OPTIMIZING SALES AREAS OF COMBINED TRANSPORT CHAINS

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ABSTRACT. Background: Combined transport chains (such as intermodal transport), have certain advantages. The main advantage from customer points of view is the possibility to bundle freight and thereby decrease transport costs. On the other hand, a combined transport chain can cause longer transport times, due to the necessary transshipment processes.
Methods: The area around a terminal, in which a combined service has favourable properties to a customer in comparison to a direct transport, can be understood as a sales-area, in which a combined transport product is marketable. The aim of this paper was to find a method to determine the best shape and size of this area.
Results and conclusions: The paper at hand lined out a method in order to calculate such a sales area and determine which geographical points around a terminal have an advantage in comparison to a direct transport service.

Key words: sales area, intermodal transport, marketing.

INTRODUCTION

Combined transport services (such as intermodal transport), have certain advantages. The main advantage from customer points of view is the possibility to bundle freight and thereby decrease transport costs. On the other hand, a combined transport chain can cause longer transport times, due to the necessary transshipment processes. The area around a terminal, in which a combined service has favourable properties to a customer in comparison to a direct transport, can be understood as a sales-area, in which a combined transport product is marketable.

DETERMINING THE ECONOMIC CATCHMENT AREA OF A TERMINAL OR FREIGHT VILLAGE

In the study at hand, the catchment area of a terminal or freight village shall be defined as an area around a terminal from within which a combined transport chain is superior to the pure road transport alternative. Superiority shall be defined in three possible ways: economically (cost superiority), environmentally (lower CO_2 emissions) and over time (transport duration superiority).

A combined chain can be describes as a system, consisting of several subsystems. In the paper at hand, a shuttle train connection (or long haul truck connection), as well as a pre-/post-carriage-truck-connection constitute such subsystems, which are combined by the transshipment process.

Each subsystems is described by the distance it covers and - due to the framework conditions - each subsystem has certain features in regards to operational costs, CO_2-emissions, and transport time. If a load factor is assumed, these features can be calculated as a value per load unit and trip:

$$C_{CRi}(d_i) = \frac{1}{2} * \frac{C_{Ri}(d_i)}{\square} l_{Ri}$$

$$E_{CRi}(d_i) = \frac{1}{2} * \frac{E_{Ri}(d_i)}{\square} l_{Ri}$$

with:

C_{CRi}: Transport costs per load-unit at a distance d of a train- or truck-transport-relation i in TEU.

$C_{Ri(di)}$: Costs per roundtrip at a distance d of a train- or truck-transport-relation i.

$E_{CRi(di)}$: CO_2 emissions per load unit at a distance d of a train- or truck-transport-relation i.

$E_{Ri(di)}$: CO_2 emissions per roundtrip at a distance d of a train- or truck-transport-relation i.

l_{Ri}: Average load of a train or truck on a train- or truck-transport-relation i in TEU.

In the case of a "one-rail-leg" intermodal port hinterland connection, the port would be connected with a hinterland terminal by train.

From there on a load unit would be transported by truck to its final destination. Alternatively a truck could run directly from the port to the final destination in question.

As an intermodal shuttle train bundles freight for numerous final destinations, these final destinations could be located anywhere around the terminal in different distances. In order to ascertain if a given destination should still be served through an intermodal chain or if a direct connection by truck would be more feasible, the distance dilation when switching from the pure road transport to the intermodal chain needs to be calculated.

When the geometrical structure of the intermodal chain is known, the alternative straight line distance between the port and the final destination can be calculated through the law of cosine (in a simplified model, where all connections are represented by straight lines and no bendiness exists):

$$d_{RO} = \sqrt{d_{RA}^2 + d_{PPC}^2 - 2 * d_{RA} * d_{PPC} * \cos(\gamma)}$$
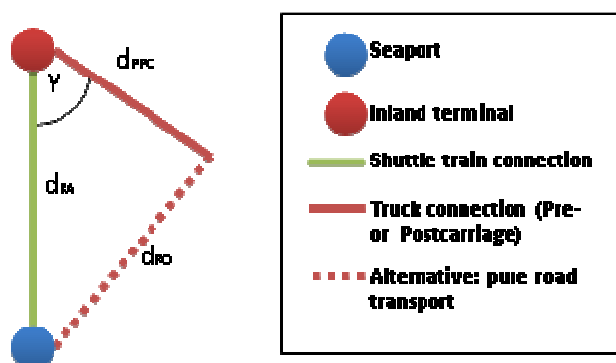
Source: own depiction

