Greening the Last Mile in Port Cities: Environmental Benefits of Switching from Road to Railway for the Port of Naples

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Abstract. The aim of this study is to assess the CO2eq impact due to the shift of the container transport from road (trucks) to rail (electric trains). This specific case study involves the Port of Naples, in the South of Italy. In particular, different scenarios were identified in which mixed solutions for road and rail freight transport could replace the current scenario (freight transport by road only). The results show that, for the same amount of TEU handled, rail transport allows a 50% reduction in global CO2eq emissions (Well-To-Wheels) compared to road transport.

Keywords: Port · Energy consumption · Urban real driving cycles · Well-To-Wheels analysis

1 Introduction

Last mile connections are a critical issue of any port system and may significantly affect the efficiency and the environmental sustainability of the entire logistic process, especially in urban contexts. In the maritime sector, last mile is assuming an increasing role and it is attracting important investments from the European Union.

Currently, the last mile of many urban ports is mainly supplied by road transport, with not negligible effects on the environment, on the urban congestion, on road safety and the quality of life of the involved urban communities.

Indeed, it is well known, in fact, that road transport (cars, trucks, buses and vehicles) is responsible for almost three quarters of total CO2 emissions in the transport sector [1] and that the European Union (EU) has set the goal of achieving low-emission mobility by 2050 and zero-emission mobility in the long term.

In such a context, as also clearly specified by the EU in the White Paper for Transport [2], one of the main objectives is to "Optimize the effectiveness of multimodal logistics chains, by increasing the use of more energy-efficient modes of transport". To this end, the EU has set the following objectives and intervention strategies:

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i. Shift 30% of road freight transport to other modes on journeys over 300 km by 2030. In 2050, this share should increase up to the 50% thanks to efficient and environmentally friendly freight corridors. Adequate infrastructures will have to be introduced to achieve this target.
ii. Complete the European high-speed rail network by 2050. Triple the existing high-speed rail network by 2030 and maintain a solid connection among Member States.
iii. Make a multi-modal TEN-T 'core network' fully operational across the EU by 2030 and a high quality and capacity network with a range of related information services by 2050.
iv. Ensure by 2050 that all major seaports are sufficiently connected to the rail freight system and, where possible, to inland waterways.

To this aim, acting on the ports last mile is becoming a priority in Transport Planning of port communities that have the core port located in densely populated contexts.

This is the context of a project of the Central Tyrrhenian Sea Port System Authority (AdSPMTC), which envisages the construction of a freight rail yard inside the port area equipped with 5 pick-up and delivery tracks with 750 m electrically driven trains and a capacity per train of 50 TEU.

The present study aims at assessing the changes of CO2eq emitted in the considered study area, City of Naples, for containerized freight transport in the new configuration.

In particular, different scenarios have been identified in which mixed solutions for road and rail freight transport could replace the current scenario (freight transport by road only).

The rest of the paper is organized as follows: in Sect. 2 the case study and the different scenarios analyzed are reported; the methodology is reported in Sect. 3; Results and Conclusions end the paper.

2 Case Study

The scenario analyzed includes a possible future development of the Levante Terminal and the construction of a rail link between the Port of Naples and the Naples San Giovanni Barra Station. The project envisages a new railway terminal to serve the Port of Naples, guaranteeing the presence of an arrivals and departures segment of length of 750 m. The considered solution envisages a junction at the station of Napoli S. Giovanni Barra which is connected to the port by a new arrivals and departures (A/D) bundle.

The object of the analysis is, therefore, the city of Naples on which the port of Naples directly impacts through the flows of incoming and outgoing road freight demand. In particular, the attention was focused on the road arteries accessing/exiting to/from the Port of Naples. The routes considered for the evaluation of the energy consumption are one for road transport (see Fig. 1 - Input: AB, Green line $\cong$ 4 km; Output: BA, Yellow line $\cong$ 2 km) and one for rail transport (see Fig. 1 - Input/Output: CD/DC, Red line $\cong$ 3 km). The total length of entry/exit from the port for the two cases, road and rail, is about 6 km so that comparisons can be made in the two modes of transport on similar distances.



