Performance improvement of liquid bulk terminals

An application of the OEE concept for liquid bulk terminals

Bas Verheul, Tebodin Netherlands B.V., The Netherlands

Imagine you are a terminal manager with plans to expand your tank storage capacity. You already know that your plans will increase throughput, resulting in unacceptably high berth occupancies of 85 per cent. You would like to invest in new pumps and berths, but your board asked you to prove that these investments will be effective. They would like to get an idea of how your existing infrastructure is performing compared to industry peers and whether improvements are possible. You are looking for a Key Performance Indicator (KPI) to provide these answers.

This article shows how the Operational Equipment Effectiveness (OEE) concept will provide this KPI for your liquid bulk terminal. The OEE concept is widely used in the manufacturing industry and can be used for analyzing and optimizing liquid bulk terminal performance. Furthermore it can be used effectively for benchmarking of terminals regardless of their specific characteristics.

The concept and benefits of OEE

The manufacturing industry defines Operational Equipment Effectiveness as the fully productive time of a manufacturing line divided by its planned operating time. In this definition, the fully productive time is defined as the time a manufacturing line is producing goods of required quality at maximum speed. Therefore, all losses related either to unavailability and underperformance of the equipment or quality of the product are subtracted from the planned operating time. The way OEE is calculated, including the four loss categories defined in the manufacturing industry, is illustrated in Figure 1. Maximizing the OEE, which is the job of the operational manager, ensures maximum productivity of equipment and thus maximizing financial return during operating hours.

A variation on OEE is the Total Effective Equipment Performance (TEEP), which also includes the planned production time losses like planned maintenance. For TEEP, productive time is divided over calendar hours instead of operating hours. This calculation results in a bottom line equipment utilization, which can be used for forecasting of financial results.

OEE calculation is a matter of measuring time and categorizing it into productive and non-productive hours. Doing this per equipment type facilitates simplification of complex systems into easy-to-follow subsystems. Calculating OEE is practical and difficult to tamper with, which makes it an excellent KPI to base performance incentives on. Categorization of the non-productive time per type of loss provides a good yardstick with which to measure where you are and how you can improve your operations. This is the reason why OEE is often used in Operational Excellence and Lean Manufacturing programs.

Existing terminal KPIs and their limitations

As terminal manager, you would first consider which existing KPIs can be used (see ‘Liquid Bulk Terminal KPIs’). Each one of them does however have limitations, making them unsuitable for measuring terminal operational effectiveness.

• First of all, each of the existing KPIs has a focus on a specific part of the terminal system only. Berth occupancy and turnover factor are often used, but are limited to a focus on the (un)loading function only. They do not include logistic services like blending or heating, as these services do not require a berth. Also, such KPIs cannot be used to directly analyze the performance of the complete (un)loading system including pipes and pumps.

• A second limitation of the KPIs is their significance in the identification of operational constraints. Most of the KPIs represent availability only and answer questions like: “How much time is this berth occupied?” instead of “How much time could it have been occupied in optimal circumstances?”

• Finally, the benchmarking possibilities of the existing KPIs are limited. When benchmarking two terminals with identical berth occupancies, the overall productivity and financial return of the terminals can be very different. As this return is also dependent on other KPIs, such as average handling time per vessel, average pump...
capacity, and investments in equipment, a variety of KPIs should be analyzed. This can make benchmarking a complex exercise.

For these three reasons, one would search for a single operational KPI to be used for benchmarking as well as optimizing operations.

**Liquid bulk terminal subsystems**

In order to be able to serve both purposes mentioned above, three levels of subsystems are defined within the terminal (as illustrated in Figure 2):

1. **The transport and service system**
   Irrespective the terminal’s characteristics, an OEE calculated on terminal level can be used for benchmarking as it includes the productive time of all main equipment at the terminal. Terminal specifics might cause OEE differences per equipment type, but on aggregation level 1 the terminal should always aim for an optimal OEE. This enables comparisons between, for example, a terminal with dedicated systems per product, and a fully flexible terminal. Where the latter is expected to have more set-up losses, these should be compensated by a gain of availability due to the flexible use of equipment.

2. **Subsystem per equipment group**
   A more detailed system per equipment group (level 2) facilitates optimization of equipment productivity. A low performance factor for pumps will, for example, indicate that the investments in pumps are not effective. Analyzing and reducing typical productivity losses can improve the return on investment of this type of equipment.

