ASSESSING PERFORMANCE INDICATORS FOR INLAND TERMINALS

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ABSTRACT

In this paper, an approach for recognizing and defining correct and operable performance indicators will be shown for evaluating the effectiveness and efficiency of processes in inland terminals (intermodal hubs). The challenge in evaluating the possible improvements of the underlying processes lies in the special nature and t complex structure of inland terminals. It is important to consider that all the processes are highly interconnected and that changes in parameters in one process also have an impact on parameters in other processes. Furthermore the performance of intermodal hubs, as they can be seen as the backbone of the system, has a significant impact on the overall performance of the whole transportation network. Therefore it is consistent to integrate measures that allow performance evaluation from different perspectives which correspond to the needs of all stakeholders. The underlying research question is how to work out the drivers of performance and to measure the quality of processes in inland terminals correctly.

Keywords: performance indicators, causalities, inland terminals

1. INTRODUCTION

Growing industrialized competition and higher demand on reliability of efficient intermodal systems require a continuous and integrated transport planning process. In fact, reliable and robust networks need more attention in future. Therefore better interfaces are needed to ease intermodality, in order to improve the quality of planning (Sammer, Idea, and Retzko 2008). Long term effective transportation networks require better communication and participation-consensus-oriented planning to guarantee acceptance of public and political decision makers both on national and European level. As a consequence innovative measures should be developed to stimulate self-organizing processes towards improved control and operation of intermodal and multimodal transportation (Sammer, Idea, and Retzko 2008). To minimize the risk of stranded costs when planning life-cycle assessment of intermodal hubs, more consideration has to be given to maintenance and extension of existing and future infrastructure. Innovative logistics concepts require

better forecasts, quality management and reliable performance indicators for a more intelligent use of limited infrastructure. Therefore new concepts which encourage improvement of infrastructure performance and agreed definitions and standards for robust and objective comparison of performance are needed (Stölzle, Browne, and Pfohl 2008).

We focus on a conceptual approach for measuring process quality of Austrian inland terminals because performance measurement is not only a powerful method for inland terminal operators, but also constitutes a most important input for informing regional and national authorities (Cullinane, Song, and Wang 2005). In fact, improving the performance of a inland terminal system improves the country's international market access. As a consequence, efficient inland connection raises the productivity and profitability and leads to increased trade and higher levels output, income and employment (Park and De 2004).

Increasing overload of capacity at inland terminals and the concentration of freight transport on fewer main hubs force the need to understand the cooperation requirements of all transportation modes (Stölzle, Browne, and Pfohl 2008). In near future intermodal services and the quality of existing inland terminal operations will not suffice to keep up with the transhipment capacity needed (Klotz 2007). In fact, inland terminals are fundamental nodes in transportation networks that allow the frictionless turnover of goods between different modes of transportation. Most of the intermodal hubs are constrained in their storage capacity, are faced with high load unit diversity and hardly predictable time windows for delivery and pickup. Increasing flows of goods along with increasing road transportation emphasizes the important role of intermodal hubs to match future demands with regard to economical and ecological needs. As a consequence intermodal container turnover and the corresponding infrastructure have to be evaluated exactly to guarantee efficient, quick and flexible intermodal transportation (Hansen, Rießberger, and Hollborn 2008). It is important to evaluate inland terminals as part of the whole transportation system because the effectiveness and efficiency of these intermodal hubs substantially contributes to the overall competitiveness and attractiveness of an industrial area. Further the efficiency and performance of inland terminals affects to a large extent the economic well-being of a country.

In inland terminals the problem of obtaining data on each of the variables across large samples is likely to be virtually insurmountable. Actually comparisons of productivity between inland terminals are usually made at a high level of aggregation, excluding major influencing factors. Quite often efficiency and productivity analysis are exclusively based on financial reports because of data unavailability.

Our ambition is to develop suitable metrics and to collect data on the determinants of inland terminal efficiency. The point in the conceptualization task is to avoid unnecessary complexity and focus on finding causalities and effects, often unnoticed in the pressure of day-to-day inland terminal operations. The result is intended to be an integrative perspective for decision makers of different areas. The complexity of operations and the significant number of participants in the process of planning and operating intermodal infrastructure emphasize the need for a standardized way of measuring the quality of processes to gain benefits of a coordinated strategy of hub development.

