A Demand Model for Freight Movements in City Logistics Applications

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CityGoods project overview

- Which field is focused?
  - urban goods traffic, trips for shopping (to be done)

- Which are the objectives for modelling
  - diagnosis, allocation of the flows of vehicles, help for the decision-makers understanding the urban logistics mechanisms

- The design of the model
  - (see presentation)
CityGoods project overview

- The type of data used to calibrate the model
  - registers or surveys towards hauliers, shippers, establishments, drivers
- Which are (as far as possible precisely) the mathematical relationships
  - (see presentation)
- The model is currently a prototype, a software package is under development
  (first release: october-november 2006)
CityGoods project overview

- Does it need a large competence to be used?
  - Familiarity with classical people transportation models
- Is it in progress or achieved? In progress
- Who is using the model and to obtain which results?
  - Emilia-Romagna region as a followup activity of Interreg III/b CityPorts Project and to study regional freight mobility
The CityPorts Project and the CityPorts approach to urban logistics
Emilia-Romagna’s towns logistic surveys
Towards a unified modeling framework for Urban Logistics (CityGoods)
  Step 1: a demand generation model
  Overview and preliminary results
Conclusions and further study directions
The CityPorts Project

CityPorts (EU INTERREG III/B 2003-05), coordinated by Regione Emilia-Romagna, proposes a general methodological framework for the design and evaluation of City Logistics Actions (support initiatives):

- Infrastructures
- Policies and regulations …

The approach relies on the analysis of the different supply chains and their impact on the different zones of the urban area.
Logistic characterization of towns is based on the construction of the Zones-Supply Chains (ZS) Grid as a “reading guide” of the town in Logistic terms.

**The Zones-Supply Chains Grid**

- Measure of criticity:
  - Qualitative (️, 🔴, 🟡)
  - Quantitative (n. of opns)
Logistic Actions Evaluation

- Action mapping into a ZS Grid gives the basis for Action effect evaluation (and possible re-design)
- Need of a quantitative ZS Grid
- Need of a Supply-Chain-based Demand Generation Model
  - to define the ZS Grid
  - to be used within classical transp. models
CityGoods Modeling framework

- Unified modeling approach:
  - Description of City Logistics phenomena
    - For a specific town and for a regional territory
  - Definition of qualitative and quantitative indicators of City Logistics in ER towns
  - That may be used for evaluation and planning purposes
    - CityPorts methodology and Classical transportation analysis
- Main element is a specifically designed Logistic Demand Generation Model
In the years 2003-05 Emilia-Romagna performed an extensive survey of City Logistics phenomenon for all ER towns

- CityPorts, Merope, Regional programmes …

- Huge and fine-grained data source
  - Quite homogeneous (CityPorts survey model)
  - 3 main surveys: Demand Generation, Attraction and flows/operations

- A unique modeling opportunity!
Demand Generation Models

  - \textit{input-output} (Harris & Liu, 1998)
  - \textit{spatial price equilibrium} (Oppenheim 1994, Nagurney, 2002)
- the first is more suited to a urban scale
Demand Generation Models

- Some problems:
  - Generation: intrinsic approximation introduced by aggregating many economic activities into few categories
    - a given economic activity generates movements belonging to different Supply Chains
  - Distribution: a vehicle performs many deliveries/pickups in a tour
Other experiences

- **FRETURB (L.E.T., Lyon, Fr)**: general model for the evaluation of the impact of Logistic Actions
  - Based on 3 detailed surveys on French towns (Marseilles, Bordeaux and Dijon)
  - Regression-based model
  - Software tool distributed by French Ministry of Transport to all French Municipality

- **VISEVA (Friedrich et al 2003), Good Trips (Boerkamps, 1999)**
Objective: estimate the yearly number of operations generated by each SC - Zone

Starting Points:

- ER surveys on Demand Generators:
  - Small samples wrt Universe (BO: 250-500 of 35131)
  - Rich of logistic information (opns generated per SC, time distribution, type of vehicles …)

- Universe
  - Municipality, CCIAA Data … ASIA ER Database
  - No Supply-chain related classification (only ATECO/NACE economic classification, NAICS in USA …)
Demand Generation Model (2)

- Overall approach:
  - No “a-priori” aggregation of activities into categories (SC)
  - Characterize demand generation directly using the ATECO/NACE classification of the generators (operations per NACE code)
  - Hundreds of codes and small samples! Exploit the hierarchic structure of the classification within the model
  - Use survey data to calibrate the model and define the specific SC generation models

- Result:
  - Very fine-grained information wrt to classical index-by-category approaches
5 Digits code with hierarchic structure
Mapping of the Universe into the NACE tree gives immediate indicators of town structure (overall and spatial=per Zone)
Main assumption

