

Report of the study trip in Germany



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1. About the trip

Every year the Transport Department of Civil Engineering of the university of Rome La Sapienza organizes a study trip in other Countries to meet other realities concerning the transport activities. This year this trip was set in the week 11th-17th Febraury 2018, in Germany, travelling between 3 important German cities [Figure 1]:

- Munich, the capital of the Bavaria Land;
- Hamburg, the capital of the homonym Land;
- Berlin, the capital of Germany and of the Berlin Land.



Figure 1: The trip

The visits in these cities were so organized:

DAY	PLACE	VISIT
Monday 12 th February	Munich	DB Operational Center Info center 2.Stammstrecke
	Hamburg	Boat Tour of Hamburg Port
Tuesday 13 th February	Hamburg	Meschen Marshaling Yard
		Alternwerder Terminal
		Miniatur Wunderland
Wednesday 14 th February	Berlin	Rail Logistics Centre Wurstermark
		Trafö and Linde Company
Thursday 15 th February	Berlin	STADLER Company
		Technisce Universität of Berlin
Friday 16 th February	On Train	VDE 8 Project
	Munich	DUSS Terminal



Figure 2: ICE Train

The movings between the three cities were done by Intercity Express (or ICE), the German high speed trains [Figure 2], operated by the Deutsche Bahn (or DB), with a maximum speed of 280 km/h, but allowed only to reach a speed of 250 km/h, connected to a voltage of 15 kV.

Instead the trips inside the cities or in their neighborhoods were done by private bus (for example in Hamburg) or by public transport (with buses, U-Bahn and S-Bahn).

The group of this trip was so composed:

-)] 2 Professors of the University of Rome La Sapienza;
-)] 2 Researchers of the University of Rome La Sapienza;
-)] 2 External People;
-)] 10 Students of 5 different Countries.

During the week, there were also other people that have been part of the group, working for several rail companies among Germany and Austria.

In Appendix A it's possible to see the complete plan of the study trip, taking in account also the timetables of the movements with the public transport, while in Appendix B some brief information about the visited cities and their transport system are reported.

In Appendix C the timetables of the trains used during the trip are reported. During the travel back to Italy, a passenger train has had a technical problem between Gallese and Capena at 8 am: this has caused several delays for all the trains on the high speed line between Firenze and Roma (the so-called *Direttissima*) because they were forced to deviate on the old line connecting the two stations on which the speed is lower (the so-called *Linea Lenta*): because of this, the NJ 295 has had 2 hours of delays, arriving in Roma Termini at 11.30 instead of 9.30: in Appendix D the analysis of the delay of this train is reported.

2. Monday 12th February 2018

MUNICH

DB Operational Center

The center is located near the station of Donnersbergerbrücke, in Munich [Figure 3]. It's managed by DB NETZE. It's one of the 7 operational center in Germany and it's composed by two main buildings: the building of the offices and the one of the command center.

It manages 6000 km of tracks inside Bavaria on which they run 11000 trains each day, carrying 1.2 millions of passengers. The importance of this center grows up in the morning, because, together with the Hamburg Operational Centre, it represents an important node for rail traffic management, managing the over-400 companies inside the Country.

In the center there are 62 signal operators (handling the Electric Signal Boxes), 15 dispatchers and 6 operators for the Failure and Solution Centre. There are also people involved in the administration of the provided services and of the electronic components.



Figure 3: The building of the DB Operation Centre

In total the center counts 117 employees.

The center utilizes two types of technological systems:

- TIME-DISTANCE LINES: dynamic representation of a train as a line, comparing the desired values with the actual ones;
- TRACK-MIRROR: global view of the stations and the trains.



Figure 4: A command position

The center has the following tasks and functions:

MAIN TASKS	
<i>Dispositions</i>	<ul style="list-style-type: none">) Coordination and responsibility of all trains; <ul style="list-style-type: none">) Quality management;) Compensating measures;) Organize and control construction;) Order emergency equipment;) Create timetables.
<i>Customer Services</i>	<ul style="list-style-type: none"> ▪ Contact partner for all companies; ▪ Provide information in case of delays; <ul style="list-style-type: none"> ▪ Provide current position.

FUNCTIONS	
<i>Shift Coordinator</i>	<ul style="list-style-type: none"> ○ Responsible for the entire area; ○ Communication with superior instances; ○ Final decision during disputes.
<i>Territorial Dispatcher</i>	<ul style="list-style-type: none"> ❖ Contact partner for the railway companies and the Netzeentrale; ❖ Realization of short term diversions; ❖ Analysis and control of delays.

To obtain the data, the system has a semi-continuous exchange of information between the trains and the center through loop circuits.

