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EU Terminal Productivity Indicator

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1 INTRODUCTION

PORTOPIA's aim is to develop one or two high level indicators of the productivity of port terminals. This position paper describes the complexities of developing such an indicator and proposes an approach.

2 BROADLY DEFINED DATA REQUIREMENTS

A productivity indictor would have to measure a certain output in relation to a certain input. An indicator could either focus on a broad picture per port, be specific for a specific type of terminal (e.g. container terminal) or even a specific measure per ship. Table 1 gives some potential measurements of inputs & outputs, for the three potential 'units of analysis'.

Table 1. Potential parameters for productivity outputs and assets.

	Outputs	**Input**
Port level	Throughput volume Ship calls	Length of quays number of berthing places. Size of land for terminal activities Size of the port area (land + water). Number of employees
Terminal level	Throughput volume	Quay length Size (m2) of terminal Number of employees
Ship visit	Volume loaded and unloaded	Time at berth

Source: Authors

3 DATA COLLECTION CHOICES

The core choice regarding data sources is whether it would be best to work with publicly available data[1] or it would be best to work with proprietary data of port authorities,

[1] In this approach, ports and / or other stakeholders can be asked to validate the data.

terminals or shipping lines. Ideally, owners of proprietary data would provide these data, however, PORTOPIA efforts in this direction have not been very successful.

For port authorities:

- Ports are burdened with data requests in PORTOPIA frequently.
- The response to data requests in other work within PORTOPIA is limited, leading to indicators for only ports that did provide data.
- PORTOPIA partners cannot validate data provided by the ports and in some cases there are differences in definitions between ports.
- Past experience shows that the number of ports that are willing to put effort in calculating & collecting data is limited.
- Past experience shows that when ports are not/ insufficiently convinced on the value of a collective indicator development effort, the number of ports that provide data is limited. Generally, ports are relatively positive towards indicators on environmental issues and safety, but sceptical about efforts focused on productivity.

Data provision by terminals is problematic for a number of reasons:

- The terminals do not even publish throughput data. His goes to show the extent of confidentiality of market data.
- Previous industry efforts aiming to involve terminal operators have failed. This applies both for initiatives within the ESPO-led PPRISM project and the Container Terminal Quality Indicator (CTQI) an initiative by the Global Institute of Logistics (GIL) together with Germanisher Lloyd.
- Terminal operators are reluctant to share data that enables productivity benchmarking with third parties. This may be especially problematic given the perceived relation of PORTOPIA with EU policy initiatives. Terminals are especially cautious because of this. Conversations terminal operators confirmed that they are reluctant regarding involvement in the productivity indicators in PORTOPIA.
- PORTOPIA partners cannot validate data provided by the terminals and uniform definitions across all terminal operating companies are unlikely. Therefore, simply using data from third parties is problematic, as experienced in other indicators in PORTOPIA.

Reaching out to shipping lines also has not been successful.

- Shipping lines provide data specifically in the container segment, to JOC. This is the only established terminal productivity indicator. The PORTOPIA consortium has reached out to JOC to include (modified versions) of the data in PORTOPIA, without success. Furthermore, PORTOPIA has approached shipping lines to ask if they were willing to share the same data with PORTOPIA, but this request was also declined. See Appendix 3 for some details on contacts with third party data providers and shipping lines.

For this reason, the approach to collect publicly available data first hand is the only feasible way forward. In this approach, the PORTOPIA research partners collect data first hand, and ask ports to validate the data. Based on an explicit validation & modification process, the data are revised where appropriate. For the ports that do not validate, the data as collected will be used. However, this approach implies a productivity indicator will have to be confined to publicly available data. The table below reviews public data availability of input and output variables.

Table 2. Public availability of data

Data	**Publicly available?**
Throughput volume at port level	Yes, for most ports, available in PORTOPIA.
Throughput volume at terminal level	No, terminals do not disclose their volumes.
Total ship calls per port	Yes but imperfectly, not all ports report this publicly
Volume loaded and unloaded per ship	No, this is proprietary to shipping lines (& terminals)
Ship's time at berth	No, even though for ships with AIS such data can be generated.
Size (m2) of terminal	Imperfectly, for some terminals this is available, based on satellite images from Google, for others not, given the absence of visible 'boundaries' between terminals.
Quay length	Yes, based on satellite images from Google.

Size of the port area (land + water).	No, satellite images may allow an approximation, but not an accurate one, given the absence of visible clear borders between ports & non-port activities.
Size of land for terminal activities	No, satellite images may allow an approximation, but not an accurate one, given the absence of visible clear borders between ports & non-port activities[2].
number of berthing places.	No, these cannot be derived from satellite images; some ports have port maps with all berthing places.
Employment in port.	No uniform data publicly available, large differences in organisation of labour between ports.
Employment at terminals.	No uniform data publicly available, large differences in organisation of labour between ports, impact employment levels at terminals.

