LA FATTIBILITÀ ECONOMICA DEI SERVIZI DI TRASPORTO MERCI DEPERIBILI DI MEDIO RAGGIO

Francesco Russo, Giovanna Chilà

Dipartimento di Ingegneria dell'Informazione, delle Infrastrutture e dell'Energia Sostenibile
Mediterranea University of Reggio Calabria
francesco.russo@unirc.it, giovanna.chila@unirc.it, www.last.unirc.it

Index

- Introduction
- State of the art on modal choice models
- Database
- Modal choice model specification, calibration and validation
- Speed ship properties
- Evaluation and transport scenarios
- Conclusions

Index

- Introduction
- State of the art on modal choice models
- Database
- Modal choice model specification, calibration and validation
- Speed ship properties
- Evaluation and transport scenarios
- Conclusions

Introduction

The European freight transport in recent years has been characterized by a prevalent use of road transport mode

Lower level of service on road

Higher accident risk

Higher air pollution

Why road transport mode is chosen?

What factors can produce a readjustment among modal choices, encouraging sustanaible and efficient development?

Introduction

Demand of goods between Sicily and Europe is about 45000 t in a day, net of liquid and dry bulk by sea (which are early 205000 t).
National quota is about 73 %, international quote is about 27 % (Advisor, 2001).

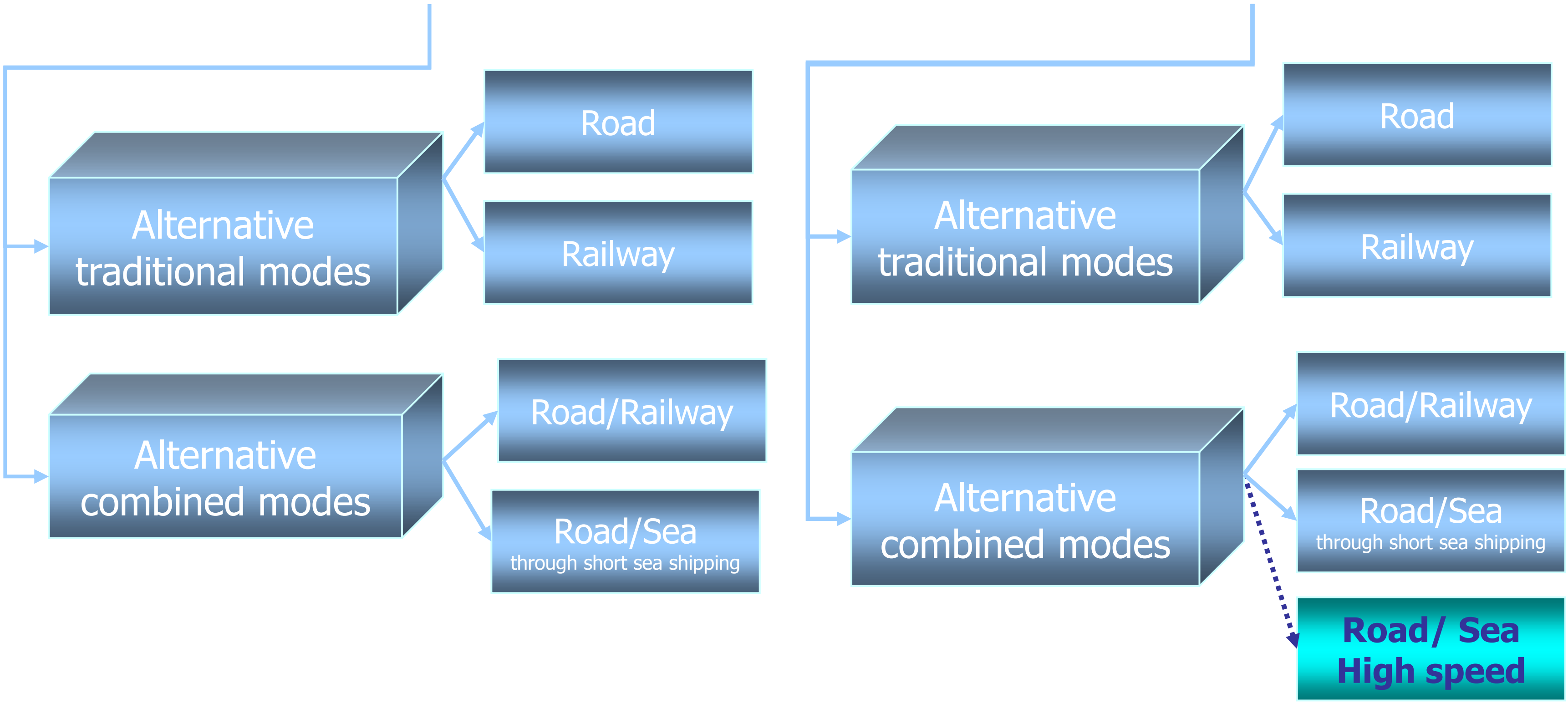
	Daily demand of goods	**Growth trend (trend % 99-95)**
	26511 t	+ 43 %
	8068 t	+ 27 %
	10500 t	+ 110 %

Introduction

OBJECTIVES

to construct a consignment model in order to simulate modal choice for national and international freight transport

to assess variation in demand caused by the introduction of combined road-sea high speed mode



