TOOLS FOR MODELING URBAN FREIGHT DISTRIBUTION

Daniele Vigo – DEIS Univ. Bologna

Bruxelles, May 4, 2011

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Talk outline

Backround and Motivation:

- CityPorts and Merope Interreg III/B projects
- Emilia-Romagna’s towns logistic surveys

A unified modeling framework for Urban Logistics (CityGoods)

- Step 1: a demand generation model
- Step 2-3: distribution and assignment models
- Step 4: GityGoods modeling suite

Conclusions

The CityPorts Project

CityPorts (EU INTERREG III/B 2003-05), coordinated by Regione Emilia-Romagna, proposed a general methodological framework for the design ad 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

Another twin project, Merope, involved other towns of the region with similar objectives

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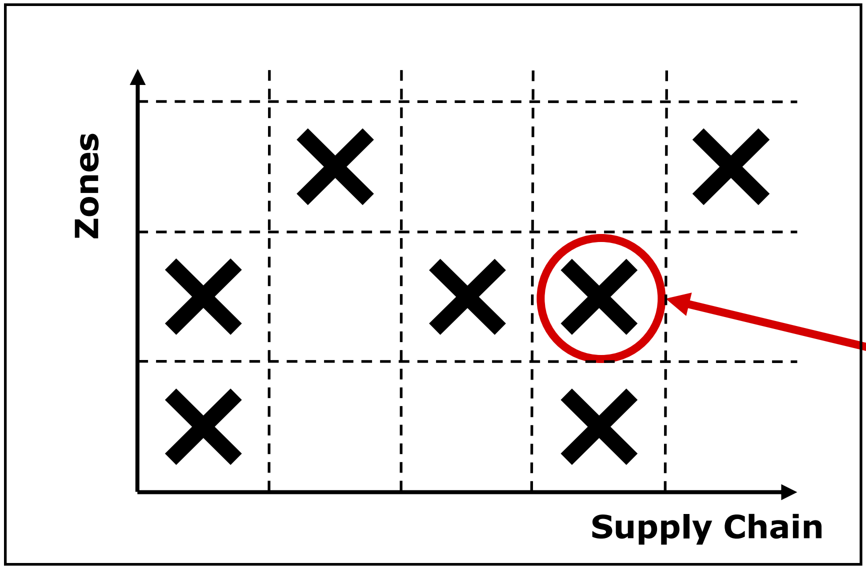
The Zones-Supply Chains Grid

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

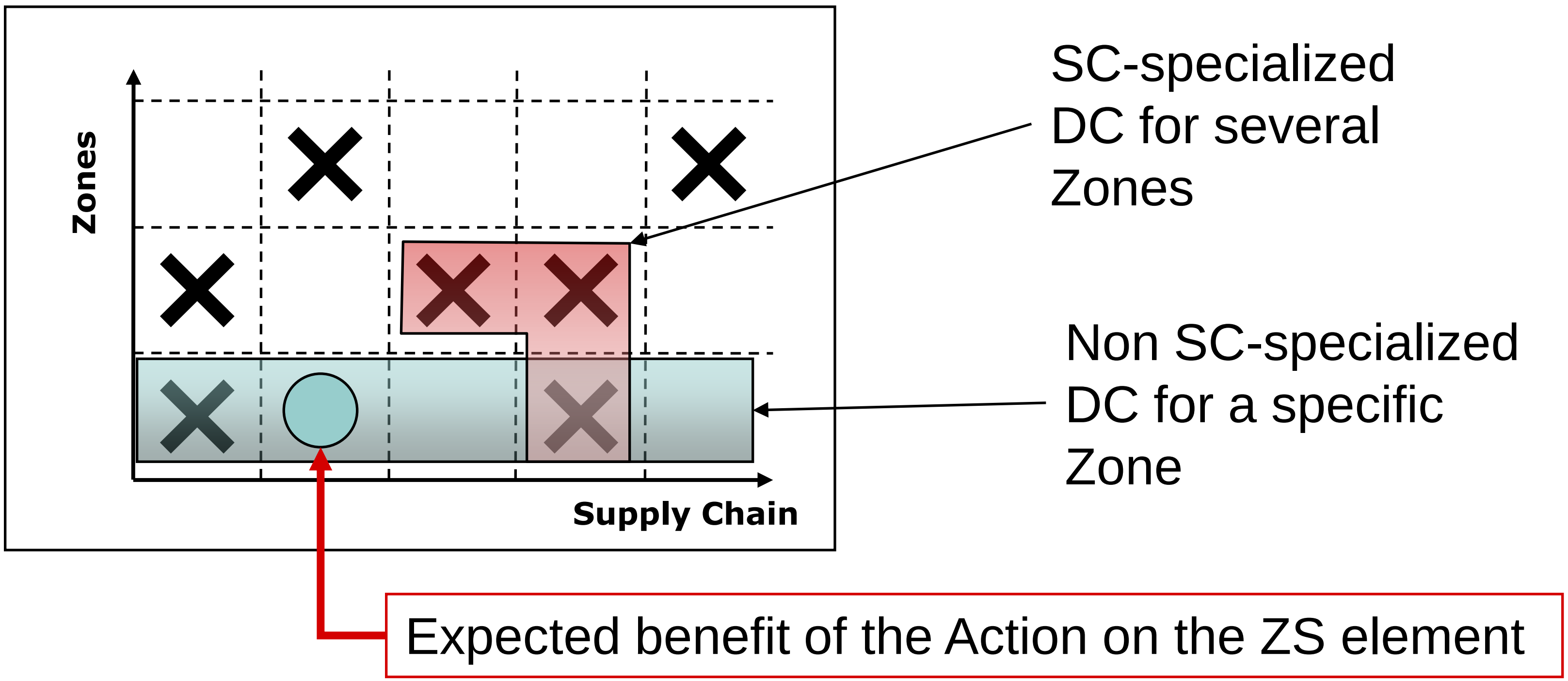


measure of criticity:

- qualitative (, ,)
- quantitative (n. of opns)

Logistic Actions and ZS Grid

A Logistic Action (Infrastructure, Policy) may be mapped into the ZS Grid to evaluate it effectiveness



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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

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ER City logistic surveys

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 (interviews at shops…),
  - Demand Attraction (interviews at logistic operators)
  - Flows/operations (interviews to vehicles)
- 11 towns (all with > 50K inhabitants), thousands of interviews

A unique modeling opportunity !

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

Classical modeling framework
(Generation, Distribution, Assignment)

Demand Generation exploits the hierarchical structure of activity classification systems

Distribution takes into account that vehicles can perform more than one stop in a tour

CityGoods package development

- The prototypes of the models were developed in 2004 for RER
- In 2005-06 models are validated on real-world data from RER surveys
- In 2006-07 the models were integrated into a unified package (CityGoods) tested and adopted by RER
- CityGoods is developed and commercialized by OPTIT and Sistema

Demand Generation Models

General survey: Russo & Comi (2004)

- *gravitational, 4 Phases* (Hutchinson 1974, Odgen 1992, List & Turnquist 1994, Taylor 1997, He & Crainic 1998, Gorys & Hausmanis 1999 …): more suited to a urban scale
- *input-output* (Harris & Liu, 1998)
- *spatial price equilibrium* (Oppenheim 1994, Nagurney, 2002)

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)

Demand Generation Model

Objective: estimate the yearly number of operations generated by each SC - Zone

Starting Points:

- ER surveys on Demand Generators:
  - Small samples wrt Universe
    (e.g. Bologna: 250-500 out of 35131)
  - Rich of logistic information (operations 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