Fig. 1. Distance travelled by road and rail freight vehicles to and from the Port of Naples from the entrance of the city and to/from suburban areas.

With respect to the operational context described above, 4 scenarios have been implemented.

1. Scenario 0: represents the current state or Do-Nothing Scenario in which all goods enter/exit the Port by road.
2. Scenario 1: identified as "Realistic-Regional" which foresees a purely regional catchment area and, therefore, only Import freight flows interested in rail services. It is also assumed that the maximum freight flow on rail is 75,000 TEU (current annual limit with respect to the number of trains that can be handled).
3. Scenario 2: identified as "National", which foresees both Import and Export demand interested in rail services. It is foreseen, therefore, that rail freight transport is also shared in the Export phase. The maximum permissible freight flows are always the same.
4. Scenario 3: Assumes a higher number of trains per day that can be operated on the line. An increase from 5 to 9 trains per day is foreseen and therefore demand flows up to a maximum of 135,000 TEU per year by rail.

Finally, the analyses have been carried out by assuming a 50% split between Import and Export (Statistical Bulletin 2018 - AdSPMTC) and assuming two growth scenarios: the first involving a movement of 600,000 TEU (Statistical Bulletin 2018 - AdSPMTC) and the second with an increase in the transport of goods of 40% (1 million TEU).

In Table 1 a detail of the four Scenarios is reported.

Table 1. Scenarios for the preliminary analysis of environmental impacts in the new AdSPMTC project hypothesis for container freight transport in the port of Naples.

Scenarios	50% Import & 50% Export		600k TEU		1000k TEU	
			Export	Import	Export	Import
0	Do-Nothing	Road	300k	300k	500k	500k
		Rail	*0*	*0*	*0*	*0*
1	Realistic-Regional	Road	300k	225k	500k	425k
		Rail	*0*	*75k*	*0*	*75k*
2	National	Road	225k	225k	425k	425k
		Rail	*75k*	*75k*	*75k*	*75k*
3	9 Trains (instead of 5)	Road	225k	165k	425k	365k
		Rail	*75k*	*135k*	*75k*	*135k*

3 Methodology

The approach used in the analysis is the Well-To-Wheels (WTW) one. This consists of two sub-analyses:

- a Tank-To-Wheels TTW (from the tank to the wheels) analysis which considers the in-use consumption and emissions of the vehicle,
- a Well-To-Tank WTT (from well to tank) analysis which takes into account the extraction, conversion and transport processes of the energy carrier used.

For the estimation of consumption and emissions in use in road freight transport (TTW analysis), microscopic models known from the literature were adopted in which specific fuel consumption is calculated as a function of speed profile over time [3–5].

The adopted polynomial relation is the following:

$$SFC\left[\frac{l}{km}\right] = a \cdot v^2(t) + b \cdot v(t) + c \tag{1}$$

In particular, the values of parameters a, b and c are given in [3] for a large truck and the specific consumption as a function of speed has a trend as shown in Fig. 2.

These models have been subsequently applied to real urban cycles in the city of Naples for a realistic estimation of the consumption considering the driving behaviour in a real urban environment. Indeed, the consumption evaluated on real urban driving cycles, for conventional vehicles, has different values from an average consumption value assumed constant and referred to a fixed speed for the whole route considered. Especially in urban areas for conventional vehicles the consumption is higher because, in the case of microscopic analysis, a driving dynamic is considered, which is influenced by the actual traffic conditions, the driving style of the driver and the characteristics of the route (e.g. gradients). The speed profile in the real case is therefore characterised by

