GOR

Arbeitsgruppe Praxis der
Mathematischen Optimierung

PROLOGOS

73rd Meeting of the GOR Working Group "Mathematical Optimization in Real Life"

- Optimization Services in Europe -

"Network Design and Optimization of complex many-to-many logistical networks for express and parcel service providers"

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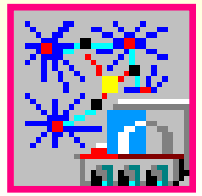
Contents

Company Portrait: Our Products

- PRODISI (SCO / CEP)

  Analysis and optimization of complex logistical networks

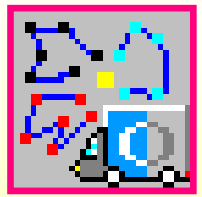
  - industrial supply chain networks
  - forwarder networks
  - CEP systems / network structures
  - ➡ **Consultancy and Software**



- PROTOUR

  Operational and strategical vehicle routing and delivery area planning

  - operational vehicle routing
  - strategical planning of delivery (tour) areas
  - ➡ **Consultancy and Software**



Company Portrait: System History

- Development of planning algorithms for industrial supply chain networks since 1985 (Prof. Dr. Bernhard Fleischmann, Universities of Hamburg / Augsburg, Germany)
- Further development towards the database-driven software system PRODISI SCO since 1994 (PROLOGOS)
  - numerous applications for industry and logistics service providers
  - numerous installations in different companies with different kinds of distribution / network design problems
- Continuous enhancement of the system and the incorporated algorithms with regard to
  - the users' needs and
  - our own experience of the tool employment within consultancy projects
- Development of PRODISI CEP for parcel service network planning and design since 2000
  - developed in close cooperation with and used by global CEP service providers
  - application for various international CEP network design projects
  - proven to deliver realistic results, e.g. linehaul, P&D areas
  - continuous enhancement

Company Portrait: Our References

- Bahlsen
- CSM Bakery (MeisterMarken)
- DACHSER
- DaimlerChrysler
- Deichmann
- Deutsche See
- DHL Express / DP Euro Express
- DHL Solutions (Danzas)
- DPD Deutscher Paket Dienst
- Electrolux / AEG Hausgeräte
- Hellmann Worldwide Logistics
- Holsten Brauerei
- Honold Logistik
- Intersnack
- Alfred Kärcher
- Kellogg
- Linde Gas
- Lorenz Bahlsen Snack World
- Minolta
- M-Preis
- Schöller
- Unilever Bestfoods
- Wincanton (P&O)
- …

Forwarder and CEP Networks

Similarities

- direct links

  customer - consignee, customer - depot, depot - consignee, depot - depot

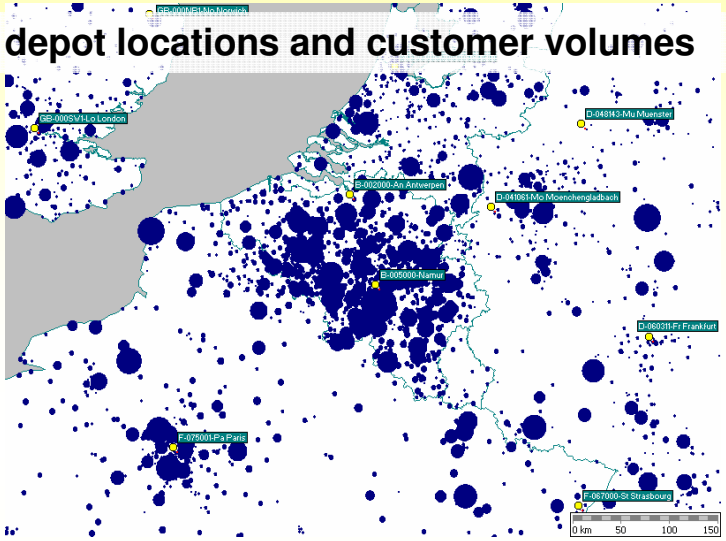
- system links
  - **pickup:** customer - pickup depot
  - **linehaul:** pickup depot - hub / consolidation depot - delivery depot
  - **delivery:** delivery depot - consignee

Differences

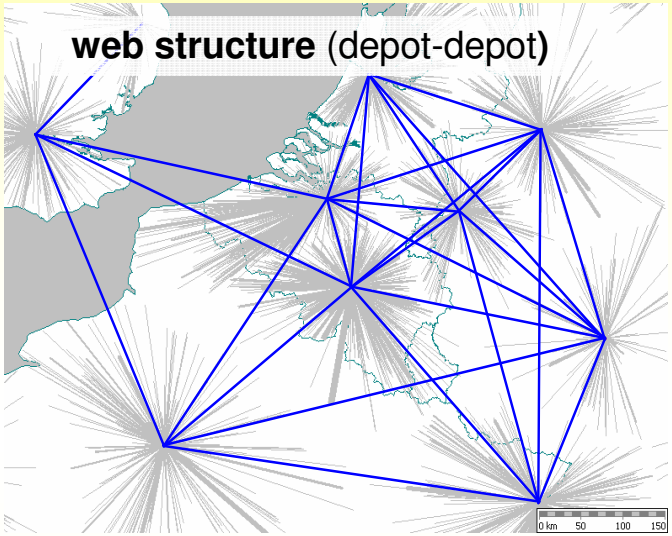
	Forwarder	CEP
Product	**inhomogeneous (pal., partial load)**	**homogeneous (parcel)**
Service Level	**individual**	**standardized and time critical**

Network Design: From customer volume to optimized network structure

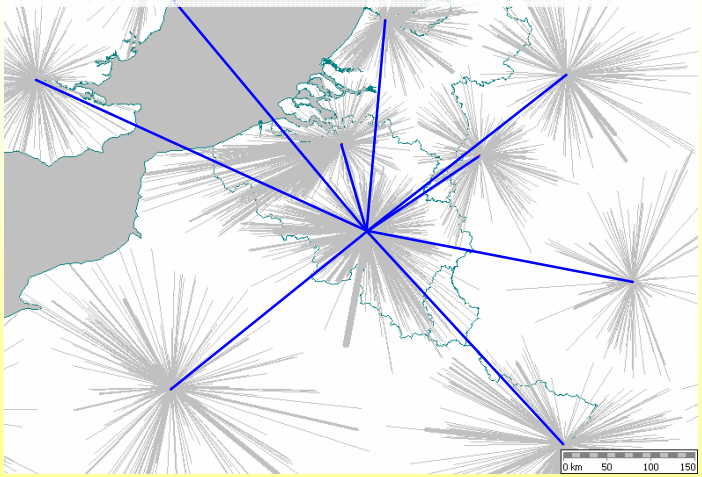
depot locations and customer volumes



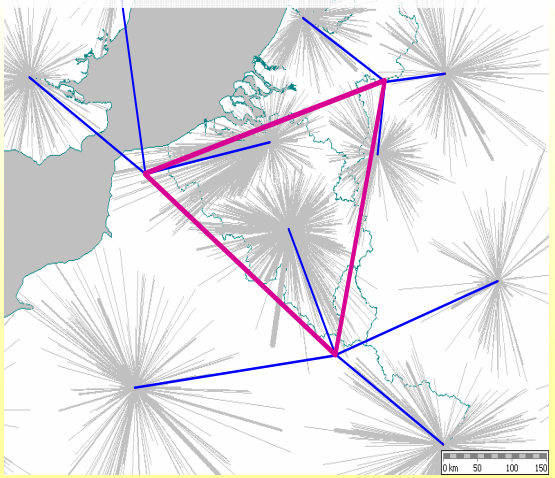
web structure (depot-depot)



one hub structure (depot-hub-depot)



three hub structure (depot-hub [-hub]-depot)