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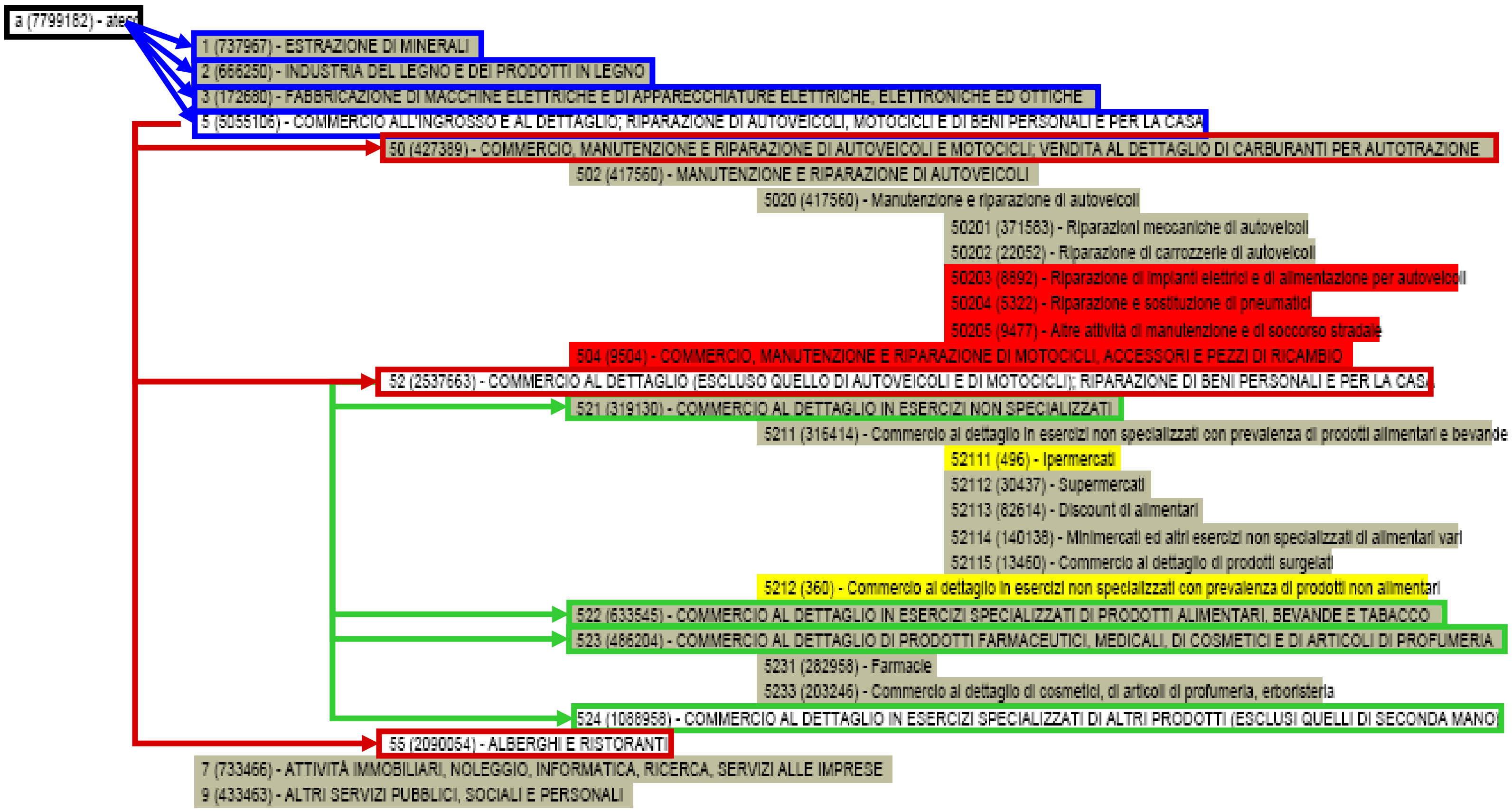
ATECO-NACE classification tree

5 Digits code with hierarchic structure



ATECO-NACE tree (2)

Mapping of the Universe into the NACE tree gives immediate indicators of town structure (overall and spatial=per Zone)

- a (35131) - ateco
  - 0 (137) - AGRICOLTURA, CACCIA E SILVICOLTURA
  - 1 (1196) - ESTRAZIONE DI MINERALI
  - 2 (1375) - INDUSTRIA DEL LEGNO E DEI PRODOTTI IN LEGNO
  - 3 (1024) - FABBRICAZIONE DI MACCHINE ELETTRICHE E DI APPARECCHIATURE ELETTRICHE, ELETTRONICHE ED OTTICHE
  - 4 (3332) - PRODUZIONE E DISTRIBUZIONE DI ENERGIA ELETTRICA, GAS E ACQUA
  - 5 (14074) - COMMERCIO ALL'INGROSSO E AL DETTAGLIO; RIPARAZIONE DI AUTOVEICOLI, MOTOCICLI E DI BENI PERSONALI E PER LA CASA
    - 50 (1001) - COMMERCIO, MANUTENZIONE E RIPARAZIONE DI AUTOVEICOLI E MOTOCICLI; VENDITA AL DETTAGLIO DI CARBURANTI PER AUT
    - 51 (4567) - COMMERCIO ALL'INGROSSO E INTERMEDIARI DEL COMMERCIO, AUTOVEICOLI E MOTOCICLI ESCLUSI
    - 52 (6254) - COMMERCIO AL DETTAGLIO (ESCLUSO QUELLO DI AUTOVEICOLI E DI MOTOCICLI); RIPARAZIONE DI BENI PERSONALI E PER LA C
      - 521 (378) - COMMERCIO AL DETTAGLIO IN ESERCIZI NON SPECIALIZZATI
      - 522 (892) - COMMERCIO AL DETTAGLIO IN ESERCIZI SPECIALIZZATI DI PRODOTTI ALIMENTARI, BEVANDE E TABACCO
      - 523 (362) - COMMERCIO AL DETTAGLIO DI PRODOTTI FARMACEUTICI, MEDICALI, DI COSMETICI E DI ARTICOLI DI PROFUMERIA
      - 524 (3514) - COMMERCIO AL DETTAGLIO IN ESERCIZI SPECIALIZZATI DI ALTRI PRODOTTI (ESCLUSI QUELLI DI SECONDA MANO)
      - 525 (48) - COMMERCIO AL DETTAGLIO DI ARTICOLI DI SECONDA MANO
      - 526 (759) - COMMERCIO AL DETTAGLIO AL DI FUORI DEI NEGOZI
      - 527 (291) - RIPARAZIONE DI BENI DI CONSUMO PERSONALI E PER LA CASA
    - 55 (2252) - ALBERGHI E RISTORANTI
  - 6 (3596) - TRASPORTI, MAGAZZINAGGIO E COMUNICAZIONI
  - 7 (7815) - ATTIVITÀ IMMOBILIARI, NOLEGGIO, INFORMATICA, RICERCA, SERVIZI ALLE IMPRESE
    - 70 (2771) - ATTIVITÀ IMMOBILIARI
    - 71 (224) - NOLEGGIO DI MACCHINARI E ATTREZZATURE SENZA OPERATORE E DI BENI PER USO PERSONALE E DOMESTICO
    - 72 (1172) - INFORMATICA E ATTIVITÀ CONNESSE
    - 73 (70) - RICERCA E SVILUPPO
    - 74 (3578) - ATTIVITÀ DI SERVIZI ALLE IMPRESE
      - 741 (1065) - ATTIVITÀ LEGALI, CONTABILITÀ, CONSULENZA FISCALE E SOCIETARIA; STUDI DI MERCATO E SONDAGGI DI OPINIONE;
      - 742 (419) - ATTIVITÀ DEGLI STUDI DI ARCHITETTURA, INGEGNERIA ED ALTRI STUDI TECNICI
      - 743 (31) - COLLAUDI ED ANALISI TECNICHE
      - 744 (442) - PUBBLICITÀ
      - 745 (90) - SERVIZI DI RICERCA, SELEZIONE E FORNITURA DI PERSONALE
      - 746 (30) - SERVIZI DI INVESTIGAZIONE E VIGILANZA
      - 747 (423) - SERVIZI DI PULIZIA E DISINFESTAZIONE
      - 748 (1052) - ALTRE ATTIVITÀ DI SERVIZI ALLE IMPRESE
  - 8 (585) - ISTRUZIONE
  - 9 (1994) - ALTRI SERVIZI PUBBLICI, SOCIALI E PERSONALI

Bologna Universe

UB	colore
0,1	
0,2	
0,5	
1	
2	
5	
10	
1000	

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NACE-Based Model

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

Model Formulation

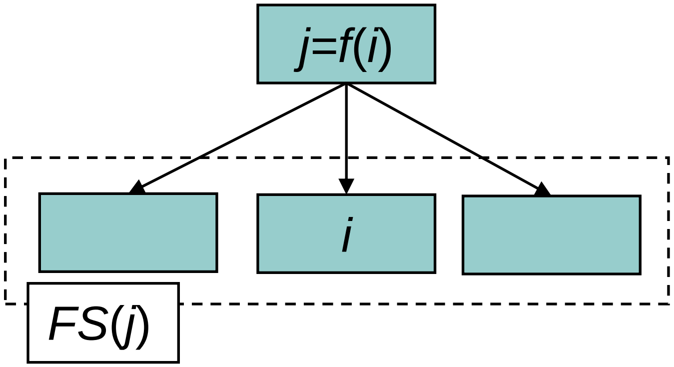
NACE tree structure:

N set of NACE codes

f(i) father of code $i \in N$

$FS(j) = \{i \in N: f(i) = j\}$ $j \in N$

r root of the tree



M_{is} number of yearly operations of the supply chain $s \in S$ generated by code $i \in N$ (model output)

m_{is} number of yearly operations associated to the link entering $i \in N$ (parameters to be determined by calibration)

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Model Formulation (2)

$M_{is} = W_{is} + H_{is}$ $\qquad i \in N$

W_{is} contribution to M_i of the subtree with root i

H_{is} contrib. to M_i of the path from i to r (for leaves $M_{is} = H_{is}$)

$H_{is} = m_{is} + H_{f(i)\,s}$ $\qquad i \in N$

(computed in topological order)

$W_{is} = \sum_{j \in FS(i)} \beta_j \cdot (W_{js} + m_{js})$ $\qquad i \in N$

(computed in reverse topological order)

β_i probability that the child of f(i) is $i \in N$

(computed statistically from the Universe)

NACE-Based Model (2)

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

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NACE-Based Model (3)

