A city logistics system for long distance freight transport provisioning

F. Russo, C. Rindone, P. D'Agostino, C. Lanciano
& T. Scattarreggia
*DIIES – Dipartimento di Ingegneria dell'Informazione,
delle Infrastrutture e dell'Energia Sostenibile,
Università Mediterranea di Reggio Calabria, Italy*

Abstract

This paper focuses on the provisioning of goods which come from a long distance to a city. A city logistics system introduced in an urban area is studied. The arriving freight, from national origins, is investigated, considering different modal alternatives. Different transport mode services and relative models to estimate principal attributes (times, costs and prices), are considered.

The aim of the paper is to compare attributes modelled and revealed of different mode-service alternatives for long distance freight transport.

An application in a real context is carried out, considering the city of Reggio Calabria in the south of Italy. The case study is relative to the organization of a city logistics system centered on an urban distribution center.
Keywords: city logistics, freight transport, long distance transport, transport modelling, urban distribution center.

1 Introduction

1.1 Introduction of the problem

In 2006, the European Environment Agency (EEA) indicated that around 75% of the European population live in an urban area [1]. The urban population continues to grow, and in perspective can reach more than 80% by 2050 [2]. The urban challenges related to sustainability are increasing. Among these challenges, urban sustainability linked to freight distribution is relevant.

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Urban Freight Transport (UFT) is essential for a city's economic and social sustainability, but inefficient planning and management of this component produce impacts on congestion, noise, and air pollution, then in environmental sustainability [3]. Total urban goods transport *accounts for 14% of the vehicle kilometers, 19% of the energy use and 21% of the CO_2 emissions in urban areas. Transiting heavy goods vehicles travelling through the area add another 4% of the vehicle kilometers, 12% of the energy use and 10% of the CO_2 emissions* [4].

A European transport White Paper [5] has set out a scenario in which freight deliveries and collections in Europe's urban areas are sustainable, both economically and environmentally.

Specific EU research initiatives have been developed. In the COST Action 321 measures to improve the environmental performance of freight transport in urban areas are studied and designed [6]. CIVITAS 2020 initiatives include *urban freight logistics* among principal thematics to increase urban sustainability. Best practices to implement sustainable urban distribution are defined and disseminated [7]. BESTUFS I and II have collected best practices, success criteria and the elimination of bottlenecks with respect to city logistics solutions [8].

City logistics is one of the recommended actions to implement a smart city as indicated by the European Commission in recent Strategic and Operative Implementation Plans (SIP and OIP) [9–12].

In recent years, models and best practices to design and implement city logistics measures are produced in order to contribute towards urban sustainability goals [13, 14]. The measures have been classified in: material infrastructure, including linear measures referred to urban/metropolitan transportation network and surface (or nodal) measures referred to areas reserved for freight operations; immaterial infrastructure including not only consolidated ones (e.g. research, learning, and training), but also telematics or intelligent transportation system; equipment including measures on loading units, referred to the introduction of new standards or low-emission vehicles and measures on the characteristics of transportation units; governance of the traffic network including traffic regulations such as time window access, heavy vehicle network, and road pricing.

1.2 Aim of the paper

In this paper, the operability of an urban distribution center (UDC) in the context of material and governance measures, is considered.

The hypothesis is that the public decision makers organize a city logistics system based on the substitution of all traditional good vehicles, with Euro 6 or electrical vehicles towards the zero emission goal indicated by EU [5]. In this way, different measures could be introduced, in particular a UDC gives the possibility to deliver the consignee for national carriers that arrive in the city without a local distributor with low emission vehicles. With this organization, the carrier arrives in the UDC and then a local private-public company delivers with low emission vehicles in the city. The relative share of own-account vs. third-party transport is as high as 78% in Italian cities [15].

To realize provisioning by carriers that only move long distance, different freight transport modal alternatives must be analyzed [16]. In this paper, full road, combined road–maritime and road–rail transport are compared in terms of attributes (time, costs and prices). Models to represent freight transport supply (infrastructures and services) and to calculate attributes are available in literature [17, 18].

A case study relative to provisioning of the city of Reggio Calabria, in the south of Italy, is presented. Long distance freight transport attributes are calculated by literature models (sections 2 and 3) and by experimentations based on measures obtained from different sources (section 4).

Analysis will be useful to analysts to assess an alternative mode to provisioning an urban area, implementing a UDC.

2 Long distance transport attributes

In the city logistics system hypothesized, the carriers concentrate their attention on the long distance movements, analyzing in depth all the main aspects of cost functions, representing time and distance dependent freight costs of transport modes, including loading/discharging [19, 20].

