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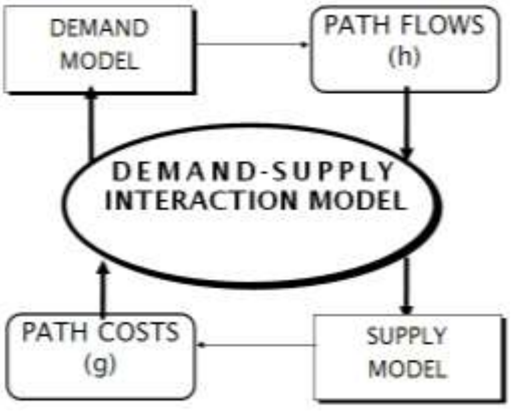
Macroscopic multi-class simulation models for the evaluation of freight policies in urban area

Stockholm, May 10-11, 2012
VREF workshop

ASSIGNMENT MODELS

SIMULATE DEMAND-SUPPLY INTERACTIONS, RESULTING FLOWS AND PERFORMANCES ON NETWORK ELEMENTS.



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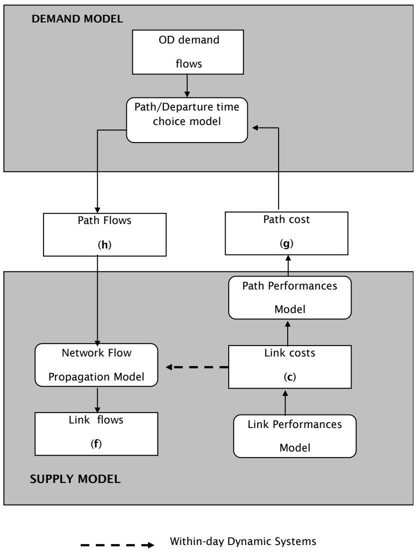
ASSIGNMENT MODELS

Not congested network



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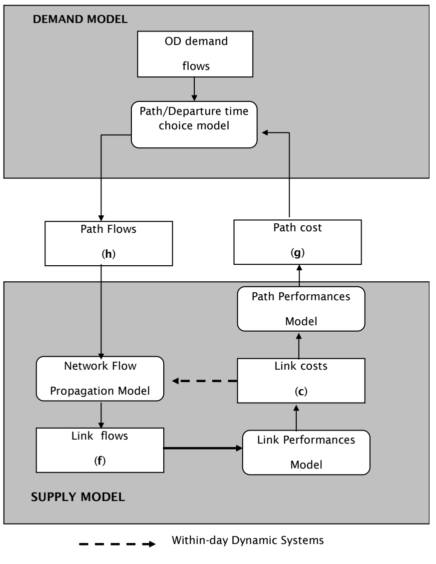
ASSIGNMENT MODELS

Congested network – Equilibrium models



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MULTI-CLASS ASSIGNMENT MODELS

Users/goods fall into a number of distinct *classes.* Users/goods of a given class share all the behavioral characteristics such as specification, parameters and attributes of the relevant demand models, including path choice. All these features may be different from those of other classes.

For example, in urban systems, classes may be identified on the basis of

- trip purpose (delivering, procurement / work, shopping)
- vehicle type (auto, light and heavy commercial vehicles),
- commodity types (e.g. perishable, oil, raw materials)
- activity duration (e.g. parking duration)
- cost functions (e.g. different travel costs and time values)

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MULTI-CLASS ASSIGNMENT MODELS

SUPPLY MODEL

- $\boldsymbol{g}_{od,i} = \Delta_{od,i}^T \boldsymbol{c}^i \quad \forall\, od \quad \forall\, i$
- $\boldsymbol{c}^i = \boldsymbol{c}^i(\boldsymbol{f}^1, \ldots, \boldsymbol{f}^i, \ldots) = \boldsymbol{c}^i(\boldsymbol{f}) = \boldsymbol{c}^i(\mathrm{S}_i\, \boldsymbol{f}^i) \quad \forall\, i$
- $\boldsymbol{f}^i = \mathrm{S}_{od}\, \Delta_{od,i}\, \boldsymbol{h}_{od,i} \quad \forall\, i$