Source: Authors

4 FEASIBILITY OF AN AGGREGATED PORT LEVEL INDICATOR

Given the limited data availability, an option is to develop one 'high-over' indicator' at the level of the port as a whole. Such an indicator would need to provide a meaningful indication of the productivity of the whole port system. Various options are available, but all have such serious shortcomings that they do not have value for the ports industry, see the table below.

Table 3. Potential indicators at port level and their shortcomings

Potential indicator at port level	*Shortcomings*
Throughput per m2 of port land.	• The number of m2 port land cannot be measured based on publicly available data. • Given underlying differences in commodities as well as value propositions (in some cases terminals focus on offering long term storage, in other cases not) this

[2] LLoyds Port Directory, a database that can be accessed for a fee has data, however these are not fully reliable and not publicly available.

	indicator is not very meaningful. Generally, industrial/value added ports would have a low throughput per m2, while transshipment ports will have a high throughput per m2. Likewise, ports with important liquid bulk flows with end up with a high throughput per m2, breakbulk ports with a low throughput per m2. These data are fairly meaningless.
Throughput per meter port quays.	• At the port level, the fact that ports have different 'commodity portfolios' reduces the value of such an indicator. • The length of quays is not relevant for liquid bulk, liquid bulk is often (un)loaded at jetties.

Source: Authors

To conclude, indicators for the port as a whole are flawed and implementation is problematic given the lack of publicly available data on quay length and port land.

5 DISAGGREGATED PRODUCTIVITY INDICATORS FOR TERMINALS

As a consequence, the potential value of disaggregated indicators needs to be assessed. A disaggregated indicator would have to deal with productivity of a specific type of terminal. Developing disaggregated terminal productivity indicators would require indicators for different types of commodities, the most important ones are given below[3]:

- Crude oil
- Oil products
- Gas
- Chemical products (liquid)
- Liquid biofuels

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3 This list of commodities is more detailed than most 'categorisations', that distinguish dry bulk, liquid bulk, containers RoRo and other general cargo. This level of disaggregation is needed as each commodity is handled through a different terminal. Note that this list covers about 99% of all volumes handled in seaports but is not fully complete. For instance, some ports also handle fruit juice and offshore wind equipment.

- Iron ore
- Coal
- Grains
- Biomass
- Containers
- RoRo (ferries)
- Cars (car carriers).

For some commodities, there are such significant differences between terminals that productivity indicators are unlikely to be meaningful in practice. Three examples illustrate this:

- Some oil terminals are focused on a fast turnaround of liquid bulk products, while other terminals focus on long term storage (in some cases strategic storage agreed upon by EU member states). A productivity indicator cannot meaningfully capture that difference.
- The call size (average volume of cargo unloaded & loaded) deeply influences port productivity. For example, deepsea lines may onload around 4000 TEU in the large ports in North-West Europe, while the average unloading volumes in medium-sized ports may be around 500-1000 TEU or less. This deeply impacts productivity. Likewise, parcel tankers may unload small volumes of liquid bulk in one port, while other ports may receive dedicated vessels that unload all liquid bulk in their port.
- In some cases, terminals are not the core business, but are part of integrated manufacturing sites. For instance, coastal steel plants generally have a dedicated steel terminal. Such a terminal is run differently compared to a third party steel terminal.

To conclude, even within a commodity, developing a meaningful terminal performance indicator is problematic due to the underlying differences between terminal operations. Thus, the value of an indicator differs between commodity segments. An assessment of the relevance is provided below:

Table 4. Assessment of relevance of a terminal productivity indicator per commodity segment

Segment	**Relevance**
Crude oil	Limited, terminals are often user owned.
Oil products	Limited, variety of products and parcel sizes is too large.
Gas	Limited, small number of terminals in Europe, most (partly) user owned.
Chemical products	Limited, variety of products and parcel sizes is too large.
Liquid biofuels	Limited, variety of products is too large. Often handled at tank terminals together with other commodities
Coal	Moderate, some terminals are user owned.
Iron ore	Limited, the number of iron ore terminals is limited, most of them are user owned.
Grains	Limited, terminals handle different commodities, have different business models, some deal with export flows, other with import flows.
Biomass	Limited, often handled at bulk terminals together with other commodities. Volumes are very small.
Containers	Large, terminal productivity is a key concern for shippers and shipping lines, containers account for a large (and growing part) of European trade flows.
RoRo (ferries)	Limited, ship design is key determinant of productivity, the key factor is the number and size of ramps. Furthermore, there often is not a terminal operator in charge of operations. Finally there is a different mix of semi-trailers, trucks and passengers.
Cars (car carriers)	Limited, huge differences in call sizes.

