**Summary**

**Introduction**

Especially in the previous century, the passenger and freight mobility has increased significantly. The development to mass mobility stimulated world trade and human exchange. Although the benefits of a growing transportation are considerable, the negative side effects of the mobility industry cannot be denied. Transportation causes local air pollution, acidification and contributes to the global greenhouse effect. To outline the subject, the report focuses on the Port of Rotterdam, located in the south-west of Netherlands. As a result of the aim of the port to improve their accessibility, a modal shift and modal split are considered. However, besides accessibility, sustainability is also a key issue. An insight in the environmental effects of modal shifts and splits is therefore of great interest. Only passenger and container transport on the landside of the port will be considered. Both freight types are of great importance for the harbour and can be handled multimodal. The main research question of this literature report is:

*What are the emissions of CO₂, NOₓ and PM of the different transportation modes with respect to passenger and container transport in the port of Rotterdam, in 2010 and in 2020?*

**Modalities**

The modalities are split into road, rail and water transport for both passenger and container transport. As a result of the infrastructure characteristics of the Port of Rotterdam, air transport is not included.

**Calculation method**

Not only the operational emission, but the whole lifecycle emission is used in this report to compare the different modalities. Three types of emissions are considered: the globally acting greenhouse gas CO₂, the locally acting smog gas NOₓ and the locally acting particular matter (PM₁₀). The emissions are measured in gram per passenger-kilometre (g/p-km) or gram per tonne-kilometre (g/t-km). Per considered route, the total emissions per modality are calculated in gram per passenger or gram per tonne. As a result of differences in global and local emission and immission, this report does not integrate all emissions into one environmental score.

**2010 emissions**

The analysis of 2010 emissions showed a remarkable difference between passenger commuter traffic and container transport. *Figure a* shows the performance of passenger transport modalities filled up to its maximum capacity based on average values per group of transport modes. It can be concluded

![Figure a: The emission of passenger modalities at 100% load rate (this implies the lowest possible emission in g/p-km per modality)](image)
that a shift from road to water and rail does not necessarily result in a decrease of emissions, moreover, in some cases it would lead to an increase of CO$_2$ and NO$_x$ emissions. Figure b shows the performance of container transport modalities filled up to its maximum capacity based on average values per group of transport modes. The best case scenario shows that a shift from road to water (4x barge) will result in a decrease of all emissions, however, a shift of road to rail will result in a decrease of NO$_x$ and PM$_{10}$ levels, but an increase in CO$_2$.

**2020 emissions**

2020 is a short term future outlook. Since most technology has a long lifetime and a slow development trajectory, many phenomena will still be the same in 2020 as in 2010. The changes are expected to happen slowly.

Not all described future developments have an effect on all considered emissions. A number of developments do only effect the CO$_2$ emissions (for example the CO$_2$ capturing and storage), while others effect the levels of NO$_x$ and PM only (for example filtering and catalysing). The combustion of bio diesel is a rare phenomena, although the amount of emitted CO$_2$ is decreased, the emission level of NO$_x$ will increase under normal operation methods. The shift from fuel combustion to grey electric energy results in an increase of all emissions. Changing grey electric energy to green will cause a decrease of CO$_2$, but as a result of the large biomass content, it will also result in an increase of NO$_x$ emissions. To decrease all levels, combinations of different developments are possible: a shift to green electricity, centralized filtering and catalysing and the use of plug-in hybrids.

**Conclusions**

The environmental performance of both passenger and container transport in the Port of Rotterdam is a complex, multidimensional and interrelated field of study. Technological development, human behaviour and governmental regulations all interact in this field.

The choice of modalities does influence the life cycle emissions per p-km or t-km, however, the degrees of freedom, such as the operation mode and length of route does influence the life cycle emissions even more. A general trend towards economy of scale exists, but the biggest challenge is to only operate the vehicles under maximum capacity. A large vehicle combined with a low load rate will result in high emissions per p-km or t-km.

An overall best concept concerning environmental performance does not exist. Modalities with the lowest levels of CO$_2$ do not have the lowest levels of NO$_x$ or PM and vice versa. Prioritizing is very important to be able to make decisions. The question to be answered is: are global CO$_2$ emissions more important than local NO$_x$ and PM$_{10}$ emissions in the Port of Rotterdam? Concerning the future, combinations of developments can cause synergy and will result in a decrease of all emissions.