On each control location, there are 2 screens for each technology system [Figure 4]: for the dynamic diagram, THALES software is used, while for the track-mirror a SIEMENS one is installed.

Some colors are used to identify the utilization of a track and the trains:

- GREEN: Route setting;
- YELLOW: Running train;
- RED: Blocked section;
- GREY: Unutilized route;
- BLACK: Closed track.

2. Stammstrecke in München

All the lines of the S-Bahn in Munich run in the 1. Stammstrecke, a tunnel built for the Olympic Games of 1972. In case of a problem in the tunnel, the whole city would be paralyzed: this possible failure and the fact that the maximum capacity of 200000 passengers has been reached have brought the administration of the city to design a second tunnel with only 3 stops, 40 m deep (because of the cellars of the buildings):

- 1) München Hauptbahnhof;
- 2) Marienhof (the only new station);
- 3) München Ostbahnhof.

The construction provides the realization of two branches from the 2 main stations, joining in Marienhof. It started in 2017 and should end in 2026, also contemplating the stop times due to archeological studies (they have been found over 45000 finds from the XIV Century).

The line will be provided with wall against noises and noise absorbing tools. The energy will be provided by a third rail and an ECTS system will be implemented.

The Infozentrum [Figure 5] will let people informed about the works.



Figure 5: 2. Stammstrecke Infozentrum in Marienhof

HAMBURG

Waterways on river Elba



Figure 6: Landungsbrücken

Because of the position of the city, HVV has realized several boat services implemented in the public transport system. The main port of this service is Landungsbrücken [Figure 6], the port from which many liners sailed to America. From the boats, it's possible to have a view of several infrastructures of Hamburg Port [Figure 7]. The boats usually travel at a speed of 15 knots, with an average stop time of 2 minutes because of the docking maneuvers.



Figure 7: View of the port

3. Tuesday 13th February

Maschen Marshalling Yard



Figure 8: View of the Marshalling Area

With an area of 5 km² (7000x700 m), Maschen represents the biggest marshalling yard in Europe [Figure 8], managed by DB Cargo, in which about 1000 employees work for the whole year without interruptions and 47 diesel locos and 200 electric ones run in the center. It owns 2 cargo regions, one direct to North (Hamburg and Scandinavia) and one to the South (Bremen and South Europe): in North direction there are 17 rails for receiving trains and 48 rails for marshalling, while in South direction there are 16 receiving rails and 40 marshalling rail. Each direction has its own hump, dropping the wagons from a height of 2.5 m for a length of 100 m (the slope is 25 ‰). In any case this yard is not the only one in Hamburg region: there is another one near the port that doesn't sort the wagons, but only create a train that will be sorted in Maschen.

The yard utilizes the German system of braking, with 2 brakes during the run of the wagons. Each track is also provided with a roller to push wagons that have not reached the other ones.

Every process is controlled by the IT that manages also the received trains and the destination of every wagon: an employee must control only if there is the exact number of wagons, walking parallel to the train.



Figure 9: Automatic control system

Along the track, there is a control system [Figure 9] that measures the dimensions of the wagon, the weight and the speed, in order to decide the braking force to give to the 2 systems of braking [Figure 10] to reach a final speed of 1 m/s.

The distance between each set of wagons depends on the number of wagons, their length and weight and also on the switch change (0.6 s).

Each wagon stays inside the yard for an average time of 10÷12 hours, because the yard is open 24-7.

There is no snow problem in a range of 10÷15 cm, otherwise the snow must be removed manually.

Maintenance time is not expected because of the high number of tracks.



Figure 10: First and Second Braking System

Altenweder Container Terminal



Figure 11: Model of the port

It's one of the several ports managed by HHLA: it was founded in 1885 and now it bills 1200 million every year, handling 6.7 million of TEU: the only terminal of Altenweder handles 2.6 million of TEU, brought in/out the port with several modes and companies, in which about 750 employees work. The main competitor of Hamburg port is Rotterdam.

This terminal is composed by the quays (able to allocate 4 ships to be served by 14 portainers), the storage area, fully automatized, the receiving area

of the trucks and the receiving area of the trains (this one managing 350 connections every week on 9 tracks and with 4 gantry cranes, covering South and East Europe) [Figure 11]. The empty containers are stored in a different part, near the rail tracks, while the full containers remain in the storage area for 5 days in average.