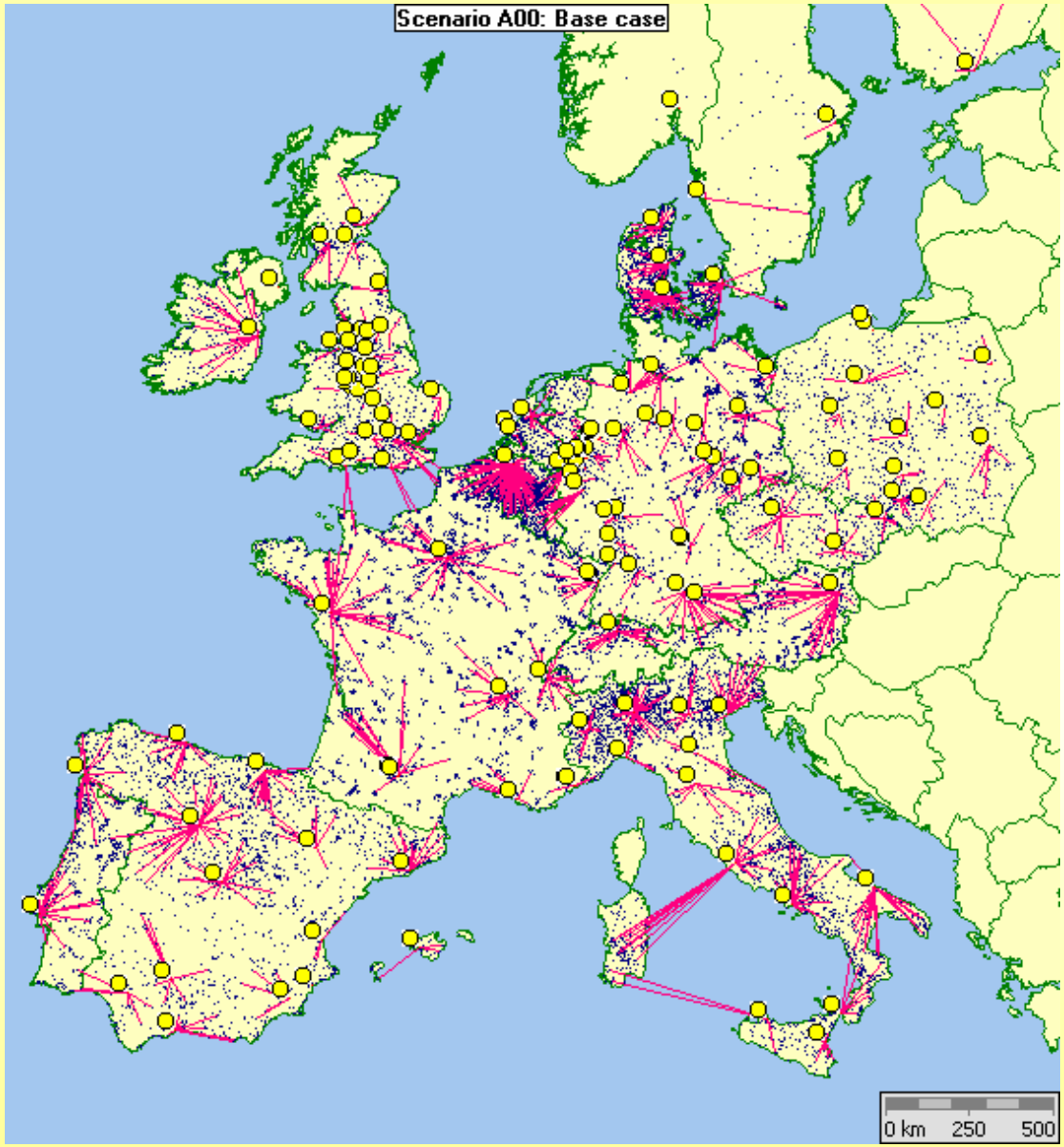


Network Design

- number, location and function of facilities
- definition of pickup and delivery areas
- dimensioning of sorting / throughput capacities (incl. peaks)
- definition of products and service levels

Linehaul Planning

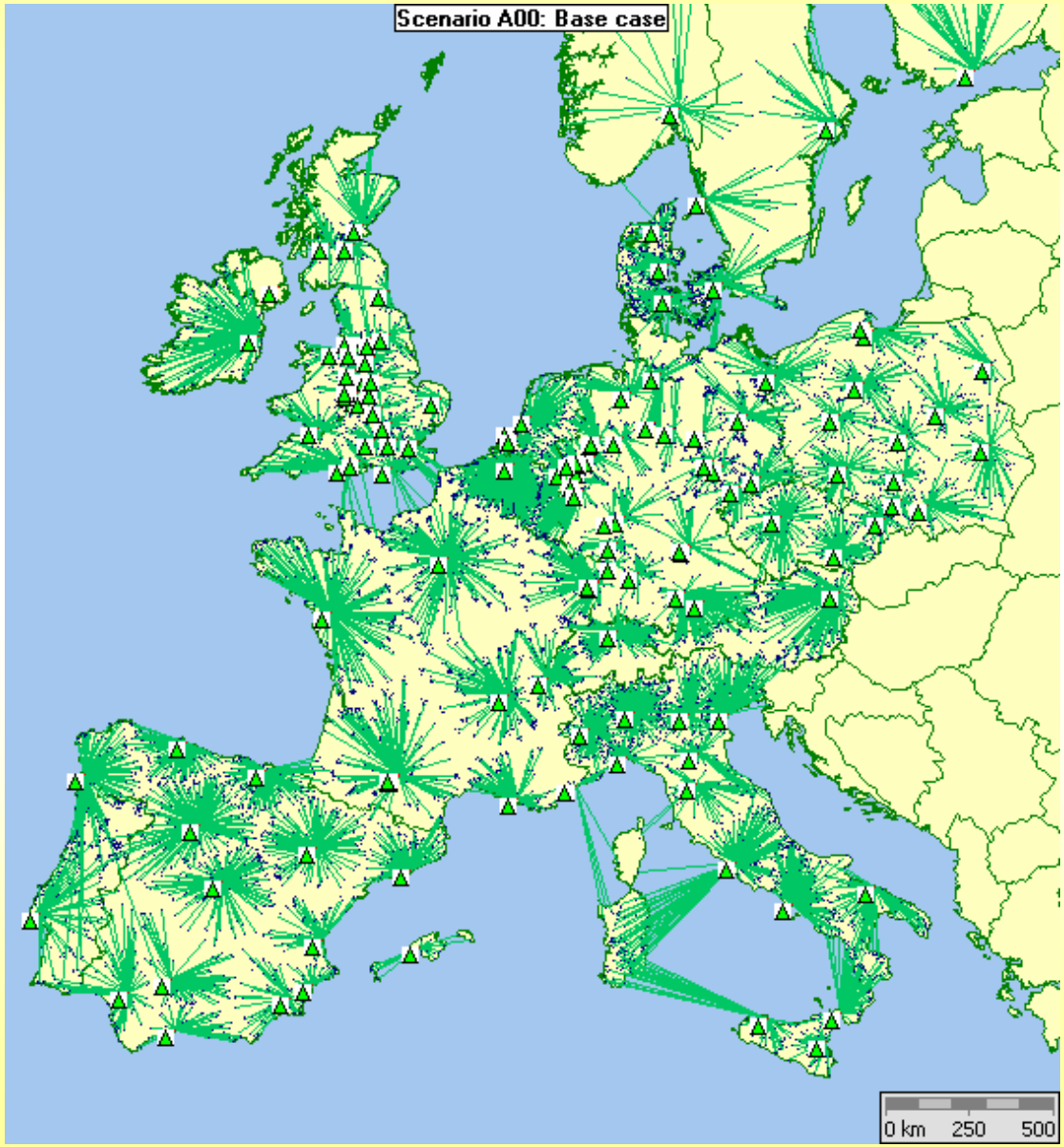
- number and type of vehicles between facilities (truck movements)
- decision about direct / non direct links
- routing based on volume and product
- scheduling of transports
- continuous adaptation to changes in volume