2. REVIEW OF LITERATURE

Performance measurement and benchmarking are a commonly accepted method to identify and adopt best practices in the field of open sea ports. In a more traditional context Tongzon and Heng (2005) mention that the performance of ports traditionally has been evaluated by measuring a single factor or by comparing actual with optimum throughput over a specific time period (Cullinane, Song, and Wang 2005). Tongzon and Heng (2005) postulate that the efficiency of inland transport has become a critical factor of port's potential future. The quality of hinterland connectivity and the accessibility of port facilities are already an important indicator for port evaluation and further a requirement for port users' port selection (Tongzon and Heng, 2005). In recent years more holistic approaches like the data envelopment analysis (DEA) and the stochastic frontier analysis (SFA) were applied on container port to analyze container terminal efficiency and productivity. DEA is the most prominent approach in literature to measure port and container terminal efficiency. Wang and Cullinane (2006) mention that it is extremely important to note that although the results derived from DEA provide important information on 'theoretically' optimum production; such results should be always interpreted with a fair degree of caution in practice; especially with respect to applications to the port industry. The optimal production achievable in one port is not necessarily achievable for another port. The findings of Tongzon (2001) show that there is no clear relationship between port's efficiency level and its size and its function. Cullinane, Wang, Song, and Ji (2006) compare the efficiency of land use and point out that city ports, where land is at a premium, are invariably more efficient than where this is less a constraint.

Pestana Barros and Athanassiou (2006) note that large seaports, with higher book value of assets, tend to have higher efficiency; an effect explained by the economies of scale. Cullinane, Wang, Song, and Ji (2006) also emphasize that high levels of technological efficiency are associated with scale, private sector participation. Cullinane, Song, and Wang (2005) postulate that appropriate variable definition of input and output factors is a crucial element of meaningful applications in the area of DEA. Wang and Cullinane (2006) point out that an important area deserving of further study is the analysis of the relationship between DEA efficiency estimates and more widely used industry data and indicators. Cullinane, Wang, Song, and Ji (2006) conclude that input and output variables should reflect the objective and the process of container port production as accurate as possible.

Coto-Millán, Baňos-Pino, and Rodríguez-Álvarez (2000) found that the type of organization has a significant effect on efficiency and they showed that port size is not significant when trying to explain economic efficiency. Le-Griffin (2008) points out that comparison of productivity between major container ports and terminals are usually made at a high level of aggregation. Most studies are based on publicly available data, such as facility characteristics and physical resources and annual throughput demand. One of the main challenges to terminal operations and port authorities is how to improve productivity to accommodate a large portion of the anticipated increase in container traffic (Le-Griffin and Murphy 2006). Keller and Hellingrath (2007) highlight the problem of diversity of indicator definition in practice and theory. In fact, it is virtually impossible to compare indicators of different areas of application or even within the same industry.

A common conclusion drawn in the literature is that a uniform system for evaluating the productivity of container terminals would require the disclosure of a substantial amount of data. Experience showed that needed data for analysis is not accessible it is related to data which terminal operators generally consider to be proprietary in nature (Le-Griffin and Murphy 2006). As a consequence comparisons of productivity between major container ports and terminals are usually made at a high level of aggregation, excluding major influencing factors (Le-Griffin and Murphy 2006). Wang and Cullinane (2006) postulate that the ambition is to develop suitable metrics and to collect data on the determinants of port efficiency. There is a need for commonly accepted and accessible data and measures for the future. The data has to be included within models to measure the direct quantitative influence over estimates derived to have a more profound basis for comparison (Wang and Cullinane 2006). Cullinane, Wang, Song, and Ji (2006) conclude that container terminals no longer enjoy monopoly and that they are not only concerned with whether they can handle cargo, but also whether they can successfully compete for it.