When approaching the port, the ship is visited by 2 different pilots: the *River Pilot*, bringing the ship from North Sea to the river, and the *Port Pilot*, for the last part. Once reached the quays, the ship is served by the portainers: each portainer needs 4 people: 1 inside the portainer and moving the crane, 1 guiding the crane



Figure 12: AGV

from the ship and 2 locking the container to the crane. After the locking, it starts the full automated part of the storage: the portainer lifts on the container and places it on an Automated Guided Vehicle (or AGV) [Figure 12]. This vehicle will move in a human-free area bringing its load to one of the 26 yard locks in the storage area far 100 m from the berths. The AGV follows a prepared route therefore it's possible to know the exact position of a container.

Each yard lock has 2 fully automated gantry cranes [Figure 13], one serving the sea-side (lifting on/off the container on the AGV) and one serving the land-side.



Figure 13: Gantry Cranes

The dimension of each lock can accommodate 37 container for the length and 10 rows for the width (about 225x25 m). Each crane is equipped with optical sensors for taking the containers. In case of heavy fog, if the system fails twice in bringing a container, the control is passed to a remote controller, with consequent queues.

On the road area between the yard locks and the rails, trucks and not-automated vehicle bringing containers between rail and storage area move. The positioning of the containers on these vehicles is partially automated: the precise positioning is controlled by men.



Figure 14: Battery supplying

Maintenance of the full automated area is guaranteed by controlled partial shutdowns of the structure, while icing problem is solved loading an AGV with a container full of salt and let it run on the area.

In the terminal the batteries of the AGV are also changed, in a building next to the operational center [Figure 14]: the change of batteries instead of refilling them directly on the AGV was chosen because more convenient: in fact each battery is filled till 30÷80%, with a recharging time of about 30 minutes. Inside the building there are 18 charging stations.

Miniatur Wunderland

This is a museum placed inside an old warehouse on the river Elba [Figure 15]. Inside, on two completely full floors and 1500 m² of area, 9 localities and several systems are reproduced, creating a perfect representation of the world. Several transport systems are reproduced too, for example an entire airport or the rail systems of different Countries. Some events occurred in history are also represented (from the eruption of Vesuvius to the accident occurred to Air Canada Flight 143 [Figure 17]).



Figure 15: Miniatur Wunderland Building

What is very impressive is the rail systems implemented inside the area: there are 15400 m of tracks, run by 1040 trains formed by 10000 wagons. It's also reproduced the safety system, with 1400 signals. Like a real train system, all the trains are controlled by an operational center with 50 computers, with software showing the occupation of the routes in every location [Figure 16].



Figure 16: Control Room



Figure 17: Example of miniatures

For 2021, it's expected an expansion of the area, with the opening of the area of Venice. This new opening will increase the area to 2300 m², with an increment of the train system too.

4. Wednesday 14th February

BERLIN

Rail Logistics Center Wustermark

Wustermark rail station was built in 1909 on an area completely empty. It was used to bring trains to Berlin from Hamburg, Bremen, Hannover... It had 2 marshalling area directions and 13 electric signal boxes, powered by a substation placed in the station. After World War II, it was merely destroyed and rebuilt for only one direction. It continues to serve as station till 2000 when there was a redesign of the network. Finally in 2004 DB sold the area that had no other use than rail use. In 2008 it was bought by the private company HVLE: this company, which duties are the transport of heavy and dangerous goods and the logistics for construction, has spent 10 years and 5 million € to restore a complete abandoned area and transform it into the actual biggest private shunting yard in Germany, usable by all the transport companies [Figure 19]. The business idea behind the project is to rent one of the 17 tracks: each track costs 10000 € per year. In this yard it's also provided the repairing and the maintenance of the rolling stocks. The switches are moved manually [Figure 18]. There are many modern locos to push the wagons. There is also an area for loading and unloading of wagons.



Figure 19: RLC Wustermark



Figure 18: Manual Switch

This area is used a lot by DB Cargo, while the first international customer was Polish.

Trafö and Linde Company



Figure 20: Trafö Warhouses

This company realizes devices for handling goods (for example pallets). It was founded in 1990 and manages about 1000 devices per year, with revenue of 32.5 million €. It provides the sale and the rent of equipment, but also the academy for the release of the licenses to use the equipment.

There are future projects into full automatic implementation and E-commerce, developing robotics, incorporating GPS and safety systems inside the devices to reduce the risk.

One of the results of Linde is an automatic warehousing with the help of new technologies (for example drones), realizing the constructions and the services.

A much sold device is the forklift [Figure 21] because it's very customizable and can lift up to 18 t. It's also provided of a control system able to define the maximum reachable height according to the lift weight.

The academy was found in 1991 to train drivers in the use of the devices in order to improve safety: each year about 600 drivers obtain the license. There are courses also for emergency events and refresher courses.