Considering the relationships north–south in Italy, long distance transport attributes can be calculated in relation to the modes-services:

- full road;
- combined road–maritime;
- combined road–rail.

For a generic *od* pair, referring specific trip characteristics, travel times, travel costs and prices can be estimated adopting long distance transport models.

In section 2, all the adopted function specifications have been assumed according to Russo [21].

2.1 Road transport

2.1.1 Times

The total time for road transport for freight belonging to the class m ($T_{road,\,m}$), can be estimated by means of:

$$T_{road,\,m} = \Sigma_c \left(T_{R,\,c} + T_F + T_S\right)$$

where:

c is the class of road infrastructure (e.g. highway, urban, extra urban);
$T_{R,\,c}$ is the running time in the road link belonging to class c (h);
T_F is the break period (h);
T_S is the rest period (h).

Running time ($T_{R,\,c}$) is obtained by adopting:

$$T_{R,\,c} = \Sigma_c f_c \left(L_c, v_{max,\,c}, p_c, \alpha_{i,c}\right)$$

where

$f_c(\cdot)$ is the time function specific for the road link belonging to the class c;
L_c is the length of road infrastructure belonging to the class c;
$v_{max,\,c}$ is the maximum velocity of road infrastructure belonging to the class c;
p_c is the longitudinal slope of road infrastructure belonging to the class c;
$\alpha_{i,c}$ is the generic calibrated parameter for the function $f_c(\cdot)$.

Break period (T_F) is obtained with the following relation:

$$T_F = 0.75\ int\ (T_R / 4.5) \qquad [h]$$

Rest period (T_S) is obtained with the following relation:

$$T_S = 8\ [int\ (T_R + T_F/9)] \qquad [h]$$

2.1.2 Costs and prices

Long distance road freight transport cost by road can be estimated in the following form:

$$C_{road,\ m} = \Sigma_c(c_{gas} \cdot m_u + c_{op} + c_{to})\ L_c + c_{dr} \cdot T_{road,\ m}$$

where:

c_{gas} is unitary fuel cost (€/liter);
m_u is unitary fuel consumption (liter/km);
c_{op} is unitary operative cost (€/km);
c_{to} is unitary toll cost (€/km);
c_{dr} is unitary driver cost (€/h).

To obtain final prices, the following assumptions are considered:

- road freight transport is operated by outsourcing shippers;
- heavy vehicles are used (weight > 20 ton).

With this assumption the model to obtain prices is:

$$P_{road,\ m} = m \cdot C_{road,\ m} + q \cdot b$$

where:

q is the shipped quantity (tonn);
m, b are calibrated parameters.

2.2 Combined road–maritime transport

2.2.1 Times

Total travel time, relative to combined road maritime transport for freight belonging to the class *m*, can be estimated using:

$$T_{r\text{-}s,\ m} = T_{road,\ m\ (A/E)} + T_{sea,\ m} + T_{p,\ m}$$

where

$T_{road,\ m\ (A/E)}$ are access and egress times by road to and from ports estimated using relations reported in section 2.1;
$T_{sea,\ m}$ is the time by sea using available maritime services between departure and arrival ports;
$T_{p,\ m}$. is the total time for handling in maritime terminals.

Time by sea is obtained by:

$T_{sea,\ m} = L_{ij} / v_{sea}$

where

L_{ij} is the distance between origin (*i*) and destination ports (*j*) (miles);
v_{sea} is the commercial speed of ro-ro services (miles/hours).

2.2.2 Prices

To obtain the final prices of combined road–maritime transport ($P_{r\text{-}m}$), a truck with 18 meters of length is considered. With these assumptions, the model to obtain prices is:

$$P_{r\text{-}m} = m_{18}\, L_{ij} + b_{18}$$

where

L_{ij} is the distance between origin (*i*) and destination ports (*j*) (km);

m_{18}, b_{18} are calibrated parameters.

Total prices relative to combined road–maritime transport are obtained summing road transport price, estimated using relations reported in section 2.1.

2.3 Combined road–rail transport

2.3.1 Time

Total travel time by combined road rail transport for freight belonging the class *m* can be estimated in the following form:

$$T_{r\text{-}r,\, m} = T_{road,\, m\, (A/E)} + T_{rail,\, m} + T_{r,\, m}$$

where

$T_{road,\, m\, (A/E)}$ are access and egress times by road to and from railway terminals, estimated using relations reported in section 2.1;

$T_{rail,\, m}$ is the time by rail using available railway services between departure and arrival railway terminals;

$T_{r,\, m}$ is the total time for handling in railway terminals.

