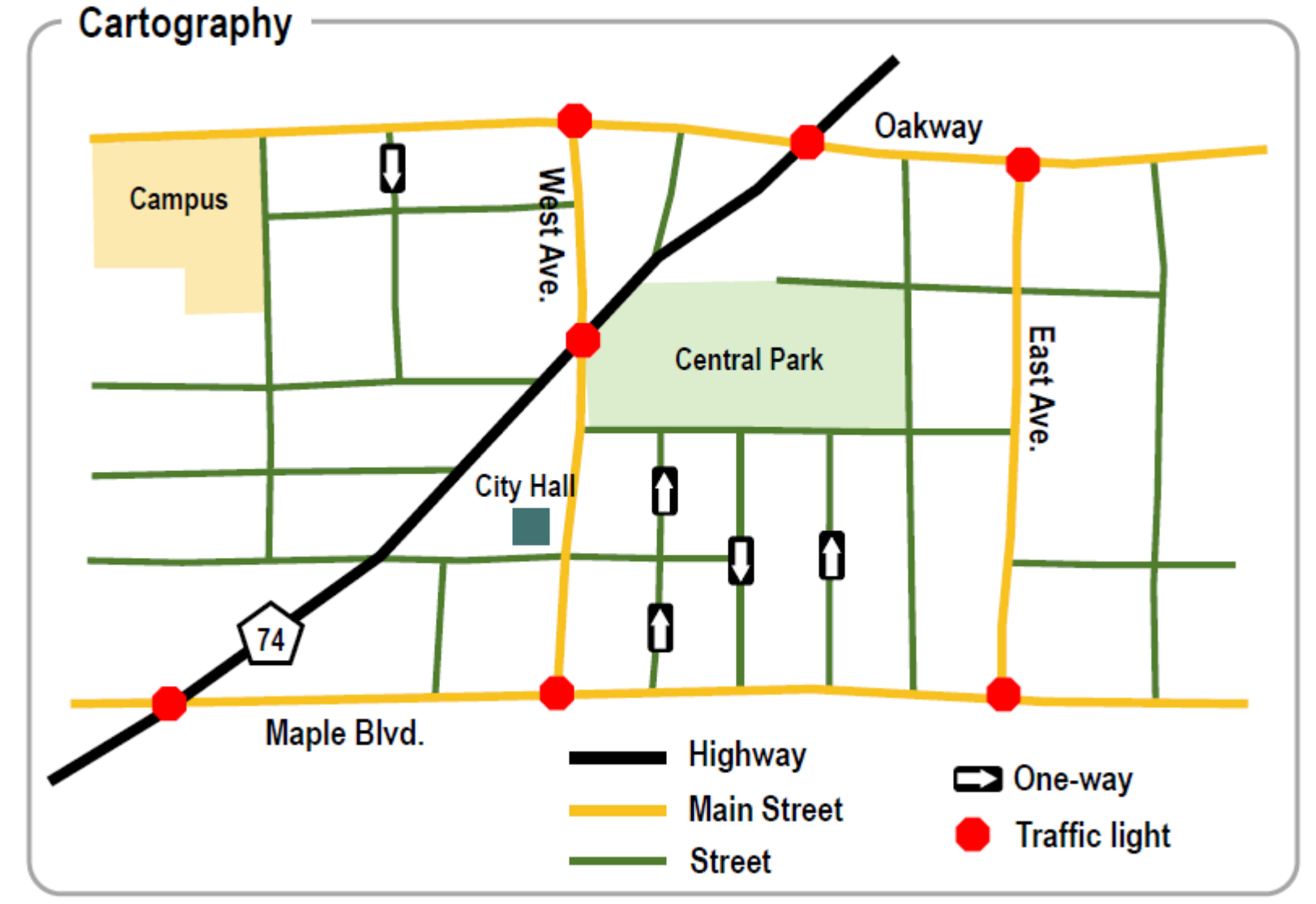


Modelling of road networks



Source: Rodrigue, J-P et al. (2020) The Geography of Transport Systems, Hofstra University, Department of Global Studies & Geography, https://transportgeography.org/