Introduction

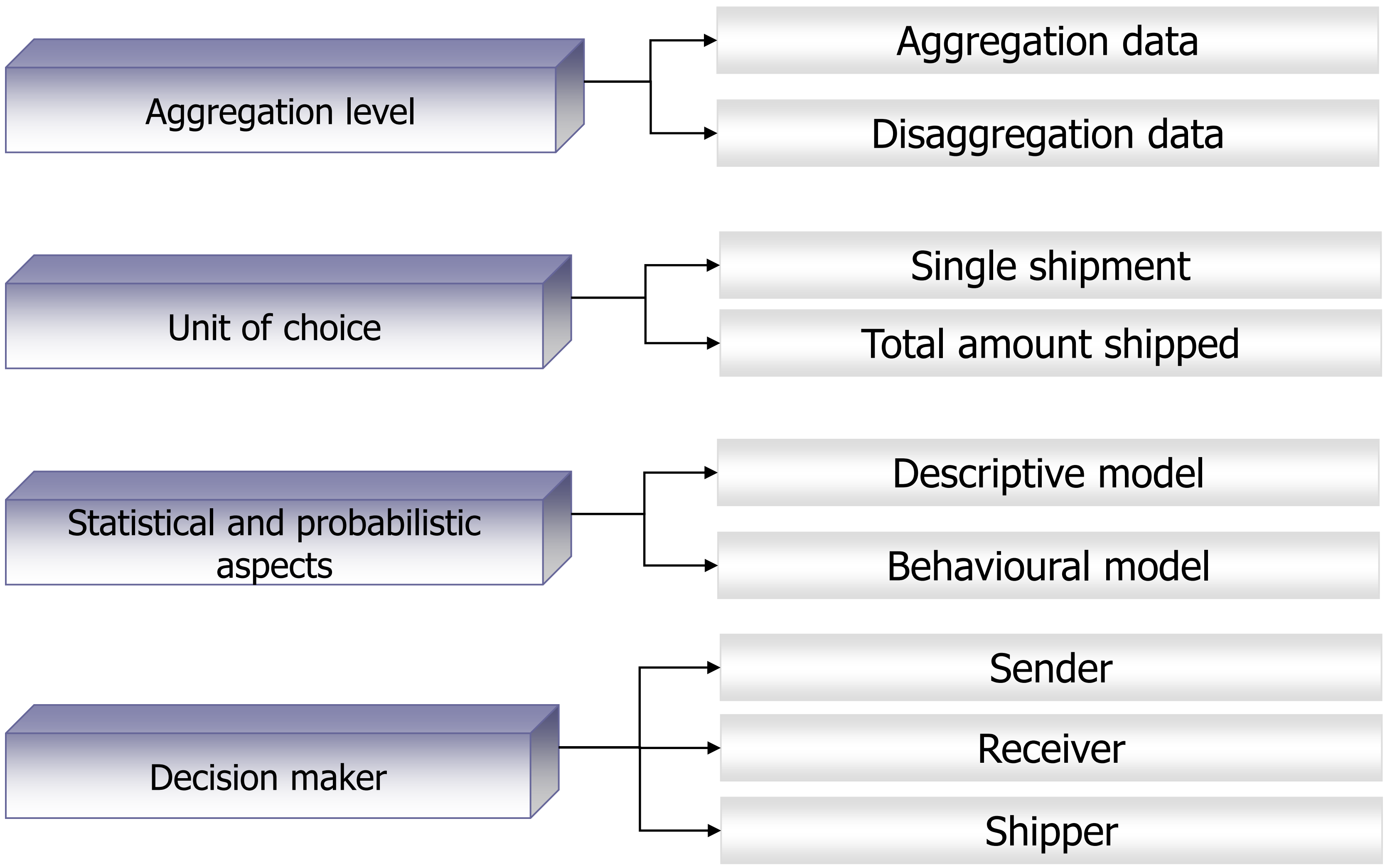
2001	White Paper *European Transport Policy for 2010*	European Commission introduced the concept of motorways of the sea in its 2001 transport White Paper
	Freight Transport and Logistics Masterplan	
2003	Van Miert Report	Motorway of the Sea European Transport is included in TEN priority projects
2004	Approvazione orientamenti comunitari per lo sviluppo Reti Ten - T	Motorway of the Sea European Transport is passed as priority projects
2011	Logistic Plan is passed	Role of road transport is confirmed
2013	Proposal TEN-T	Motorway of the sea is not considered in the Proposal TEN-T (29 may)

Index

- Introduction
- State of the art on modal choice models
- Database
- Modal choice model specification, calibration and validation
- Speed ship properties
- Evaluation and transport scenarios
- Conclusions

State of the art on modal choice models

Modal choice model classification



State of the art on modal choice models

	Consignment models – Nationale scale	Consignment models – European scale	Logistic models
Aggregation level	Disaggregate data	Aggregate data	Disaggregate data
Unite of choice	Single shipment		Total amount
Functional form	Behavioural model		Behavioural model
Decision maker	Sender		Sender