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 …

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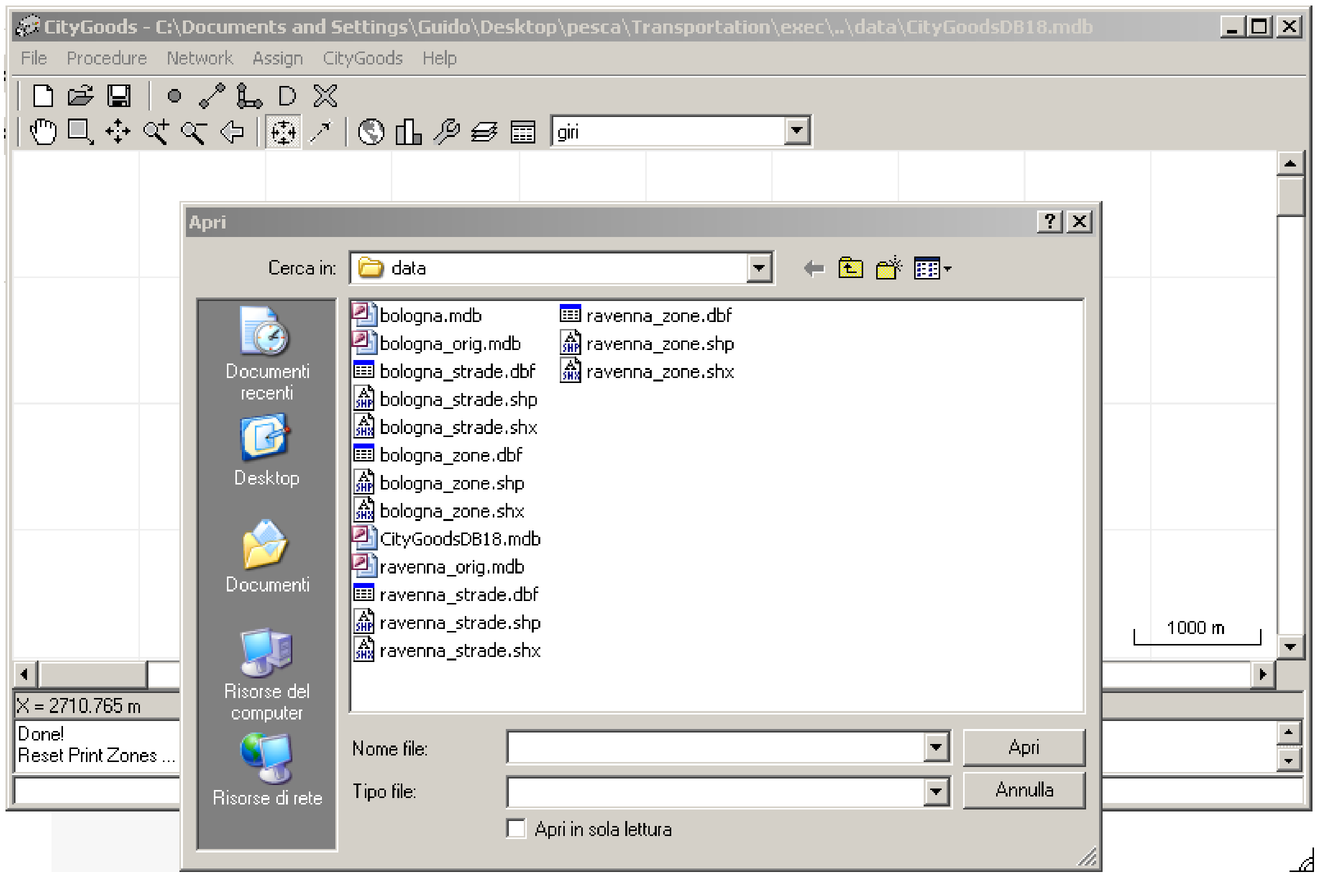
CityGoods Overview

CityGoods is a GIS application based on an ACCESS-like DBMS …



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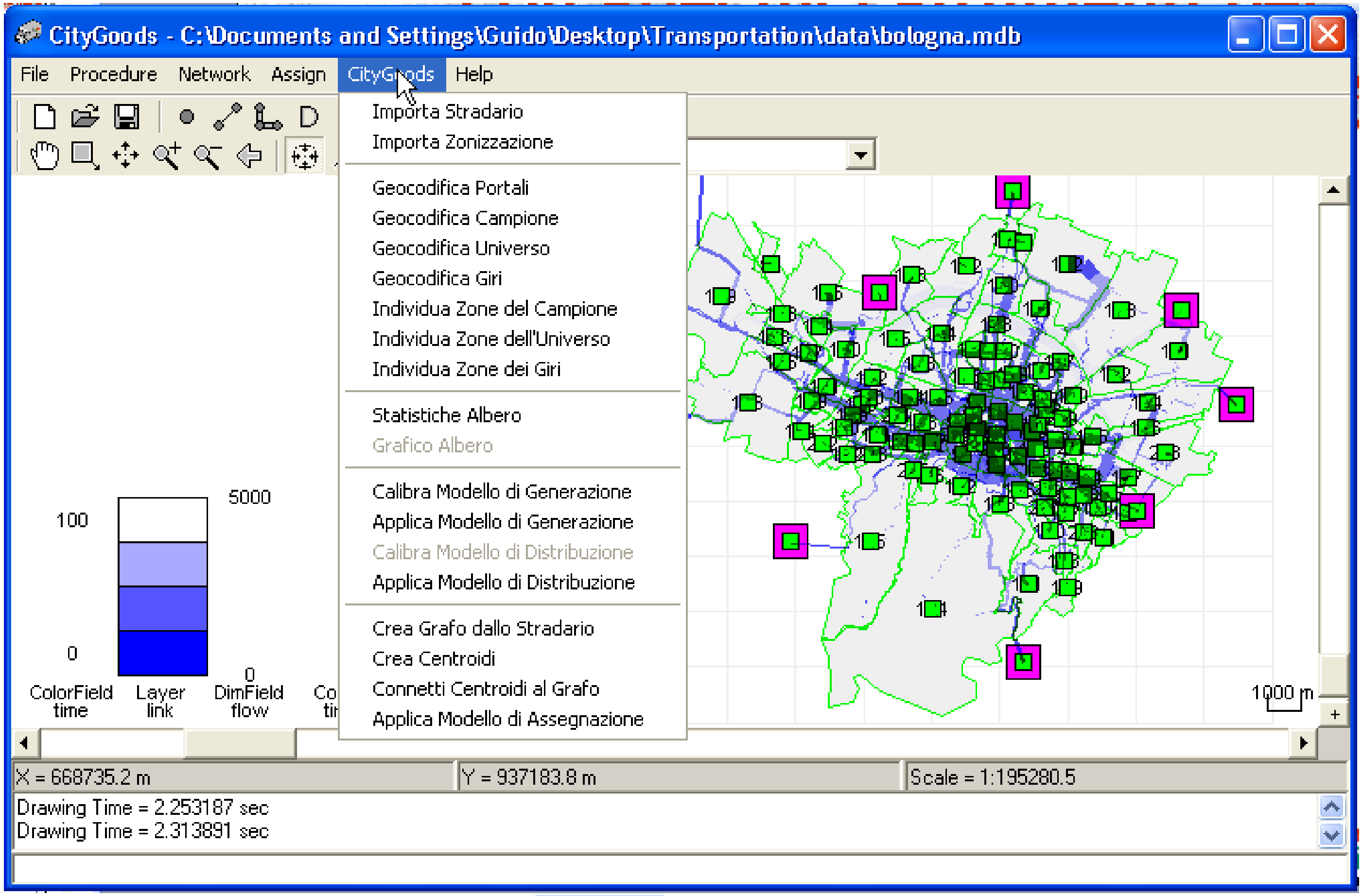
CityGoods Overview

