Dry bulk terminal expansion or redesign?

G. Lodewijks, Professor, D.L. Schott, Assistant Professor, & J.A. Ottjes, Associated Professor, Transport Engineering and Logistics, 3mE, Delft University of Technology, Delft, The Netherlands

Summary
Due to the high demand for energy and mineral resources many dry bulk terminals around the world are expanding and seriously increasing their capacity. One approach to expansion can simply be copying the existing facilities until the required capacity is reached. In this way however the terminal does not only lose the opportunity to utilise the developments made over the last decades on terminal design, it will also end up with a costly operation. In addition it may not be able to reach the environmental restrictions imposed on terminal operations nearby environmentally sensitive areas. This paper discusses a modern design approach of dry bulk terminals. It starts with the description of a typical dry bulk terminal. It further discusses the application of discrete event simulation as a tool to determine the best operational control of the terminal and the required number of equipment and their capacity related to the requested service level for the terminals customers. It finally points out other design aspects for terminal maintenance, dust and sound emission control methods.

Introduction – a typical bulk terminal
Dry bulk terminals are used worldwide as a buffer between either international or intercontinental transportation and inland or domestic transportation or the other way around. An example of a dry bulk terminal is shown in Figure 1. This Figure shows the iron ore exporting terminal of the port of Chennai (previously called Madras) in India. Figure 2 schematically shows the lay-out of that terminal. The port was first commissioned in 1977 [1]. The plant is capable of receiving, stockpiling, reclaiming, weighing, sampling and shiploading eight million of iron ore per annum. Bulk carriers of sizes 150,000 DWT can be loaded at a rate of 8,000 MTPH. The ore stockyard has a capacity of about 800,000 tonnes and can cater four different grades of iron ore.

The ore handling facilities consist of receiving lines and shipping lines. In the receiving lines there are two rotary wagon tipplers (Tippler 1 & 2), four belt conveyors (C1, C2, C3, & C4), and two rail-mounted stackers (ST1 & ST2).

The shipping line comprises two rail mounted bucket wheel reclaimers (RE1 & RE2), six belt conveyors (S1, S2, S3, S4, S5, & S6), and two rail mounted shiploaders (SL1 & SL2). The conveyors and equipment in both the receiving and shipping lines are grouped to form two streams which are capable of functioning independent of each other as interconnected systems. It is not possible to by-pass the stockyard. More detailed information is published in [2].

The iron ore handling facility of the port of Chennai, India can be characterised by the following, when compared to other terminals around the world:
• There is no by-pass option. Some terminals have bypass facilities whereby the dry bulk can be transported directly from the incoming side (here the train side) to the outgoing side (here the exporting vessels). This not only physically not possible (no bypass conveyors) also the capacities of the incoming and outgoing side are not matched.
• According to the harbour records it takes about 40 hours to load a 150,000 DWT vessel. In theory loading a 150,000 DWT vessel can take less than 20 hours if the maximum shiploader and shipping belt conveyor capacity is reached. Due to operational issues the average capacity in this case is about 46 per cent of the maximum capacity. This is typical for iron ore handling bulk terminals. Worldwide the average capacity of shiploading equipment varies between 40 per cent and 55 per cent. This is not only due to operational/maintenance problems. The average capacity is calculated with respect to the total time a shiploader is available. In general it can be said that the utilisation percentage of dry bulk handling equipment normally is less than 50 per cent, where the operational availability is normally around the 80 per cent.

• The terminal uses separate stackers and separate reclaimers. Other terminals show only combined stacker/reclaimers or a combination of both separate and combined. The choice for either separate machines or combined machines obviously affects the reliability and accessibility of the stockyard.

• The terminal does only use one-way belt conveyors. Comparison between the availability of one-way versus two-way conveyors shows that the availability of one-way conveyors is significantly higher than that of two-way conveyors. The same holds for conveyors using a fixed head pulley versus conveyors using a movable head. The reliability of the first is significantly higher than the reliability of the latter. In general it can be said that the more mechanical components a piece of equipment contains the lower its availability is.

Terminal expansion or redesign

If this terminal had to be designed today, would the design have been different? Alternatively, if the terminal decides to expand, would they keep the same design or would they adopt a different design philosophy? These questions are not so easy to answer. In this section some of the design considerations will be discussed.

One of the most important design considerations is trying to increase the utilisation of the terminal equipment. Where today utilisations of about 40 per cent to 50 per cent seem to be quite normal as mentioned in the previous section, this obviously means that all the machines have a much higher capacity than required if better utilisation is possible. This significantly increases the costs of the terminal equipment.

Another design aspect is the amount of storage area used by the terminal. Where in the industry a possible stock of about 10 per cent of the annual throughput seems to be accepted, as is also the case with the terminal discussed in the previous section, this obviously means that all the machines have a much higher capacity than required if better utilisation is possible. This significantly increases the costs of the terminal equipment.