3. METHOD

The special nature of inland terminals and the complexity of its operations, arising from the complex operational interactions between the different service processes, are the most challenging aspects when analyzing and evaluating the performance. The study is focused on a set of selected Austrian inland terminals. A total of 16 terminals in Austria can be classified as bimodal (rail and road) and tri-modal (rail, road and inland waterway navigation). There are 11 locations for unattended combined transportation, two for rolling road and three offering both unattended combined transportation and rolling road. We decided to concentrate only on locations which offer unattended combined transportation, including the three locations offering both services. The reason for this lies in our focus on intermodal container turnover that only takes place in these inland terminal locations. The objective of our work is to collect analyze data through questionnaires and to develop recommendations on performance indicators related to the process quality of inland terminals.

In a first round of field visits we collected data on infrastructure. utilization, reliability the and performance of each location. In this context it was important to work out standard processes to get an idea of inland terminal operations and to locate the sources of performance indicators. During our field visits we also applied a first questionnaire to check the availability of generic data and collect available information on the performance of the terminals to define the gap between needed indicators and availability of data. The combination of field visits and workshops ensured the integration of practice based data and know-how on both operational and strategic level. The aggregated information then was used to design the second questionnaire which was then sent again to the operational terminal managers who were intended to rate the information quality of each indicator. The returned questionnaires were analyzed to define the performance indicators for the causal loop diagram.

Further we focus on causal loop diagrams to work out the connectivity in a small space. In a first step we want to develop a purely qualitative model, a sketch of cause and effect, to understand the interconnected processes and the resulting dynamics (Reiner 2005). When building the model of inland terminal dynamics it is important to be aware of operating details and causality that lie behind the scenes. It is important to be clear and precise about how such links actually work in terms of underlying behavioral responses and dependencies. Further we also have to keep in mind the numerical strength of the effects by specifying underlying relationships with reasonable accuracy. The complexity of the underlying system emphasizes that the linking of the indicators has to be done with care. Otherwise the comparison of these indicators can lead to misplaced efforts.

The study is based on a discrete event simulation which was developed in an earlier stage of our research. The simulation model is based on three standard processes (Gronalt, Benna, and Posset 2006). It takes consequently into account the delivery and pick-up process of train and truck, the storage of containers in the yard and the handling of empty containers. In this context the aim of the simulation model was to conduct experiments regarding causes and effects within the underlying processes. The simulation model is used to quantify and evaluate performance indicators which are used as input for the evaluation of the dynamic cause and effects model by setting the following parameters:

- Throughput (ITU/Year)
- Rate of fast movers and non stackable ITU (%)
- AVG storage time of fast movers (days)
- AVG storage time of slow movers (days)

Based on the findings of Benna and Gronalt (2008) the simulation collects performance indicators on the overall performance (AVG = average) of the terminal, the utilization of resources and the quality of services (see Table 1).

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Overall	AVG rate of Unproductive Moves
	AVG Moves per day
	AVG Lifting Time (minutes)
Utilization	AVG usage rate Crane (%)
	AVG usage rate Reach Stacker (%)
	AVG ITU on Stock
	AVG fill rate of Storage (%)
Quality	AVG dwell time Train (hours)
	AVG dwell time Truck (hours)
	AVG dwell time ITU (days)

Table 1: Performance Indicators

The setting of the simulation model was done according to the expert opinion of inland terminal managers. The simulation was used to analyze the behavior of the system when changing parameters in the setting. By analyzing the results of the different scenarios it was possible to work out first causes and relations between parameters (see Figure 1).



Figure 1: Causes and Effects

The plots in Figure 1 show the effects of changing parameters in the simulation setting. The upper four graphs emphasize the effect on the fill rate of the storage when changing dwell times or proportions of not stackable ITU and fast movers. Fast movers are ITUs with dwell time less than two days (measured in hours). Intermodal transport units having an average dwell time of seven days and up to twelve days are called slow movers (measured in days). Plot 1 (top left) in Figure 1 shows the effect of increased slow mover dwell time on the fill rate of the storage. The longer the slow mover ITU dwell time in the terminal, the more ITUs are in the storage at the same time, the higher the fill rate. Because of the shorter dwell time, slow movers are typically not stored within the block, but in front of the block, to avoid unproductive moves.