Case Study (Base Case)

Pickup Input Data

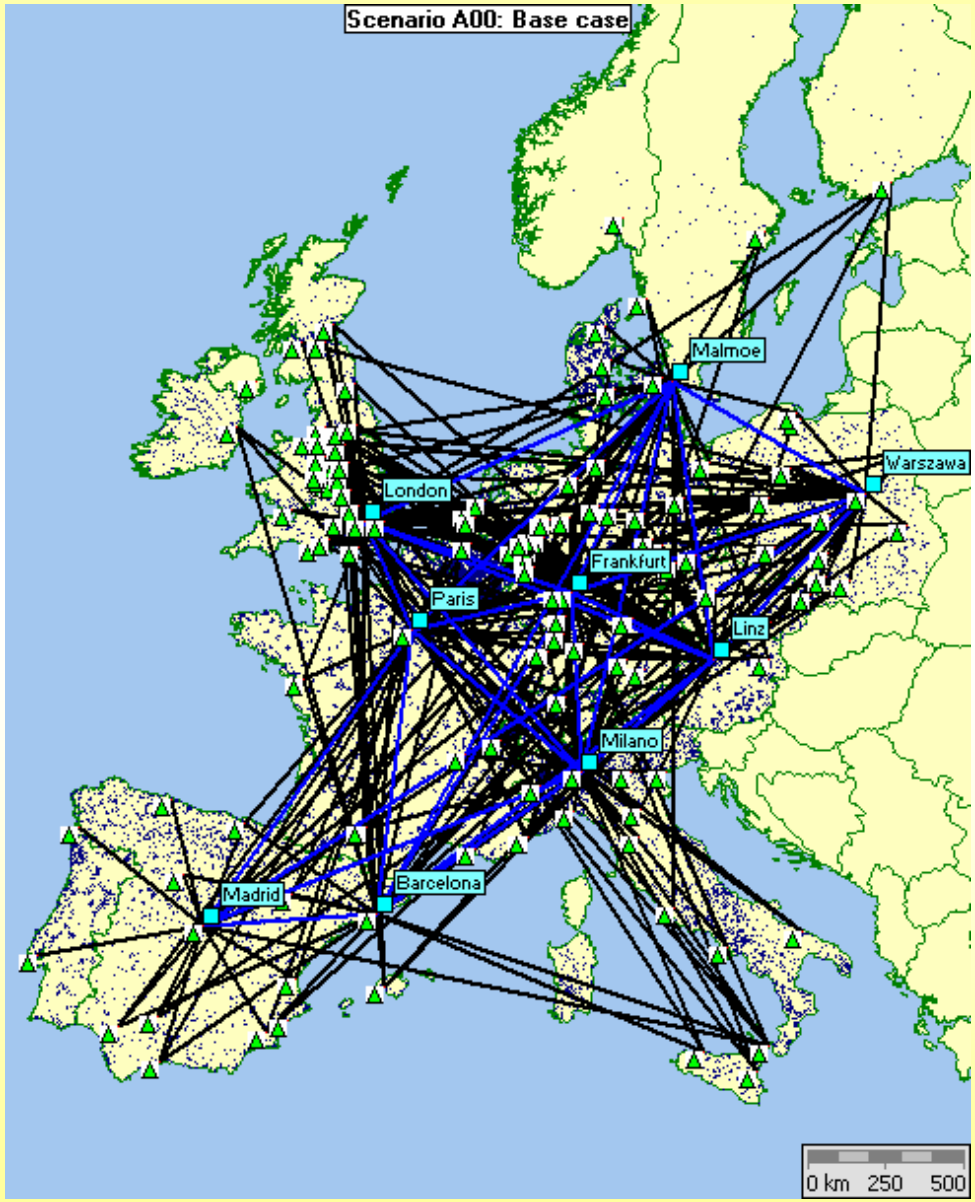
19	countries
1.342	pickup customers
1.342	pickup shipments (one day) with given customer-to-site allocation
2.442	tons (weight)
5.390	pallets
95.698	parcels
143	pickup depots



Case Study (Base Case)

Delivery Input Data

19	countries
24.460	consignees
23.831	standard product &
4.351	Pre12 product delivery shipments (one day) with given site-to-customer allocation
144	delivery depots



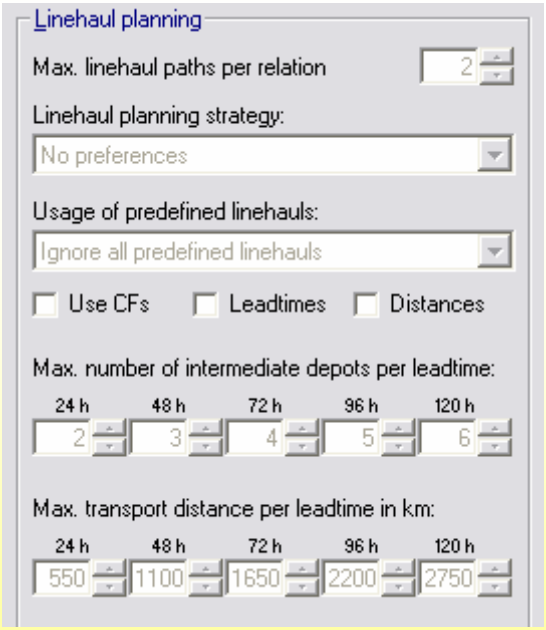
Case Study (Base Case)