Figure 21: Forklift

5. Thursday 15th Febraury

Stadler Company

The company was founded in 1942 in Switzerland. The boom has occurred in 1987, when the company was bought by Peter Spuhler for the 83%. In 2001 it was built the Stadler building in Pankow, near Berlin [Figure 22].

Nowadays, the HQ is in Switzerland, while there are many locations all around the world (in Germany there are 4 sites), in which they work about 7000 employees.

Pankow division manages the construction of trams and metro trains taking the components from other locations.

The most sold unit is the regional train FLIRT [Figure 23], while there is a project to develop a train able to reach 250 km/h for international trips (the SMILE model). Another sold model is the tram Citylink&Tango



Figure 23: FLIRT

[Figure 24], a 75% low floor tram, using different voltages, available with Diesel or Electric traction.

But the most sold products are the metro trains, someone also fully automated: there are several of them in Berlin metro system, together with several trams. Now the city is planning the implementation of free-catenary tram.



Figure 24: Citylink & Tango Model

Company fleet can guarantee a capacity varying from 150 to 1600 passengers per train, guaranteeing at the same time high speed and low land use, reducing environmental impact.

In this factory [Figure 25], the components are not stored inside the division, but they are ordered when an order is obtained, with long period of constructions.



Figure 25: Stadler Factory



Figure 22: Stadler Company

Technische Universität of Berlin

TU is developed on several buildings inside Berlin, devoted to the disciplines of engineering and applied sciences. There are many labs and many researches carried on inside the faculty.

EURNEX

It was a project to analyze European networks and now, from 2007, it became a group formed by several universities. It has participated in 5 proposals for Shift2Rail in 2017 (it's a way to channel studies in a practical way, formed by 8 founders, among which there are 2 infrastructure managers, and many other associations) [Figure 27].

It has several aims:

-) Knowledge transfer;
-) Facilitate jointed European projects;
-) Research strategy at EU level;
-) Provide cross-modal networking.

There are also 10 poles of excellence (for example the one related to the Operation and Systems Performance developed by the university of Roma La Sapienza and by the TU of Berlin).

There are several EU projects:

- USE IT & FOX: analysis in other fields beyond railways;
- FOSTER RAIL: reinforce the research in transport industries;
- SKILLFUEL: identification of skills and competences for future projects.

Another membership is the European Transport Research Alliance (or ETRA).



Figure 26: TU Building in Ernst Reuter Platz

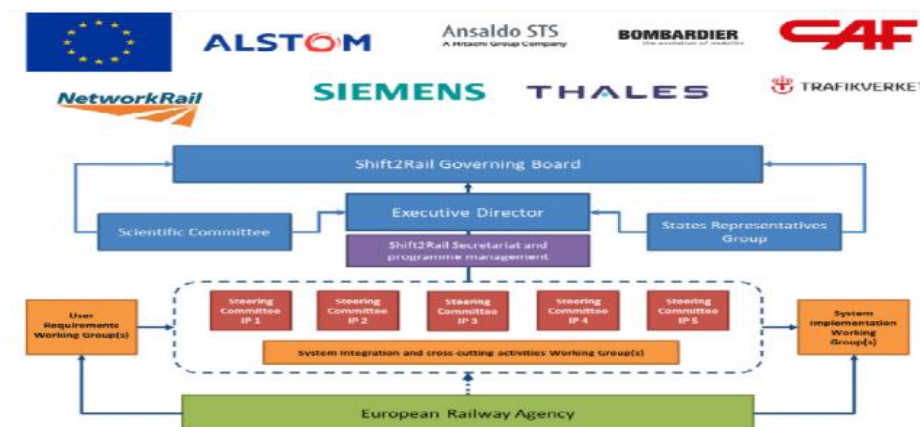


Figure 27: Shift2Rail

ENERGY EFFICIENCY IN RAIL

In Europe, the second cause of greenhouse gas emission is the transport. In Germany there was an increment of this emission of 2% because of the increment of traffic: the aim of the government was to put on the roads 1 million E-vehicles, but that was not possible and, in addition, these vehicles didn't give great advantages.

The main problem is related to the presence of DMU traffic equal to 60% of total traffic. Also heat-loss is important, especially in winter: about DMU, the main cause of loss is related to exhausted gases.

The priorities of the government are:

- Safety;
- Reliability;
- Efficiency.

To obtain these ones, many practices should be adopted:

- ❖ ADOPT CAPACITY: full train and avoid deviations;
- ❖ ELECTRIFICATION WITH BRAKING ENERGY RECUPERATION;
- ❖ REDUCE RESISTANCES;
- ❖ LIGHT WEIGHT CONSTRUCTION.