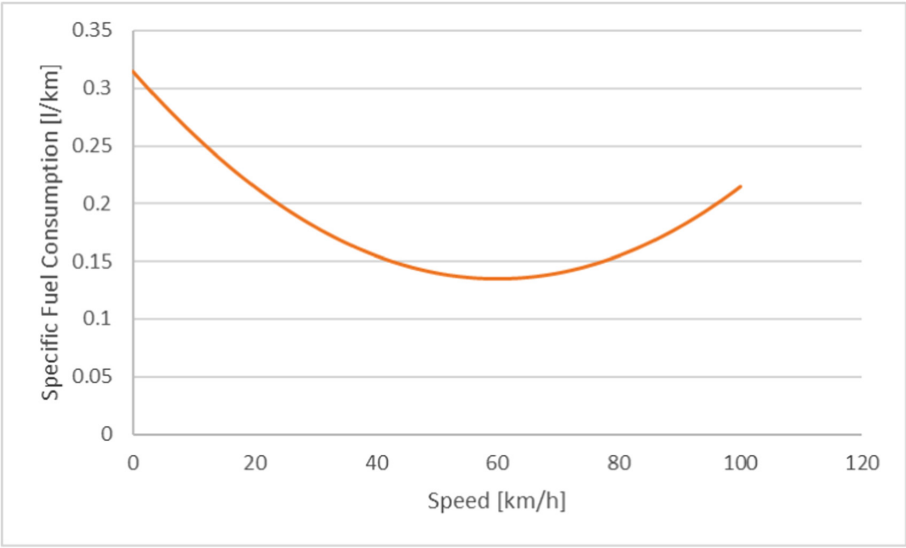

Fig. 2. Specific fuel consumption trend as a function of speed.

frequent start & stop phenomena with acceleration and deceleration phases which are not considered when estimating the consumption of a vehicle on a route based only on an average consumption referring to a specific constant speed value [4–7].

Figure 3 shows an example of an urban cycle in the city of Naples.

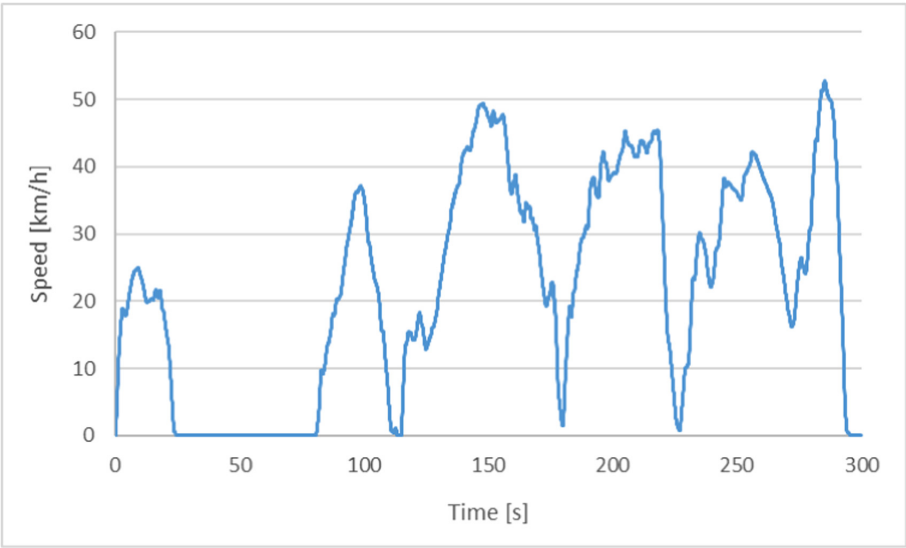

Fig. 3. Example of a real speed profile on an urban cycle in the city of Naples.

Additionally, specific payload factors were also applied to these models to account for the impact of the weight on board the vehicle.

The TTW calculation of train consumption was instead based on data from the report "Railway Handbook, Energy Consumption and CO2 Emissions" for goods trains [8].

Additionally, available coefficients from the literature were used to estimate WTT emissions [9, 10].

Finally, the methodology was applied to the scenarios reported in Table 1 by assuming for all scenarios trucks (1 TEU) and electrically driven goods trains (750 m of 50 TEU). In addition, it was assumed that both Import and Export freight transport is carried out using vehicles moving with a load factor of 1.

4 Results

In this section the results in the 4 Scenarios have been reported and discussed. In particular, results of CO2eq for the four scenarios in the two cases analyzed: the 600k and the 1000k TEU, respectively, are shown.

4.1 Scenarios Comparison: Well-To-Wheels Analysis – 600k TEU Case

Figure 4 shows the results of the tonnes of CO2eq, in the Tank-To-Wheels (TTW) and Well-To-Tank (WTT) analysis, produced in the 4 scenarios considered in the case of a yearly movement of 600k TEU.