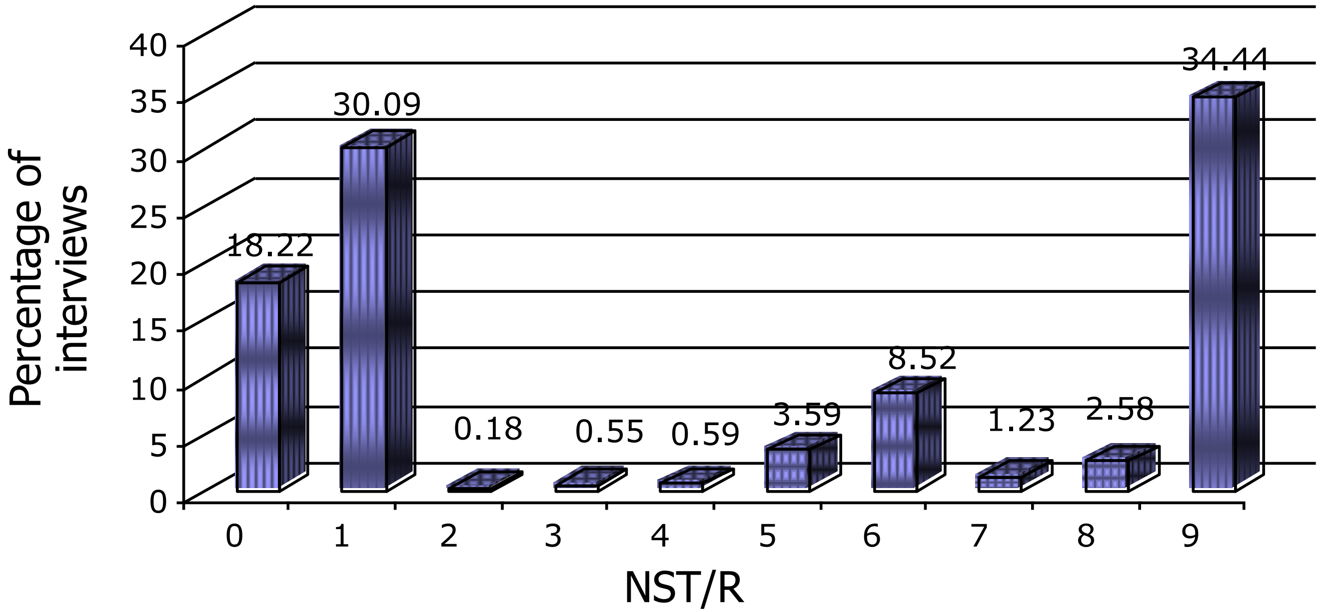
Index

- Introduction
- State of the art on modal choice models
- Database
- Modal choice model specification, calibration and validation
- Speed ship properties
- Evaluation and transport scenarios
- Conclusions

Database

Road Transport

Statistical analysis in respect of O/D and kind of freight
(NST/R classification)



NST/R	Description	NST/R	Description
0	Agriculture products and live animals	5	Metal products
1	Foodstuffs and animal fodder	6	Crude and manufacture minerals
2	Solid mineral fuels	7	Fertilizers
3	Petroleum products	8	Chemicals
4	Ores and metal waste	9	Machinery

Database

Railway

Statistical analysis in respect of O/D and kind of freight
(NST/R classification)

DEPARTURES

TRADITIONAL RAIL

NST	Total number of wagons
VEHICLES	274
FERTILIZERS	15
FOODSTUFFS AND ANIMAL FODDER	534
MACCH.,VEHICLES, HAND-MANUFACTURES, SPEC. TRANSACT.	3447
MINERALS AND METAL WASTE	1375
CRUDE AND MANUFACTURE MINERALS	450
AGRICULTURE PRODUCTS AND LIVE ANIMALS	482
CHEMICALS	1337
METAL PRODUCTS	3420
PETROLEUM PRODUCTS	1675
TOTAL	13009

COMBINED ROAD/RAIL

NST	Total number of wagons
LOADED SWAP BODY	6347
LOADED CONTAINERS	143
LOADED SEMITRAILERS	328
TOTAL	6818

Database

Railway

Statistical analysis in respect of O/D and kind of freight
(NST/R classification)

ARRIVALS

TRADITIONAL RAIL

NST	Total number of wagons
VEHICLES	1543
FERTILIZERS	17
FOODSTUFFS AND ANIMAL FODDER	22
MACCH.,VEHICLES, HAND-MANUFACTURES, SPEC. TRANSACT.	8174
MINERALS AND METAL WASTE	8807
CRUDE AND MANUFACTURE MINERALS	699
AGRICULTURE PRODUCTS AND LIVE ANIMALS	384
CHEMICALS	193
METAL PRODUCTS	499
PETROLEUM PRODUCTS	3808
TOTAL	24146

COMBINED ROAD/RAIL

NST	Total number of wagons
LOADED SWAP BODY	16241
LOADED CONTAINERS	437
LOADED SEMITRAILERS	645
TOTAL	17323

Database

Database related to different time dimensions → **Expansion Factors extending all the information available to a period of a year**

Hypothesis

Road		Number of sendings = (Total of interviews*100/Rate of sampling)*2
Railway	Combined Road/Railway	Number of sendings = Number of wagons
	Traditional	Number of sendings = Number of wagons
Combined Road/Sea		CMVP (Average of load for heavy vehicles) = 15 t Number of sendings = Total tons in a year/CMVP

Database

Combined Road/Sea

Since unaccompanied combined road–sea transport is an important share of the transport by sea, particularly if the distance between origin/destination ports is longer than 200–250 sea miles, we obtained information about this transport mode by conducting a survey of Sicilian firms in July 2006.