2.3.2 Prices

To obtain final prices combined road–rail transport ($P_{r\text{-}r}$), a swap carrying a quantity of 30 tonnage is considered. With this assumption, model to obtain prices is:

$$P_{r\text{-}r} = m_{30}\, \mathrm{L}_{ij} + q\, b_{30}$$

where

L_{ij} is the distance between origin (*i*) and destination terminal railways (*j*) (km);

m_{30}, b_{30} are calibrated parameters.

Total prices relative to combined road–rail transport are obtained summing road transport price, estimated using relations reported in section 2.1.

3 Modelled attributes of different alternatives (2005)

Models recalled in section 2 with the calibrated parameters [21] are applied to estimate attributes of transport services to the provision of a designed urban distribution center in Reggio Calabria (UDC-RC).

Freights, from national origins, are transported to the UDC by different mode services. In the UDC, freights are transferred to low emission vehicles that reach final urban destinations nulling pollution impacts of urban good vehicles [22–25].

3.1 Route alternatives for long distance provisioning

Two origins are analyzed in relation to two different hypotheses for provisioning UDC-RC: from Bologna Freight Village (*hypothesis 1)*; from Torino Freight Village (*hypothesis 2*).

For each hypothesis, different alternatives of travel are considered:

- in the *hypothesis 1* freight transport is realized using
  1a) full road transport from the origin to destination (*full road*);
  1b) rail service from Bologna Freight Village to Villa San Giovanni station and road transport from the station to UDC-RC (*combined road-rail*);
  1c) road transport from Bologna Freight Village to the port of Salerno, maritime services to the port of Messina, maritime services to the port of Villa San Giovanni and road transport to UDC-RC (*combined road-maritime*);
- in the *hypothesis 2* freight transport is realized using
  2a) full road transport from the origin to destination (*full road*);
  2b) rail service from Torino Freight Village to Villa station and road transport to UDC-RC (*combined road-rail*);
  2c) road transport from Torino Freight Village to the port of Genova, maritime services to the port of Palermo, road transport to the port of Messina, maritime services to the port of Villa San Giovanni and road transport to UDC-RC (*combined road-maritime1*);
  2d) road transport from Torino Freight Village to the port of Salerno, maritime services to the port of Messina, maritime services to the port of Villa San Giovanni and road transport to UDC-RC (*combined road-maritime2*).

The alternatives considered are represented in Fig. 1. In Table 1 the unitary parameters, calibrated in 2005 [21] to obtain cost attributes, are reported.

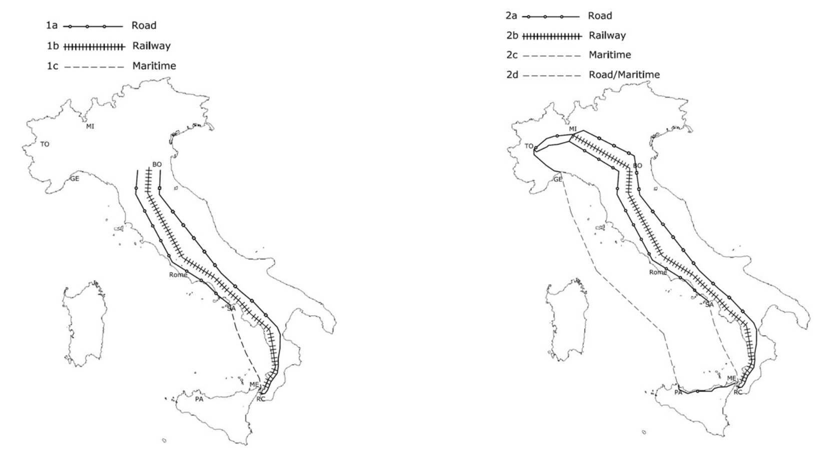

Figure 1: Alternative routes for each hypothesis of provisioning.

Table 1: Parameters to calculate road transport attributes.

Attribute	Parameters	Quantity
Cost	fuel cost (c_{gas})	0.99 €/liter
	fuel consumption (m_u)	0.40 liter/km
	operative cost (c_{op})	0.56 €/km
	toll cost (c_{to})	0.11 €/km
	driver cost (c_{dr})	19.00 €/h

3.2 Calculations of long distance attributes by models

The models specified in section 2 are applied to the different alternatives using calibrated parameters.

The input characteristics calculated by open GIS are:

- distance by road [26];
- distance by sea [27];
- distance by rail (Italian Railway Operator website).