Source: Authors

6 PRODUCTIVITY OF CONTAINER TERMINALS

This topic has received significant attention. The most relevant academic literature on container terminal performance is provided in appendix 1. Some industry initiatives to measure port performance are briefly discussed below.

1. Drewry shipping consultants made a for sale report on container terminal productivity in 2010, but have not repeated this effort since. Likewise, Ocean Shipping Consultants also developed productivity benchmarks, but also do not publish results regularly. Likewise, the container terminal quality initiative of DNV and GIL initially aimed for delivering benchmarking methods, but these have not materialized.
2. The only initiative with benchmarking data available is JOC's terminal productivity indicator. This indicator is also widely embraced by the industry. The productivity is measured with the use of data provided by shipping lines; terminals do not provide any data, nor were they involved in this project.

6.1 The JOC indicator

The JOC indicator measures hourly moves based on shipping line data on arrival time, departure time and number of lifts. Data are collected at the level of terminals, they can be aggregated to ports. Only deep sea terminals are included. In total, about 700 terminals worldwide are included. However, as some EU core ports handle shortsea volumes only, not all core ports are included in the JOC indicator.

JOC makes a distinction between calls of ships with a capacity below 8000 TEU and ships with a capacity of more than 8000 TEU. Even though some disclaimers can be made (see textbox), this indicator is relevant and broadly accepted.

Two shortcomings of the JOC indicator

- The indicator is relevant for carriers but misses some elements, such as utilisation rates, that are relevant for terminal operators and port authorities, as they want sufficient utilisation of their resources. Likewise, the costs and productivity of 'production factors' are not taken into account. The costs of high productivity may not always be passed on to the user, but may instead be assumed by the government (i.e. through making land cheaply available).
- The indicator does not take into account differences in types of operations, even though these are known to influence productivity. For instance, transhipment flows are associated with higher productivities, the same applies for the call size (the number of containers that are loaded & unloaded); larger call sizes lead to higher productivities. Finally, the position of a port in a rotation also matter, 'first ports of call' in a certain market generally benefit from the fact that large volumes are unloaded, enabling efficiency of loading containers (ample space), while the 'last port of call' is generally associated with more complex (un)loading operations.

As the JOC indicator is widely used, it does not make sense to replicate it, and efforts to use either the results or the raw data have been declined. Therefore an additional indicator would have to be complementary. A potential complement from the port's perspective would be to develop an indicator that focuses on the productive use of *port assets*. The JOC indicator is fully focused on performance for the shipping lines. However, a higher performance may be associated with a higher cost. For instance, a high number of moves per hour is easier to achieve in relation with a low occupancy rate. In this case, while shipping lines are well served, the use of port assets is low. An indicator on the use of port assets can be developed with throughput as output, and quay length[4] as input. The indicator throughput per meter quay wall is widely used in

[4] Throughput is more relevant than ship calls, as the throughput creates value, not the ship call per se. As asset indicator, quay length seems most appropriate, as the quay is the most costly infrastructure asset of a port. Furthermore, the size of the terminal may be hard to define uniformly (some terminals may have empties on the terminal, in other cases these may be stored in specific empty depots, the same applies for cleaning & repair activities. Furthermore, the terminal area may not be publicly available whereas the quay length can be derived from publicly available resources (i.e. google satellite).

port planning. Note that this indicator would have to be developed at the level of the port as a whole –where various container terminals may operate- as terminals do not publicly report throughput volumes.

Similarly, throughput per meter quay length could also be calculated for coal terminals. Coal is one of the largest single commodities handled in the EU and therefore relevant. However, given the political commitment to reduce the CO_2 footprint, it is widely expected that the use of coal in the energy mix will decline. That may lead to reduced volumes of coal in EU ports. In this context, this productivity indicator is imperfect as there are huge costs involved in reducing the size of coal terminals. Nevertheless in our view it is sufficiently relevant to include coal terminals in the analysis. As indicated above, this indicator is not valuable for liquid bulk, as these ships often have jetties instead of berths, not for most other commodities.