In practice, some solutions could be the *automatic coupling* and the *electrification with brakes*. This last solution is possible with the new vehicles, but the problem is the presence of traditional substations, not able to take energy from this system.

EXPERIMENTS IN THE LABORATORIES



Figure 28: Klingel Theory Model

This university owns many laboratories in which several experiments related to railways are done. In the division on Salzufferstraße experiments related to the infrastructures are performed, for study purpose and for external researches. There are models of the rails in straight line or in curve on which a scaled wheelset model runs, reproducing the Klingel Theory [Figure 28].

For external research, the university has also a system able to measure the deformation of a rail because of the wear [Figure 29]: it's a system that is posed on the rail, then a sensor runs along the rail measuring the difference between a reference height (imposed at the beginning of the measurement) and the punctual height along the rail, obtaining the graph of the wearing in order to manage the maintenance of the track. This meter is one of the only 3 present in Germany.

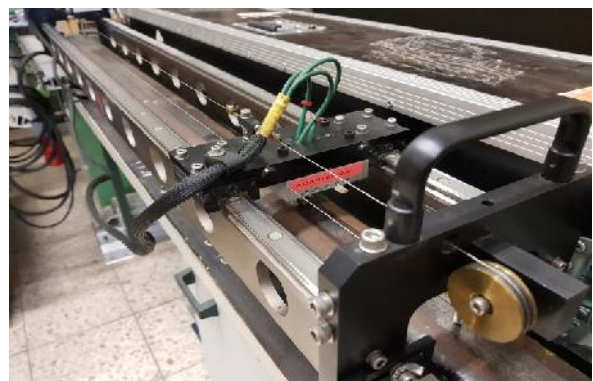


Figure 29: Wearing meter



Figure 31: EBUEF Building

In the Rail Operation & Experimentation Center (the EBUEF) on Bundesstraße studies regarding the operations on railways are performed [Figure 31]. On the outside there are rails and disused signals donated by the DB that retrace the history of German railways [Figure 30].



Figure 30: Disused Signals

Instead inside the building it's build a 2 floor diorama reproducing a rail system on which the different safety system used in Germany are studied [Figure 32]. On this line it's possible to reproduce

3 different safety systems:

-) Manual Electric Block System, with levers and mechanical joints [Figure 35];
-) Semi-Automatic Block System, with buttons and a reproduction of the station full of lights [Figure 34];
-) Automatic Block System, with the use of computers [Figure 33].

Each station and signal is reproduced in a very accurate way and the simulator is used for teaching purpose but also for research studies because it's possible to modify the diorama according to the needs.



Figure 32: Rail Diorama



Figure 35: Manual Block

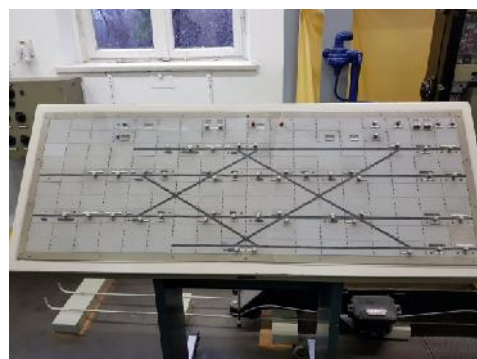


Figure 34: Semi-Automatic Block



Figure 33: Automatic Block

6. Friday 16th February

VDE 8

After 1990, German government has carried on 17 projects among which 9 are related to railways. The VDE 8 is devoted to the construction of a high speed line between Berlin and Nürnberg. In December 2017 it was opened the first section, long 107 km with which it was registered the fastest time ever between Berlin and München under 4 hours, beating the usual time of 6 h and 15 min. The line is controlled by ERMTS and the new fleet of ALSTOM is provided by ECTS on board.