3. **Subsystem per functional process**
   It can be useful to define a subsystem per functional process type (level 3) in order to answer detailed questions like: “What is the set-up loss caused by switching between loading and unloading?” and “How often is the pump blocked for product A due to pumping of product B?” Figure 2 shows two examples of subsystems per product.

![Figure 2. Example of a liquid bulk terminal system including subsystems.](image)

**Figure 3. Simplified example of an OEE calculation for a liquid bulk terminal.**

<table>
<thead>
<tr>
<th>6 Berths</th>
<th>8 Pumps</th>
<th>Terminal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OEE = 84% x 75% x 100% = 63%</strong></td>
<td><strong>OEE = 49% x 47% x 100% = 23%</strong></td>
<td><strong>OEE = 60%</strong></td>
</tr>
<tr>
<td>Weight: (6*25) / 162 = 93%</td>
<td>Weight: (8*1.5) / 162 = 7%</td>
<td><strong>83%</strong></td>
</tr>
<tr>
<td>85%</td>
<td>49%</td>
<td><strong>Total installed pump capacity: 14k m3/hr. Realized simultaneous pumping capacity: 6.6k m3/hr</strong></td>
</tr>
<tr>
<td>75%</td>
<td>47%</td>
<td><strong>73%</strong></td>
</tr>
<tr>
<td>Yearly arrival of 1,120 vessels, average handling time 40 hours. Planned operating time: 6`*8,760 = 52,560</td>
<td><strong>Availability:</strong> Total pumping hrs: 14k for loading, 12k for heating and 8k for blending. Planned operating time: 8`*8,760 = 70k</td>
<td><strong>Total installed pump capacity: 14k m3/hr. Realized simultaneous pumping capacity: 6.6k m3/hr</strong></td>
</tr>
<tr>
<td>Realized handling time 40 hrs. Ideal handling time 30 hrs.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
As OEE is always calculated by measuring productive time, the OEE for each of the subsystems can be calculated from the OEEs of lower level subsystems (e.g. the productive time of all pumps is the sum of the productive time of each pump). Therefore all levels in the organization can use one dataset. With this set, an operator is able to analyze the efficiency of equipment into detail, and the terminal manager can calculate the terminal’s OEE, to assess overall performance and benchmarking.

**OEE applied on liquid bulk terminals**

Having defined the subsystems, you can start calculating your OEE. For this calculation, all productivity-related time and capacity data should be gathered (see examples in Table 1).

<table>
<thead>
<tr>
<th>OEE</th>
<th>Required terminal data (examples)</th>
<th>Typical productivity losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>P: Planned operating time</td>
<td>Berths &amp; pumps: 24 hr operation Truck loading: day shifts only</td>
<td>1) Planned shutdowns (Maintenance, holidays, seasonal or night restrictions)</td>
</tr>
<tr>
<td>A: Operating time</td>
<td>Berth: Handling Time (occupancy) Pumps: running hours</td>
<td>2) Setup/change over time (Planning inefficiencies (irregular arrival), Setup time between products or processes, equipment blocked or not available)</td>
</tr>
<tr>
<td>Pe: Net production time</td>
<td>Pump: Realized vs. name plate capacity Berth: Realized vs. optimum handling time</td>
<td>3) Small stops (equipment start-up losses, no personnel available)</td>
</tr>
<tr>
<td>Q: Fully productive time</td>
<td>Unproductive hours due to quality incidents</td>
<td>4) Reduced speed (startup, small vessel, System losses, sub optimum line-up, external influences)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5) Startup rejects (samples or paperwork rejected)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6) Production rejects (Leakage/spillage, line-up errors, accidents)</td>
</tr>
</tbody>
</table>

Figure 3. Required data and typical losses for application of OEE on liquid bulk terminals.

This can, however, be a simple exercise, as most of this data is already available from other KPIs (e.g. berth operating time from berth occupancy and realized pump capacity from realized loading rate).