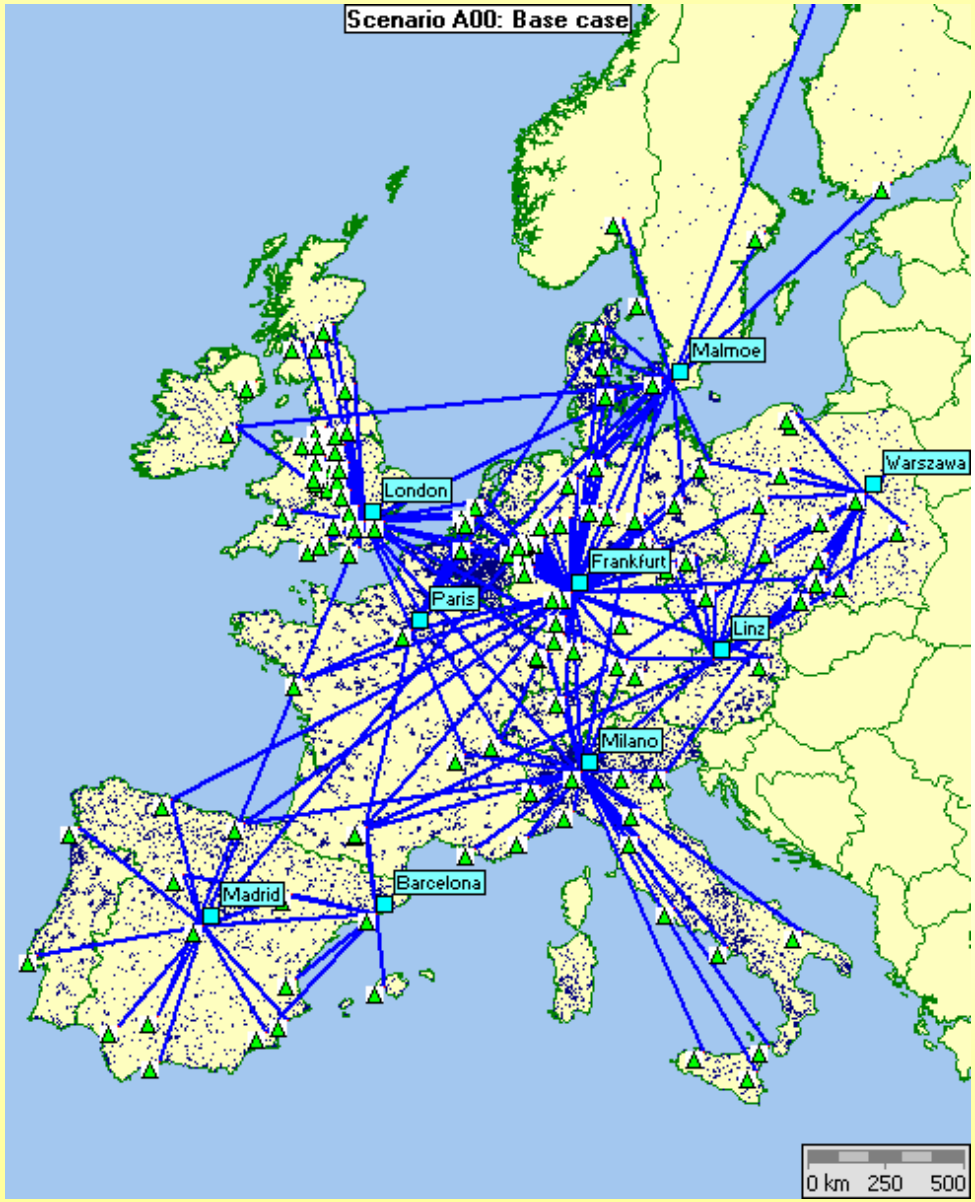
Pre-optimized hub structure

(pickup depot – hub [– hub])

with respect to

- 9-hub structure
-





Case Study (Base Case)

Pre-optimized hub structure

(hub - delivery depot)

with respect to

- leadtime settings

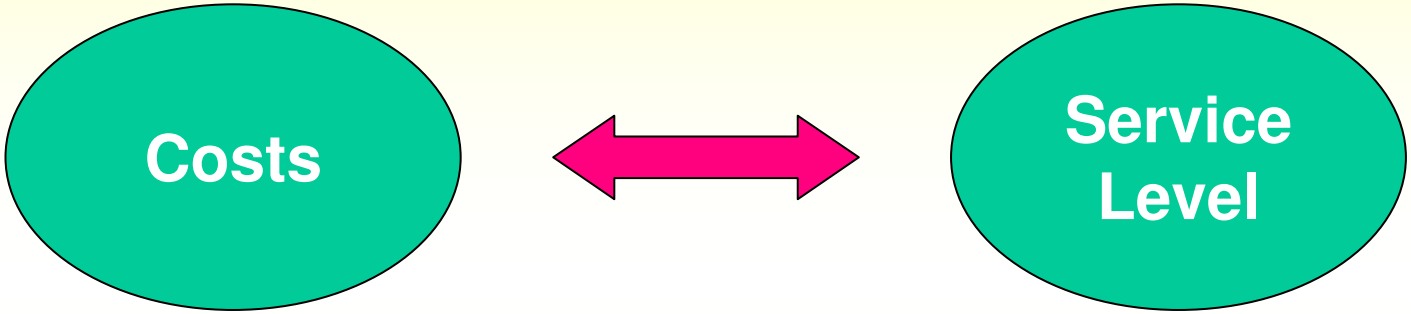
Product leadtimes

	No	PG	PG name	Radius 24h	Percent 24h
▶	1	A	Express Paket	500	100

Rad. 48h	Perc. 48h	Rad. 72h	Perc. 72h	Rad. 96h	Perc. 96h
1.000	100	2.000	100	9.999	100

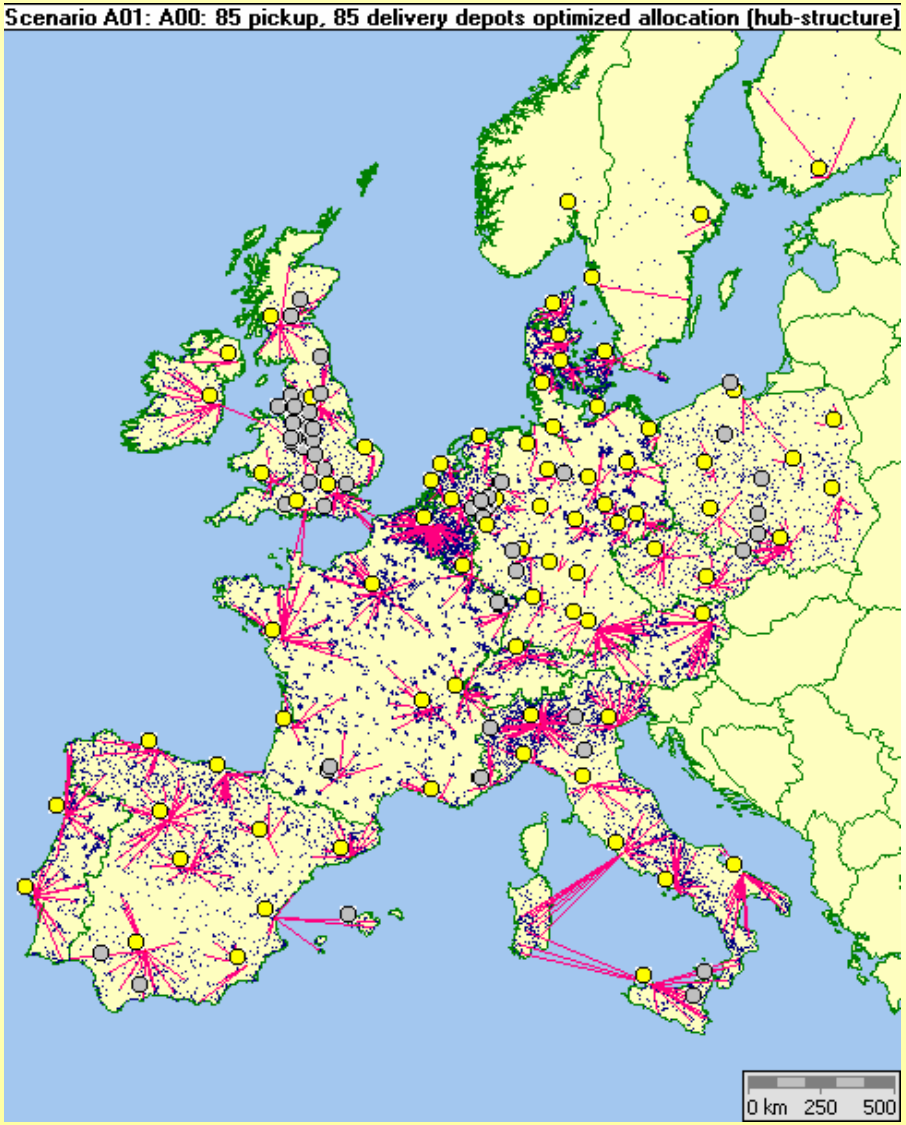
[also possible: Express-parcel latest 6:00 a.m. at DD]