Modelling of road networks



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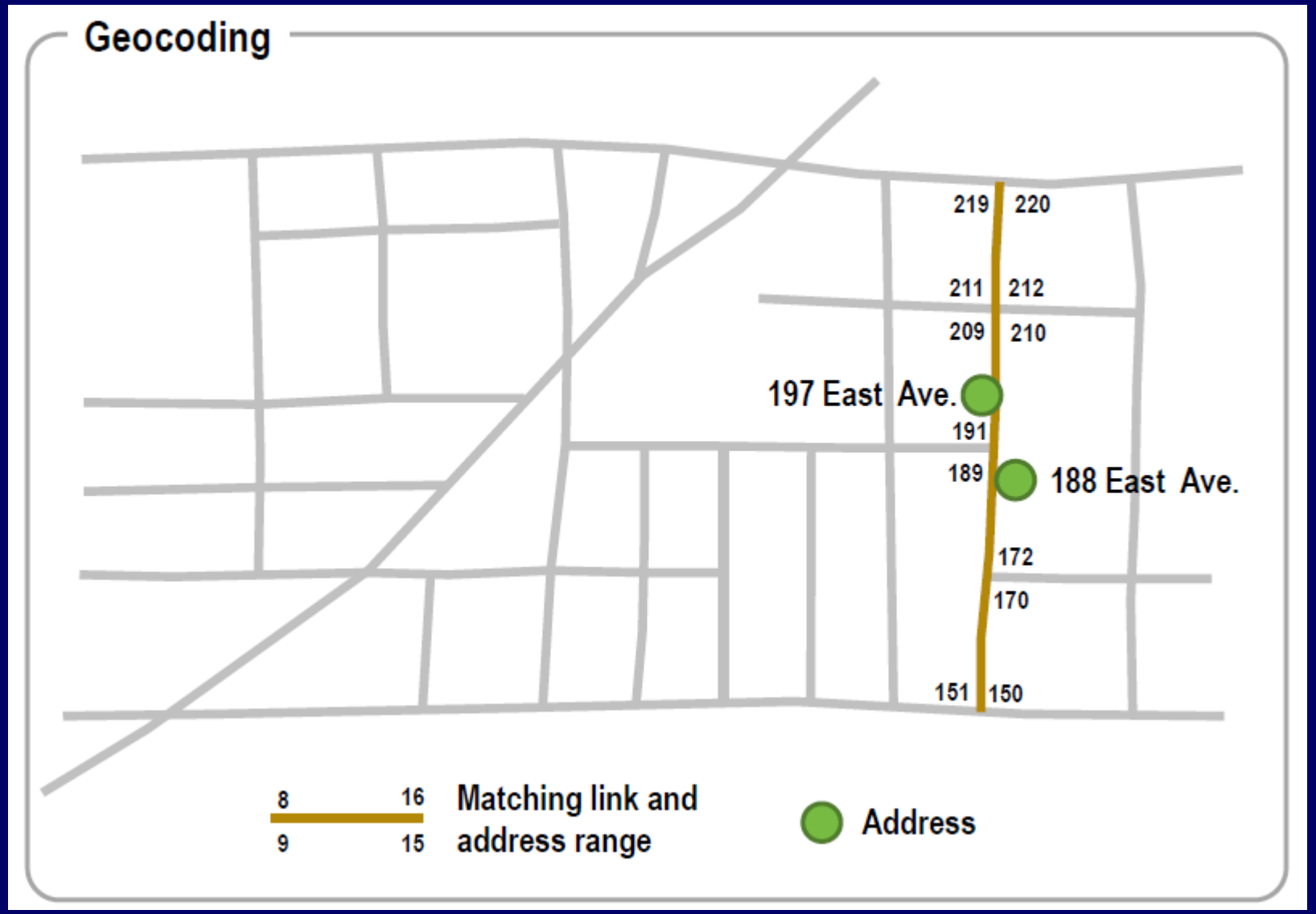
Modelling of road networks