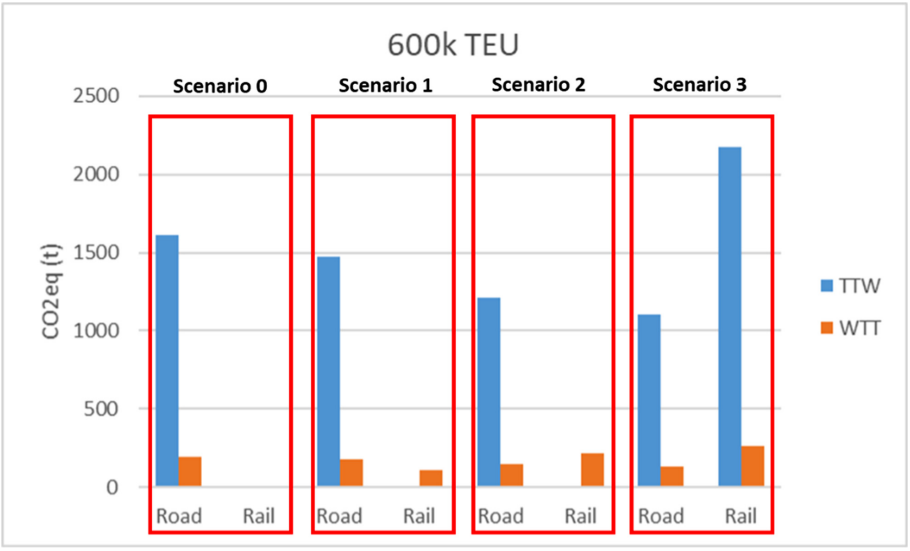

Fig. 4. Comparison of the 4 scenarios in the Tank-To-Wheels and Well-To-Tank analysis in the 600k TEU case.

Figure 5 shows the results of the tonnes of CO2eq, in the Well-To-Wheels (WTW) analysis, produced in the 4 scenarios considered in the case of a yearly movement of 600k TEU.

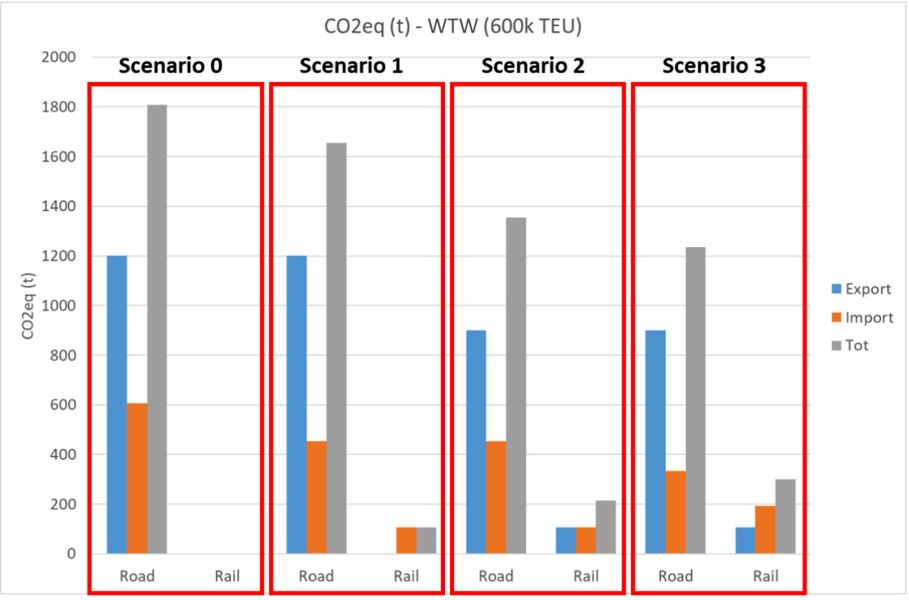

Fig. 5. Comparison of the 4 scenarios in the Well-To-Wheels analysis in the 600k TEU case.

Comparing Scenario 1, 2 and 3 with the do-nothing scenario (Scenario 0) results show that in Scenario 1, shifting 75k TEU of freight from road to rail a reduction of the 8.4% of CO2eq (WTW) emissions in the road mode and a 6% increase in the rail mode are observed.