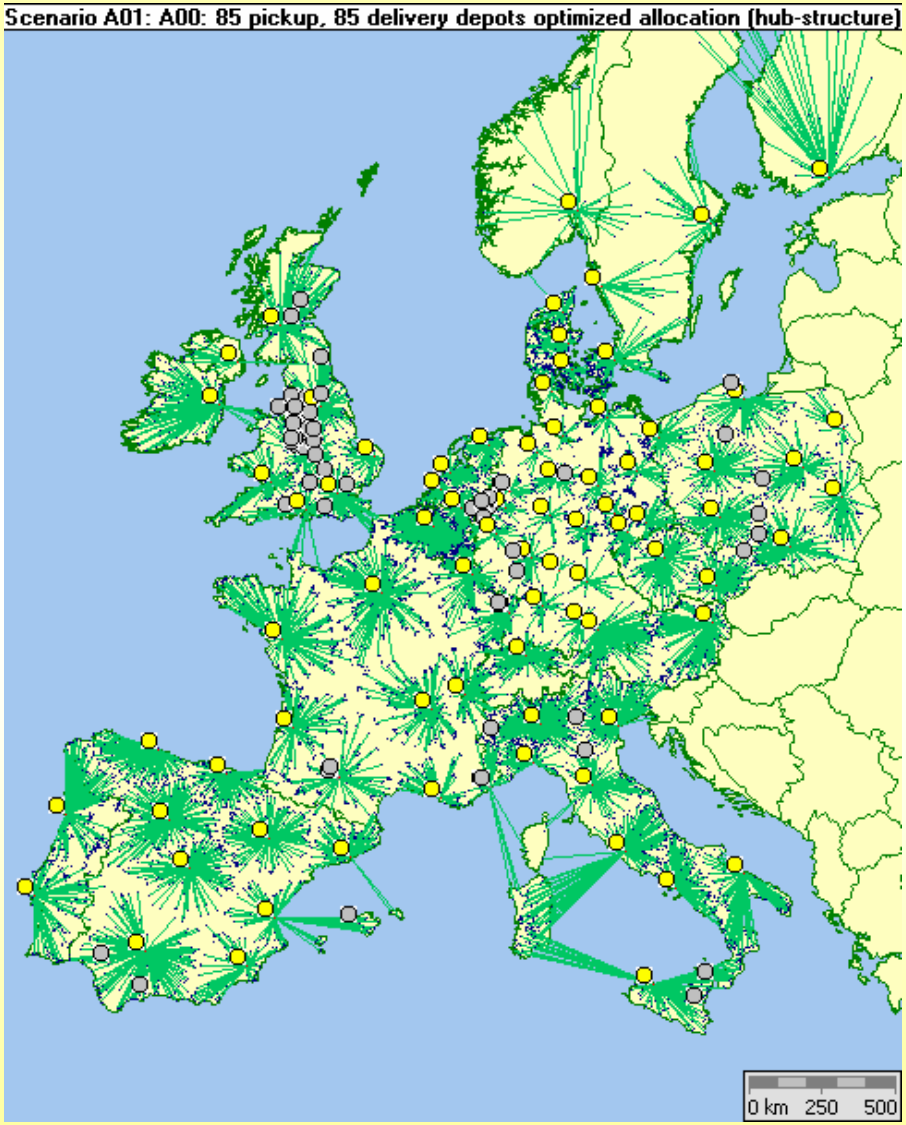
Conflict Between Objectives

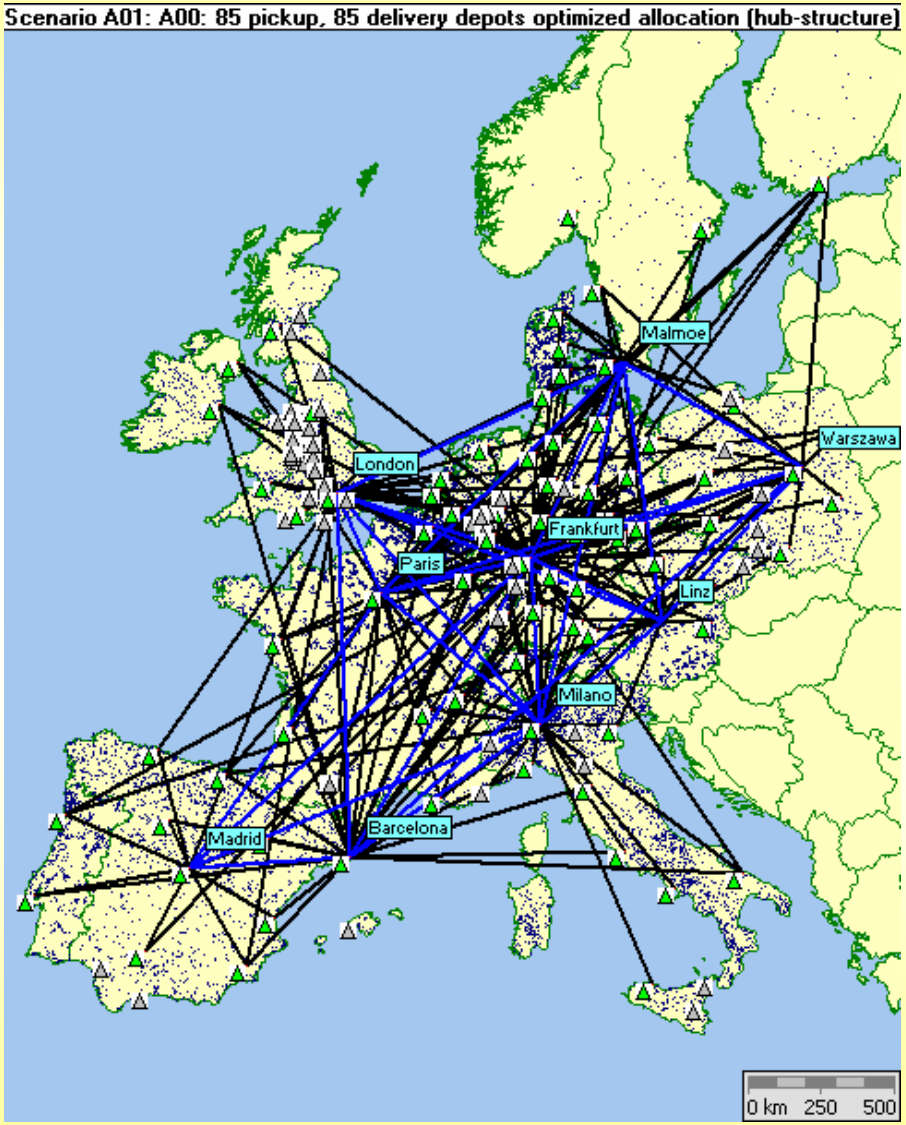


- few facilities
- consolidation of transports
- few direct links
- huge containers/trucks
- huge depot areas