However, like all indicators, this indicator is not without shortcomings. First, such an indicator does not correct for the 'scale effect': handling larger volumes per ship increases efficiency and thus leads to a higher output per asset. Second, not all ports may measure throughput volumes in precisely the same way (e.g. some ports may include barge volumes handled at deepsea terminals, others not). Third, in large ports, all relevant terminals need to be included. Generally, that implies both terminals aimed at shortsea volumes and terminals aimed at deepsea terminals. However, terminals to handle barges need to be excluded.

7 IMPLEMENTATION PROCESS

The throughput volumes of ports are available in PORTOPIA. For berth length, we analysed the annual reports and websites of the port authorities of all EU core ports. This analysis shows only 8 of the >90 EU core ports have publicly available berth length data. However, none of the ports provide data for specific terminals. In line with the arguments provided above, we looked for the first hand data collection by the research partners and a validation process with the involved ports.

The initial process to collect data was as follows:

1. To work with first hand data collection.
2. To collect data to calculate productivity at the level of commodities.
3. To use berth length as the input variable, and throughput as the output variable.

4. To select two commodities based on highest relevance: containers and coal.
5. To ask ports to validate or modify the data collected by the research partners.

7.1 Data collection and validation – lessons learnt

Due to limited information on quay lengths in public sources the project team measured the container and coal quay lengths in Google Earth which provides measuring accuracy within reasonable safety margin (see more in appendix 2).

Easiness of measuring varied from port to port. For containers the quays were often unambiguously recognised while the coal quays tended to be less identifiable. Some of the coal quays were discovered only after observing in the statistics that there is a coal volume in port (Copenhagen, Malmö and Stockholm). E.g. in case of Malmö the port web site confirmed the location of the quay since the satellite image had only scrap metal in the nearby port yard. Stockholm coal quay was not identifiable in spite of the fact that coal is handled in the port according to the statistics. The "dedicated" coal quays may also be in transition to other uses due changing energy policy, thus posing a problem what to include in calculations (like in case of Malmö). Another example of the energy transition, as referred earlier, is in the port of HaminaKotka where the coal power plants were demolished in 2015 although still visible in air images. The measurements were contrasted to public information on quay lengths when available to support validation.

The aim was to use the throughput data of 2015 for indicator[5]. This statistics for that year was ready in spring 2016. By that time the project team had experience of data validation by port authorities of the roro connections of their ports. This exercise was executed for roro connectivity indicator (see Deliverable 4.2.). The validation to back up of the collected data was minimal, probably due to survey fatigue and relatively limited support of the indicator amongst the stakeholders (ESPO committees). This led to withdrawal to the plan to validate data by the port authorities.

The table 5 presents the calculations of the indicator for the Baltic Sea core ports. The both commodities are presented in order of largest to smallest volume. The general overview reveals that the largest volume ports tend to also show better performance as anticipated. In containers, as a generally growing segment the indicator shown

[5] Eurostat for containers, Baltic Port List for coal (2014 figures available only).

efficiency may result from the capacity lagging behind of the growing volumes. Meanwhile, the coal as a generally decreasing market may show decreased efficiency in some ports that used to handle a lot of coal. One example is Tallinn where tons/m in 2014 were 1643 and in 2006 as high as 7425 (more than 4 times higher).

Table 5. Baltic Sea core ports productivity indicator calculations.

	Container			Coal			
TEN-T Core Port	Quay meters	volume 2015	TEU/meter	Quay meters	volume 2014	Tons/meter	TEN-T Core Port
Gdansk	997	1 041 346	1 044	1 657	14 935 300	9 013	Riga
Goteborg	1 772	805 465	455	1 507	5 852 000	3 883	Ventspils
Gdynia	1 246	676 443	543	2 781	4 320 238	1 553	Sczecin-Swinoujscie
HaminaKotka	2 385	487 374	204	306	3 454 443	11 289	Gdansk
Aarhus	1 283	445 170	347	898	2 051 420	2 284	Gdynia
Helsinki	1 452	411 094	283	470	1 430 000	3 043	Lulea
Riga	1 201	355 417	296	257	1 233 527	4 800	Rostock
Klaipeda	1 793	350 392	195	201	654 000	3 254	Copenhagen
Tallin	866	208 784	241	378	621 224	1 643	Helsinki
Lubeck	294	150 003	510	159	599 739	3 772	Turku Naantali
Copenhagen	457	141 837	310	none	203 678	n.a.	Stockholm
Sczecin-Swinoujscie	1 228	75 620	62	199	165 125	830	HaminaKotka
Stockholm	234	51 215	219	1 006	151 451	151	Tallin
Malmo	272	22 175	82	527	91 000	173	Aarhus
Turku Naantali	320	1 332	4	200	54 621	273	Malmo
Rostock	none	692	n.a.	none	0	n.a.	Lubeck
Ventspils	none	0	n.a.	none	0	n.a.	Klaipeda
Lulea	none	0	n.a.	none	0	n.a.	Goteborg
Trelleborg	none	0	n.a.	none	0	n.a.	Trelleborg

The exercise presented for the Baltic Sea core ports shows that the indicator is feasible but on the other hand having imperfections regarding data quality and the risks in interpretation of results. Data collection cannot either be automated therefore requiring manual labour. The port authority motivation is primarily in the data input for indicators which are conceived already more mature and meaningful. This approach to port productivity is providing, however, with contextual analysis of other sources and PPIs, insights for port performance regarding productivity.