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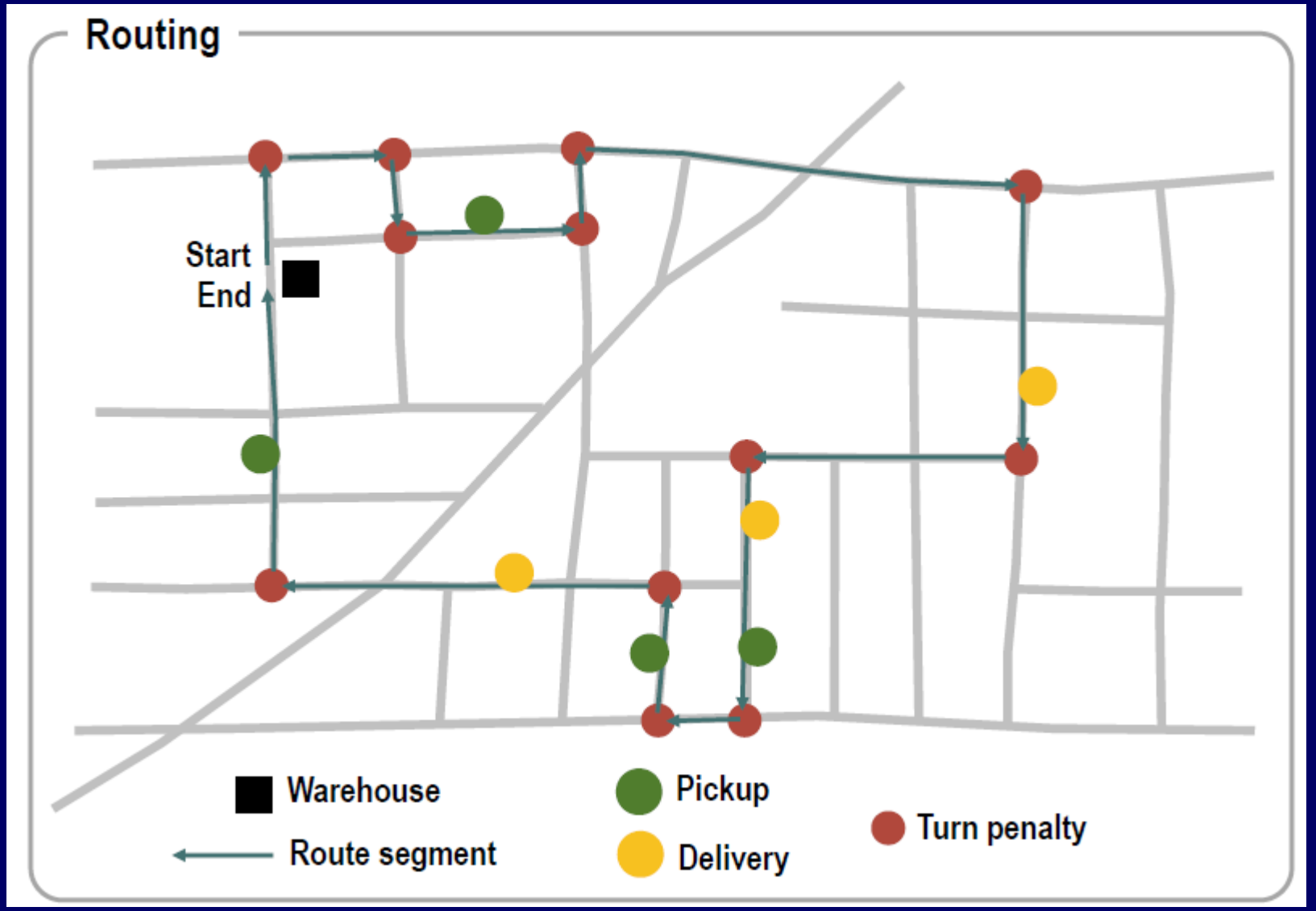
Modelling of road networks