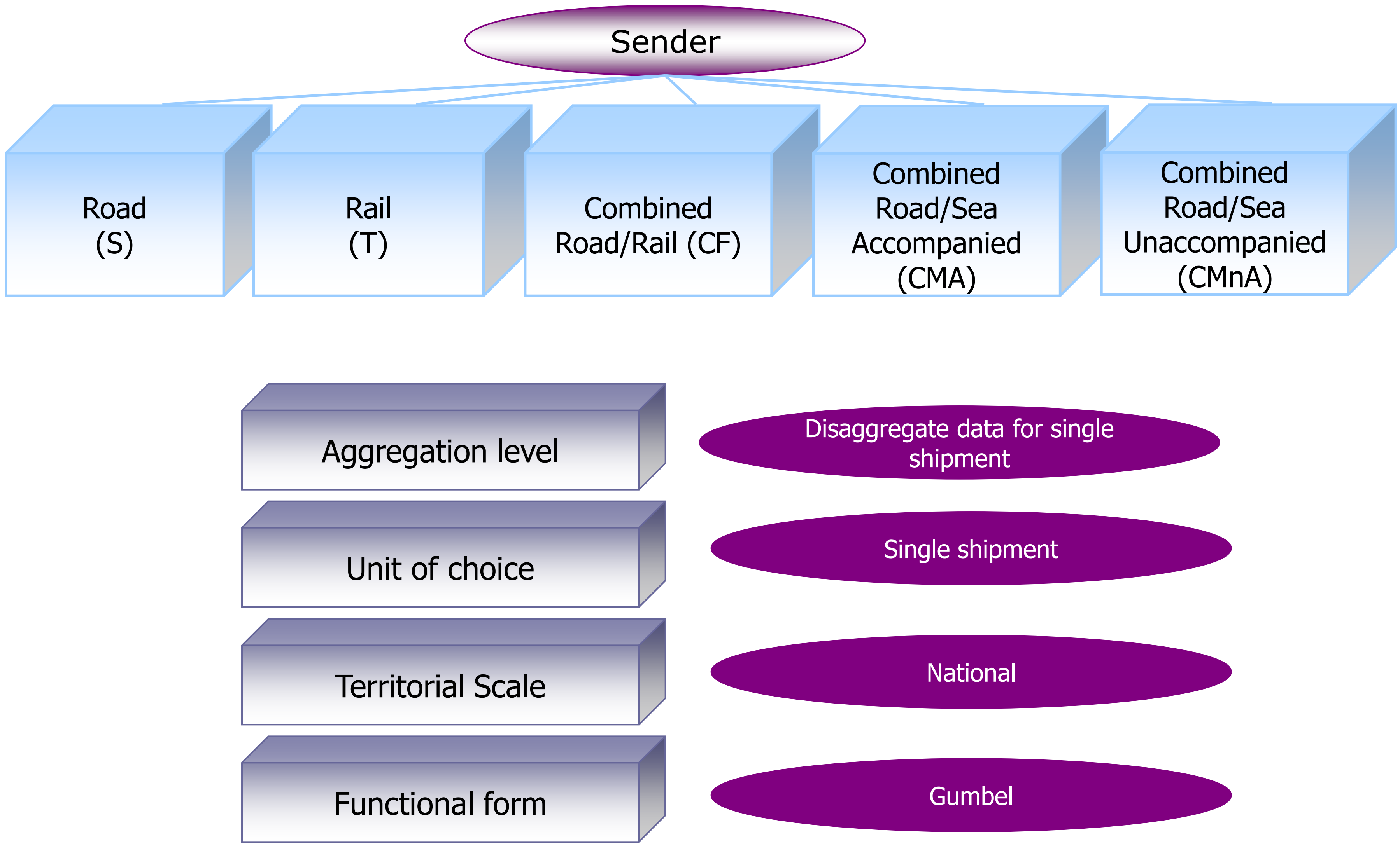
In this work we made the following assumptions:

- the combined road–sea transport is mainly accompanied (70 %), and to a lesser extent unaccompanied (30%), of the global demand by combined road-sea transport mode, if the distance between origin/destination ports is shorter than 230 nautical miles;
- combined accompanied road–sea transport accounts for (10 %) and unaccompanied for the remaining 90 % of the global demand by combined road-sea transport mode, if the distance between origin/destination ports exceeds 230 nautical miles.

Index

- Introduction
- State of the art on modal choice models
- Database
- Modal choice model specification, calibration and validation
- Speed ship properties
- Evaluation and transport scenarios
- Conclusions

Model Specification



Model Specification

P	price of transport service;
T	travel time specified for each transport mode and sometimes subdivided, for the combined transport mode, into: • amount of access/egress time and handling time at the terminals; • run time between origin and destination terminals;
NCD	dummy variable which is 1 if combined transport mode is not direct available between origin and destination terminals, 0 otherwise;
CD	dummy variable which is 1 if NCD=0, 0 otherwise;
$PERISHABLE$	dummy variable which is 1 if the freight is perishable, 0 otherwise;
P_{30}	dummy which is 1 if the freight quantity is less than 30 tonnes, 0 otherwise;
$RAIL$	ASA for rail transport mode;
$INDUSTRIAL$	dummy variable which is 1 if freight is industrial, 0 otherwise;
CF_{M30}	dummy variable which is 1 for combined road – rail transport mode if freight exceeds 30 tonnes, 0 otherwise;
CF_{M30ND}	dummy variable which is 1 for combined road–rail transport mode if freight exceeds 30 tonnes and the combined road–sea transport mode is not directly available between origin and destination terminals, 0 otherwise;
D_{AE}	amount of access and egress distance to the terminals, in kilometres;
$CMnA$	dummy variable which is 1 for unaccompanied combined road-sea transport mode if the distance between origin and destination ports is higher than 230 nautical miles, 0 otherwise.