8 APPENDICES

8.1 Appendix 1: academic studies on performance metrics for terminals

The following performance indicators are useful for port operators, including port authorities that provide terminal operations.

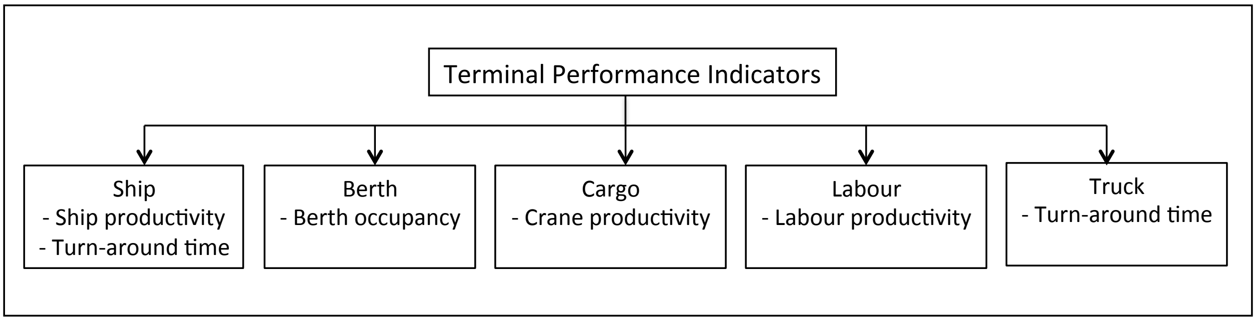

Figure 17: Main terminal performance indicators for operating ports

Each of the indicators in figure 17 is discussed in some more detail below focusing the discussion on container operations, the most important and fastest growing segment for many ports.

1. Ship productivity

The broadest measures of ship productivity relate container handling rates for a ship's call to the time taken to service the vessel. It is important to note that this indicator does not consider resources put into operation and that high ship productivity is a determinant of better ship turn-around time.

It can be expressed in gross and net values:

- Gross Moves per Hour (GMPH) = $\frac{Containers\ moved\ to/from\ a\ ship}{Hours\ between\ first\ ans\ last\ lift\ (period)}$
- Net Moves per Hour (NMPH) = $\frac{Containers\ moved\ to/from\ a\ ship}{Hours\ between\ first\ ans\ last\ lift\ minus\ idle\ time\ (period)}$

The difference between GMPH and NMPH is that in the latter indicator, the idle time is excluded. That may be relevant in cases where there may be idle time that is not related to terminal operations, for instance ship inspections of custom procedures. However, in general, the GMPH is the most relevant indicator from a shipping line's perspective.

2. Ship turn-around time

The second ship related indicator is the turn-around time of ships. As mentioned before, shipowners and cargo owners benefit from a fast turn-around time of ships. For shipowners, this means they can make more trips with their vessels; and for cargo-owners, it means that they have their cargo available earlier. Therefore, ship turn-around time is also an important performance metric for port operators and port authorities.

Ship turn-around time can be defined as the total time spent by the vessel in port during a given call and it is influenced by al kinds of services to the ship, such as loading & unloading, pilotage, towage, competent master, bunkering and ship supplies as well as by the waiting time and the sailing delay. From the port perspective, the TAT should include as much relevant elements of a port call. Ideally, ship turn-around time should be only marginally longer than ship's time at berth and thus waiting time in particular should be as short as possible. Ship turn-around time can be calculated as follows:

- $TAT = T_w + T_b + T_{ber} + T_{unber}$

Where:

- T_w = waiting time for free berth;
- T_b = service time at terminal;
- T_{ber} = berthing time;
- T_{unber}= unberthing time.

This indicator reflects the performance of various companies in the port and clearly relevant for shipping lines. As an indication: daily charter rates for medium sized bulk ships may be around $30.000-50.000. This means that a reduction of the TAT with one day creates at least this amount of value for the shipping company.