Source: Rodrigue, J-P et al. (2020) The Geography of Transport Systems, Hofstra University, Department of Global Studies & Geography, https://transportgeography.org/

Traffic planning of road networks

- **For the traffic planning of a road network there is a need to collect some land-use characteristics by zones:**
- **type and function of land-use**
- **population size and its spatial distribution**
- **economic metrics such as GDP/person**
- **motorisation rate cars/1000 inhabitants**
- **number and location of flats**
- **number and location of workplaces**
- **number and location of services such as schools, shops, health centres etc.**

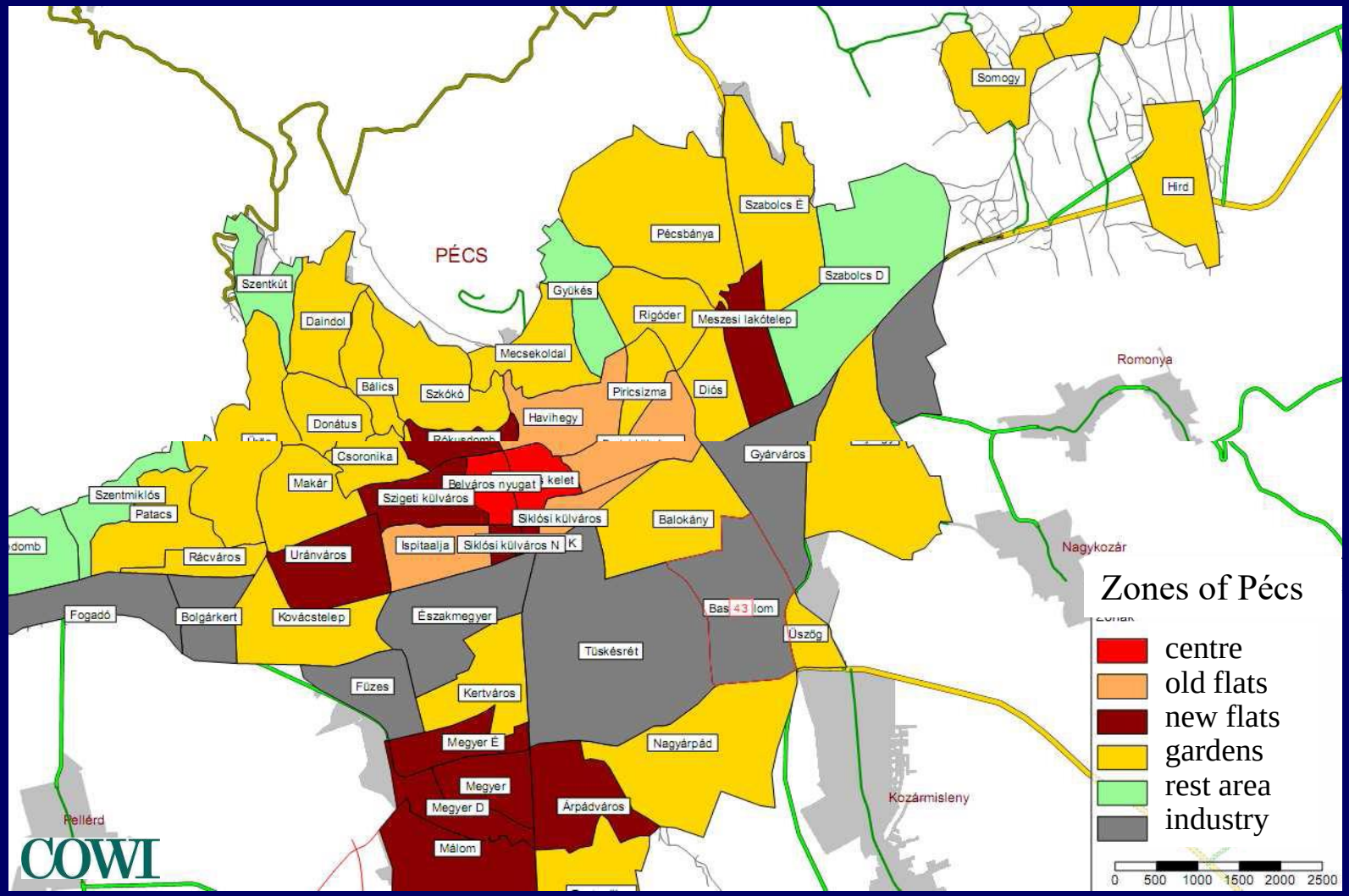
Traffic planning of road networks

- **Further essential input data for modelling traffic:**
- **Characteristics and condition of the road network and the public transport network (speeds, junctions, congestion, travel cost, public transport frequency etc.)**
- **Travel characteristics of passengers collected from household interview, cordon questionnaire, public transport census, differentiated by trip type (according to the destination), trip time, mode choice, preferences (revealed or stated), reactions for planned changes.**

Traffic planning of road networks

- As a first step of traffic planning, the settlement or area shall be divided into zones. Resolution of zoning shall correspond to the study objective, basic input data required by zones shall be available (population, motorisation rate, economic parameters, land-use type etc.).
- Road sections at the border of the planning area form cordons, supplementing zones.
- Trips are generated and attracted by zones. Movements within a zone are usually neglected.

Traffic planning of road networks



Source: COWI Magyarország Kft: Pécs Megyei Jogú Város és környéke hosszú távú térségi közlekedés-fejlesztési terve. 2010.