Model Calibration

Calibration method ▶|

Maximum Likelihood

Likelihood

(Logit Multinomial Model)

$$\ln L(\beta,\theta) = \sum_{i=1\ldots n} \left[\beta^T X^i_{j(i)} / \theta - \ln \sum_{j \in I_i} \exp\left(\beta^T X^i_j / \theta \right) \right]$$

Software

Alogit

Database

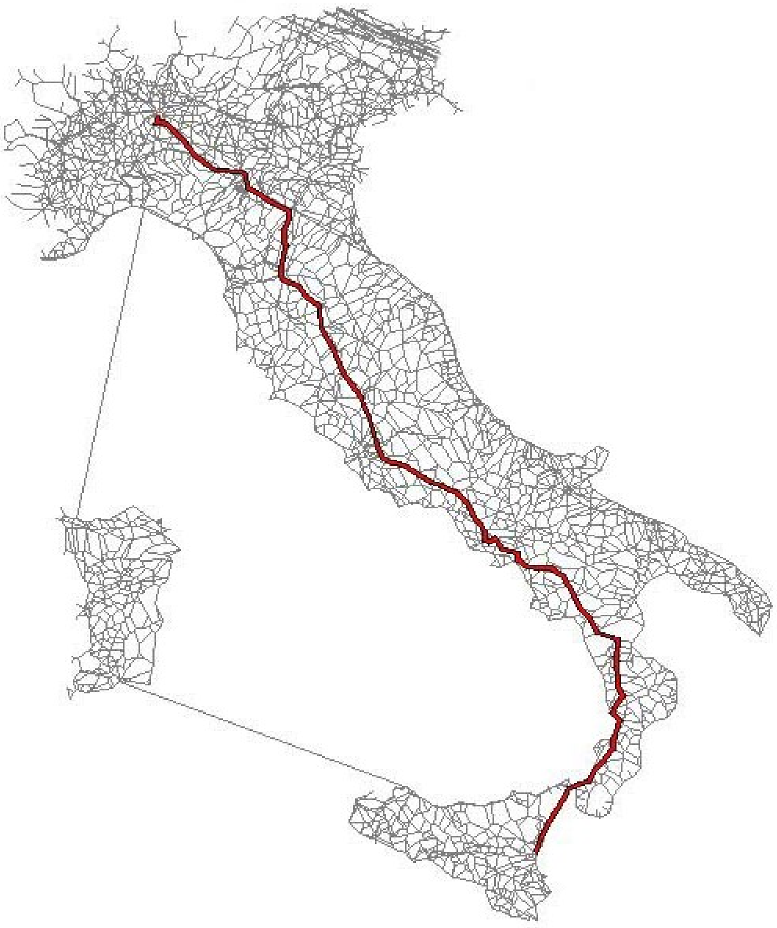
	Num. Sendings	Period of reference
Road S	362	1 year
Rail T	37	1 year
Combined CF	24	1 year
Combined CMA	98	1 year
Combined CMnA	140	1 year

Level of service attribute

Estimated on network using Transcad4

Model Calibration

Level of service attributes

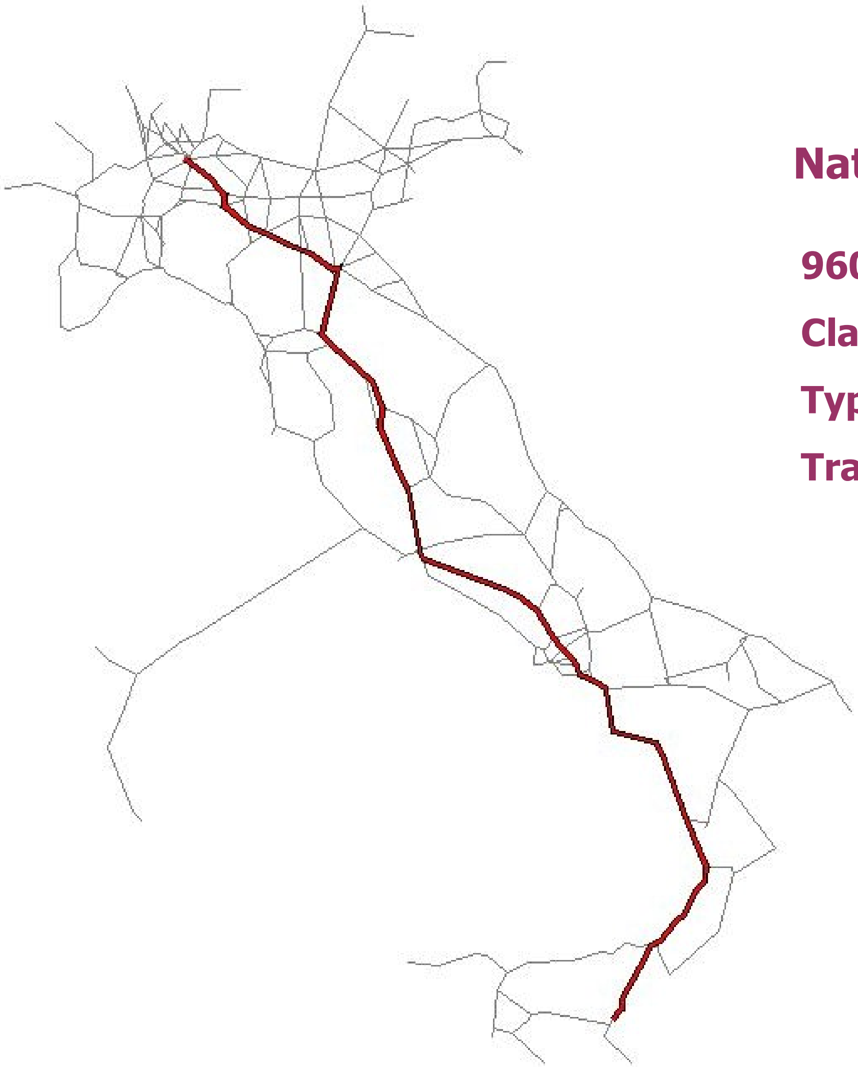


National road network

- 32022 links, 4854 nodes
- Length
- Class
- Slope
- Speed
- Tortuosity
- Travel time
- Cost