Fig. 1. Simplified distance-relations between an intermodal port-hinterland transport chain and the alternative of pure road transport

Rys. 1. Uproszczone zależności odległości pomiędzy intermodalnym węzłem łańcucha na odcinku port-wnętrze lądu a alternatywnym czystym transportem drogowym

With:

d_{RO}: Road-distance (in this model also straight line distance) between the port and the final destination

d_{RA}: Rail-distance between the port and the inland terminal.

d_{PPC}: Road-distance between the inland terminal and the final destination

γ: Angle between the straight line distances of a rail-connection and the pre-/post-carriage-connection.

Transport costs and transport time are highly important competition factors for any transport service. With the environment conscious of retail customers on the rise, CO_2 emissions are as well becoming a competitive factor. The aim of optimizing a transport chain

is to create a chain, were at least one factor is superior to an analogue factor in pure road transport, e.g. costs, transport time and/or CO_2 emissions of an intermodal chain are lower, than those of an alternative truck transport. In case of a superior intermodal transport chain, the quotient of the road-transport-feature-value and the intermodal-transport-feature-value would be larger than one:

$$\frac{C_{CRiT}}{C_{CRiI}} > 1 \text{ indicates cost superiority of}$$
an intermodal chain towards pure road transport.

$$\frac{E_{CRiT}}{E_{CRiI}} > 1 \text{ indicates } CO_2 \text{ emission superiority}$$
of an intermodal chain towards pure road transport.

$$\frac{t_{CRiT}}{t_{CRiI}} > 1 \text{ indicates transport time superiority of}$$
an intermodal chain towards pure road transport.

With:

C_{CRiT}:   Transport costs per load-unit on a truck.

C_{CRiI}:   Transport costs per load-unit on an intermodal chain

E_{RiT}:   CO2 emissions per load-unit on a truck.

E_{RiI}:   CO2 emissions per load-unit on an intermodal chain

t_{RiT}:   Transport time per load-unit on a truck.

t_{RiI}:   Transport time per load-unit on an intermodal chain

The larger the quotient for a given covered distance is, the more competitive an intermodal chain would be. If the quotient is one, a point of equilibrium is reached, where road and intermodal transport would be equal.

The set of all points of equilibrium constitute the rim of the set of all points of superiority (with the rim not being a part of this set).

A larger area of this set (i.e. a larger area of the terminal) would imply a potentially larger possible demand for intermodal transport. In conclusion, to maximize this area would lead to a larger demand - and thereby potentially larger revenue - for an intermodal transport operator.

Theoretically it could be possible, that direct transport is superior in all points. This case shall be excluded, as the aim of this study is to find superior combined services.

A point of equilibrium can be formally defined as follows:

$$C_{CRi}(d_{RAi}) + C_{tj} + C_{CRi}(d_{PPCi}) = C_{CRi}(d_{ROi})$$

$$E_{CRi}(d_{RAi}) + E_{tj} + E_{CRi}(d_{PPCi}) = E_{CRi}(d_{ROi})$$

$$t_{CRi}(d_{RAi}) + t_{tj} + t_{CRi}(d_{PPCi}) = t_{CRi}(d_{ROi})$$

With:

$C_{Cri(dRAi)}$:   Transport costs per load-unit at a distance d of the rail leg of an intermodal chain.

$C_{Cri(dPPCi)}$:   Transport costs per load-unit at a distance d of the pre-/post-carriage leg of an intermodal chain.

C_{tj}:   Transshipment costs per load unit in an intermodal chain.

$C_{Cri(dROi)}$:   Transport costs per load-unit at a distance d of the road transport alternative.

$E_{Cri(dRAi)}$: CO_2-emissions per load-unit at a distance d of the rail leg of an intermodal chain.