Besides some losses already mentioned for the manufacturing industry, Table 1 also shows some new productivity losses typical for liquid bulk terminals:

- **Availability losses**
- Planning inefficiencies may, for example, cause a berth to be unproductive when waiting for a new vessel, generating an availability loss. These losses can never be reduced to zero, as a terminal always needs a certain flexibility to cope with variations in inter-arrival times or external influences. Typical examples of external influences causing planning inefficiencies are: weather, ...
tidal windows, approach channel congestion and availability of marine and administrative services like rowers, customs officials and tugboats.

* Increased setup time: Except for terminals with dedicated systems, operators often have to create a new line-up of equipment to be able to start a new process.
* Equipment blocked or not available: When key equipment is used in a line-up this might disqualify other line-ups and block the use of other equipment.

* Performance losses
  * System losses: As pumping is a continuous process, and no inventory will be kept between tank and loading point, low-capacity equipment can be a bottleneck for overall line capacity.
  * The previously mentioned block of equipment might force the operator to use a sub-optimal line-up, which generates a performance loss.
  * The external influences mentioned before will also result in performance losses when, for example, berth-handling times are negatively influenced.

* Quality losses
  * Wherever quality losses for manufacturing lines are defined as the number of off-spec products, it will have much more of a safety character for a terminal. The terminal is not responsible for the specs of the product, but for the specs of the service. All quality issues that negatively influence the productivity of the terminal (leakage/spillage, accidents; line-up errors) should be included in the quality factor.

Where a manufacturing line is mostly dedicated to production of a limited number of products, terminals require much more flexibility. This flexibility, combined with the limited influence of a terminal on its losses, makes optimizing the terminal’s OEE a challenge. The OEE will effectively facilitate this challenge, as a limited amount of data is required and unknown data can easily be gathered by measuring productive time.

Terminal specific losses are often also the reason that benchmarking terminals is considered difficult. As the OEE value provides a summary of all operational losses at the terminal, it can be used as a proxy for the operational performance of a terminal. Terminals can, for example, outperform by conducting maintenance during planning inefficiency losses, or reduce operating hours and increase OEE.

**Back to the example**

Now let’s go back to your problem. Figure 3 shows the OEE calculation of your terminal after the tank expansion, but without expansion of berths and pumps. A quality factor of 100 per cent is assumed, while benchmarking enables you to conclude that 60 per cent is a good OEE value for your terminal. Now you will be able to conclude that investments in new infrastructure will not be effective (they will increase operating hours and thus reduce OEE). However, you will have to reduce your berth occupancy, reflected in the 83 per cent availability factor, by increasing the low pump and berth performance factors. This is the KPI you can show to your board.

**Conclusion**

The example used in this article shows how the OEE can effectively contribute to optimization of the operational and financial performance of a terminal. Furthermore, it can effectively be used as a KPI for benchmarking terminals with their peers.

**Terminal functions and types**

Besides its storage function, a terminal has two other main functions:

1. A transport function facilitating the storage function.
2. A value added logistics function (e.g. blending, tank to tank transfers and adding additives).

One way to classify a liquid bulk terminal is by its position in the supply chain. Depending on this position, the logistics function will have a more prominent role. The list below shows the four main terminal types ranging from the strategic terminals to hub terminals. The terminal type is expected to affect the productivity losses at the terminal, which results in an optimum OEE for each terminal type.

**Strategic terminals**, used for strategic storage by governments.

**Industrial terminals**, used for storage of raw materials and finalized goods at the production site.

**Import or export terminals**, primarily focused on make or break bulk services.

**Hub terminals**, high volume market places with many logistics services.

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**ABOUT THE AUTHOR**

**Bas Verheul** has a Masters degree in Shipping Management at Delft University of Technology, and has been involved in numerous financial and operational studies in the port and shipping industries. In his current function as logistics consultant, he conducted several feasibility and optimization studies for liquid bulk terminals ranging from inland river terminals to major hub terminals.

**Tebodin Netherlands B.V.**, is an independent engineering and consultancy firm providing a wide range of services, ranging from design, procurement and project management to environmental and logistic consultancy. In recent years, Tebodin’s logistics experts have effectively advised liquid bulk terminal owners and operators during expansion and optimization projects. Several specialized in house developed tools are available for this purpose.

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**ENQUIRIES**

Tebodin Netherlands B.V.
Laan van Nieuw Oost Indie
P.O. Box 16029, 2500 BA The Hague
The Netherlands

Email: b.verheul@tebodin.com
Web: www.tebodin.com