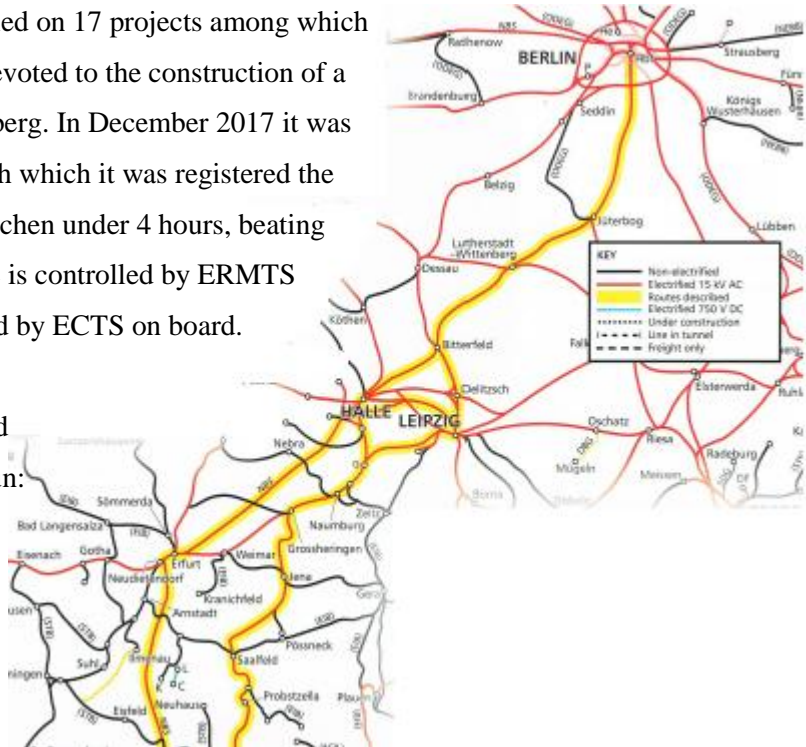
The line is electrified at 15 kV AC.

On the line both passenger trains (ICE and Regional Trains) and freight trains can run:

the problem is related when

a train passes in one of the 22 tunnels because of the double track line that can cause destabilization when 2 trains pass in the same tunnel at the same time.

The frequency of this new line is 3÷4 trains/h/direction.



MUNICH

DUSS Terminal

This intermodal container terminal (open in 1992) is placed at East of Munich, managed by DUSS (a part of DB Netze) and it's formed by 3 modules in which many truck and train companies operate on a total area equal to 1400x300 m. The terminal is open for the entire year. When a truck arrives, it receives the position of the plant in which it has to go to bring/leave the container [Figure 36]: this is the Module 1.

In Module 2 and Module 3 there are the 14 tracks of the rail system of the terminal: these tracks are long 700 m. On each module there are 2 gantry cranes [Figure 37], able to lift up to 42 t.

During the operations on the trains, the loco is detached and parked in the specific yard: this causes a lack of pressure inside wagon braking systems, so it's needed external air pressure to brake them.



Figure 36: DUSS Truck Terminal



Figure 37: Gantry Crane

In the operational center at the entrance the dispatchers manage the arrival and departure trains and also snow management, provided by the center itself.

In 2018 they are planning to change 2 gantry cranes and buy a new one to improve processes.

In Module 2 and Module 3 there is also the possibility to refill the trains, saving up to 40 minutes per hour. In addition, Module 3 is mono-directional, while Module 2 is bi-directional.

At now, in the terminal the intermodal goods represent the 50% of the total goods. Furthermore, the beer export represents the 10%.

APPENDIX A: The Travel Plan

<i>Departure</i>	<i>Arrive</i>	
		SUNDAY 11th FEBRUARY
	18.15	Appointment in Roma Termini
18.58		<i>NJ294 from Roma Termini to München Hauptbahnhof</i>
		MONDAY 12th FEBRUARY
	8.19	Arrive in München Hauptbahnhof
		<i>S-Bahn from München Hauptbahnhof to Donnersbergerbrücke</i>
9.00	10.00	Visit of DB Operational Centre
		<i>S-Bahn from Donnersbergerbrücke to Marienplatz</i>
10.40	11.40	Visit of 2.Stammstrecke in Munich
		<i>To München Hauptbahnhof</i>
12.00	13.00	Lunch in München Hauptbahnhof
13.18	18.53	<i>ICE 586 from München Hauptbahnhof to Hamburg Hauptbahnhof</i>
		Drop of the luggage in A&O Hamburg Hauptbahnhof
20.10	20.50	<i>Boat Transport from Landungsbrücken to Teufelsbrücke</i>
21.00	22.45	Dinner at Dübelsbrücker Kajüt
23.00	23.30	<i>Boat Transport from Teufelsbrücke to Landungsbrücken</i>
		TUESDAY 13th FEBRUARY
8.00	8.50	<i>Bus transfer to DB Marshelling Yard in Maschen</i>
9.00	11.15	Visit of DB Marshelling Yard in Maschen
11.15	12.00	<i>Bus transfer to Authof Altenweder</i>
12.00	13.20	Lunch in Authof Altenweder
13.20	13.40	<i>Bus transfer to Altenwerder Terminal</i>
14.00	16.20	Visit of Altenweder Terminal
16.20	16.40	<i>Bus transfer to Miniatur Wunderland</i>
16.50	19.20	Visit of Miniatur Wunderland
		WEDNESDAY 14th FEBRUARY
9.00	9.15	<i>To Hamburg Hauptbahnhof</i>
9.38	11.21	<i>ICE 599 from Hamburg Hauptbahnhof to Berlin Hauptbahnhof</i>
		Drop of the luggage in A&O Berlin
12.58	13.22	<i>Regional Train 56567 from Berlin Hauptbahnhof to Elstal</i>
13.40	15.00	Visit of RLC Wustermark
15.22	15.25	<i>Regional Train 56571 from Elstal to Wurstermark</i>
15.36	15.49	<i>Bus 649 from Wustermark to Wustermark-Bremen Ring</i>
16.10	17.30	Visit of Trafö Company
17.49	17.58	<i>Bus 649 from Wustermark-Bremen Ring to Brieselang</i>
18.15	18.46	<i>Regional Train 18527 from Brieselang to Berlin Hauptbahnhof</i>
19.55	20.02	<i>S-Bahn from Berlin Hauptbahnhof to Alexanderplatz</i>
20.30	22.15	Dinner at Georgbräu