Hypothesis:
- *fixed demand*
- *single mode assignment fully pre-trip path choice behavior*
- *non-additive cost not considered*

DEMAND MODEL

- $\boldsymbol{h}_{od,i} = d_{od,i}\, \boldsymbol{p}_{od,i}(-\boldsymbol{g}_{od,i}) \ \forall\, od \quad \forall\, i$

were:

$\Delta_{od,i}$ be the link-path incidence matrix for the O-D pair *od* and class *I*

$d_{od,i}$ be the demand flow for the O-D pair *od* and class *i* (for a given mode and time band);

$\boldsymbol{f}^i$ be the link flow vector for class *i*,

$\boldsymbol{c}^i$ be the link cost vector for class *i*,

$\boldsymbol{g}_{od,i}$ be the additive path cost vector for O-D pair *od* and class *i*

$\boldsymbol{h}_{od,I}$ be the path flow vector for O-D pair *od* and class *I*

$\boldsymbol{p}_{od,i} = \boldsymbol{p}_{od,i}(-\boldsymbol{g}_{od,i})$ be the path choice probabilities vector for O-D pair *od* and class i

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MULTI-CLASS ASSIGNMENT MODELS

CLASSIFICATION

Link congestion function of each class is:

- a linear transformation of a common congestion function (***undifferentiated congestion***)
- different between classes (***differentiated congestion***)

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MULTI-CLASS ASSIGNMENT MODELS

Undifferentiated congestion

link cost function becomes:

$$c^i_a = c^i_a(\boldsymbol{f}) = \gamma_i\ \bar{c}_a(\boldsymbol{f}) + c^i_{0,a} \quad \forall i$$

where:

$\bar{c}_a = \bar{c}_a(\boldsymbol{f})$ is the reference cost function of link a;

$\gamma_i \geq 0$ is the ratio (assumed independent of the link) between the link cost for class i and the reference cost; if $\gamma_i = 0$ the class i costs are uncongested;

$c^i_{0,a}$ is the cost of link a specific to class i, assumed independent of congestion

Undifferentiated congestion equilibrium multi-class assignment models

$$\boldsymbol{f}^{\,i} = \Sigma_{od}\, \boldsymbol{\Delta}_{od,i}\, \boldsymbol{p}_{od,i}(-\gamma_i\, \boldsymbol{\Delta}_{od,i}^T\ \bar{c}_a(\boldsymbol{f}) - \gamma_i \boldsymbol{\Delta}_{od,i}^T \boldsymbol{c}^i_0\,) \quad \forall i$$

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MULTI-CLASS ASSIGNMENT MODELS

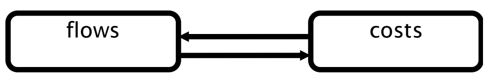
Differentiated congestion

Differentiated congestion multi-class assignment models can be formulated with respect to the path or link flows of each class. These must be consistent with the corresponding costs experienced by each class. In the case of congested network assignment, cost functions generally differ for each class, and depend on the total flow of all classes

Differentiated congestion multi-class equilibrium assignment models

$$\boldsymbol{f}^{i} = \Sigma_{od}\, d_{od,i}\, \Delta_{od,i}\, \boldsymbol{p}_{od,i}(-(\Delta_{od,i}{}^{T}\, c^{i}{}_{a}(\boldsymbol{f}))) \quad \forall \boldsymbol{c}_{i}\ \forall i$$

Mutually consistent flows and costs



DEMAND MODELS

A travel demand model can be defined as a mathematical relationship between travel demand flows and their characteristics on the one hand, and given activity and transportation supply systems and their characteristics on the other.

$$d\,[K_1, K_2, \ldots] = d(\boldsymbol{SE}, \boldsymbol{T}; \beta)$$

A demand flow is an aggregation of individual trips, and each trip is the result of multiple choices made by the transportation system users, i.e. an <u>individual traveler</u> in the case of passenger transportation or <u>an operator</u> (manufacturer, shipper and carrier) for freight transportation