Model Calibration

Level of service attributes



National railway network

960 links, 371 nodes

Class

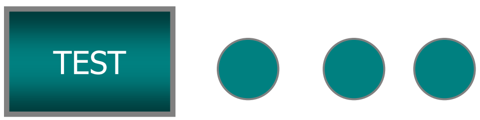
Type

Travel time

Model validation

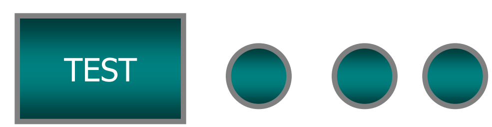
INFORMAL TESTS

SIGNS OF THE CALIBRATED PARAMETERS

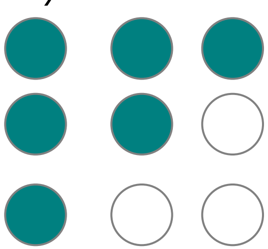


VALUE OF TIME (V.O.T.)

TRANSPORT MODE	V.O.T. (€/h)
Road *S*	245.0
Rail *T*	2.0
Combined Road/Rail *CF*	70.0
Combined Road/Sea Acc. *CMA*	225.0
Combined Road/Sea Uncc. *CMnA*	95.0



Key



Very good test

Fairly good test

Very bad test

Model validation

FORMAL TESTS

T-STUDENT

$$t = \beta_k^{ML} \Big/ Var\left[\beta_k^{ML}\right]^{1/2}$$

TEST ● ● ○

RHO - square

$$\rho^2 = 1 - \ln L(\beta^{ML}) \Big/ \ln L(0)$$

0.683

TEST ● ● ●

RHO2 – square bar

$$\rho^2 = 1 - \left(\ln L(\beta^{ML}) - N_\beta\right) \Big/ \ln L(0)$$

0.668

TEST ● ● ●

Key

● ● ● Very good test

● ● ○ Fairly good test

● ○ ○ Very bad test

Model validation

DIRECT ELASTICITY

$$E_{kj}^{p(j)} = \frac{\Delta p(j)}{p(j)} \bigg/ \frac{\Delta X_{kj}}{X_{kj}}$$

CROSSED ELASTICITY

$$E_{kh}^{p(j)} = \frac{\Delta p(j)}{p(j)} \bigg/ \frac{\Delta X_{kh}}{X_{kh}}$$

HYPOTHESIS → + 10% road transport price → Elasticity evaluation with regard to road transport price increasing

Transport mode	Elasticity
Road *S*	-0.312
Rail *T*	0.318
Combined Road/Rail *CF*	0.318
Combined Road/Sea Accompanied *CMA*	0.318
Combined Road/Sea Unaccompanied *CMnA*	0.318

Model validation

TEST 1

sum of the mode choice probabilities regarding all users, for each mode, divided by total users

TEST 2

sum of value 1 for the mode with the maximum probability, of value 0 for the other modes, regarding all users, for each mode, divided by total users.

Transport mode	Num. of sendings	% aggregate of real choices	TEST 1	TEST 2
Road	362	54.77	55.12	54.77
Train	37	5.60	5.26	6.35
Combined CF	24	3.63	3.14	0.00
Combined CMA	98	14.83	11.26	8.17
Combined CMnA	140	21.17	25.22	30.71
TOTAL	661	100.00	100.00	100.00

Index

- Introduction
- State of the art on modal choice models
- Database
- Modal choice model specification, calibration and validation
- Speed ship properties
- Evaluation and transport scenarios
- Conclusions

Speed ship properties

FEDERICO GARCIA LORCA

Rodriguez Cantieri Navali SpA Italy

Ship equipped with two propelling engines
with a peak speed of 38 kn
This has been used by Balearia Eurolineas Maritimes on runs between Denia and Ibiza
and
Ibiza and Palma.

•**Building year**	**2001**
•**Lenght**	**115.25 m**
•**Beam**	**17.0 mt**
•**Propelling**	**Machinery Caterpillar**
•**Capacity**	**210 cars**
•**Maximum number of trucks**	**300 m**

Index

- Introduction
- State of the art on modal choice models
- Database
- Modal choice model specification, calibration and validation
- Speed ship properties
- Evaluation and transport scenarios
- Conclusions

Evaluation and transport scenarios

PROJECT SCENARIO

We propose the introduction of the combined road-sea high speed unaccompanied transport mode (*CMnAHS*), supposing that it is available in the same ports, with new specialized terminals, considering the current Italian motorways of the sea as routes.

In particular, we analyzed the Messina-Salerno link, seeking to ascertain whether a combined high speed transport system can give a more reasonable distribution of freight transport.