Results for each alternatives are reported in Table 2.

Table 2: Long distance attributes by model.

		1) Bologna – UDC RC			2) Torino - UDC RC			
		1a)	1b)	1c)	2a)	2b)	2c)	2d)
T road (h)	road time	20.60	0.26	8.77	24.24	2.59	5.65	11.75
T maritime (h)	maritime time	-	-	8.64	-	-	24.19	10.30
T rail (h)	rail time	-	19.99	-	-	22.21	-	-
Ttot (h)		20.60	20.25	17.41	24.24	24.80	29.84	22.05
C road (€)	fuel cost fuel consumption	423.68	8.08	262.15	540.31	62.65	164.62	378.78
	operative cost	600.21	11.45	371.38	765.43	88.74	233.21	536.60
	toll cost	651.43	-	599.03	975.17	-	323.84	891.02
	driver cost	391.47	4.96	330.73	460.49	49.17	566.87	418.87
Ctot road (€)		2066.79	24.49	1563.29	2741.40	200.56	1288.53	2225.27
P road (€)	road price	2418.15	28.66	1829.05	3207.43	234.66	1507.58	2603.56
P maritime (€)	maritime rate	-	-	444.55	-	-	780.75	444.55
P rail (€)	rail rate	-	1292.84	-	-	1394.60	-	-
P tot (€)		2418.15	1321.50	2273.60	3207.43	1629.26	2288.34	3048.11

T (h): Times in hours: C (h): Costs in Euros.
Travel alternatives for 1): 1a) full road; 1b) combined road-rail; 1c) combined road-maritime;
Travel alternatives for 2): 2a) full road; 2b) combined road-rail; 2c) combined road-maritime1; 2d) combined road-maritime2).

4 Revealed attributes of different alternatives (2015)

In this paper single analysis regarding specific attributes are presented. It is not developed a general survey to specify model and to calibrate the relative parameters and to use these models in a specific choice model of random or fuzzy utility [28]. The purpose is to obtain an experimental measure of the differences between the values obtained with the calibrated model in 2005 and the revealed values in 2015.

4.1 Road transport

Some attributes are surveyed to update unitary parameters and to highlights, the modifications happened in the last 10 years on total times, costs and prices.

Surveys are grouped for:

- times, considering,
  - running times calculated by means of a Decision Support System, provided by PTV [29] for each class of road infrastructure, shortly labeled as DSS;

- costs and prices calculation, considering,
  - fuel cost (c_{gas}) according to the Italian Government [30], shortly labeled as *fuel cost*;
  - fuel consumption (m) according to sector journals [31], shortly labeled as *fuel consumption*;
  - operative cost (c_{op}) according to sector journals [31], shortly labeled as *operative cost*;
  - toll cost (c_{to}) according to sector journals [31], shortly labeled as *toll cost*;
  - driver cost (c_{dr}) according to national rules that regulate working costs in Italy [32], shortly labeled as *toll cost*.

In Table 3, for each parameter, the updated value is reported.

Table 3: Values to validate road transport attributes.

Attribute	Survey	Value
Time	DSS	
Cost	fuel cost (c_{gas})	1.35 €/liter
	fuel consumption (m_u)	0.36 liter/km
	operative cost (c_{op})	0.84 €/km
	toll cost (c_{to})	0.10 €/km
	driver cost (c_{dr})	12.88 €/h

4.2 Combined road–maritime transport

Some direct surveys are carried out to obtain information from maritime operators [33, 34] grouped for

- times, considering schedule of selected ro-ro services;
- prices calculation, considering rates of selected ro-ro services.

In Table 4, revealed values are reported.

4.3 Combined road–rail transport

Some direct surveys are carried out to obtain information from the Italian Railway Operator grouped for

- times, considering schedules of selected rail services;
- prices calculation, considering rates of selected rail services.

In Table 5, revealed values are reported.

Table 4: Quantities to validate combined road–maritime transport attributes.

Attribute	Survey	Value
Time	Ro-Ro services schedules	
	Salerno–Messina	11 h
	Genova–Palermo	23 h
	Messina–Villa S. Giov.	0.5 h
Price	Ro-Ro services rates	
	Salerno–Messina	530.00 €
	Genova–Palermo	1,398.00 €
	Messina–Villa S. Giov.	70.00 €

Table 5: Quantities to validate combined road–rail transport attributes.