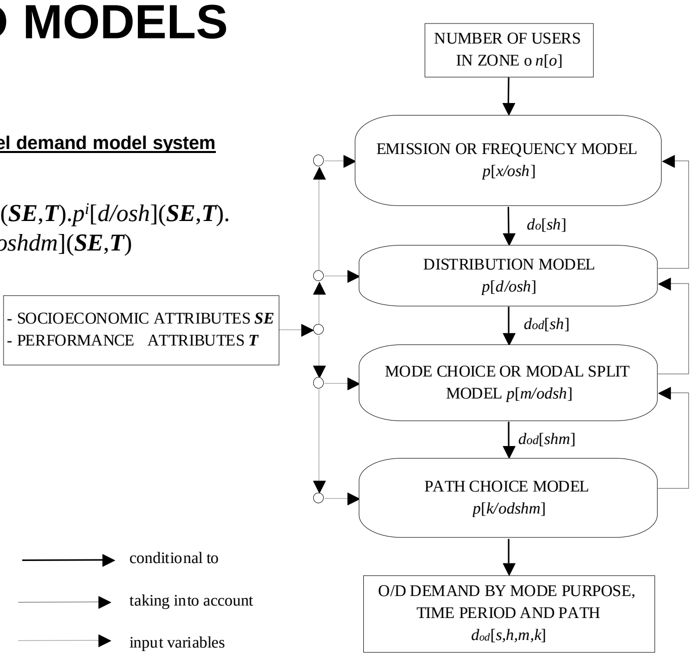
TYPE OF CHOICE	Mobility or context models
	Travel models
SEQUENCE OF CHOICES	Trip-based demand models
	Trip chaining models
	Activity-based models
LEVEL OF DETAIL	Disaggregate models
	Aggregate models
BASIC ASSUMPTIONS	Behavioral models
	Descriptive models

DEMAND MODELS

EXAMPLE

Four-level trip-based travel demand model system

$$d^i_{od}[s,h,m,k] = d^i_{o.}\,[sh]\,(\boldsymbol{SE},\boldsymbol{T}).p^i[d/osh](\boldsymbol{SE},\boldsymbol{T}).\;p^i[m/oshd](\boldsymbol{SE},\boldsymbol{T}).p^i[k/oshdm](\boldsymbol{SE},\boldsymbol{T})$$