In order to test the combined road-sea high speed unaccompanied transport mode in different conditions, we defined four *speed* scenarios according to cruising speed *VHS*:

- Scenario *speed 30*
- Scenario *speed 32*
- Scenario *speed 35*
- Scenario *speed 38*

Motorway of the Sea Messina - Salerno

Source Short Sea Shipping

Input Data

Distance Original/Destination: 156.10 miles

Distance low speed D_{LS}: 20.00 miles

Distanza high speed D_{HS}: 136.10 miles

Low Speed V_{LS}: 16 noded

High Speed V_{HS}:

Scenario *speed 30 nodes;*

Scenario *speed 32 nodes*;

Scenario *speed 35 nodes*;

Scenario *speed 38 nodes*.

Evaluation and transport scenarios

We supposed that, for every scenario, the low-speed distance is 10.0 nautical miles from the origin port and 10.0 nautical miles from the destination port; the high-speed distance is the remaining 136.1 nautical miles. Moreover, the cruising speed *VLS* is the same for every scenario, namely 16 kn.

Regarding the ship's fuel consumption, we plotted the consumption curve according to nautical miles covered and propelling machinery used, knowing the following characteristics: electrical power and efficiency of engines, fuel density, unit consumption of engines, travel time.

The cost of the high speed service was obtained by considering several attributes, related to ship acquisition and management, port charges, ship consumption, number of trips per day, etc. Some attributes can be considered exogenous in respect of this work, others can be considered endogenous, as they result from exogenous or other endogenous attributes.

Evaluation and transport scenarios

EXOGENOUS ATTRIBUTES

Attributes		Unit of measurement
E	Crew members	num
COE	Hourly wages of crew members	€/h
CA	Ship acquisition cost	10^6 €
AA	Depreciation period	years
CM_a	Ship annual maintenance cost	10^6 €/year
CC	Capacity	40 ft - containers
V_{LS}	D_{LS} speed	kn
V_{HS}	D_{HS} speed	kn
GL_m	Monthly working days of ship	days

Evaluation and transport scenarios

ENDOGENOUS ATTRIBUTES

Attributes		Expression	Unit of measurement
T	Travel time	$(D_{LSO}+D_{LSD})/16.0+D_{HS}/v_{HS}$	h
MNV_g	Maximum number of trips a day	$int(24/T)$	num/day
NV_g	Number of trips a day	$[1 ; MNV_g]$	num/day
OL_g	Daily working hours	$NV_g \cdot T$	h
CE_m	Crew's monthly salary	$COE \cdot OL_g \cdot GL_m$	€
GL_a	Yearly working days	$12 \cdot GL_m$	days
CE_v	Crew's cost per trip	$CE_m/(GL_m \cdot NV_g)$	€/trip
CA_v	Ship acquisition cost per trip	$CA/(AA \cdot GL_a \cdot NV_g)$	€/trip
CM_v	Ship maintenance cost per trip	$CM_a/(GL_a \cdot NV_g)$	€/trip

Evaluation and transport scenarios

EXOGENOUS ATTRIBUTES → SCENARIO COST ← ENDOGENOUS ATTRIBUTES

SCENARIO COST
for combined road/sea unaccompanied high speed mode

$$CV^{BE} = (CA_v + CM_v + CE_v + CT + CP)/CC$$

with

CV^{BE}	value of break even cost
CA_v	ship acquisition cost per trip
CM_v	ship maintenance cost per trip
CE_v	crew cost per trip
CT	fuel consumption per trip
CP	port charges
CC	ship's capacity

Evaluation and transport scenarios

We compare the cost of the combined road-sea high speed mode and the real transport price (traditional combined road-sea mode) for a 14-metresemitrailer on the Messina–Salerno motorway of the sea, which is nearly €340.30.

The increase in the cost of the combined high speed mode varies between 46 and 54 % if the trip number per day varies from 2 to 4.

Scenario *speed*	Ticket (€)	Percentage increasing of the break even cost $NV_g=4$
30	340.30	45.92
32		48.83
35		53.15
38		53.52

Increase in the break-even cost in respect of real cost on Messina – Salerno motorway of the sea for a semitrailer

Evaluation and transport scenarios

In order to estimate the demand variation in the Messina–Salerno motorway of the sea, the choice probabilities are evaluated among six modal alternatives

- Road *S*
- Railway *T*
- Combined Road/Railway *CF*
- Combined Road/Sea Accompanied *CMA*
- Combined Road/Sea Unaccompanied *CMnA*
- Combined Road/Sea Unaccompanied High Speed *CMnAHS*

Evaluation and transport scenarios

Combined Road/Sea
Unaccompanied High Speed *CMnAHS*

is defined by:

- cruising speed
- percentage rise in service price in comparison with the current combined road – sea transport.

We considered several ***speed.price* scenarios**, for which we determined the choice probability variations of the sample survey.

Each ***speed.price* scenario** is defined according to the service attributes of the combined road – sea high speed unaccompanied transport mode, that is:

- cruising speed *VHS*, which varies between 30 kn and 38 kn;
- increase in transport price, which varies between 20 and 70 % in comparison with the current price of the combined road–sea unaccompanied transport mode.