… with specific tools to model CityLogisitcs



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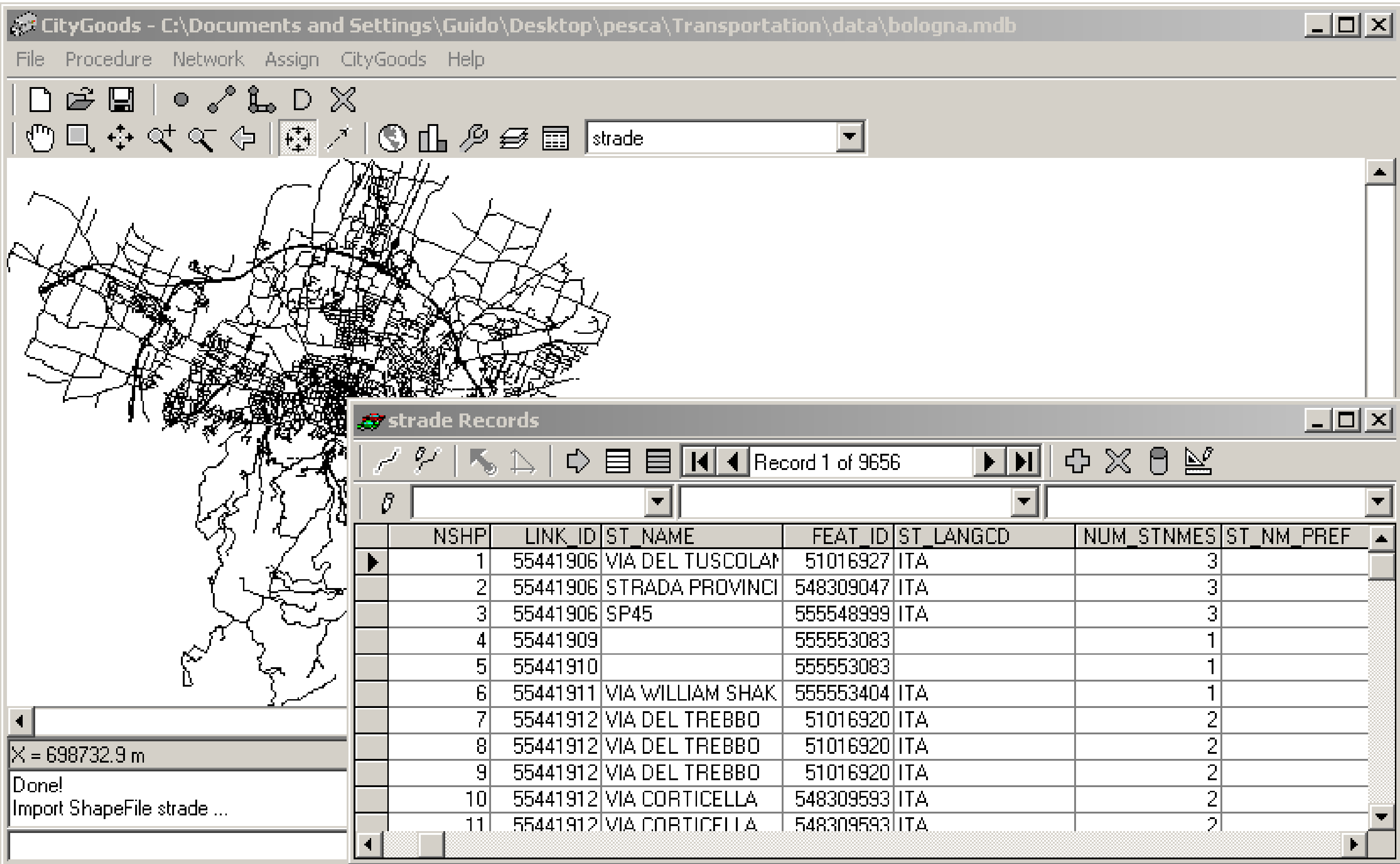
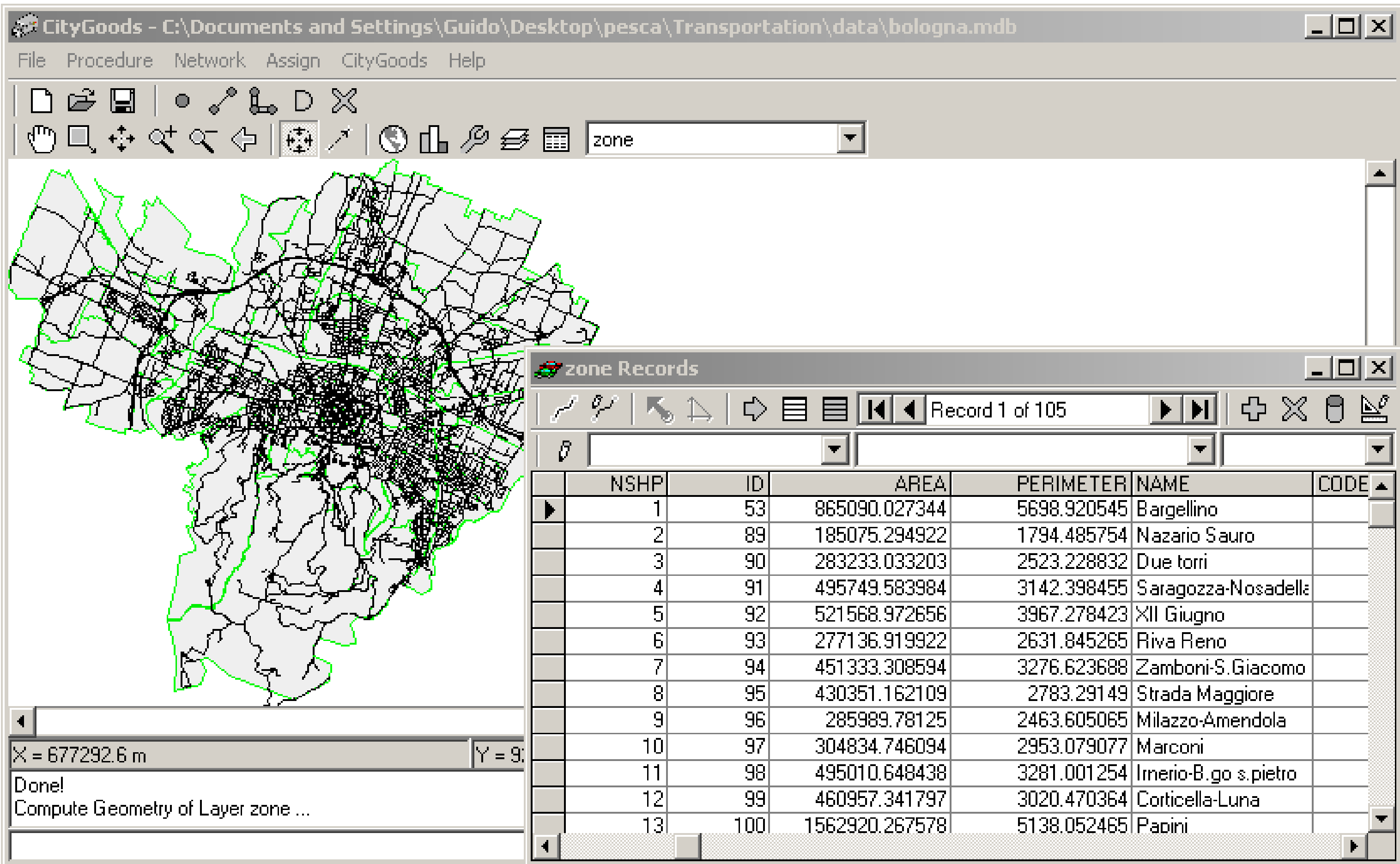
CityGoods Overview

It imports the street network (e.g. NavTeq shape file)



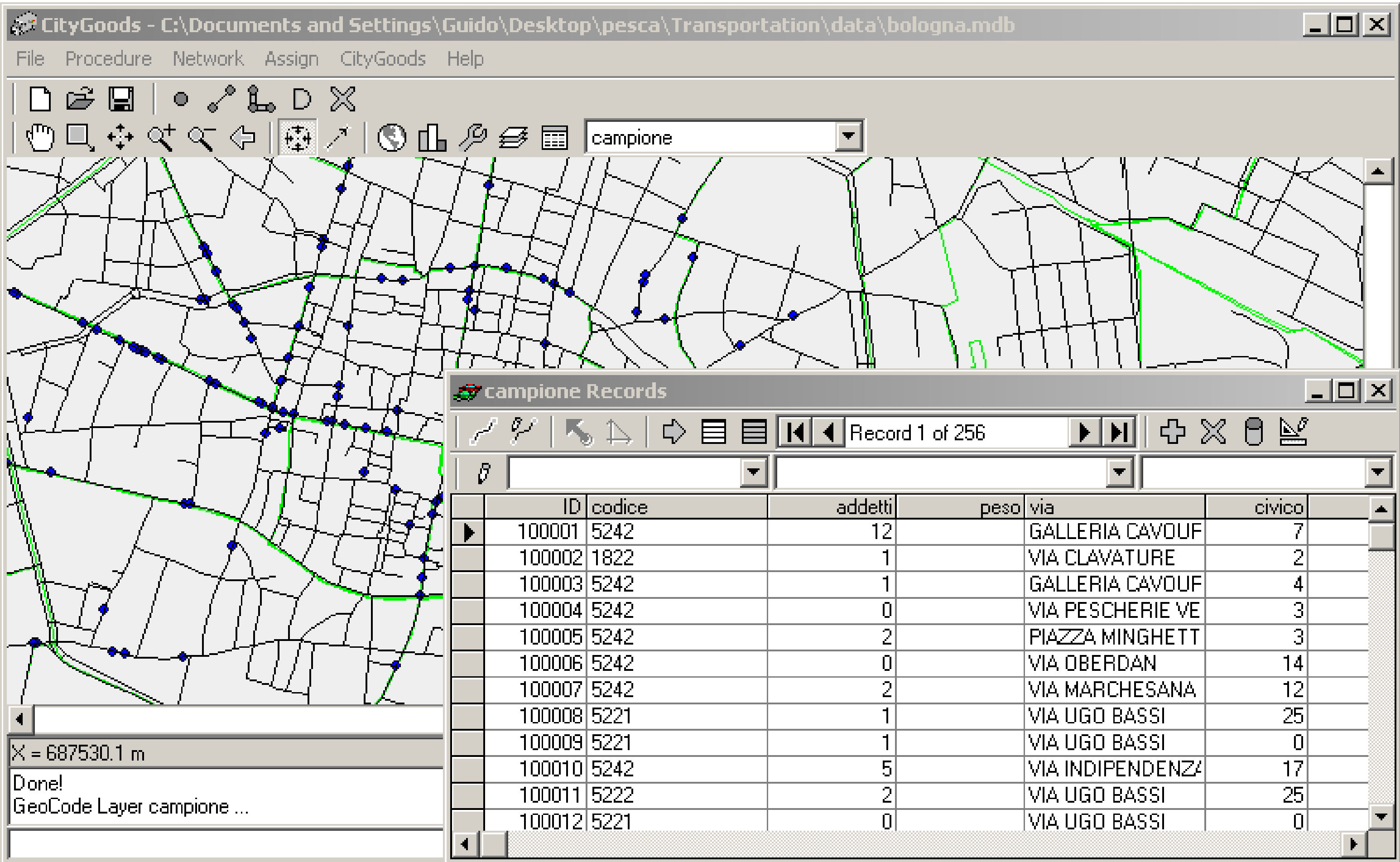
CityGoods Overview

It imports the City Zones (shape file)