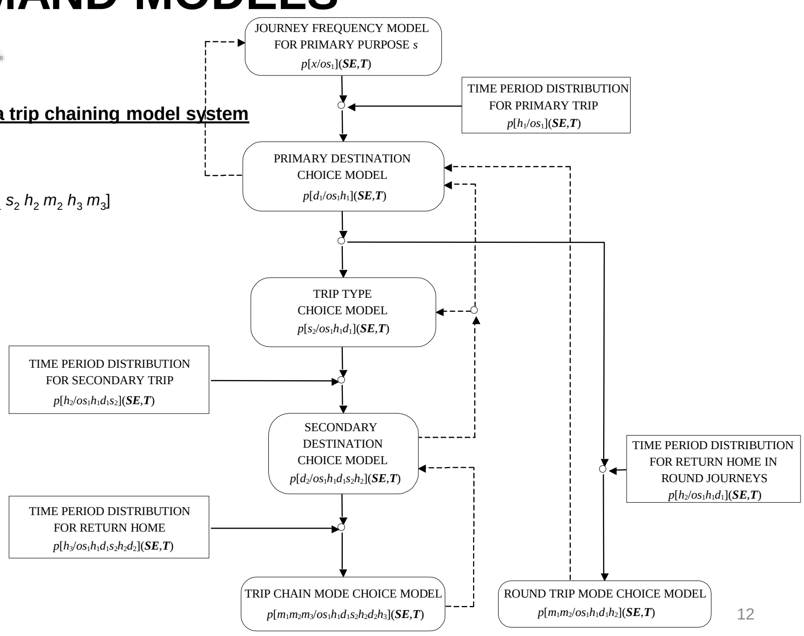


DEMAND MODELS

EXAMPLE

Structure of a trip chaining model system

$$d^i_{od_1d_2o}[s_{1\ 1}\ m_1\ s_2\ h_2\ m_2\ h_3\ m_3]$$



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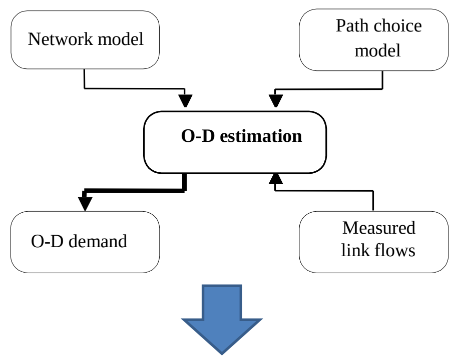
ESTIMATION OF O-D DEMAND FLOWS USING TRAFFIC COUNTS

Aggregate data

- Traffic counts for each class *i* and time interval (***f***)
- OD flows for each class *i* and time interval (***d***)

Source

- Survey (SP vs RS)
- cameras, sensors, GPS, Bluetooth, … (ITS technology)



$$\boldsymbol{d}^* = \underset{x\geq 0}{argmin}\left[z_1\left(\boldsymbol{x},\hat{\boldsymbol{d}}\right)+z_2\left(\boldsymbol{v}\left(\boldsymbol{x}\right),\hat{\boldsymbol{f}}\right)\right]$$

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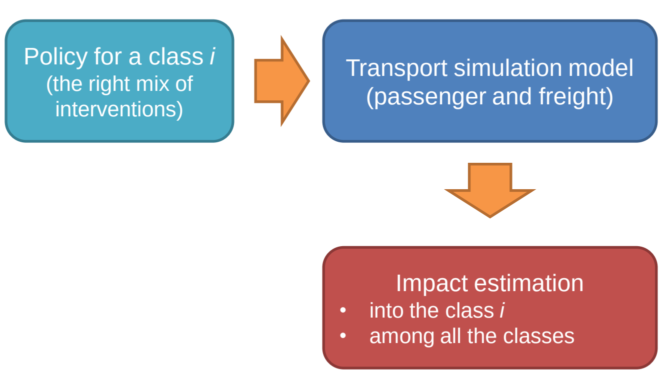
CHANGES IN OD FLOWS

Model elasticity for transportation policies



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SOME REFERENCES

- Cascetta, E. (2009) Transportation Systems Analysis: Models and Applications, Springer, New York.
- Cascetta, E. (2001) Transportation System Engineering: Theory and Methods (in English), Kluwer Academic Publishers.

NAPLES SIMULATION MODEL

Passenger and enviromental

- Cartenì A. and de Luca S. (2010); Transport and environment in urban areas: a method for estimating traffic fuel consumption and vehicle emissions; proceedinf of Kuhmo Nectar Conference on Transport Economics 2010 and Summer School, Valencia 5-9 july.
- Cascetta E., Papola A. and Cartenì A. (2005); Prediction reliability of the transport simulation models: a before and after study in Naples; proceeding of the European Transport Conference (ETC), Strasbourg, France. AET 2005; London, UK.

Cascetta E., Cartenì A. (2012); Eco-rationality and the “false friends” of urban sustainable mobility; proceeding of the Italian conference SIDT.

Freight

- Cartenì A. e Russo F. (2009); A tour-based model for the simulation of a distributive freight system; in The Expanding Sphere of Travel Behaviour Research; selected papers from the 11th International Conference Travel Behaviour Research; Ryuichi Kitamura, T. Yoshii (Eds.). Emerald Group Publishing Limited; UK.
- Russo. F e Cartenì A. (2006); Application of a tour-based model to simulate freight distribution in a large urbanized area; Recent Advances in City Logistics: Proceedings of the 4th International Conference on City Logistics, Langkawi, Malaysia, 12-14 July, 2005; E. Taniguchi, R.G. Thompson (Eds.). Elsevier B.V.; Kidlington, UK; pp. 31-46.