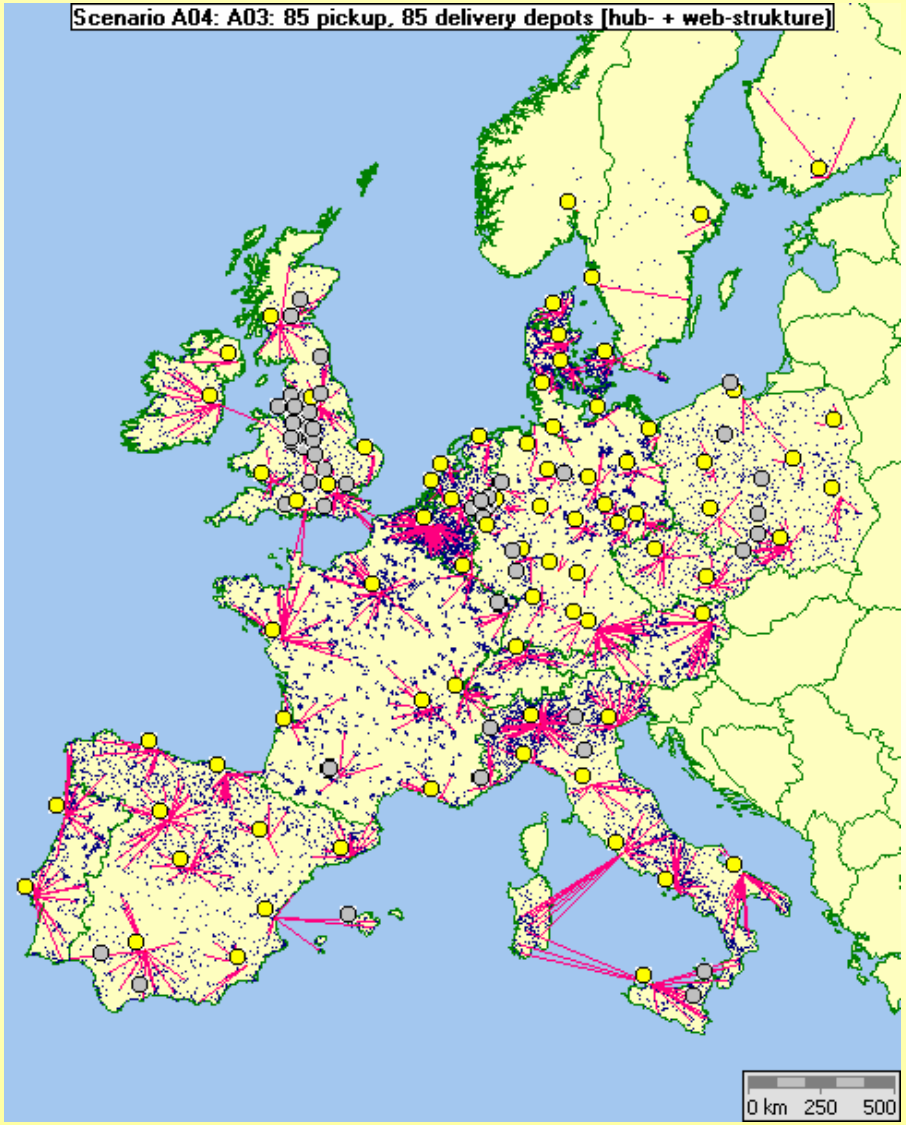
- short leadtimes
- high service reliability
- many direct links
- small and fast vehicles
- small depot areas

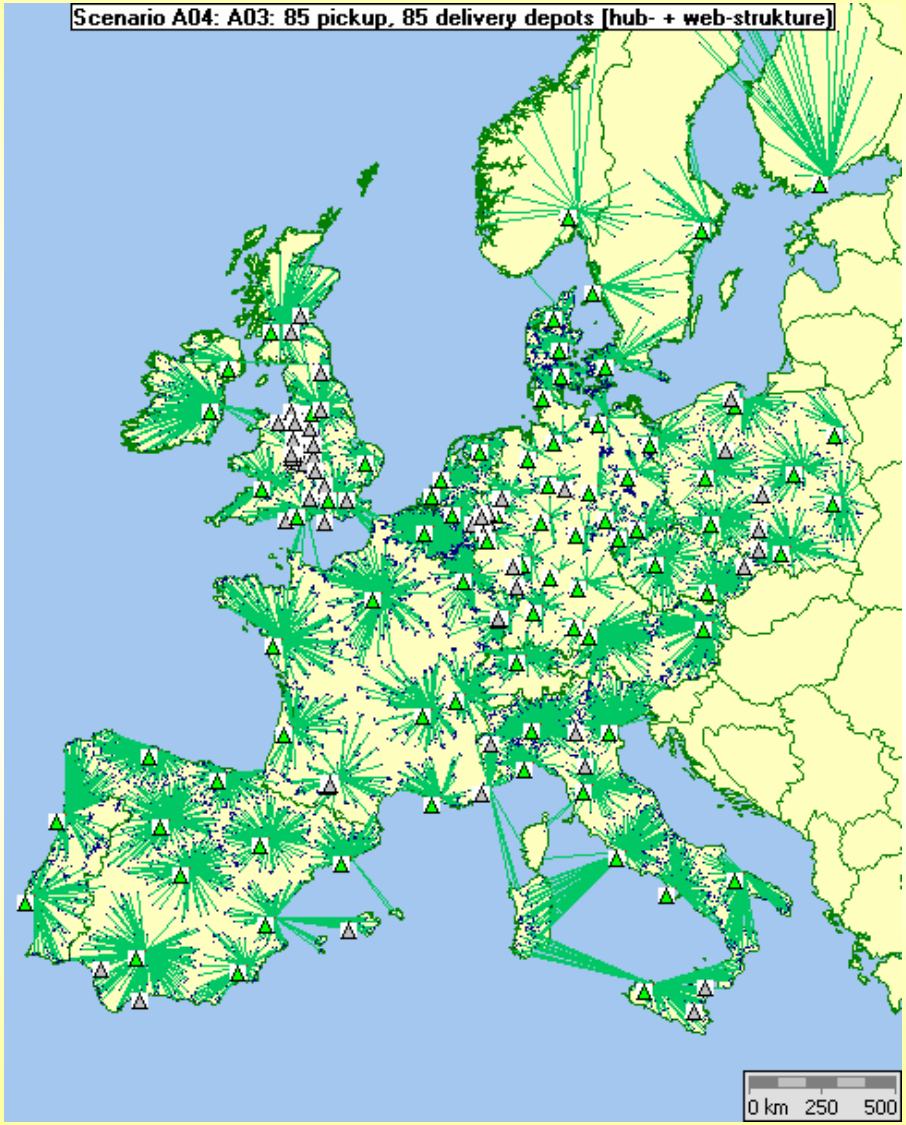

Scenario A01: A00: 85 pickup, 85 delivery depots optimized allocation (hub-structure)
0 km 250 500