Evaluation and transport scenarios

HYPOTHESIS

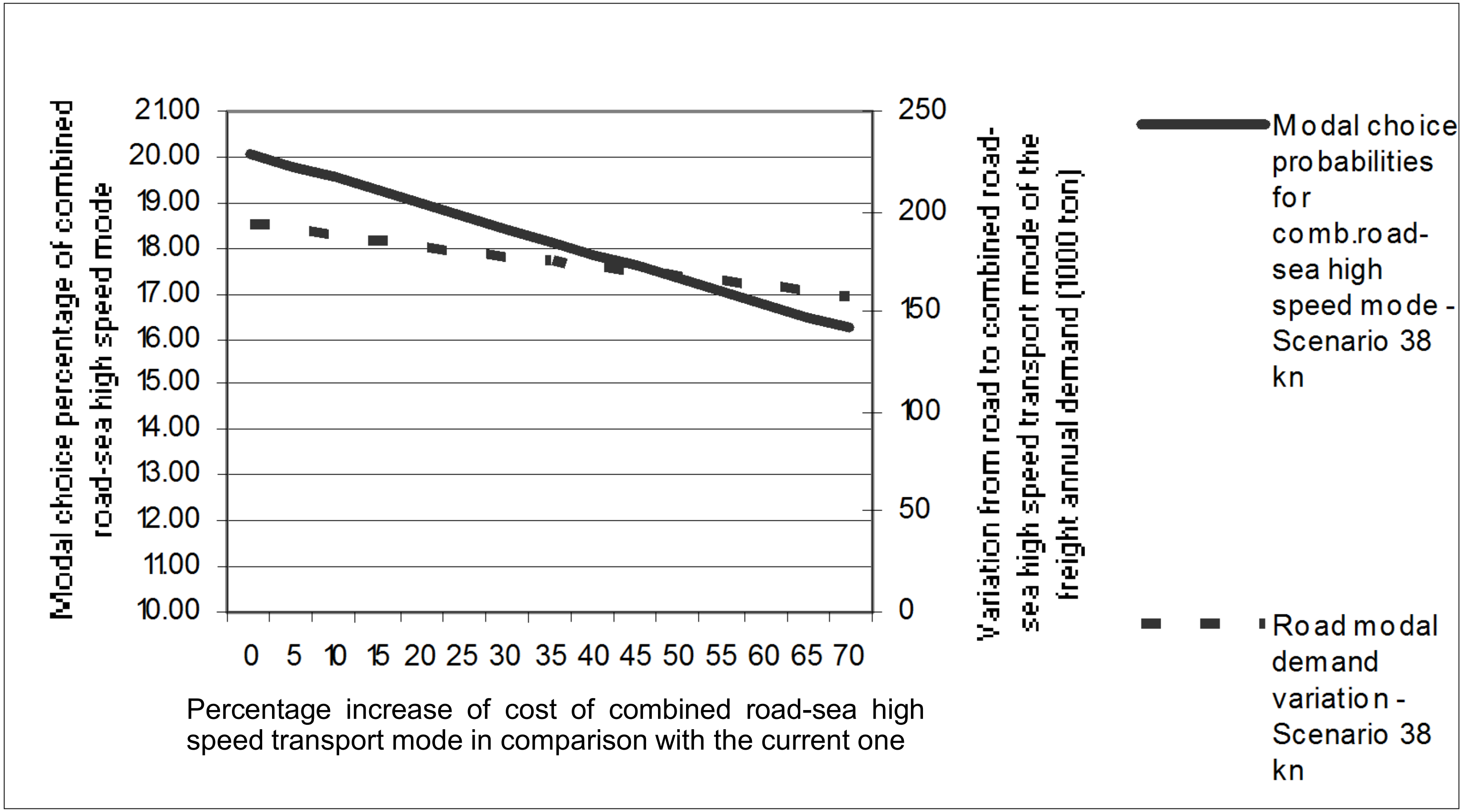
- Users do not perceive considerable differences between current and high speed combined road-sea transport alternatives.

- Choice probabilities of the combined road – sea high - speed transport mode have been evaluated using the same specification and parameters as those of the unaccompanied combined road – sea transport mode.

- The high-speed ship makes four trips per day, then the increase in the *CHS* cost varies between 45 and 55 % (45.92, 48.83, 53.15 and 53.52 % for cruising speeds of 30, 32, 35 and 38 kn, respectively). These values are comparable to cruising speed and percentage rise in service price supposed in the *speed.price* scenarios *30.45*, *32.50*, *35.55*, *38.55*.

Evaluation and transport scenarios

Comparison between break-even cost and real service price on the Messina–Salerno motorway of the sea



Index

- Introduction
- State of the art on modal choice models
- Database
- Modal choice model specification, calibration and validation
- Speed ship properties
- Evaluation and transport scenarios
- Conclusions

CONCLUSIONS

In this paper we have proposed a modal choice model with choice set which includes, for the first time in literature (in the author's knowledge), the combined road-sea transport subdivided into accompanied and unaccompanied transport.

The results obtained by model experimentation confirm that by introducing the high speed combined road-sea mode:

- a variation among modal choices is obtained, because the road choice probability decreases, thereby reducing road traffic;
- a new rate of freight demand is produced, due to travel time reduction, whit equal travel cost, or, alternatively, to travel cost reduction, with equal travel time.

The results obtained by model experimentation confirm that the high speed combined road-sea mode is a very competitive alternative to road.

Therefore, the model proposed can be considered a useful support for shipping company policies, guiding investments and the nature of services supplied.

LA FATTIBILITÀ ECONOMICA DEI SERVIZI DI TRASPORTO MERCI DEPERIBILI DI MEDIO RAGGIO

Francesco Russo, Giovanna Chilà

Dipartimento di Ingegneria dell'Informazione, delle Infrastrutture e dell'Energia Sostenibile
Mediterranea University of Reggio Calabria
francesco.russo@unirc.it, giovanna.chila@unirc.it, www.last.unirc.it