$E_{Cri(dPPCi)}$: CO_2-emissions per load-unit at a distance d of the pre-/post-carriage leg of an intermodal chain.

E_{tj}:   Transshipment CO_2-emissions per load unit in an intermodal chain.

$E_{Cri(dROi)}$: CO_2-emissions per load-unit at a distance d of the road transport alternative.

$t_{Cri(dRAi)}$:   Transport time at a distance d of the rail leg of an intermodal chain.

$t_{Cri(dPPCi)}$:   Transport time at a distance d of the pre-/post-carriage leg of an intermodal chain.

t_{tj}:   Transshipment time in an intermodal chain.

$t_{Cri(dROi)}$:   Transport time at a distance d of the road transport alternative.

The catchment area can be calculated as the sum of all triangles Fl, whereby one triangle is determined by the distances of the pre-/post-carriage dPPC, as its sides, of two different angles? The angle γ between these two sides can be calculated as:
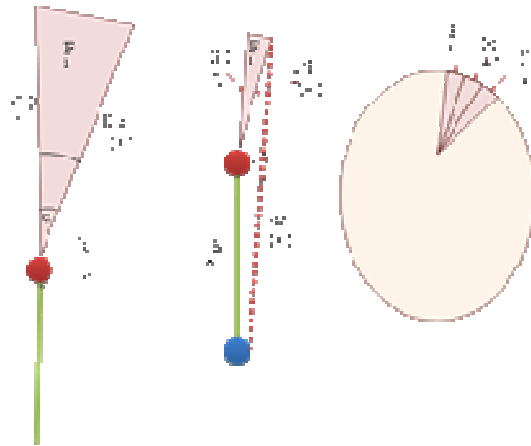
$$\alpha = \gamma_l - \gamma_{l-1}$$

The area of one triangle could then be calculated as:

$$F_l = \frac{d_{PPCl} * d_{PPCl+1} * \sin\alpha}{2}$$

The total catchment area C can then be approximated as the sum of all triangles F_l:

$$C = \sum_{l=1}^{n} F_l$$

Source: own depiction

Fig. 2. Catchment area of a terminal as the sum of triangle Fi
Rys. 2. Powierzchnia oddziaływania terminal jako suma trójkata Fi

COMBINING DEMAND EFFECTS

Differently designed combined transport services and alternative road transport services - over equal given distances - do have different features. In this case: differently designed intermodal chains and pure road transport services on a given distance. The intermodal chains mainly differ in the ratio of rail- and road-share (e.g.: does an intermodal chain over a total distance of 500 km, consist of 450 km rail transport and 50 km road transport or alternatively consist of 300 km rail transport and 200 km road transport?). In the model at hand these features are transport times and transport costs. Customers will decide if they should use a certain service (or a competing service), based on how well these features meet their own requirements.

The reaction of customers to alterations of one feature in a given service can be described with an elasticity function [Bücker 1998]:

$$\varepsilon = \frac{\Delta x}{\Delta y} * \frac{y_1}{x_1} \tag{1}$$

With:
ε: Elasticity
Δx: Absolute change of demand
Δy: Absolute change of demand-factor
x_1:   Demand before change of demand factor.
y_1:   Demand factor before change of demand factor.

The above equation can be transformed in order to calculate a change of demand based on a given elasticity:

$$\Delta x = \varepsilon * \Delta y * \frac{x_1}{y_1} \tag{2}$$

The demand factor could be a price or transport time, i.e. changing the price would change the demand.

In the study at hand, changes of transport costs, shall be equated with changes of service

prices, e.g. an increase of the operational costs by 5% would lead to an increase of the service price of 5%. This assumption is quite realistic, as expert knowledge implies that the transport market is a buyer market. Different intermodal transport operators have explained, that they aim at prices, which allow for a return on sales of about 4%, which means, that they indeed orientate prices on the operational costs.

In the study at hand, the possible transport modes a shipper can choose between shall be pure truck transport or intermodal transport. Transport prices and transport time are assumed to be the most important decision factors for a shipper, when deciding for a transport mode, this assumptions is backed up by a number of studies, such as the studies of Bühler [2005] Beute [2003] or Geiger [2011].