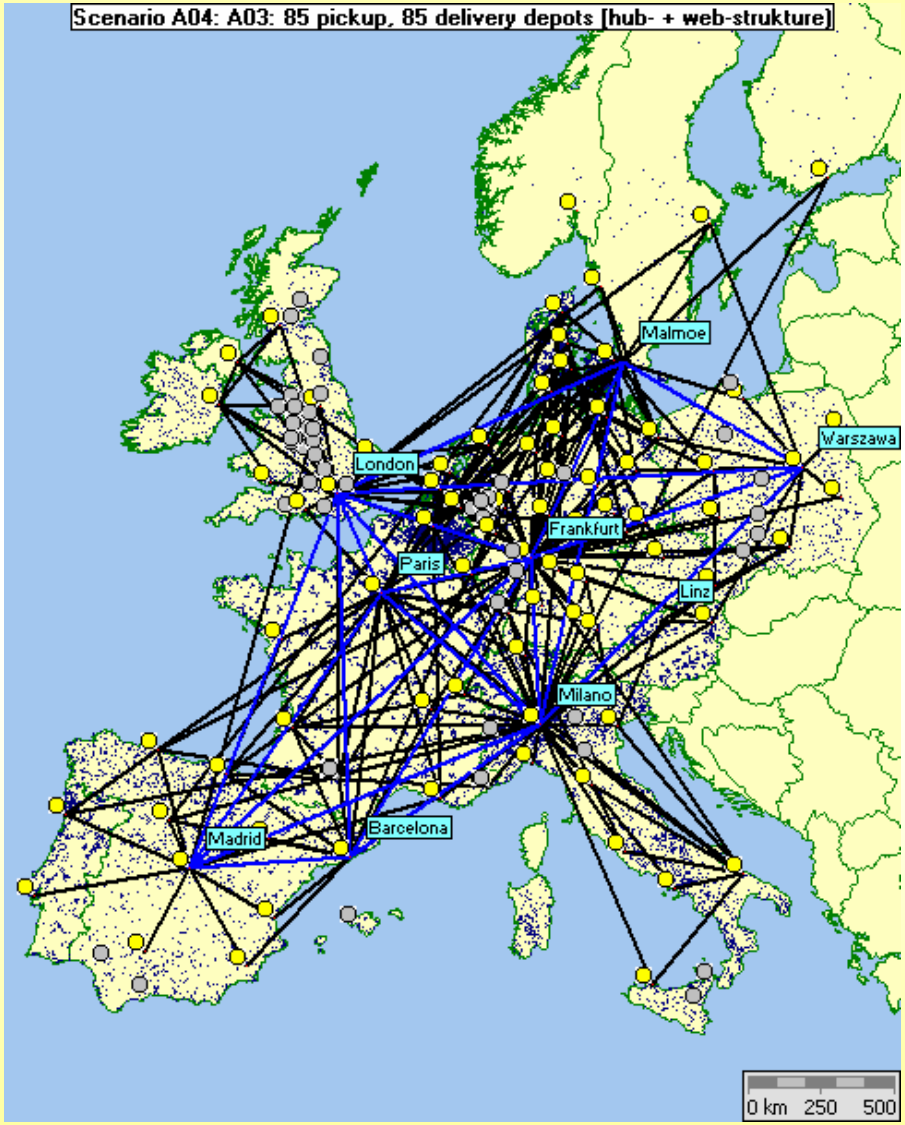

Scenario A01: A00: 85 pickup, 85 delivery depots optimized allocation (hub-structure)
0 km 250 500


Scenario A01: A00: 85 pickup, 85 delivery depots optimized allocation (hub-structure)
Malmoe
Warszawa
London
Frankfurt
Paris
Linz
Milano
Madrid
Barcelona
0 km 250 500


Scenario A01: A00: 85 pickup, 85 delivery depots optimized allocation (hub-structure)
Malmoe
Warszawa
London
Frankfurt
Paris
Linz
Milano
Madrid
Barcelona
0 km 250 500


Scenario A04: A03: 85 pickup, 85 delivery depots [hub- + web-strukture]
0 km 250 500


Scenario A04: A03: 85 pickup, 85 delivery depots [hub- + web-strukture]
0 km 250 500


Scenario A04: A03: 85 pickup, 85 delivery depots [hub- + web-strukture]
Malmoe
Warszawa
London
Frankfurt
Paris
Linz
Milano
Madrid
Barcelona
0 km 250 500


Scenario A04: A03: 85 pickup, 85 delivery depots [hub- + web-strukture]
Malmoe
Warszawa
London
Frankfurt
Paris
Linz
Milano
Madrid
Barcelona
0 km 250 500

Scenario A00: Results summary

t | A04 | Absolute

	Result item	Scen. A00	Scen. A01	Scen. A04
	Description	Base case	A00: 85 pickup,	A03: 85 pickup,
⊟	**Costs [10³EUR]**			
	Total	**879,154**	**751,504**	**731,530**
	Pickup	27,563	27,377	27,377
	Linehaul	395,510	275,047	257,499
	Delivery	418,917	417,860	417,860
	Handling/Sorting	37,164	31,220	28,794
⊟	**Cost details [10³EUR]**			
	Transport SD -> SD			
	Linehaul PD -> HB	221,451	129,163	87,424
	Linehaul HB -> HB	80,371	61,542	66,243
	Linehaul HB	301,822	190,705	153,667
	Transport SD -> VD			42,422
	Linehaul HB -> DD	93,688	84,342	61,410
	Linehaul DD	93,688	84,342	103,832
	Linehaul TOTAL	**395,510**	**275,047**	**257,499**
	Handling P&D PD	0,000	0,000	0,000
	Handling/Sort. SD			
	Handling/Sort HB	37,164	31,220	28,794
	Handling P&D DD	0,000	0,000	0,000
	Handling/Sort TOTAL	**37,164**	**31,220**	**28,794**
	Pickup PD -> Customer	27,563	27,377	27,377
	Delivery DD -> Custome	418,917	417,860	417,860
	P & D TOTAL	**446,480**	**445,237**	**445,237**
	Costs TOTAL	**879,154**	**751,504**	**731,530**
⊞	Cost rates [EUR/...]	**381,450**	**389,500**	**413,790**
⊞	Cost rate details [EUR/...]			

Scenario A00: Results summary

t | A04 | Absolute

Result item	Scen. A00	Scen. A01	Scen. A04
Quantities			
Total	**2.304,739**	**1.929,404**	**1.767,862**
Pickup	1.221,536	1.221,536	1.221,536
Linehaul	2.304,739	1.929,404	1.767,862
Delivery	1.221,536	1.221,536	1.221,536
Handling/Sorting	2.304,739	1.929,404	1.767,862
Quantities details			
Service level PD-DD (per leadtime)			
Total	**96,7%**	**97,3%**	**97,6%**
24 h	88,8%	84,5%	90,7%
48 h	98,2%	99,0%	97,9%
72 h	97,5%	99,7%	98,9%
96 h	98,9%	99,8%	99,7%
120 h	100,0%	100,0%	100,0%
Service level PD-DD (per product)			
Service level PD-DD (accumulated)			
Service level PD-Cust. (per product)			
Key Performance Indicators			
# Pickup depots	126 (143 active)	84 (85 active)	84 (85 active)
# Delivery depots	141 (144 active)	85	85
# Hubs	9	9	9
# Shipments	28.209	28.209	28.209
# Pickup stops	1.342	1.342	1.342
Total volume	6.526,8 cbm	6.526,8 cbm	6.526,8 cbm
Total handled volume			
# Pickup vehicles	71	69	69
Pickup driving distance	19.538 km	19.358 km	19.358 km
# Delivery vehicles	894	890	890
Delivery driving distance	342.008 km	341.052 km	341.052 km
# LH vehicles			
LH driving distance			
LH utilization			

PRODISI CEP Algorithm

Objective: To minimize costs

- **transportation costs**

  (pickup & delivery incl. fleet size and performance, linehaul, …)

- **handling costs** (loading, unloading, sorting)

all cost data per relation, site, product, type of vehicle, item (unit)

w.r.t.

- **time** (driving time, shifts of depots (up to three with breaks),

  thresholds (in percent of the capacity) for the departure of the first container, …)

- **number and capacities of gates and sorters**

- **service** (leadtimes, number of intermediate depots per leadtime)

for each product

PRODISI CEP – Iterative Algorithm

A1

- choose optimized layouts (iterative, if necessary);
- build a net structure with the defined layouts, relations and cost functions;
- calculate the travel distances and times based on a road map;

A2

- determine an optimized flow:

  computation of shortest paths (based on costs) for all relations
  (= pickup depot to delivery depot for each single product) w.r.t.

  - available volumes at the pickup depot at departure time
  - leadtime requirements per relation *(➡ limitation of possible paths)*
  - capacities and shift times at intermediate depots and hubs
  - type of vehicles (capacities, costs, speed profiles)
  - capacities and shift times at the delivery depot
- Post-optimization: consolidation of containers, computation of schedule, assignment of inbound trucks to unloading gates;
- store the results of this iteration if they are the best so far;

PRODISI CEP – Iterative Algorithm

if the number of iterations lower or equal to a given number of iterations ***than A3***

- local linearization of the costs (especially for linehauls)
  to change the values of the decision variables,
  for details to the solution procedure see Fleischmann, Bernhard (1993), *European Journal of Operational Research* 70, 31 - 42 and there references;
- continue with A2;

else A4

- output and presentation of the results.