CityGoods Overview

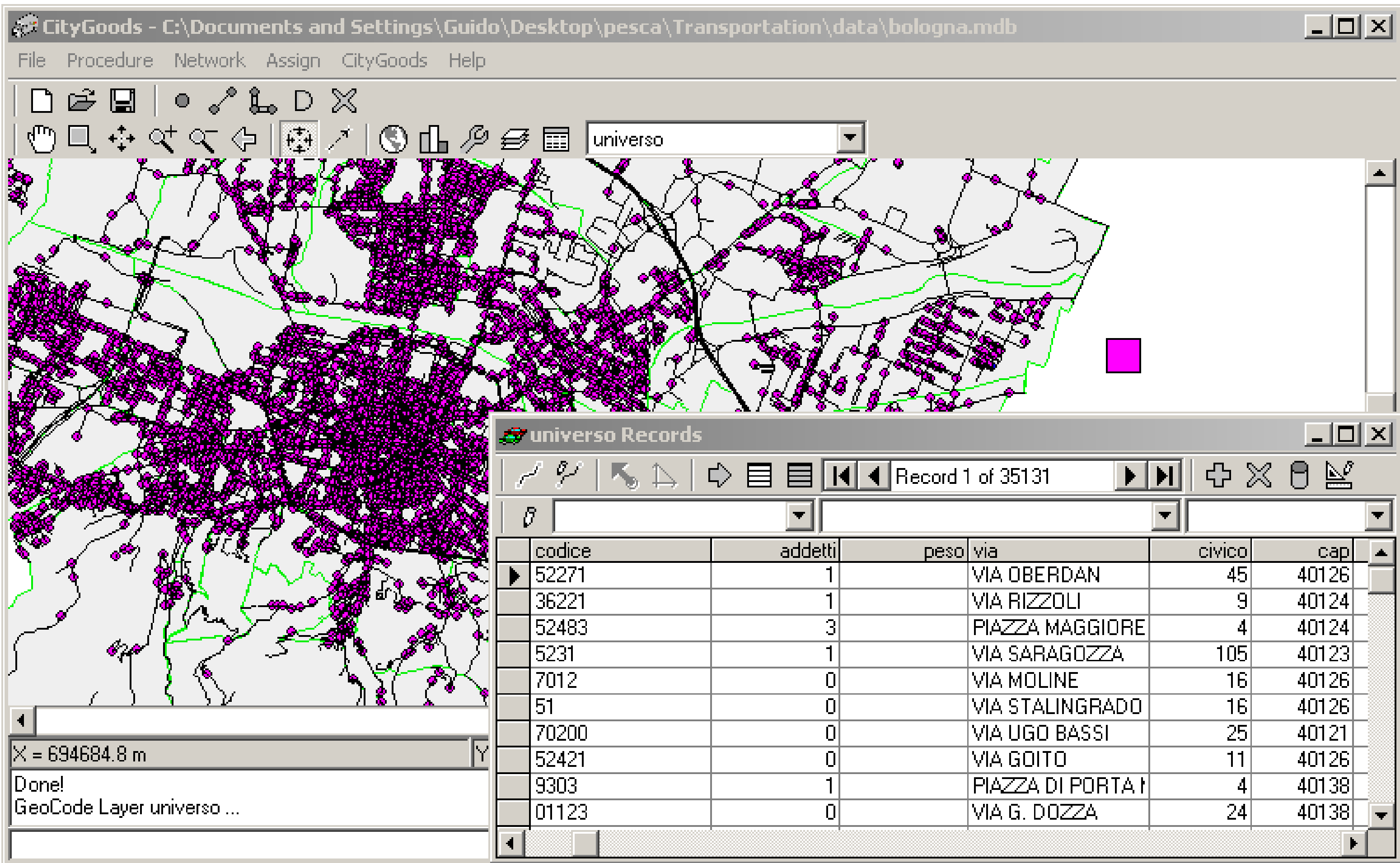
Geocodes the survey data …



SUGAR

CityGoods Overview

Geocodes the Universe data …



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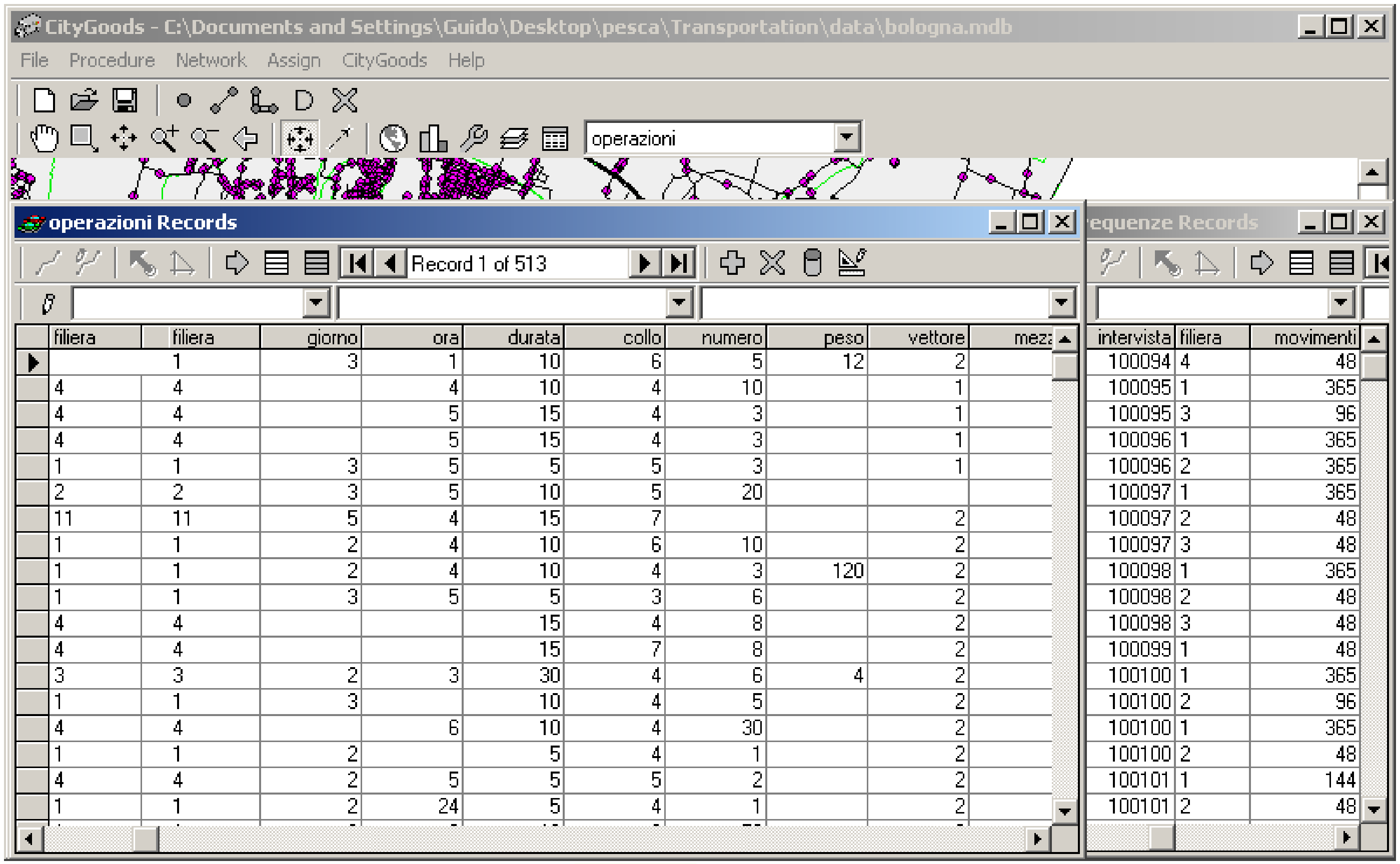
CityGoods Overview

Imports the surveys to obtain the movements per SC and other logistics attributes



filiera	filiera	giorno	ora	durata	collo	numero	peso	vettore	mezz
	1	3	1	10	6	5	12	2	
4	4		4	10	4	10		1	
4	4		5	15	4	3		1	
4	4		5	15	4	3		1	
1	1	3	5	5	5	3		1	
2	2	3	5	10	5	20			
11	11	5	4	15	7			2	
1	1	2	4	10	6	10		2	
1	1	2	4	10	4	3	120	2	
1	1	3	5	5	3	6		2	
4	4			15	4	8		2	
4	4			15	7	8		2	
3	3	2	3	30	4	6	4	2	
1	1	3		10	4	5		2	
4	4		6	10	4	30		2	
1	1	2		5	4	1		2	
4	4	2	5	5	5	2		2	
1	1	2	24	5	4	1		2	

intervista	filiera	movimenti
100094	4	48
100095	1	365
100095	3	96
100096	1	365
100096	2	365
100097	1	365
100097	2	48
100097	3	48
100098	1	365
100098	2	48
100098	3	48
100099	1	48
100100	1	365
100100	2	96
100100	1	365
100100	2	48
100101	1	144
100101	2	48