As a consequence an increased dwell time of slow movers block the storage and increase the fill rate of the storage (Plot 2, top right). Further it is significant to differentiate between stackable and non-stackable ITUs because latter decrease the capacity of the storage significantly (Plot 3, lower left). For example three nonstackable ITUs take the same storage space as nine stackable ITUs (Gronalt, Posset, and Benna 2007). An increase in the rate of non-stackable ITUs leads to an increase in the fill rate of the storage. When the rate of fast movers decreases (Graph 4, lower right) the fill rate of the storage also decreases because the average dwell time of the ITUs also decreases. The cause and effect diagrams then were used as starting point for the definition of the inland terminal sector map (see Figure 2). This allows a rough overview of links in the underlying system.



Figure 2: Sector Map

The aim is to find out the settings that determine the overall success of an inland terminal location. Within our approach we want to include possible explanations involving factors which are under the control of the management. We assume that the potential market share of an inland terminal depends on the coordination of orders and capacity. Therefore we developed a sector map which is shown in Figure 2 in a first step. The inland terminal is represented by the sectors equipment and staff, production capacity,

271

storage capacity and order fulfillment on the left side. The sectors include the strategies and policies like investment and exploitation of the terminal management. The right side of Figure 2 depicts the market or customers who order empty load units and deliver and pick up load units. When combining the inland terminal and the market, the mission of the terminal management is to force customers to use the terminal as place of transshipment for their load units through handling efficiency, optimized storage usage and to match handling capacity with customer requirements. In a next step we linked the five sectors by feedback loops (see Figure 3).



Figure 3: Causal Loop Diagram

Therefore we decided to model the system with causal loops as to guarantee a structural system including architecture that considers cause and causality relations (Morecroft 2007). The causal loop diagram in Figure 3 consists of four sub causal loops. In the middle of the diagram is the investment loop that adapts the capacity according to the management's perception of an increase in dwell time. To the right of the investment loop on the lower right is the dynamic adjustment loop that follows the customer target dwell time and to the left the storage optimization loop. At the top there is the in- and outflow growth and the market response loop. The analysis of the causal loop diagram allows for a comprehensive understanding of the underlying complexity and dynamics of the system.

Let us assume an increase in the operating efficiency of the in- and outflow growth loop in the top left of Figure 3. The better the operating efficiency of the inland terminal equipment and staff the more customers the terminal can attract and the more customers will pace handling orders. More handling orders result in an increase of the storage usage rate which also induces a greater order fulfill-rate. The higher the order fulfill-rate the higher is the available capital of the terminal and the greater the resources budget. A greater resources budget allows the management for more staff training to increase equipment exploitation which again results in an increase of operating efficiency. An increase in the operating efficiency induces extra handling orders which generates more gains and further allow for more

staff training and better equipment exploitation. As a result an increase in the operating efficiency has a reinforcing impact on customer's handling orders.

The optimization loop in the lower center of Figure 3 considers the optimization of the capacity in case of a high storage usage rate. Many handling orders result in an increased storage usage rate which leads to an increase in the dwell time of trains, trucks and load units. An increase in the dwell time attracts management's and customer's attention and after a time delay forces management's perception to expand handling capacity. The larger the handling capacity the lower the handling time and the higher is the order fulfill-rate. Finally a higher order fulfill-rate reduces the storage usage rate. As a result an increase in the dwell time of trains, trucks and load units induces a balancing capacity optimization action of the management to reduce the dwell time. Consequently the optimization loop functions as balancing loop for the inland terminal.

The target dwell time is set by the customers of the terminal in subject to the perception of the terminal's management. Depending on the power of the terminal location and the importance of the customer the management is willing to perceive customer's target dwell time. The dynamic adjustment loop allows the management to relax optimization pressure by dynamically adjusting the target dwell time pointing out the reinforcing nature of this loop. This means that an increase in the dwell time does not necessarily lead to an expansion of the handling capacity.