One of the characteristics of the Chennai terminal mentioned in the previous section is the absence of by-pass options. In other words, it is not possible to transport iron ore straight from the tipplers to the shiploaders. This means that the incoming stream and the outgoing stream of bulk material are decoupled. By-passing is an aspect that many terminals consider in an attempt to reduce the required storage area and to increase utilisation of their equipment. Although the success of the by-pass option entirely depends on the possibilities the terminal management has to control and synchronise the incoming stream of bulk and the outgoing stream of bulk, if the terminal does not have physical by-pass options then it cannot be implemented. Figure 3 shows basically the same terminal layout as shown in Figure 2 but with a by-pass option through the stackers. With this feature sixteen by-pass routes are created: R1–R3–S3–S5, R1–R3–S3–S6, R1–R3–S4–S5, R1–R3–S4–S6, R1–R4–S3–S5, R1–R4–S3–S6, R1–R4–S4–S5, R1–R4–S4–S6, R2–R3–S3–S5, R2–R3–S3–S6, R2–R3–S4–S5, R2–R3–S4–S6, R2–R4–S3–S5, R2–R4–S3–S6, R2–R4–S4–S5, R2–R4–S4–S6. For this specific terminal it is not possible to load a vessel at a rate of 8,000 MTPH by-passing the stockyard since the tipplers...
only have a capacity of 2,000 MTPH each. This shows that balancing the incoming stream and the outgoing stream in terms of capacity is required to optimise the by-pass option effectively. If a vessel on this terminal needs to be loaded with 4,000 MTPH then two by-pass routes have to be used simultaneously and both shiploaders will only operate at 50 per cent of their rated capacity. In practice it can be said that the more products a terminal has the more difficult bypassing will be. Typically by-pass percentages in terms of annual throughput are less than five per cent where terminals normally would like to go up to about 20 per cent.

Another design decision that has to be made is whether to go for single purpose machines on the stockyard (stackers and separate reclaimers like used in Chennai) or to use combined machines (stacker/reclaimers). Although this decision seems an easy one, since one combined machine is cheaper than two separate machines, it also has some operational implications that should be considered.
carefully. If in the original design for example stacker ST1 is malfunctioning, then reclaimer RE1 can still be used to reclaim material on the west side of the terminal. This is not the case in the alternative design shown in Figure 4. This of course can be solved by using more combined machines, either by doubling the routes and put two more stacker/reclaimers in or by putting in a third between the two shown, but this has a cost implication and may be a more expensive solution. If a specific area can be stacked or reclaimed by more than one machine then this area has machine redundancy. In general it can be said the more products a terminal handles the more important machine redundancy is.

In practice it should be ensured that parts of the terminal that store the most important products, in terms of throughput, have machine redundancy. Whether the whole terminal requires machine redundancy or not depends on the logistic layout of the terminal and the options terminal management has to control this. In general it can be said that if the incoming stream of the terminal and the outgoing stream are decoupled then machine redundancy becomes more of an issue since bypassing is not possible.

Finally, during the design stage it should be decided whether to use one-way conveyors, like shown in the previous designs, or to go for two-way conveyors like shown in the lay-out shown in Figure 5. In general it can be said that bi-way conveyors show a lower availability than one-way conveyors due to the fact that they are more complex (more mechanical components, tracking of the belt becomes more of an issue). Also the transfer points have to be designed more carefully due to the fact that more transfers have to be installed in a certain area. One advantage of using bi-way conveyors is that the total length of the conveyors on the terminal is less compared to the case when only one-way conveyors are used in cases where bypassing is possible.

Both the alternative layouts shown in the Figures 4 and 5 show an option a) where routes are shared between conveyors and an option b) where dedicated routes are used. In general shared routes are recommended unless there is a specific reason to use dedicated routes.

Modelling, control and maintenance

As stated in the previous section proper logistic control of a terminal is essential to ensure its optimisation in terms of utilisation of equipment and land. To study the effect of different control philosophies discrete event simulation can be used as a modern design tool. Extensive experience with discrete event simulation has been build up in the modelling and simulation of container terminals [5][6]. The application to dry bulk terminals was is demonstrated in [2][3][4] and describes an example of using discrete event simulation to design a coal terminal.

Besides the logistic control of a terminal, also the way the dry bulk material handling systems are maintained plays a crucial role in the operational availability of equipment. To gain some insight in the way maintenance is organised on a modern Western European dry bulk terminal and to determine the effect of maintenance on the operational performance of equipment, a study was performed at a Dutch dry bulk terminal. On the basis of hands-on experience on other terminals it is believed that the results of this study are worthwhile implementing to increase the operational availability of terminal equipment [2].