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CityGoods Overview

Applies the generation model to obtain the number of movements per NACE Code and per year …

mod_gen Records

Record 1 of 30492

codice	filiera	nov_ramo_am0	nov_ramo_am1	nov_ramo_bm1	sqm_ramo_am0	_ramo_am1	no_bm1	nov_nodo_am0	nov_nodo_am1	nov_nodo_bm1
52122								1272.331	1272.331	0
52121								1272.331	1272.331	0
5212		1137.966	1137.966	0	806.5079	709.2731	09.2731	1272.331	1272.331	0
5225		990.375	0	921.6	806.5079	709.2731	09.2731	1209	0	921.6
52250								1209	0	921.6
5225	2							1191	0	914.4
52250	2							1191	0	914.4
512		845	697	0	806.5079	709.2731	09.2731	845	845	0
5123								845	845	0
5122								845	845	0
51220								845	845	0
5121								845	845	0
51211								845	845	0
51212								845	845	0
51250								845	845	0
5125								845	845	0
51242								845	845	0
51241								845	845	0
5124								845	845	0
51230								845	845	0
5540								795	795	0
554		795	795	0	806.5079	709.2731	09.2731	795	795	0
55400								795	795	0
55231								716.5834	625.0557	16.05394
5523								716.5834	625.0557	16.05394
55220								716.5834	625.0557	16.05394
5522								716.5834	625.0557	16.05394

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CityGoods Overview

… and produces the ZS matrix …

mat_zone_fil Records

Record 1154 of 1908

zona	filiera	mov_m0	mov_m1
116	4	3853.106	5819.208
117	4	9573.541	11252.86
118	4	8931.61	90226.77
119	4	16658.01	23273.2
121	4	17782.69	16081.14
122	4	16109.45	17518.68
123	4	11932.43	98919.29
124	4	11861.79	23667.95
120	4	29318.97	28267.7
113	4	2652.931	1697.122
164	5	254.1905	525.525
155	5	5.567568	5.567568
156	5	526.2928	3088.591
157	5	2140.824	6281.725
158	5	2543.841	5891.189
159	5	324.7753	34034.26
160	5	873.0251	1197.292
161	5	305.0711	2046.911
163	5	289.6977	445.7951
154	5	44.07935	312.0103
147	5	458.9999	411.4262
165	5	23.75425	0.2376081
162	5	632.8671	601.8587
153	5	389.1248	734.6183
152	5	187.0145	138.8989
151	5	1050.237	1947.977
150	5	980.9411	2577.624

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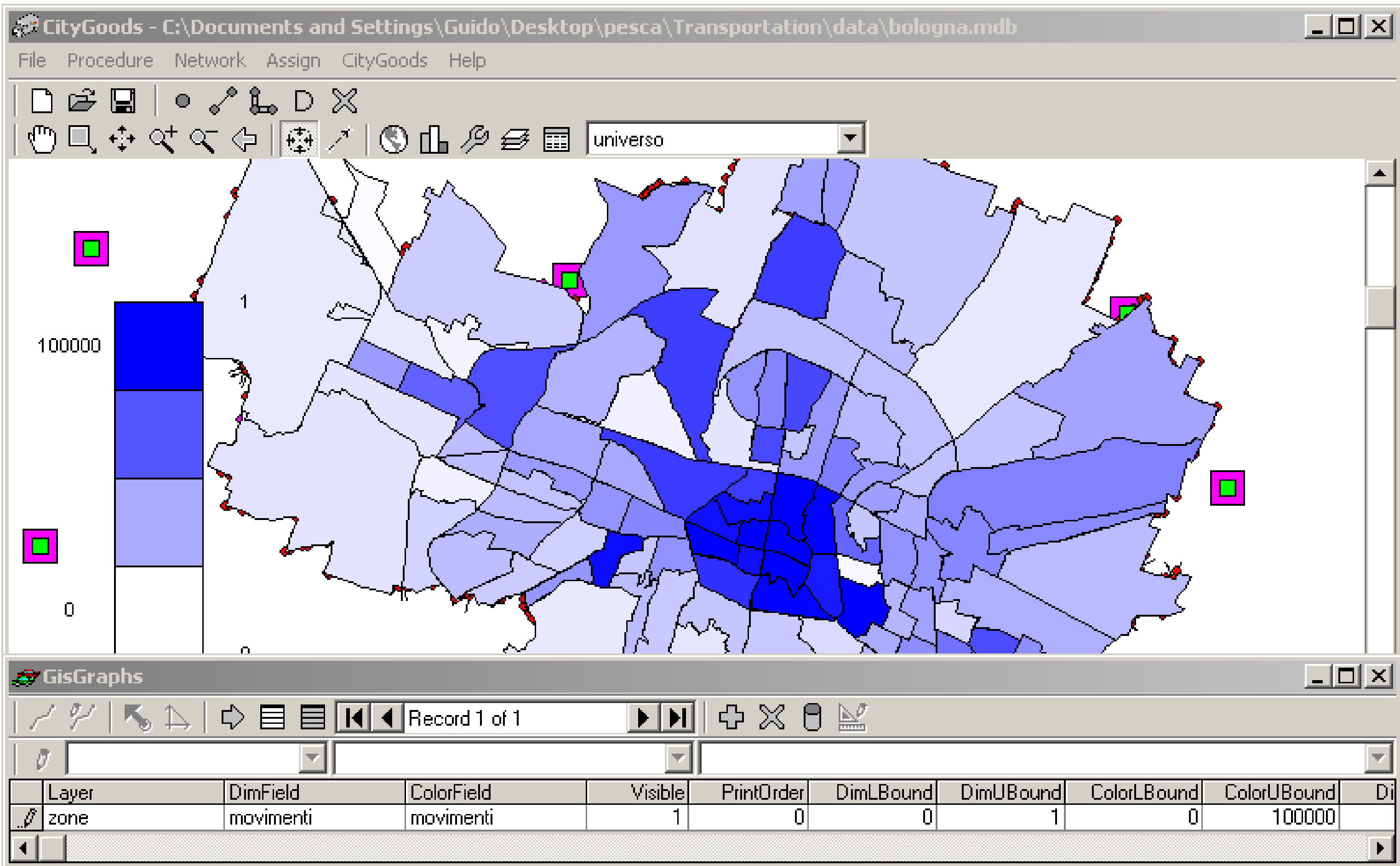
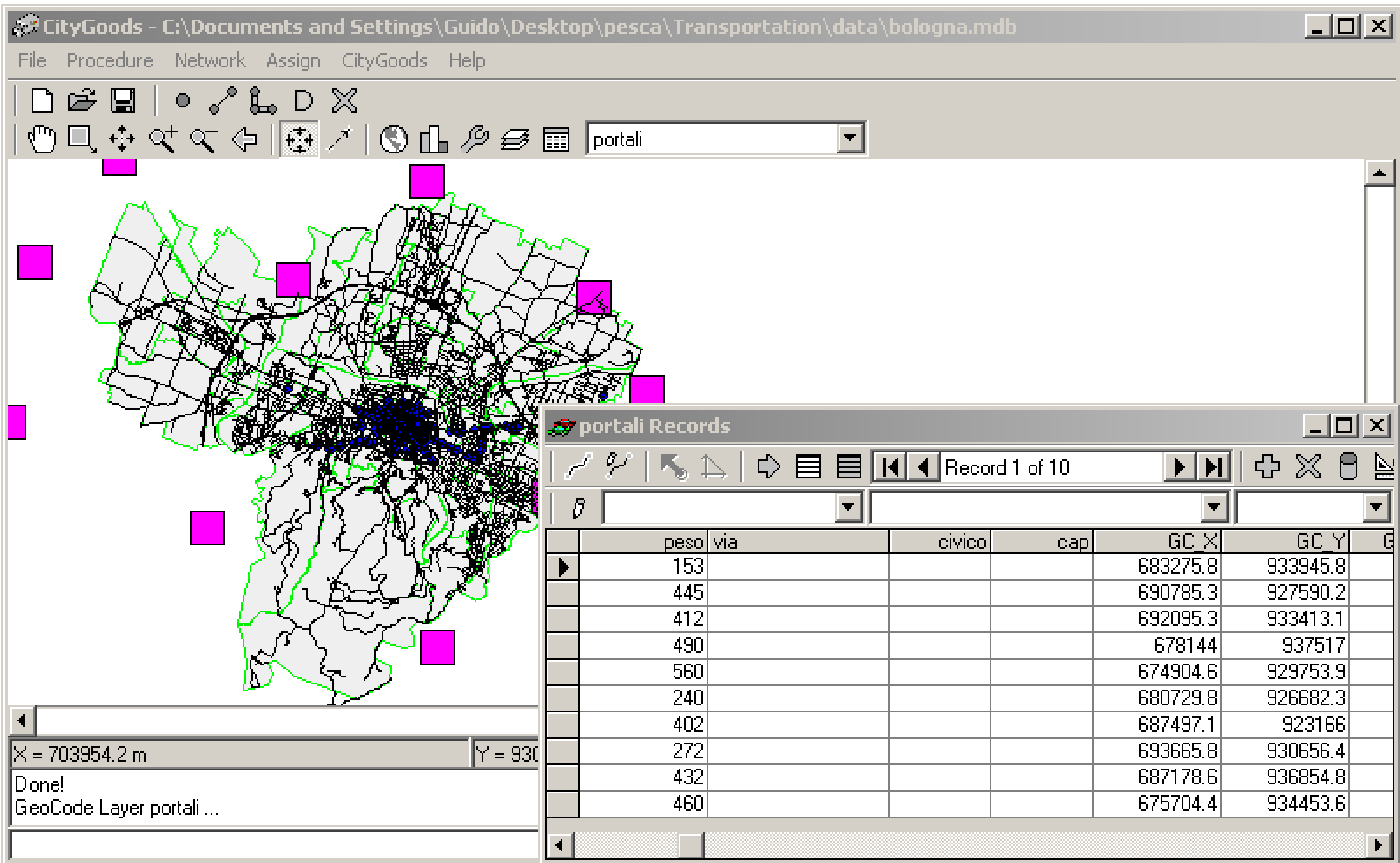
CityGoods Overview