The stated aim of the inland terminal is to attract customers by providing sufficient handling time in turn to keep dwell times low. On the other hand customers are willing to reduce handling orders if the dwell time is too long. As a result the market response loop in the upper right has a limiting impact on the handling orders. Therefore we assume an increase in the dwell time of trains, trucks and load units and imply that it has shifted the impact on customer's perception. The dwell time is the most critical parameter of inland terminal operation and therefore customer's reaction is very sensitive. An increase in dwell time will lead to a reduction in handling order in the long-run. But, a reduction in handling orders induces a lower storage usage rate and further to a reduction of the dwell time. Consequently an under fulfillment of customer expectations resulting from a too long dwell time results in a decrease of handling orders allowing dwell time to fall and match customer's target dwell time again. This indicates that the market response loop acts as a balancing loop.

4. **RESULTS**

The causal loop diagram allows the user to directly see the impact of changes in the system and therefore contributes to the understanding of the continuity of events. During our expert interviews and field studies practitioners always pointed out that there is a need for a theoretical model to support the understanding of the underlying simulation model. Although it was possible for them to validate simulation results the simulation itself remained some kind of a black box for them. Therefore we decided to model the underlying causalities in causal loop models to ease understanding. By combining the simulation input and the corresponding performance indicators with the causal loop diagram it is possible to understand causes and effects in inland terminal operations (see Table 2).

	5
PI	AVG Lifting Time
Objective	↓ Dwell Time
Loop	Optimization
Impact	Order Fulfillment
Cause	Staff qualification, Equipment
	Technology, Fill Rate Storage
PI	AVG Moves Per Day
Objective	↑ Revenue
Loop	Optimization
Impact	Operating Efficiency
Cause	Staff Qualification

Table 2: Performance Indicators and Objectives

Performance indicators are assigned to causal loops to emphasize the impact of an improvement or deterioration within the context of the system. Further it is possible to point out the corresponding causes to deduce necessary actions. When thinking of actions and the expressiveness of performance it is important to formulate corresponding objectives to measure the impact or contribution of performance indicators.

Table 2 gives a comprehensive insight into the link of performance indicators and inland terminal objectives. Imagine the performance indicator of average unproductive moves. This performance indicator gives information on the effectiveness of terminal operations. It is part of the in- and outflow loop and it has an impact on the operating efficiency. The cause for an increase of the average unproductive moves can be the qualification of the terminal staff, the usage rate of the storage or a combination of both. By measuring the average number of unproductive moves the management follows the objective of reducing dwell times of trains, trucks and load units. To reduce the dwell the management has the possibility to increase staff qualification, to optimize the storage strategy of the storage or to expand capacity. So there exists a link between the dwell time and the average unproductive moves. In fact, only the linking of the simulation results and performance indicators with the causal loop diagram allows for a comprehensive and intuitive understanding of the interplay of parameter setting as cause and the corresponding effects.

5. DISCUSSION

During our study, specifications for further research and development subjects arose. Only recently more and more work on inland terminals is done. The importance of hinterland and inland transportation is growing with the same rate as the transportation of goods increases. Larger open sea vessels and increasing capacity of deep sea container terminals require efficient inland terminals to distribute containers and goods to the consumers. Major findings showed that there is a need to go more into detail. We identified that our actual causal loop diagram that we have to incorporate much more details in the corresponding causal loops to show the impact and importance of further performance indicators. Therefore we want to incorporate details like for example the impact of the equipment failure probability. It shows the effect of increased equipment failure on the lead time of trucks. The reliability of the equipment determines the lifting performance per hour which increases or decreases the lead time of both trucks and trains. By incorporating more and more details in the causal loop diagram it will be possible to provide a comprehensive picture of the system including a more practicable set of performance indicators.

The underlying concept for assessing performance indicators to measure the process quality of inland terminals is a first approach towards a standardized process for collecting and evaluating data on the performance of inland terminals. With our approach we want to show that inland terminals have to be considered as complex systems that will need much more attention in future. This will allow bearing in mind the big picture while not losing sight of operating detail.

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