By inserting cost and time factors into equation (2), demand changes can be calculated based on transport-cost and transport-time changes:

$$\Delta x_c = \varepsilon_c * \Delta c * \frac{x_1}{c_1} \qquad (3)$$

$$\Delta x_t = \varepsilon_t * \Delta t * \frac{x_1}{t_1} \qquad (4)$$

With:
x_1: Demand before change of demand factor.
Δx_c: Demand change based on transport cost change.
Δx_t: Demand change based on transport time change.
Δc: Absolute Change of transport costs.
Δt: Absolute Change of transport time.
c_1: Initial operational costs.
t_1: Initial transport time.
ε_c: Transport cost elasticity.
ε_t: Transport time elasticity.

In the study at hand, demand effects of transport cost and transport time changes, which occur through changing from one transport system to another, shall be calculated by adding the demand changes:

$$\Delta x_{Total} = \Delta x_t + \Delta x_c \qquad (5)$$

A demand indicator shall be defined as:

$$A = 1 + \Delta x_t + \Delta x_c \qquad (6)$$

Furthermore, a Baseline Indicator $A_{Base}=1$ shall be defined for a given baseline transport service. A transport service superior to the baseline transport service would be indicated by a demand indicator $A>1$.

The optimization Problem can be described as follows:

$$Maximize \ [(A)_{Inter}(d_{PPCk}, d_{RAj}) = 1 + \Delta x_t + \Delta x_c\} \qquad (7)$$

whereby:

$A_{Base}(d_{Ro}) = 1$
$d_{Ro} = d_{Inter}$
$d_{Inter} = d_{PPCk} + d_{RAj}$
$d_{RA1} = dI_{Inter} - d_{PPC1}$ with: $d_{PPC1} = 5$ km,
$d_{RA2} = d_{Inter} - d_{PPC2}$ with: $d_{PPC2} = 10$ km,

…etc.
   until: d_{RAi} 5 km

With:
A_{nter}: Demand indicator for an intermodal chain.
d_{Inter}: Transport distance in an intermodal chain
d_{PPC}: Pre-/post-carriage distance from a terminal in an intermodal chain.
d_{RA}: Rail distance between a port and an inland terminal in an intermodal chain.
$c_1(d_{Ro})$: Initial transport costs, based on pure road transport on the given straight line distance.
$t_1(d_{Ro})$: Initial transport time, based on pure road transport on the given straight line distance
d_{Ro}: Straight line distance for pure road transport between the port and an inland destination, with an intermodal terminal on this straight line.

The optimum A found trough this algorithm, is defined through a d_{PPC} and a d_{RA}.

This optimum A however is based on the assumption that a terminal lies on the straight line distance between a port and the final destination of the consignment. In all cases where the terminal does not lie in the straight line distance dInter is longer than d_{Ro}, so A

also becomes smaller for a given d_{Ro} in most cases, as costs and transport time increase with increasing transport distances. This also means, that the AInter calculated through function (7) is the maximum AInter possible for the given straight line distance. Most AInter for destinations that do not have the terminal considered on a straight line between them and the departure point are necessarily smaller.

However, as long as these Anter are larger than 1, the associated transport chain can still be deemed superior.

Due to necessary drivers breaks, some distances are more attractive (measured by indicator A) than others [Michalk 2012]. This leads to "holes" in a catchment area. This can be seen in figure 3, which shows a scatter plot of all points around a terminal in a distance d and an angle γ (compare figure 2). Each point in the scatter plot represents a point with A>1.
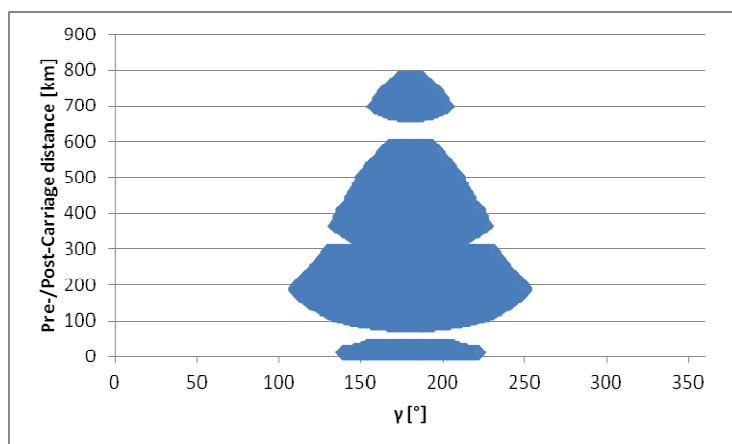
Source: own depiction