… and produces the ZS matrix …



CityGoods Overview

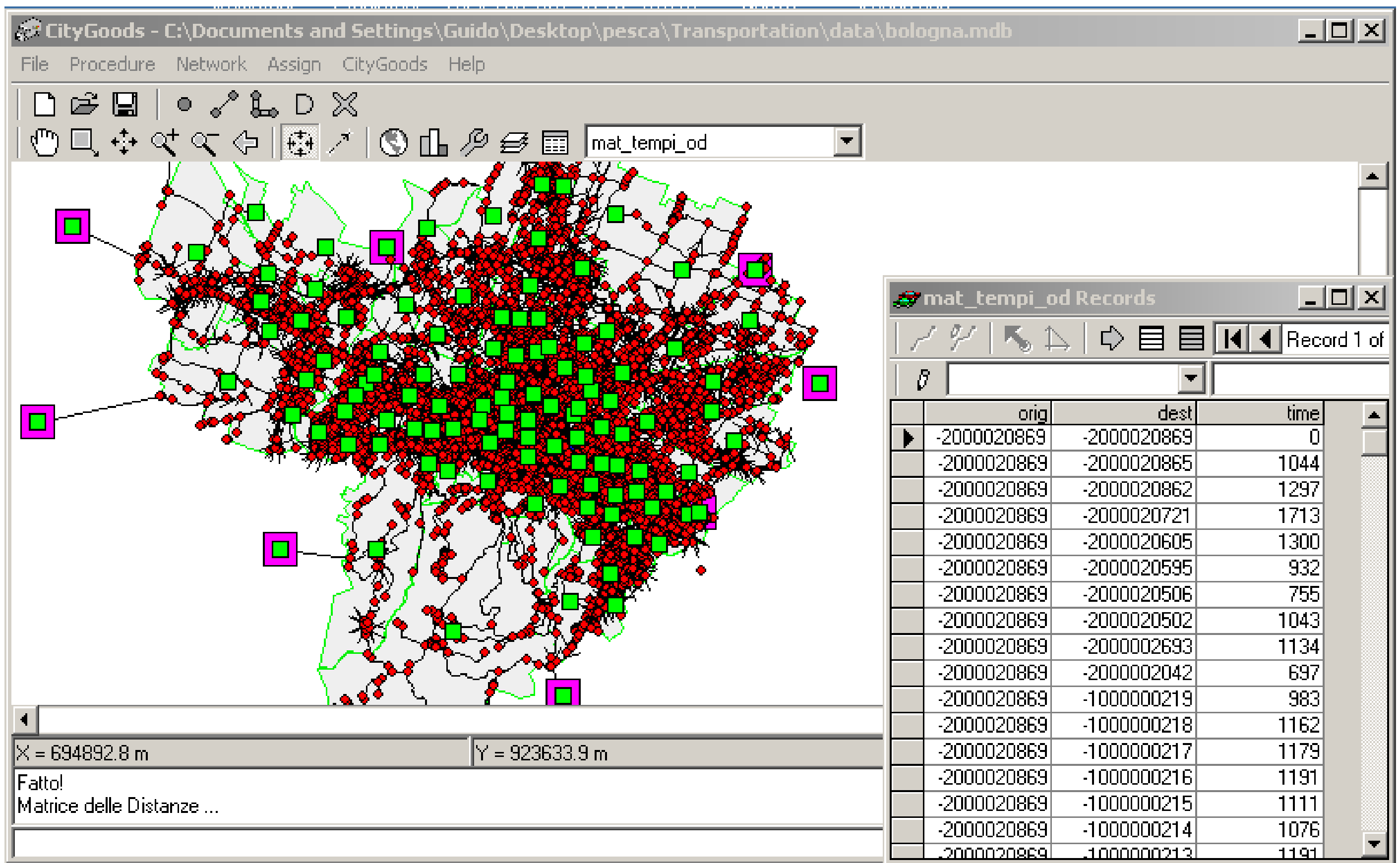
Distribution model uses Logistic Portals (Geocoded)…



peso	via	civico	cap	GC_X	GC_Y
153				683275.8	933945.8
445				690785.3	927590.2
412				692095.3	933413.1
490				678144	937517
560				674904.6	929753.9
240				680729.8	926682.3
402				687497.1	923166
272				693665.8	930656.4
432				687178.6	936854.8
460				675704.4	934453.6

CityGoods Overview

Computes all the distances between inner points and Portals



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CityGoods Overview

Distribution: Gravitational model modified to account for multiple deliveries within each Zone and applied for each supply chain

filiere Records

Record 1 of 17

ID	consxgiro	coefdistanza	coefdistanzaLB	coefdistanzaUB	orexanno	equivalenti	veicolo	descrizione
1	18	0.001			1000	1		freschi
10	17	0.001			1000	1		giornali
11	17	0.001			1000	1		fiori
12	17	0.001			1000	1		valori
13	17	0.001			1000	1		reverse
14	17	0.001			1000	1		pasti
15	17	0.001			1000	1		servizi
16	17	0.001			1000	1		carburanti
17	17	0.001			1000	1		automobili
2	19	0.001			1000	1		secchi
3	22	0.001			1000	1		surgelati
4	16	0.001			1000	1		nonfood
5	7	0.001			1000	1		appesi
6	17	0.001			1000	1		t_nonfood
7	17	0.001			1000	1		t_alimentari
8	17	0.001			1000	1		documenti
9	17	0.001			1000	1		farmaci

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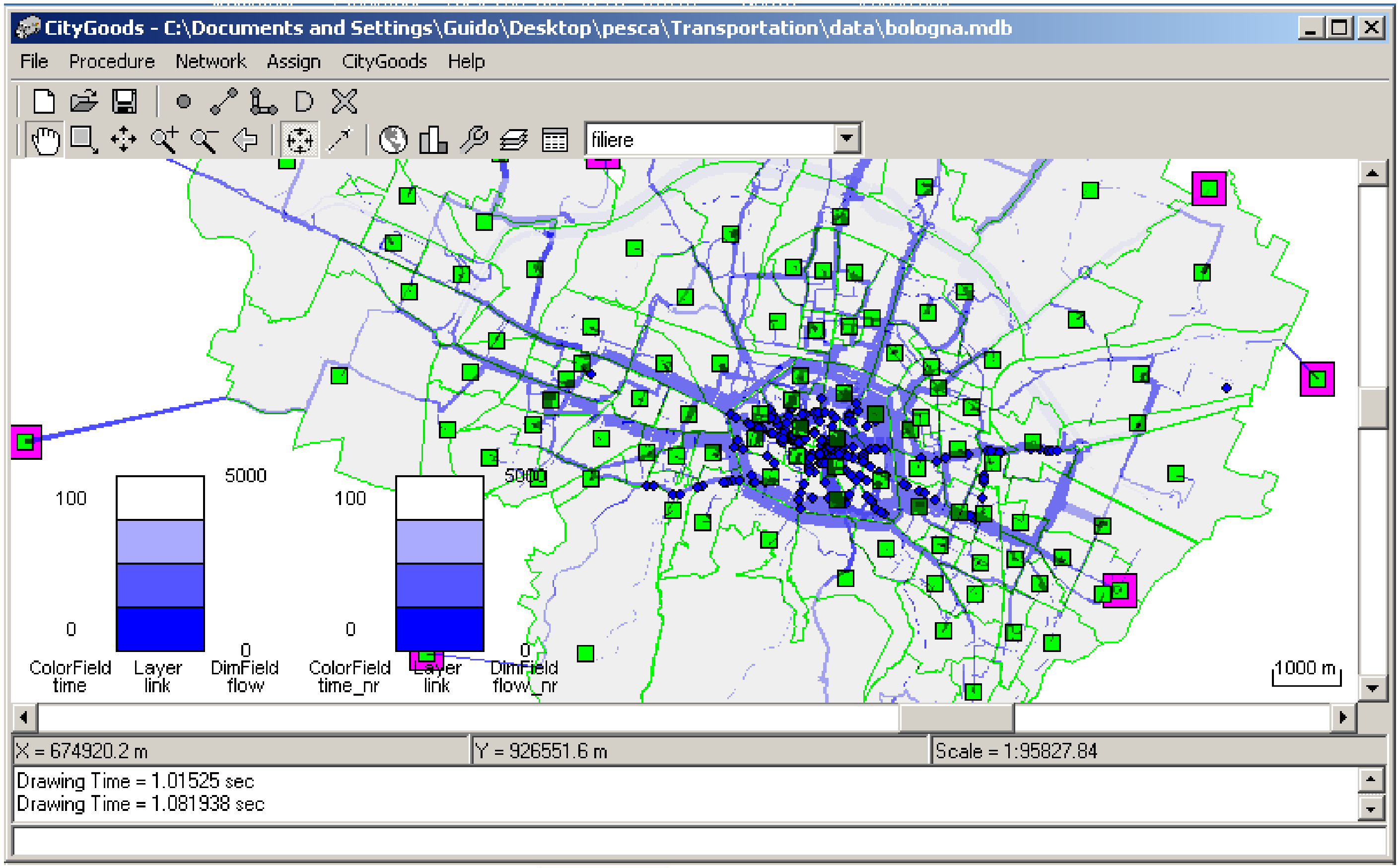
CityGoods Overview

