SUMMARY

Around the world, dry bulk import terminals facilitate the transhipment of large intercontinental flows to smaller inland flows of coal and iron ore. The Europees Massagoed Overslagbedrijf (EMO) is the largest terminal of this kind in Europe, with a supply of around 30 MT of coal and iron ore per year. EMO handles vessels from Panamax up to the largest dry bulk carriers presently trading and is a vital part of the supply chain of iron ore and coal for the European steel and electricity industries.

In the future, changes are expected in the supply volumes of coal and iron ore. Also, a new range of Very Large Ore Carriers (VLOC's) was recently introduced. The question arises if such changes, over which EMO has little or no control, affect the efficiency of the terminal in any way. It is currently unknown which of these external or input factors affect the terminal efficiency, and to what extent.

To provide this knowledge, the following research question was formulated:

> ***What input factors affect terminal efficiency and what are the quantitative effects on terminal efficiency when these factors change***

The research was scoped to include the efficiency of the quayside, as well as the storage yard. The quayside can be seen as a queuing system, where the quay cranes are the servers. The service rate, or crane unloading rate, is an important factor in the efficiency of the quayside. Higher unloading rates mean more throughput of material with the same resources.

An initial selection of input factors was made based on the analysis of the EMO dry bulk terminals processes and equipment. This list was then used as a basis for the analysis of a historic dataset of ship and load properties and the realized unloading rate. Using a linear regression model, the factors that significantly affect the

unloading rate were determined. With these factors a non-linear model was made that is more anchored in theory and literature.

Only two significant input factors were found to affect the unloading rate, ships deadweight and the load being coking coal. Bigger ships are unloaded at a faster unloading rate [thr^{-1}], with an elasticity of 0.18, in line with literature values found. Ships carrying coking coal were found to have about 15% lower unloading rates due to the stickiness of the material and associated longer trimming stage. Different fleets are used to carry steam coal and iron ore. Iron ore is therefore on average unloaded at a faster rate than steam coal, but this is basically a ship size effect.

The unloading rate formula was used in a discrete event simulation model of the terminal to determine the effects on the entire queuing system. Scenarios based on an extensive throughput study for the Hamburg-Le-Havre range (Western-Europe) were evaluated using this model. For the range of commodity mixes and ship size differences tested, only marginal changes in quayside system efficiency were found.

For the storage yard, the surface densities for coal and iron ore were determined using a new view on material reclaiming. Piles always occupy a certain area, regardless of the amount of material. Basically only the height of the pile is thought to change. Using this new view, historic storage yard data of EMO was used in a Monte Carlo simulation setting to come to a surface density estimate for coal and iron ore. The values found were found to be valid.

Using the same commodity mix scenarios used for the quayside, the surface density [$tm^{-2}y^{-2}$] for the storage yard was found to only marginally change with the commodity mix. The storage time is a much bigger determinant. With storage times increasing, the efficiency of the storage yard in terms of surface density can rapidly decrease. This means lower throughputs can be realized using the same amount of storage area. Investments in more storage area are then needed if higher throughputs are aspired in the future.

Overall, the efficiency of the quayside system and storage yard was found to only be marginally affected by changes in relevant input factors within the bounds of future predictions. Only the storage time developments call for closer attention by terminal management as this factor can have large effects on the storage yard efficiency.