Attribute	Survey	Value
Time	Railway services schedule	
	Milano–Villa S. Giov.	17.05 h
	Bologna–Villa S. Giov.	17.45 h
Prices	Railway services rates	
	Milano–Villa S. Giov.	1,939.00 €
	Bologna–Villa S. Giov.	2,310.00 €

4.4 Long distances attributes calculations by experimentations

Revealed values, reported previously are used to recalculate the attributes for each hypothesis and for each alternative in the 2015 scenario. The results are reported in Table 6.

Table 6: Long distance attributes by surveys.

		1) Bologna – UDC RC			2) Torino - UDC RC			
		1a)	1b)	1c)	2a)	2b)	2c)	2d)
T road (h)	road time	28.44	0.12	9.23	41.36	1.26	4.74	11.50
T maritime (h)	maritime time	-	-	11.50	-	-	23.50	11.50
T rail (h)	rail time	-	23.45	-	-	23.05	-	-
Ttot (h)		28.44	23.57	20.73	41.36	24.31	28.24	23
C road (€)	fuel cost	578.78	7.24	347.06	738.73	92.56	219.20	504.26
	fuel consumption	381.54	4.78	228.79	486.98	61.02	144.50	332.42
	operative cost	899.26	11.26	539.23	1147.78	143.81	340.58	783.48
	toll cost	101.70	-	59.57	86.96	-	32.20	88.61
	driver cost	265.38	3.36	224.20	312.16	33.33	384.27	283.95
Ctot road (€)		2226.67	26.64	1398.85	2772.62	330.71	1120.76	1992.73
P road (€)	road price	2605.20	31.17	1636.65	3243.96	386.94	1311.29	2331.50
P maritime (€)	maritime rate	-	-	530.00	-	-	1608.00	530.00
P rail (€)	rail rate	-	1939.00	-	-	2310.00	-	-
P tot (€)		2605.20	1970.17	2166.65	3243.96	2696.94	2919.29	2861.50

T (h): Travel times in hours; C (h): Travel costs in Euros
Travel alternatives for 1): 1a) full road; 1b) combined road-rail; 1c) combined road-maritime;
Travel alternatives for 2): 2a) full road; 2b) combined road-rail; 2c) combined road-maritime1; 2d) combined road-maritime2.

5 Conclusion

To give an immediate evidence of the modifications happened in the decade 2005–2015, a conclusive comparative table is proposed.

Each element of Table 7 reports the difference Δ_i in percentage between the generic attribute $Attr._{i,\ 2005}$ modelled and revealed attributes $Attr._{i,\ 2015}$ calculated as:

$$\Delta_i = 100 \cdot (Attr._{i,\ 2015} - Attr._{i,\ 2005}) \,/\, Attr._{i,\ 2005}$$

From the values in Table 7, some main elements emerge, first the substantial permanence of prices for full road and combined maritime, with the strong increasing of the combined rail.

Table 7: Differences between modelled and revealed attributes.

		1) Bologna – UDC RC			2) Torino - UDC RC			
		1a)	1b)	1c)	2a)	2b)	2c)	2d)
ΔT road (h)	road time	38%	-54%	5%	71%	-51%	-16%	-2%
ΔT maritime (h)	maritime time			33%			-3%	12%
ΔT rail (h)	rail time		17%			4%		
ΔTtot (h)		38%	16%	19%	71%	-2%	-5%	4%
ΔC road (€)	fuel cost	37%	-10%	32%	37%	48%	33%	33%
	fuel consumption	-10%	-41%	-13%	-10%	-3%	-12%	-12%
	operative cost	50%	-2%	45%	50%	62%	46%	46%
	toll cost	-84%		-90%	-91%		-90%	-90%
	driver cost	-32%	-32%	-32%	-32%	-32%	-32%	-32%
ΔC tot road (€)		8%	9%	-11%	1%	65%	-13%	-10%
ΔP road (€)	road price	8%	9%	-11%	1%	65%	-13%	-10%
ΔP maritime (€)	maritime rate			19%			106%	19%
ΔP rail (€)	rail rate		50%			66%		
ΔP tot (€)		8%	49%	-5%	1%	66%	28%	-6%

T (h): Travel times in hours; C (h): Travel costs in Euros.
Travel alternatives for 1): 1a) full road; 1b) combined road-rail; 1c) combined road-maritime;
Travel alternatives for 2): 2a) full road; 2b) combined road-rail; 2c) combined road-maritime1; 2d) combined road-maritime2.

Regarding the time, there is an increase in the full road with a zero or low increasing in the combined alternatives.

The calculated Δ_i can be used as rough pivot parameter to update attributes.

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