Simulation Model for Vehicle Routing (P&D)

Estimate the number of tours, driven kilometers and total tour durations via

Data:

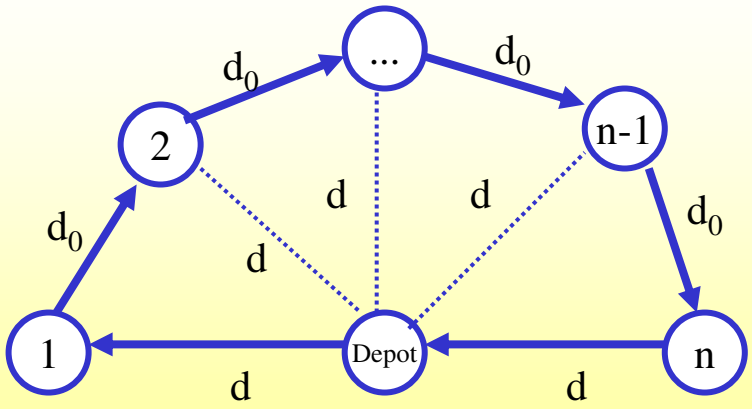
- truck capacity
- maximum tour duration per truck
- pickup/delivery time per stop (according to shipment size)
- distance between two customers d_0
- average speed
  - to first customer
  - between customers
- costs per driver and vehicle per day
- costs per kilometer
- costs per stop
- additional parameters

There are different values for distance and speed according to the type of destination as rural, urban etc.

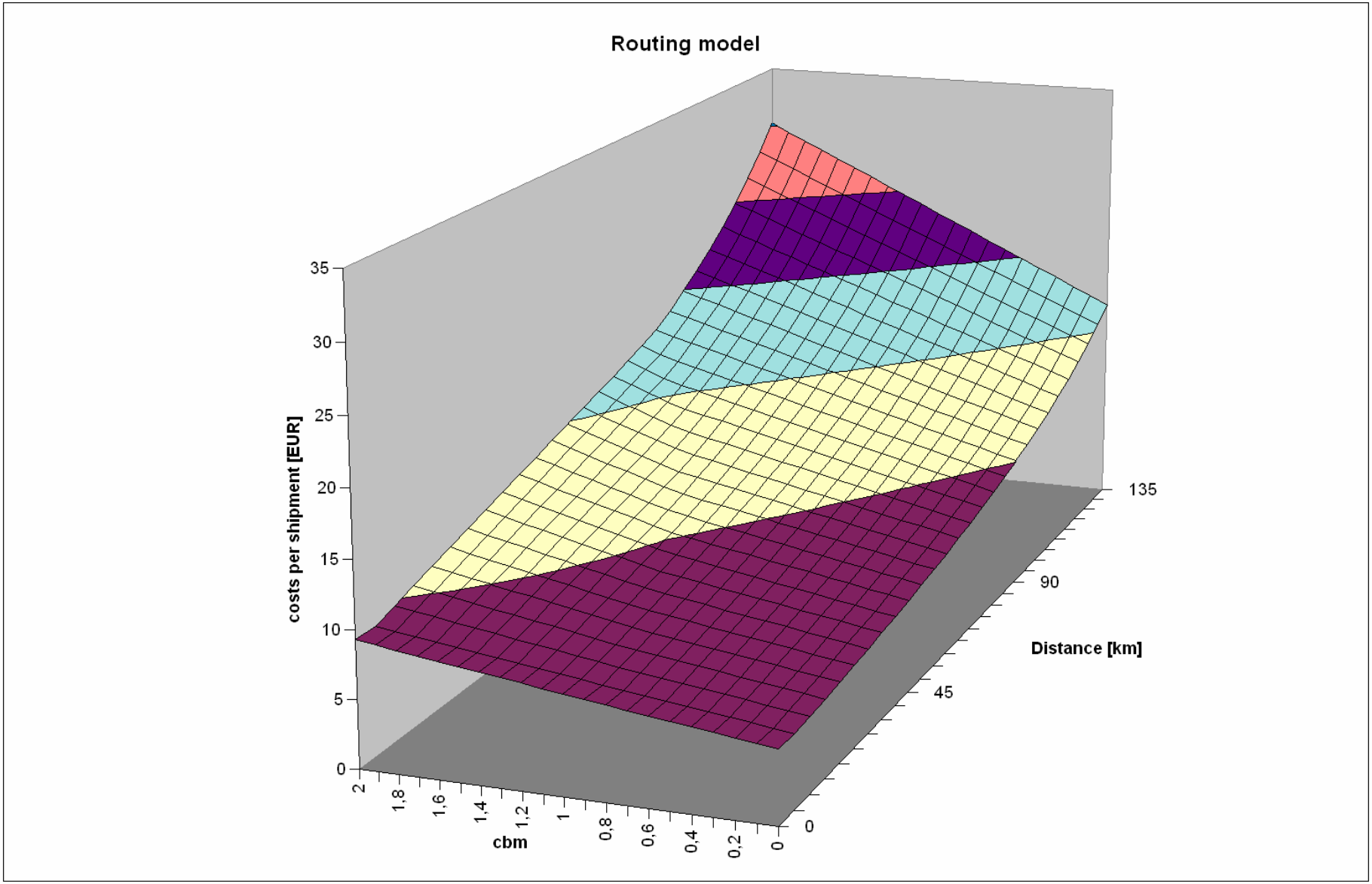
Calculation:

For each single shipment with amount q and (direct) distance d from a depot a tour with identical shipments with respect to capacities and time restrictions (maximum tour duration) of a truck will be calculated.

-> costs, times and km per shipment



Parameters for pickup and delivery tours (excerpt)	Values	Unit
…		
Vehicle capacity countryside	8.100	cdm
Vehicle capacity small towns	8.100	cdm
Vehicle capacity large towns	8.100	cdm
Vehicle employment time per day (default)	600	Minutes
Vehicle fixed costs per day	6.000	0,01 EUR/day
Driver fixed costs per day (default)	20.000	0,01 EUR/day
Costs per kilometer	55	0,01 EUR/km
…		
Fixed stop time	60	Seconds
…		
Variable stop time per volume (cbm)	2.400	0,1 Seconds/cbm
Variable stop time per pallet	0	0,1 Seconds/pallet
…		
Average stop distance (default)	100	0,1 km
Speed for drive to 1st stop	60	km/h
Average speed on tour	47	km/h
…		



7,5 t (capacity = 28 cbm; driver = 150,- EUR/day; fix costs = 35,- EUR/day; variable costs = 0,35 EUR/km; max. tour duration = 5,5h; stop time = minimum 3 min + 3,3 min/cbm)

Optimization Algorithm – Pickup and Delivery Tours

- fast calculation of costs per shipment (delivery) resp. per stop (pickup) on a tour for all possible assignments to depots w.r.t.
  - max. service area per depot
  - feasible products per depot
  - shipment weight (volume, number of pallets, …) and distance between depot and customer
  - ...

  using a simulation model for vehicle routing (”Ring model”, Prof. Dr. Fleischmann (1979))
- assignment of each shipment to the “best” depot w.r.t.
  - costs for pickup, linehaul and delivery
  - leadtimes
  - capacities
  - ...
- post-optimization (not included in PRODISI CEP)
  - using a vehicle routing tool for the calculation of standard tours