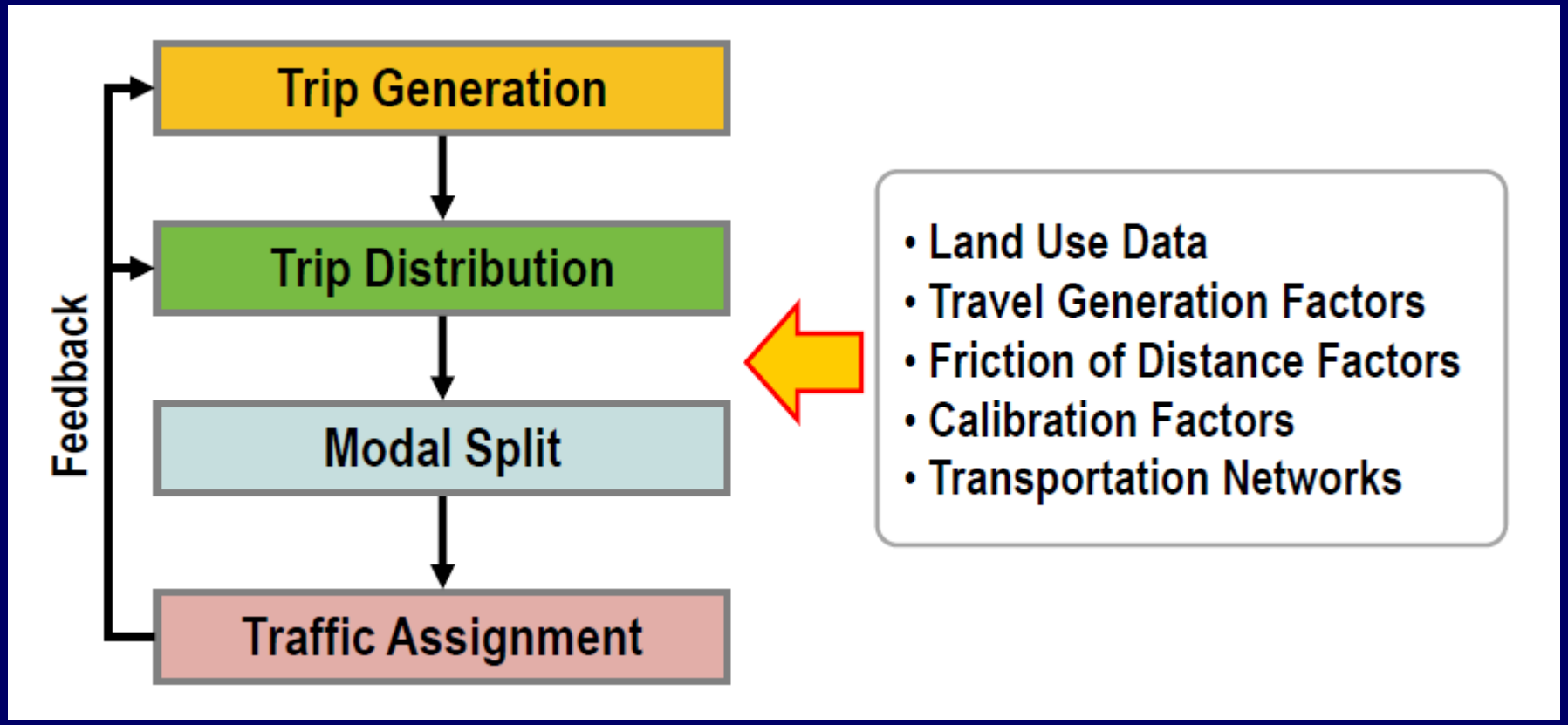
Traffic planning of road networks

The four stages of traffic planning:

1. **Trip generation (per spatial zones)**
2. **Trip distribution (between zones, matrix)**
3. **Modal split (cars, public transport, freight)**
4. **Assignment (current and future network)**

Stages 2 and 3 can be exchanged freely, depending on the consultant or the software.

Traffic planning of road networks



Source: Rodrigue, J-P et al. (2020) The Geography of Transport Systems, Hofstra University, Department of Global Studies & Geography, https://transportgeography.org/

Traffic planning of road networks

- **In the four stages of traffic planning (traffic modelling) the basic unit of movements is called a trip, defined as „motion of a person or a vehicle from an origin point (zone) to a destination point (zone) without any activity-related stops”.**
- **Usually trips are differentiated by their origin and destination:**
  - **from home to work**
  - **from home to other activity place**
  - **from other activity place**

Traffic planning – trip generation

- The objective of trip generation is to estimate the number of trips from and to the given zone for all modes, taking into account land-use characteristics and possible activities. In the majority of models the number of trips generated and attracted by a given zone is determined.
- Dimension of trips depend on the model type, usually a trip by a vehicle or a trip by a person. The latter can be motorised (using car or public transport) or non-motorised (bicyle and pedestrian movements). A total traffic model includes both motorised and non-motorised mobility.

Traffic planning – trip generation

- In a trip generation model there is a need for some explanatory variables related to travel behaviour and activities, moreover, there is a need for a function describing the connection between estimated trips and explanatory variables.