<i>Departure</i>	<i>Arrive</i>	THURSDAY 15th FEBRUARY
8.45		<i>To Berlin Hauptbahnhof</i>
		<i>Tram 10 from Berlin Hauptbahnhof to Berlin Nordbahnhof</i>
		<i>S-Bahn from Berlin Nordbahnhof to Berlin Wilhelmsruh</i>
		<i>Bus 122 from Berlin Wilhelmsruh to Lessingstraße</i>
10.00	12.00	Visit of Stadler Company
12.15		<i>Bus 155 from Lessingstraße to Pankow</i>
		<i>U-Bahn from Pankow to Ernst Reuter Platz</i>
		<i>Bus 245 from Ernst Reuter Platz to Marchbrücke</i>
13.50	15.40	Visit of Verkehrssystemplanung und Verkehrstelematik
15.45	16.00	<i>To EBUEF</i>
16.10	17.30	Visit of EBUEF
		FRIDAY 16th FEBRUARY
8.45		<i>To Hauptbahnhof</i>
9.37	14.03	<i>ICE 703 from Berlin Hauptbahnhof to München Hauptbahnhof</i>
14.25	14.50	<i>Bus transfer from München Hauptbahnhof to DUSS Terminal</i>
14.50	15.40	Visit of DUSS Terminal
15.40	16.05	<i>Bus transfer from DUSS Terminal to München Hauptbahnhof</i>
20.10		<i>NJ295 from München Hauptbahnhof to Roma Termini</i>
		SATURDAY 17th FEBRUARY
	11.30	Arrive in Roma Termini

APPENDIX B: The Cities

Munich

Munich is the capital of Bavaria Land, counting 1.5 million of residents, spread on an area of 310 km², passed by the Isar river. Its transport company is the Münchner Verkehrsgesellschaft (or MVG), managing 95 km of underground lines, 79 km of tram lines and 467 km of bus lines, serving each day 1.5 million of passengers (including residents and tourists). About the underground, the city is crossed by the 1.Stammstrecke, a single corridor in which all the 8 lines of the S-Bahn pass, connecting the neighboring areas of the city and the airport with an average headway of 20 minutes between each train, 10 minutes during the peak-hour. Inside the urban agglomeration, there are also several lines of the U-Bahn passing with a frequency of 12÷30 trains each hour (because of the overlapping). The S-Bahn network is operated by S-Bahn München, a subsidiary of DB Regio Bayern that is itself a subsidiary of the German national railway. The principal station is München Hauptbahnhof, the central station, composed by 32 tracks, used by 350.000 passengers each day, representing, in this way, one of the three busier stations in Germany.

Hamburg

Hamburg is the third most populated German city (after Berlin) with 1.8 million of residents, living in an area of 733 km². It's set on the eastuary of river Elba, on which shores it's located Hamburg port, managed by HHLA, the second-busier port of Europe for number of handled container (counting less than 10 million of TEU each year). The port is spread on an area of 75 km².

The transport system is managed by the Hamburg Verkehrsverbund (or HVV): the company owns the S-Bahn and U-Bahn lines, together with the bus lines. In addition, the presence of river Elba allows a maritime public transport, with several boats running on the river. On an average working day the S-Bahn transports about 590000 passengers.