- The n. of operations generated by a specific NACE code (e.g. 502 Vehicle Maintenance) should take into account:
  - Those generated by the “descendant” codes (5020, 5021, … 50201,…,50205)
  - Those generated by “parent” classes (50, 5)

- Measured by two contributes:
  - the relative weight (n. of elements in the Universe) of the subtree rooted at the code
  - relative weight of the path to the tree root
NACE tree structure:
- $N$ set of NACE codes
- $f(i)$ father of code $i \in N$
- $FS(i) = \{ j \in N : f(j) = i \} \quad i \in N$
- $r$ root tree

- $M_i^s$ number of yearly operations of the supply chain $s \in S$ generated by code $i \in N$ (model output)
- $m_i^s$ number of yearly operations associated to the link entering $i \in N$ (parameters to be determined by calibration)
Model Formulation (2)

- \( M^s_i = W^s_i + H^s_i \quad i \in N \)
- \( W^s_i \) contrib. to \( M_i \) of the subtree with root \( i \)
- \( H^s_i \) contrib. to \( M_i \) of the path from \( i \) to \( r \) (for leaves \( M^s_i = H^s_i \))
- \( H^s_i = m^s_i + H^s_{f(i)} \quad i \in N \)
  (computed in topological order)
- \( W^s_i = \sum_{j \in FS(i)} \beta_j \cdot (W^s_j + m^s_j) \quad i \in N \)
  (computed in reverse topological order)
- \( \beta_i \) probability that the child of \( f(i) \) is \( i \in N \)
  (computed statistically from the Universe)
The overall model defines the total number of operations of a SC per year generated as a function of:
- the NACE code
- the n. of employees in each local unit

Survey data are used to:
- calibrate the model
- obtain the distribution of the different attributes (parking type, time of service…) for each SC
A spatial model is derived by using
- user-defined Zones (Cityports Macro-Zones, Transportation studies zones …)
- distribution of the Universe in the Zones
  • through geocoding by using a commercial street network (Navteq) available for all towns
  • Municipality-owned GIS …
The CityGoods Sw prototype

- CityGoods-Demand
  - Universe and Survey Databases
  - Geocoding local units (sample and Universe)
  - Calibrate the generation model
  - Apply the model to the Universe
  - Export model output (GIS)
Example: Bologna with SC

ZONES - SUPPLY CHAINS GENERATION MATRIX (BOLOGNA)

yearly movements of goods (generation)

- < 50,000
- 50,000 - 100,000
- 100,000 - 150,000
- 150,000 - 200,000
- 200,000 - 300,000
- > 300,000

traffic zones

supply chains
- non food
- fresh
- dry
- frozen foods
- hangen garments
- other

road network
New GIS-based interface
New GIS-based interface

Procedure

- Crea Nuova Base Dati
- Apri Base Dati Esistente
- Importa Stradario
- Importa Zonizzazione
- Geocodifica Campione
- Geocodifica Universo
- Individua Zone del Campione
- Individua Zone dell'Universo
- Calibra Modello di Generazione
- Applica Modello di Generazione
- Calibra Modello di Distribuzione
- Applica Modello di Distribuzione
- Crea Grafo dallo Stradario
- Importa Grafo Stradale
- Applica Modello di Assegnazione
With the SC model we may add several dimensions (different attributes) to the ZS Grid

- day and time of service
- vehicle type
- parking
Other SC-related info (2)

parking type

parking duration
Other SC-related info (3)

service day and time
Typical Use-Cases

- Construction of the specific model for a given town using “its” surveys
- Construction of the “regional” model using all the surveys (often covering different SCs)
Typical Use-Cases (2)

- Application of the town or regional model to other towns (without additional surveys)
- Requirements:
  - Universe (ISTAT, CCIAA …)
  - User-defined Zones
  - GIS Cartography o Commercial Street Network
The NACE-based generation model is the core of a complete set of models:
- Distribution model
- Network assignment model

Developed and tested on various ER towns
will be soon integrated into City Goods
Application to Bologna
Conclusions

- Very effective modeling tool
  - “Soft” data requirements:
    - Simple Universe data, NACE tree, commercial street graphs
  - Fine granularity of results and excellent quality of preliminary testing
  - Easy portability of the model to different towns with/without specific additional surveys
... and Future Work

- Extensive validation of the proposed model with the ER data
  - construction of a Regional model
  - testing on other towns
- Integration of all models into a complete GIS-based software tool (by end 2006)
- Integration with people movement models for purchase purposes
Thank you for your attention
AIRO 2006 Conference

- Cesena, Italy
  September 12-15, 2006
  “urban and regional logistics:
  new challenges for modeling
  and optimization”

- Abstract submission deadline: May 29, 2006
- Early registration deadline: June 16, 2006
- www.airo2006.ingce.unibo.it