In Scenario 2, 150k TEU are shifted to rail mode causing a 25% reduction in emissions from road mode and an 11.9% increase in emissions associated with rail mode.

Finally, in Scenario 3, the shift of 210k TEU to rail mode produces a 31.7% reduction in emissions associated with road transport and a 16.7% increase in emissions associated with rail transport.

4.2 Scenarios Comparison: Well-To-Wheels Analysis – 1000k TEU Case

Figure 6 shows the results of the tonnes of CO2eq, in the Tank-To-Wheels (TTW) and Well-To-Tank (WTT) analysis, produced in the 4 scenarios considered in the case of a yearly movement of 1000k TEU.

Figure 7 shows the results of the tonnes of CO2eq, in the WTW analysis, emitted in the 4 scenarios considered in the case of an annual movement of 1000k TEU, thus assuming an increase in freight transport of 40%.

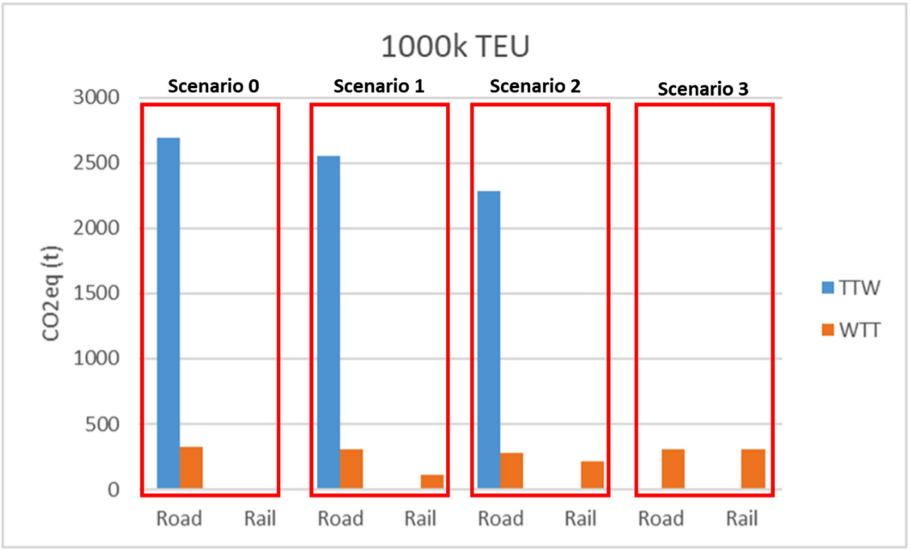

Fig. 6. Comparison of the 4 scenarios in the Tank-To-Wheels and Well-To-Tank analysis in the 1000k TEU case.

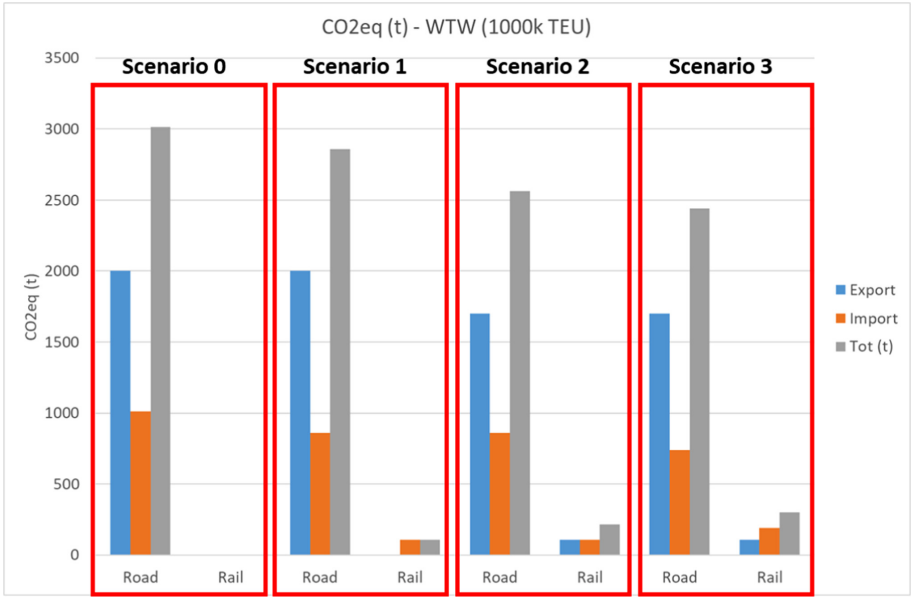

Fig. 7. Comparison of the 4 scenarios in the Well-To-Wheels analysis in the 1000k TEU case.