Berlin

Berlin is the capital of Germany and the first most populated one, with 4.5 million of residents on an area of 892 km². Its most recent history is highlighted by the division of the city for influence areas (between USSR and USA): this has left a city splitted in two after 1989. In the last 30 years the Berliner Verkehrsbetriebe Gesellschaft (or BVG) has reactivated all the stops and the connections closed during the separation. Nowadays the transport system is composed by 15 lines of the S-Bahn, 10 lines of the U-Bahn, 22 lines of tram and over 1600 km of lines of bus. There is the project to connect the U5 to the Hauptbahnhof, but there are many delays: only two branches are completed, the one between Alexanderplatz and Hönower Straße (the yet existing line U5) and the new branch U55: at now, it runs between Hauptbahnhof and Brandenburger Tor on a single line of 1.8 km, with only one train stopping in 3 stops and a headway of 8 minutes.

APPENDIX C: Train Timetables

NJ 294		
Stop	Arrive	Departure
Roma Termini		19.04
Orvieto	19.55	19.57
Chiusi - Chianciano Terme	20.21	20.23
Arezzo	20.56	20.58
Firenze S.M.N.	21.39	21.49
Bologna Centrale	22.41	22.46
Padova	00.01	00.03
Tarvisio	2.45	3.05
Villach Hbf	3.27	4.00
Schwarzach	5.18	5.20
Salzburg Hbf	6.15	6.27
Rosenheim	7.31	7.36
München Hbf	8.19	

NJ 295		
Stop	Arrive	Departure
München Hbf		20.10
München Ost	20.18	20.2
Rosenheim	20.48	20.5
Salzburg Hbf	21.52	22.02
Schwarzach	22.52	22.54
Villach Hbf	00.19	00.55
Tarvisio	1.19	1.35
Padova	4.09	4.11
Bologna Centrale	5.20	5.25
Firenze S.M.N.	6.19	6.36
Arezzo	7.10	7.12
Chiusi - Chianciano Terme	7.45	7.47
Orvieto	8.10	8.12
Roma Termini	9.22	

ICE 586		
Stop	Arrive	Departure
München Hbf		13:18
Ingolstadt Hbf	13:56	13:59
Nürnberg Hbf	14:30	14:33
Würzburg Hbf	15:25	15:28
Fulda	16:04	16:06
Kassel-Wilhelmshöhe	16:35	16:37
Göttingen	16:56	16:58
Hannover Hbf	17:32	17:36
Hamburg-Harburg	18:42	18.44
Hamburg Hbf	18:53	

ICE 703		
Stop	Arrive	Departure
Berlin Hbf (tief)		09:37
Berlin Südkreuz	09:42	09:44
Bitterfeld	10:31	10:33
Halle(Saale)Hbf	10:50	10:52
Erfurt Hbf	11:24	11:32
Bamberg	12:15	12:17
Erlangen	12:35	12:37
Nürnberg Hbf	12:55	12:58
München Hbf	14:03	

ICE 599		
Stop	Arrive	Departure
Hamburg Hbf		09:38
Berlin-Spandau	11:10	11:12
Berlin Hbf (tief)	11:21	

APPENDIX D: Analysis of the delay of NJ 295

DELAY CODE			
24	Wheel Track	84	External Cause
29	Other reason	91	Track Occupation of train itself
32	Speed Restriction	92	Track occupation of an other train
50	Waiting Time	94	Connection
68	Personnel		

LOCATION	CODE	ETA [hh:mm:ss]	RTA [hh:mm:ss]	DELTA [min]
München Hbf		20:10:42	20:10:37	0
Rosenheim	91	20:48:54	20:51:23	2
Salzburg Hbf	94	22:02:00	22:03:45	2
Villach Hbf		00:55:00	00:55:08	0
Tarvisio	61	01:35:00	01:42:30	7
Pontebba	29	01:53:00	02:14:00	21
Carnia	29	02:03:00	02:46:00	43
Dev. Est. Conegliano	68	03:14:00	03:40:30	26
Gruppo Scambi Treviso	68	03:31:00	03:54:00	23
Confluenza UD-TS	68	03:50:00	04:07:30	17
Padova Fascio Secondario	32	04:05:30	04:25:30	20
Padova	50	04:11:00	04:33:30	22
Terme Euganee	32	04:18:30	04:43:30	25
Poggio Renatico	24	04:55:00	05:19:00	24
Bologna Centrale	29	05:17:00	05:39:00	22
Prato Centrale	68	06:05:00	06:42:30	37
Firenze S.M.N.	29	06:36:00	07:14:00	38
Arezzo	91	07:10:00	07:53:00	43
Chiusi - Chianciano Terme	29	07:47:00	08:37:00	50
Orvieto	29	08:12:00	09:01:30	49
Orte	92	08:42:00	10:06:30	96
1° Bivio Orte Sud	92	08:47:00	10:23:00	96
Roma Tiburtina	92	09:09:00	11:22:00	133
Roma Termini		09:22:00	11:31:00	129