Approaches to terminal productivity

Terminal productivity is a hot topic in the terminal industry, especially for container terminals. Various industry initiatives as well as research projects have looked at terminal productivity. Productivity measures are usually expressed by the ratio of output to input, with the objective to maximize the output within the given input or minimize input while satisfying the required amount of output.

However, there still is no widely accepted metric for terminal productivity. Partial productivity indicator (PFP) compares a subset of outputs to a subset of inputs when multiple outputs and inputs are involved. For example, PFP ratios include crane throughput per hour. Many terminal operators monitor such a partial measure, specifically the number of moves per crane per hour. However, this metric depends to a large extend on the call size (the number of containers loaded and unloaded), the transhipment share the number of empties and the complexity of stowage. From a shipping line, the number of cranes is not relevant, they are more likely to evaluate terminals based on the *total moves per hour* that they realise.

Total factor productivity (TFP) combines multiple inputs and outputs into port performance measurement by using an aggregate index or using indices estimated from cost or production functions. A basic assumption in TFP measures is that output and input markets achieve productive efficiency (i.e. output price = marginal cost and input prices = marginal product value) so that the weights are estimated by output and input share in total revenue and cost respectively. A TFP index can be obtained directly from data without needing statistical estimation from a production or cost function. However, this requires output and input data, including prices, revenue shares and costs. When the data is unavailable, estimation of weights from production functions or econometric models may be used.

Past studies on port efficiency have made use of TFP to measure terminal performance, using labour and capital as input and throughput in metric tons as output. The main advantage of TFP measurements is that overall impacts of the changes in multiple inputs on total output are shown. However, the results of TFP depend largely on the definition of weights and the technique used to estimate the weights.

Box 9. Academic studies on terminal productivity

3. Berth occupancy

Berth occupancy is the measure of utilisation in percentage terms of a berth; i.e. it is the ratio of time the berth is occupied by a vessel to the total time available in that period. Assuming random arrival of ships, high berth occupancy is a sign of congestion (>70%) and hence decline of services, while low berth occupancy (<25%) implies underutilization of resources.

Berth occupancy rate can be calculated as follows:

- Berth occupancy rate (%) = $\frac{Total\ time\ of\ ships\ at\ berths\ (in\ days)}{Total\ number\ of\ berth}\ x\ \frac{100}{360\ days}$

High berth occupancy can be achieved without congestion when ship calls can be *scheduled*. For instance, container ship arrivals are scheduled, but ships very often do not adhere to these schedules, causing a knock-on effect for other (feeder) vessels. Bulk terminals can also move towards better-planned ship arrivals, but in many ports, ships are still served on a 'first come first serve' basis.

4. Crane productivity

Crane productivity measures handling rates of a crane (container moves/crane or container moves/hour). High crane productivity is also a determinant of better ship turn-around time.

As an example, container terminals at the ports of Los Angeles and Long Beach operate with approximately 28 to 35 moves per crane per hour. High rates of up to 40 moves per hour can be achieved in specific cases. Crane productivity can be expressed in gross and net values and it is calculated as follows:

- Gross Crane Rate = $\frac{Containers\ moved\ over\ the\ quay\ per\ crane}{Hours\ between\ first\ ans\ last\ lift\ (period)}$
- Net Crane Rate = $\frac{Containers\ moved\ over\ the\ quay\ per\ crane}{Hours\ between\ first\ ans\ last\ lift\ minus\ idle\ time\ (period)}$

Crane productivity is influenced by a number of factors:

- Type of cranes; some cranes work with 'double lifts' (separating the lifting in two phases), others work with a single lift.

- Skills and training of the crane operators. The productivity generally differs substantially between different crane operators, both as a result of training and as a result of the skill-set of the operator (the so-called 'eye-hand coordination' is a key factor in worker productivity).
- The 'call size' (the number of ships loaded & unloaded). Crane operations are easier when a huge number of containers have to be loaded in the same section of the ship, without a need for moving the cranes.

For shipping lines, ship turnaround is more important than crane productivity; terminals that use many cranes to achieve a fast turn-around may be considered as good as terminals that use less, but more productive (and expensive) cranes.

Academic studies: frontier approaches & Data Envelopment Analysis

The frontier approach evaluates the efficiency through the estimation or calculation of an efficiency frontier. Under this approach, units are deemed to be efficient when they operate on the production or cost frontier; inefficient units operate *below* the frontier in a *production frontier* and operate *above* it in the situation of a *cost frontier*. The technical efficiency of inefficient units can be interpreted by its distance away from the frontier allowing a relative comparison of economic units when performing benchmarking port performance.