Environmental issues

The social interest in the environmental impact of industrial facilities has shown a strong increase over the last years. The Rotterdam Port Authorities for example, have launched a plan for the year 2020, in which they are striving for a cleaner harbour. This means: less noise, cleaner water, better air quality, but also equality in environmental measures and preservation for the ports in Europe. This is not only regarding the better life environment but also to strengthen the competitive position of regions and countries. An example of the influence of imperative legislations in the Netherlands is the idling of a construction site in 2005. The reason for that was exceeding the reference values for fine dust concentration [7]. Increasingly compelling legislation threatens the working conditions of important industries in countries.

Here, the environmental impact and ongoing research on three aspects will be discussed: areas: dust, spillage and noise.

Dust

Dust emissions (see Figure 6) are a common problem in many forms of industry: dry bulk terminals, construction, agriculture, and mining. The result of progressive (medical) knowledge recognises dust as being hazardous for health and will lead to increasing legislations [8][9][10]. In the foreseeable future the generation of dust will put pressure on the environment as well as industry all over the world. The overall challenge is therefore to reduce dust emissions in among others bulk materials handling, also see Figure 7.

The increasing requirements in EU legislations for ‘dust free’ operations result mostly in secondary measures, which means basically treatment of the symptoms. The challenge is to develop primary measures i.e. prevention of the generation of dust during handling of particulate materials. This can be done only under one condition: a validated tool that inherently takes into account the bulk material behaviour and the dust generation both in interaction with the equipment. This makes it possible to develop new or adapted handling equipment where dust generation is taken into account explicitly. Furthermore, it becomes possible for both the industry and the legislator to evaluate existing equipment on ‘dust free performance’. For the general public this means eventually that the environmental and health pressure will decrease.

Figure 6. Dust emissions.

Figure 7. Environmental protective measures at a Dutch bulk terminal.
Spillage
The regulation issues are not only posted on a European level, the implementation of the legislation (still) differs from country to country. Depending on the circumstances, this is threatening the competitive positions of stevedoring companies at the forefront countries. However the competitive position is not only at stake on a European level. In The Netherlands, for example, is a difference in preservation policies depending on the province, type of waterways, location etc. This observation motivated material handling companies (bulk terminals and stevedores) to start a research project with Delft University of Technology, The Port of Rotterdam and the government to perform a risk analysis of spillage in the water surface during the unloading and loading of ships. [11]

Noise
Noise pollution will play a very important role in the near future as well. Having a clean environment should not be the only reason for taking environmental measures. Noise pollution for example is getting more critical as urbanisation comes closer and closer to the ports, due to the scarcity of land. On the other hand, from a personnel point of view, protection of personnel is important as well. The existing mechanical operations of systems and subsystems with moving parts might be noisy, especially when the equipment gets older and is worn out. The reduction of noise could therefore be closely related to the maintenance strategies. Finally, this means that choice of equipment is not only a matter of loading and unloading capacities, but also on the requirements for the terminal, the type of material and its surroundings.

Discussion
When designing terminals, choices on flexibility or multifunctionality have to be made. The use of discrete event simulation can support the decision process. Often continuous loaders or unloaders are promoted because of their dust and spillage free operations. However, the applicability of continuous loaders or unloaders depends on the material properties of the material, but as well on the flexibility required. Grabs are popular because they are energy-efficient, flexibility is high for floating or mobile cranes, and their efficiency is less dependent on material properties.

In addition, it is expected that modern engineering tools such as Discrete Element Method can contribute to increase performance during bulk material handling, i.e. reduction of energy consumption, wear, dust, spillage and noise. Essential in that is the validation and calibration of the interaction between material and the equipment.

It is believed that the design process of new or upgraded modern dry bulk terminals should account for the discussed aspects and therefore should be carried out by a multi-disciplinary team.

REFERENCES


ABOUT THE AUTHORS
Gabriel Lodewijks is professor of transport engineering and logistics at the faculty of mechanical, maritime and materials engineering (3mE) of Delft University of Technology and head of the department of Marine and Transport Technology. He is further president of Conveyor Experts B.V.
Ms. Dingena L. Schott is assistant professor in the transport engineering and logistics group at the faculty of 3mE of Delft University of Technology.
Jaap A. Ottjes is associated professor in the transport engineering and logistics group at the faculty of 3mE of Delft University of Technology.

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The Faculty of 3mE at Delft University of Technology educates committed engineers and PhD graduates and conducts breakthrough scientific research in the fields of mechanical engineering, maritime engineering and materials science. The department Marine and Transport Technology aims at the further development of the knowledge of the dynamics and the physical processes involved in terminal design, transport, dredging and marine systems, the logistics of the systems and the interaction between the equipment and control systems.

ENQUIRIES
Mekelweg 2
2628 CD, Delft
The Netherlands
Emails:
Gabriel Lodewijks: G.Lodewijks@tudelft.nl or G.Lodewijks@conveyor-experts.com
Dingena L. Schott: D.L.Schott@tudelft.nl
Jaap A. Ottjes: J.A.Ottjes@tudelft.nl
Web: www.3me.tudelft.nl/mtt