Fig. 3. Scatter plot of a terminal catchment area with a 500 km long rail connection
Rys. 3. Obszar oddziaływania terminal połączonego 500 km odcinkiem kolejowym

Using Bühlers elasticity values with equation (7) is not without problems; as the elasticity values have been determined independently from each other. A customer that would not ship his goods with a given service when the price increases, might be completely insensitive towards a change in transport time when his shipment is not time-sensitive and vice-versa.

This indicates the necessity for further examinations in this area, in order to determine true more-dimensional demand patterns of shippers. Such an examination should be designed in order to lead to a multi-attribute compositional model. Such an analysis would present survey participants with a number of possible services, each consisting of different combination of features, which constitute different tradeoffs to each other.

However, it can be argued, that these elasticity values still depict the different importance of the features "transport-time" and "transport-price". Also the demand estimation does aim at a large number of potential shippers, thus meaning, that for any customer who would not ship his goods after the transport price increases, another customer might just choose this service because of a simultaneous decrease in transport time. A high importance of lower transport prices would then lead more customers to use a different service, while the number of customers attract by the now changed service would be smaller, which is implied by the lower transport-time-elasticity. In conclusion, the demand indicator might not be a reliable parameter to estimate exact demand-developments, but it still can be used to make qualitative statements about the superiority of a service as compared to a competing service.

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OPTYMALIZACJA POWIERZCHNI OBSŁUGI PRZEZ ŁAŃCUCH TRANSPORTU KOMBINOWANEGO

STRESZCZENIE. **Wstęp**: Łańcuch transportu kombinowanego (takiego jak na przykład transport intermodalny) ma szereg zalet. Z punktu widzenia klienta najważniejszą zaletą jest możliwość łączenia różnych przewozów i w efekcie obniżenie kosztów transportu. Z drugiej strony transport kombinowany wymaga często dłuższego czasu realizacji, ze względu na potrzebne czasy przeładunków.
Metody: obszar położony wokół terminala, na którym realizacja dostaw poprzez transport kombinowany jest korzystniejsza od transportu bezpośredniego, jest określany jako obszar sprzedaży. Celem tej pracy było znalezienie metody wyznaczania takiego obszaru.
Wyniki i wnioski: Przedstawiono metody obliczania obszaru sprzedaży oraz wyznaczania punktów geograficznych ograniczających ten obszar..

Słowa kluczowe: obszar sprzedaży, transport intermodalny, marketing

OPTYMALISIERUNG DES BEDIENUNGSAREALS DURCH KOMBI-VERKEHR-KETTE

ZUSAMMENFASSUNG. Einleitung: Die Kette des Kombi-Verkehrs (wie beispielsweise des intermodalen Transportes) besitzt viele Vorteile. Aus dem Gesichtspunkt des Kunden ist die Möglichkeit von Anbindung unterschiedlicher Beförderungstypen und damit der Verminderung von Transportkosten der größte Vorteil solcher Ketten. Zum anderen verlangt aber der Kombi-Verkehr des Öfteren eine längere Ausführungszeit wegen der nötigen Zeiten für Verladung.
Methoden: Das um einen Terminal gelegene Areal, auf dem die Ausführung von Lieferungen mithilfe des Kombi-Transportes günstiger als der direkte Antransport ist, wird als Verkaufsareal bezeichnet. Das Ziel der Arbeit war es, eine Methode für die Bestimmung eines solchen Areals auszuarbeiten.
Ergebnisse und Fazit: Es wurden die Methoden für die Berechnung des Verkaufsareals und die Bestimmung von geographischen, dieses Areal konturierten Punkten dargestellt..

Codewörter: Verkaufsareal, intermodaler Transport, Marketing

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