- The result of the trip generation stage is the number of trips generated and attracted for all zones by travel types and modes. Trips are ordered to a square matrix of zones, that is called the traffic matrix. Row sums represent generated trips and form column sums represent attracted trips in the traffic matrix.

Traffic planning – trip generation

- **Trip generation method can be projective or analytic.**
- **The projective model applies one or more growth factors that may differ by zones. Projective forecast is useful in shorter time ranges, in cases when no significant future land-use changes are expected.**
- **Basic formula of the projective or growth factor model:**

$$F_i = t_i \cdot f_i$$

where:
T_i number of predicted trips
t_i current amount of trips
F_i growth factor

Traffic planning – trip generation

- **Analytic models proceed from expected future land-use and explanatory variables, applying a regression function, resulting generated and attracted trips. Calibration of function parameters is performed using values of current traffic and current explanatory variables, for example:**

$$P_i = a_1 L_i + a_2 M_i + a_3 I_i + a_4 S_i$$

where:

P_i trips originated from the i^{th} zone
L_i population of the i^{th} zone
M_i workplaces of the i^{th} zone
I_i school spaces of the i^{th} zone
S_i service sector employees of the i^{th} zone
$a_{1...4}$ weighing parameters

Traffic planning – trip distribution

- The objective of trip distribution is to estimate the number of trips between zones for every zone pair, represented in the traffic matrix, filling in the elements based on row and column sums. Since trips within a zone are neglected, the elements of the main diagonal of the matrix have zero value.
- Moreover, the traffic matrix contains elements for the origin-destination traffic and the through traffic as well, that means there are more rows and columns in the traffic matrix for cordons and elements for trips between zones and cordons (plus between cordons and zones (origin-destination traffic) and between cordons (through traffic).