Two methods can be used to locate the frontier, namely parametric methods or non-parametric methods. Parametric methods make use of econometric methods to estimate the statistical frontier production function and assume a particular functional form of variables while nonparametric approaches do not need such a pre-defined production function.

One of the commonly applied nonparametric techniques is data envelopment analysis (DEA). Non-parametric approaches are suitable for measuring efficiency of observations with multiple inputs and outputs, as well as providing information about the sources of the relative efficiency. Furthermore, rather than to benchmarking ports against a statistical measure, DMUs are benchmarked against a real 'best' unit in nonparametric approaches.

However, major disadvantages of DEA are:

- In DEA, the sensitivity of efficiency scores to the choice and weights of variables.
- DEA does not capture the effects of investments. For instance, there are huge differences in container cranes, while in DEA they are generally counted as one unit.
- DEA does not incorporate the negative effects of highly utilised terminals on waiting times. DEA may show a port is very productive when waiting times for shipping lines are huge.
- The level of data availability generally does not allow for rigorous DEA analysis.
- DEA does not capture the specifics of terminal operations, such as the percentage of transhipment containers, the number of empty moves and so on.

In short, even though researchers advance in the development of productivity indicators, there is no widely agreed upon indicator and most independent studies of productivity fail due to a lack of data.

Box 1. Academic studies on port performance: Frontier Approaches

5. Labour productivity

Labour costs form a large part of total terminal costs, even with a high level of automation. Thus, it is important to monitor labour and measure the productivity per man-hour (moves/man-hour).

Gross labour productivity is a measure of gang productivity which is defined by the number of moves per man-hour. It can be calculated as follows:

- Gross Labour Productivity = $\frac{Annual\ throughput\ (TEUs)\ per\ FTE}{Annual\ labour\ per\ employee}$

Taking as an example the standard annual labour of one person (also known as a full-time equivalent, FTE[6]) which equates with approximately 2000 man-hrs a year and a container terminal that achieves an annual throughput of 800 TEUs per FTE, this means a gross labour productivity of 0.4 TEUs per man-hr. For such an indicator, it makes sense to include all operational employees in the analysis. Such indicator may be useful in specific cases but also deeply depends on the terminal operations (ship size, % of transhipment containers, stacking methods and so on).

Additionally, General Turnover per Employee can be calculated by dividing a firm's turnover by its total number of workers. This ratio is used to know the contribution of every employee in the firm's turnover for any period. Turnover per Employee can be calculated as follows:

- Turnover per Employee = $\frac{Total\ turnover\ in\ any\ period}{Average\ number\ of\ employees}$

6. Truck turn-around time at terminal

For shippers/receivers (and trucking companies) the most important measure of a terminal's service quality is the time required to collect a container from the terminal or to deliver one.

Trucks generally arrive at the gates in peaks. During those peaks, waiting times can become very high, with detrimental effects for trucking companies and port users. Therefore, most terminal operating companies as well as port authorities recognise the

[6] A full-time equivalent (FTE) is the equivalent of one person working full time (8 hrs/day x 5 days/week x 50 weeks/year).

need for service levels to trucks. Terminals have developed truck appointment systems to better plan these operations and spread out the arrival of trucks more evenly over the day. The most relevant metric regarding handing of trucks is the truck turn-around time.

The time between a truck's arrival at the terminal and receipt of instructions to pick/up deliver a container is defined as truck waiting time (or queue time). The time from the instructions to the exit of the terminal is the truck flow time. The sum of the *truck waiting time* and the *truck flow time* is the *truck turn-around time*. When measuring truck turn around time it is critical to also take into account the waiting time of a truck outside the gate. Even though this may not be part of terminal operations, it is relevant through the eyes of the users of the port.

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8.2 Appendix 2: Data collection test

Based on a review of annual reports (of ports, or in the case of Spain the national port governing body) and websites 12 of the EU core ports have publicly available berth length data.

1. Port of Wilhelmshaven (Germany): total quay length of 6 km
2. Port of Koper (Slovenia): 3 282 m
3. Port of Algeciras (Spain): 6 672 m
4. Port of Cartagena (Spain): 13 800 m
5. Port of Gijón (Spain): 10 085 m
6. Port of Huelva (Spain): 7 839 m
7. Port of Las Palmas (Spain): 16 395,5 m
8. Port of Palma de Mallorca (Spain): 11 335,8 m
9. Tallinn (Estonia) 1 km (containers)
10. Gdansk 1,015 m (containers)
11. Szczecin-Swinoujscie 300 m (containers)
12. Gothenburg 1,8 km (containers)

As a test to see whether satellite analysis through Google Earth is in line with data by published websites, we analysed some ports. For example for port of Koper the Google Earth calculation method of total berth length gives 1,560+500+500+650 = 3,210 m (see figure 1 below, red lines are only indicative). The difference between the figure published by the port authority and measure was minimal (72 m, 2,2%). The test was continued further with container quays of four ports (table 6).