Also, for the 1000k TEU case, a comparison among Scenario 1, 2 and 3 with the do-nothing scenario (Scenario 0) is reported. Results highlight that in Scenario 1, shifting 75k TEU of freight transport from road to rail results in a 5% reduction in CO2eq (WTW) emissions in the road mode and a 3.5% increase in the rail mode.

In Scenario 2, 150k TEU are shifted to rail mode causing a 15% reduction in emissions from road mode and a 7.1% increase in emissions associated with rail mode.

Finally, in Scenario 3, the shift of 210k TEU to rail mode results in a 19% reduction in emissions associated with road transport and a 10% increase in emissions associated with rail transport.

4.3 Scenarios Comparison: Summary

The analysis shows that for the same number of TEU handled, rail transport allows a reduction in global CO2eq emissions (Well-To-Wheels) of 50% compared to road transport.

It is also noted that the limit of 75k TEU in the proposed configuration for rail transport produces a limited reduction in global emissions because the modal shift to rail is limited compared to the total volume of goods to be handled. Specifically, in the 1000k TEU scenarios the percentage reduction compared to the do-nothing scenario is smaller (–1.5% to –9%) than for the 600k TEU scenarios (–2.4% to –15%) (see Table 2).

Finally, the increasing of the capacity of rail transport from 75k TEU to 135k TEU (from 5 to 9 trains) reduces the overall impact by 15% and 9% in comparison with the do-nothing scenario, for the 600k and 1000k TEU cases respectively (see Table 2).

Table 2. Comparison of the 4 scenarios in the WTW analysis in the 600k and 1000k TEU cases.

Scenarios		600k TEU *CO2eq (t)*		1000k TEU *CO2eq (t)*	
0	Do-nothing	1807		3012	
1	Realistic-Regional	1763	**–2.4%**	2968	**–1.5%**
2	National	1571	**–13.1%**	2775	**–7.9%**
3	9 Trains (instead of 5)	1535	**–15%**	2740	**–9%**

5 Conclusion

Aim of the present study is to assess the CO2eq impact due to the shift of the container transport from road (trucks) to rail (electric trains). This case study focused on the Port of Naples, in the South of Italy. Different scenarios were identified in which mixed solutions for road and rail freight transport could replace the current scenario (freight transport by road only). Specifically, Scenario 0 is the Do-nothing scenario in which all goods enter/exit the Port by road; Scenario 1 named “Realistic-Regional” foresees a purely regional catchment area and, therefore, only Import freight flows interested in rail services. It is also assumed that the maximum freight flow on rail is 75,000 TEU

(current annual limit with respect to the number of trains that can be handled); Scenario 2, identified as "National", foresees both Import and Export demand interested in rail services. It is foreseen, therefore, that rail freight transport is also shared in the Export phase; Scenario 3 assumes a higher number of trains per day that can be operated on the line. An increase from 5 to 9 trains per day is foreseen and therefore demand flows up to a maximum of 135,000 TEU per year by rail.

Additionally, the analyses have been carried out by assuming a 50% split between Import and Export (Statistical Bulletin 2018 - AdSPMTC) and assuming two growth scenarios: the first involving a movement of 600,000 TEU (Statistical Bulletin 2018 - AdSPMTC) and the second with an increase in the transport of goods of 40% (1 million TEU).

The analysis shows that for the same number of TEU handled, rail transport allows a reduction in global CO2eq emissions (Well-To-Wheels) of 50% compared to road transport.

It is important to highlight that the limit of 75k TEU in the proposed configuration for rail transport produces a limited reduction in global emissions because the modal shift to rail is limited compared to the total volume of goods to be handled.

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