Traffic planning – trip distribution

- Trip distribution also requires explanatory variables and functions. Explanatory variables are usually on one hand travel times or travel costs between zones, and on the other hand activity characteristics of origin and destination zones, resulting traffic demand.
- The result of the trip distribution stage is the number of trips between zones (for each zone pair) by travel types and modes, that means the filled-in traffic matrix. Every travel type and mode is represented by a layer in the traffic matrix. There can be layers for the average daily and for the pek hour traffic as well.

Traffic planning – trip distribution

- In the trip distribution stage frequently used models are the growth factor model and the generalised gravity model.
- In the growth factor model the current traffic volumes between zones are known, and based on these values the near future values can be forecasted.
- A simple case applies the same growth factor for each matrix element, but it is possible to apply different growth factors for every row and column, which requires an iterative balancing in order to get back the same row and column sums.

Traffic planning – trip distribution

- **In the generalised gravity model the value of the resistance (characterising the connection between zones) is usually depending on the distance or on the travel time or more often on the cost of the trip.**

$$f_{i,j} = \alpha \frac{P_i \cdot A_j}{r_{i,j}}$$

where:

f_{ij} trips or traffic between the i^{th} and the j^{th} zones

α connection factor

P_i trips generated from the i^{th} zone

A_j trips attracted to the j^{th} zone

$r_{i,j}$ resistance between the i^{th} and the j^{th} zones

Traffic planning – trip distribution

- A simple case is where the trip distribution is determined by the proportion of attracted trips:

$$f_{i,j} = P_i \frac{A_j}{\sum A_j}$$

where:

f_{ij} trips or traffic between the i^{th} and the j^{th} zones
P_i trips generated from the i^{th} zone
A_j trips attracted to the j^{th} zone

- There is usually a need for an iterative balancing in order to correct the differing row and column sums

Traffic planning – trip distribution

- **An example of a traffic matrix after steps of trip generation and trip distribution:**
- **The settlement is divided into zones, practically a few zones, eight to ten. The zones cover the current inhabited area of the settlement (in the example: 1 - 4) as well as the area of the planned bypass road (in the example: 5 - 7) if there will be significant new investments along the bypass road with traffic generation and attraction.**
- **Added to the zones there are the so called cordon points outside the joining points of the former main road and its bypass road. These cordons represent the through traffic (in the example: 11 - 14).**

Source: Útmutató az országos közúthálózat új külterületi szakaszainak és új forgalomvonzó létesítménnyel érintett útjainak forgalmi előre becsléséhez (kidolgozta: COWI Magyarország Kft., kiadta: Gazdasági és Közlekedési Minisztérium, 2003.) Függelék - Egyszerűsített módszer kistelepülések elkerülő útjai esetében. (in Hungarian)