… produces the OD matrices per supply chain that are assigned to the network (jointly with people movements)



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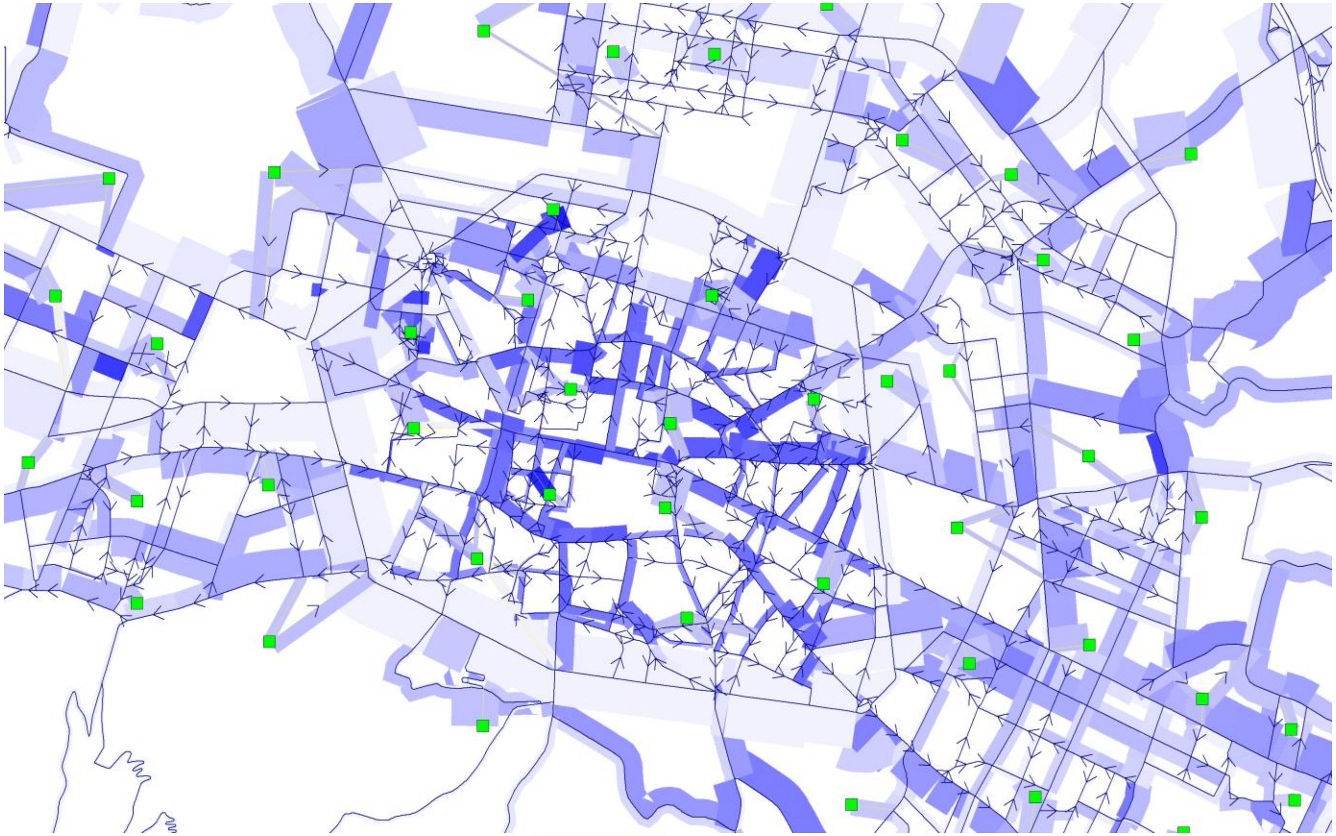
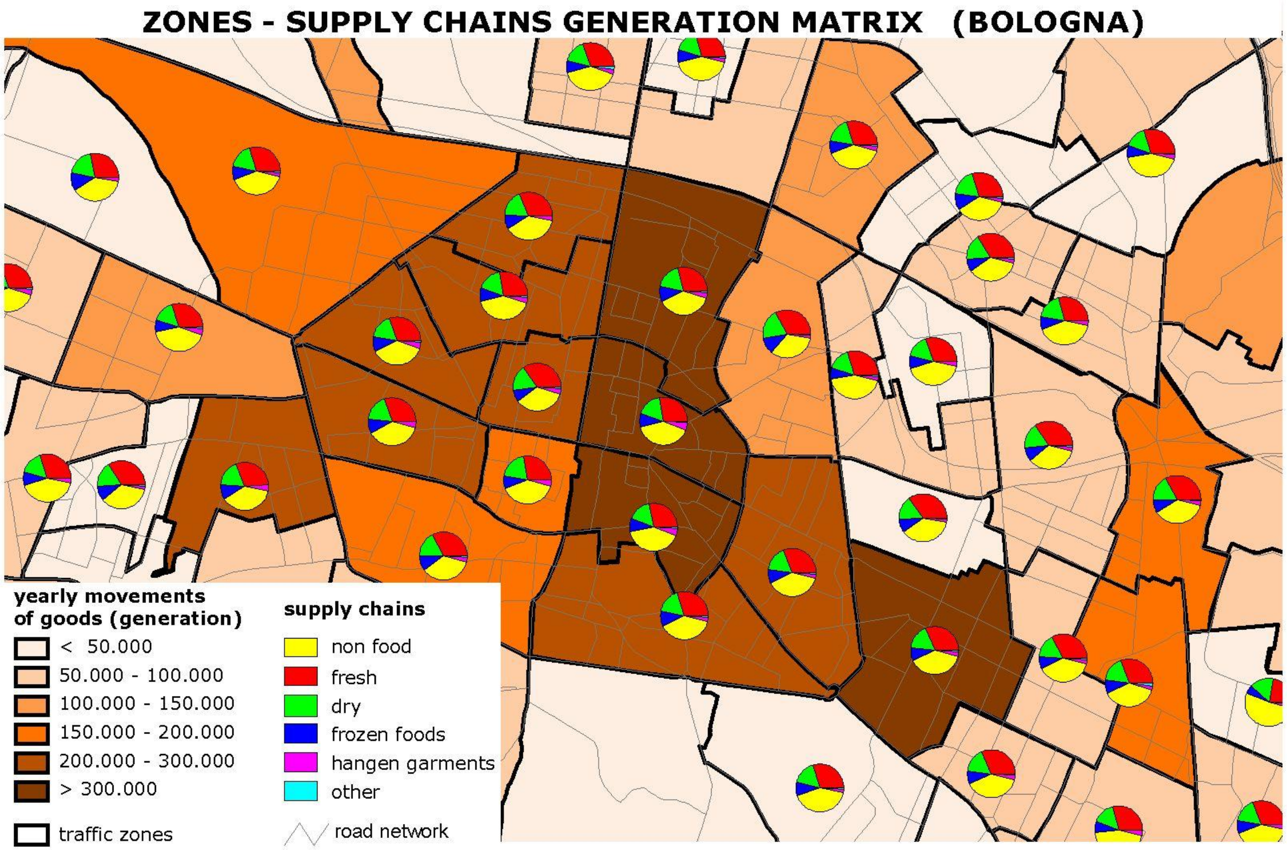
CityGoods Overview

… obtaining the freight vehicles flows



CityGoods Overview

… data may be easily exported to be used by other applications (e.g. GIS)



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Bruxelles, 04/05/2011

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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)

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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

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Conclusions …

Very effective modeling tool

- “Soft” data requirements:
  - Simple Universe data, NACE tree, commercial street graphs
- Fine granularity of results and excellent quality of real-world testing
- Easy portability of the model to different towns with/without specific additional surveys

Thank you for your attention

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