Table 6. Quay lengths published by the port authority and measured in Google Earth.

Port	Port (m)	Google Earth (m)	Difference (m)	%
Koper	3282	3210	72	2,2 %
Tallinn	1000	866	134	13,4 %
Gdansk	1015	997	18	1,8 %
Szczecin-Swinoujscie	1275	1228	47	3,7 %
Gothenburg	1800	1722	78	4,3 %

The common feature in all studied ports is the port authority given quay lengths being longer than ones measured in Google Earth. This may not be surprising since ports tend to rather round up their capacity the figures for marketing purposes. The port of

Tallinn tells container quay length to be 1 km in total which can be a rough approximate, therefore resulting larger difference between measured and port given figure. Otherwise differences are fairly modest, under 5%.

Figure 1: Satellite Analysis of Port of Koper

Source: Authors

This compares very well with the data from the annual report, the difference is less than 3%. Collecting these data for all EU core ports may lead to some ambiguous situations. However, given the fact that all terminals have to be fenced (ISPS regulation), we are confident that in virtually all cases the quay can be identified without problems. Google provides precise distances for any two points on a map, so deriving the length from a map is straightforward. We propose only to collect data for containers and RoRo if ports have dedicated terminals to handle these commodities. That is the cases in virtually all EU core ports.

8.3 Appendix 3: Information on interaction with potential data providers

Below, we have added an example of a letter send to one specific data provider, JOC. Table 7 summarises the interactions with potential data providers.

Table 7. Assessment of relevance of a terminal productivity indicator per commodity segment

Data provider	**Interactions**	**Comments**
JOC	Q3 2013-Q2 2014, A formal letter, various phonecalls and e-mails	JOC was not willing to engage with PORTOPIA within budget constraints.
Marine Traffic	Q2 2014-Q1 2015, various mail & phone calls	The data quality and computational problems with the DATA make developing a productivity indicator impossible. Most importantly, the data on loading & unloading volumes are missing.
Container shipping lines (associated in World Shipping Council and for Europe, ECSA).	Q1-Q2 2014, various calls and mails.	The WSC was not willing to help reaching out to the carriers to replicate the JOC analysis.
Terminal operators	Long ranging contacts, already started before PORTOPIA proposal was submitted. Meetings with various leading terminal operators in Europe.	Ongoing reluctance to participate.
Port authorities	Ongoing within PORTOPIA	Port authorities do not have harmonized data that could help in developing a productivity indicator.

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Journal of Commerce
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Subject
Contact

Date
7 October 2013

Contact
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Dear mr. Gorman,

Eindhoven University of Technology is working with 12 industry partners, including the European Sea Ports Organisation (ESPO) on a EU funded project, PORTOPIA, to develop a set of port performance indicators. The goal is to realize a permanent 'observatory' that is rooted in academic expertise, supported by the industry, and financially self-sustaining. Most indicators will be developed based on data provided by the ESPO members, the port authorities. In addition, we will also develop some indicators based on other data. A central one is a *maritime connectivity indicator*. This indicator expresses the quality of connections of EU ports with markets overseas. The indicator deals with containers only. We have developed a method to calculate a connectivity indicator based on the connectivity between 'port pairs' (e.g. Rotterdam Shanghai). Ideally the indicator should capture data on:

- Frequency of services
- Transit time of services
- Ship size of services
- The number of competing carriers that provide services

We strongly believe such an indicator is valuable for port authorities, shipping lines, shippers and policy makers.
A major challenge is the data collection. These data are available from the shipping lines, but collecting them is time consuming. Alternatively, we may be able to develop a partnership with JOC, where JOC provides the data (with clearly defined limits regarding the use of the data) and Eindhoven University of Technology (the lead partner for the development of this indicator) performs the calculations to develop the indicators. The project does not allow for purchasing the data, so we would have to discuss a potential win-win partnership on another basis. We see two potential benefits for JOC:

1. Visibility as leading data provider on shipping schedules and related data for shippers and forwarders (PORTOPIA only aims at developing performance indicators).
2. Potential to (jointly) develop a 'connectivity product' either in other parts of the world or in addition to the data provided for free through PORTOPIA.

Therefore, we would like to further explore opportunities to cooperate, addressing the first of all the data you have and could provide, and second a partnership model that would work.

Looking forward to hearing from you,

Very best regards,

Prof. dr. Peter de langen