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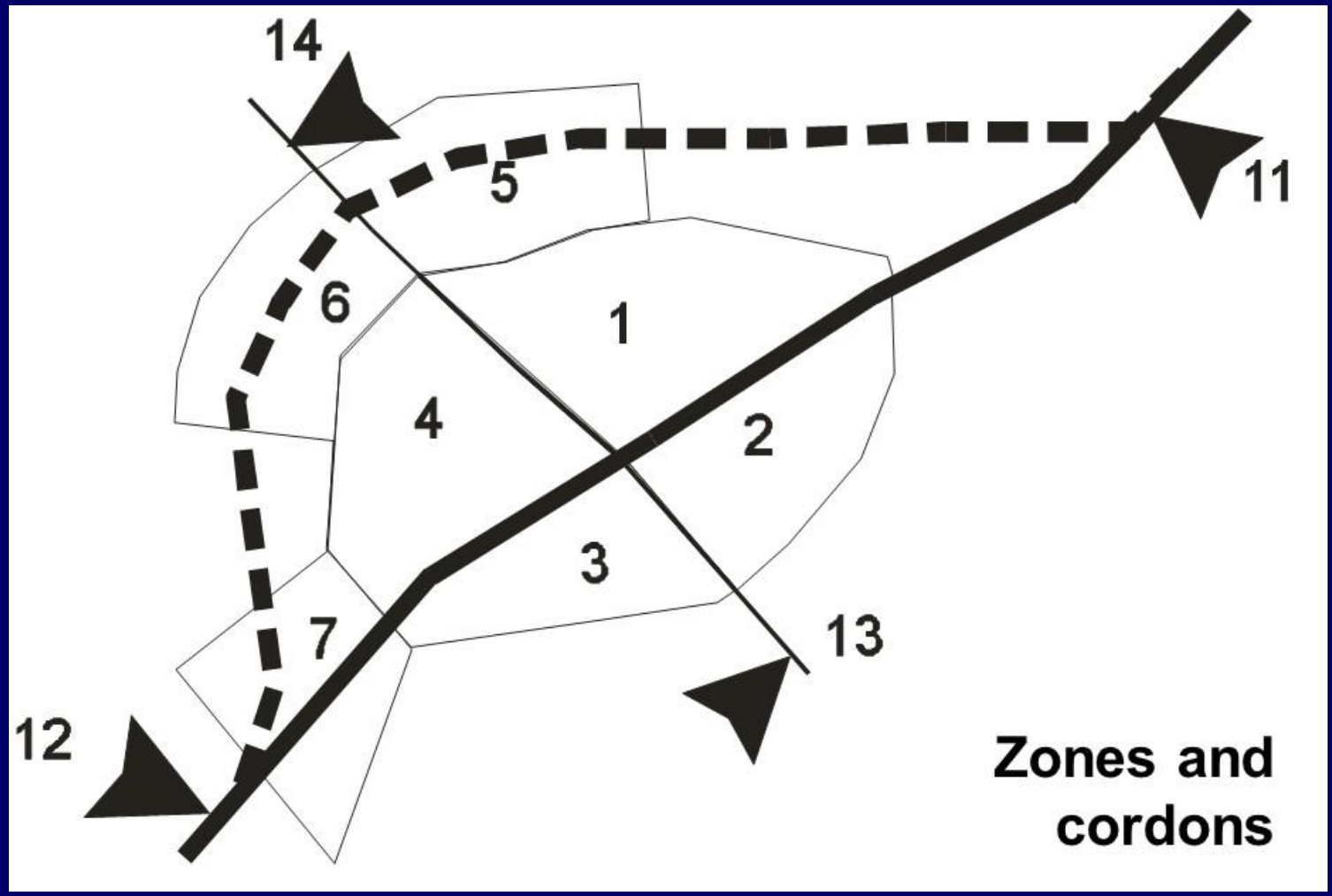

Traffic planning – trip distribution

Traffic matrix	1 - 4	5 - 7	11 - 14	sum
1 - 4	Inner traffic	inner developed	origin-destination	generation
5 - 7	inner developed	Inner developed	O-D developed	generation
11 - 14	origin-destination	O-D developed	through traffic	generation
sum	attraction	attraction	attraction	total traffic

Summary

- The objective of traffic planning is to satisfy travel and mobility demand.
- Relations of settlement and traffic: through traffic, origin – destination traffic, inner traffic.
- The four stages of traffic planning: trip generation, trip distribution, modal split, traffic assignment.
- The trip generation determines the number of trips generated and attracted by a given zone.
- The trip distribution determines the number of trips between zones for every zone pair.

Thank you for your attention!

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