Bridging the Gap
A Model of Co-modal Terminal Clusters

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ABSTRACT

Purpose of this paper

With the emergence of the concept of co-modality solely focusing on single facilities e.g. ports, airports, intermodal terminals, etc. in the study of the node is no longer sufficient. There is need for considering all modes of transportation in a co-modal node at the same time in order to enable explaining the emerging flow patterns. For this reason the concept of co-modal terminal cluster (CTC) is introduced. The purpose of this paper is to develop and empirically validate a model of a CTC.

Design/methodology/approach

The CTC model has been conceptually developed, and, empirically validated through a single case study consisting of 38 different organizations present in a CTC. Predominantly qualitative data has been collected. In addition, company specific quantitative flow data, public records, official statistics and 12 site visits have been employed.

Findings

The findings indicate that CTC can be meaningfully modelled using the terminal metaphor. The CTC modelled as a terminal is main outcome of this study.

Research limitations/implications (if applicable)

The CTC model provides a basis for evaluating the efficiency and effectiveness of a co-modal node in the network while at the same time being able to account for more of the complexity of the real world system. The model needs to be further refined for it to be applicable in quantitative analysis.

Practical implications (if applicable)

The CTC-model provides both a descriptive and explanatory tool for practitioners and researchers alike.

What is original/value of paper

The resultant model though partially based on existing literature is novel. The model can be used to explain emerging flows and evaluate the performance of CTC.

Multimodal, transmodal, co-modal, gateway, hub, terminal model, terminal cluster

1. Introduction

The role of an effective and efficient transportation system as a critical enabler of trade and economic growth is well established in the literature (McKinnon, 2006, Rodrigue et al., 2006). Equally, the negative environmental impacts and risks of our current transportation system are well documented as well (Stern, 2007, Taylor, 2007). From air and water pollution, emissions (e.g. NO_X, HC, CO_2, etc.), noise pollution and congestion to traffic hazards and the looming energy crises, the woes of the transportation system has garnered a lot of attention from researchers and policy makers alike (European Commission, 2006). Three categories of approaches for dealing with these issues can be identified; conservation, application of new technologies and redesign/more efficient use of existing systems. The two later categories presuppose continued economic growth whereas the first one does not. Most likely, a sustainable solution will contain elements from all three categories.

Co-modality, i. e. on their own merit, optimally combining various modes of transport within the same transport chain (Jarzembowski, 2007), is promoted by the EU as a central concept regarding obtaining a more effective, less polluting and more energy efficient transportation system (Gustavsson, 2007). According to Giannopoulos (2008) for the beneficial development and implementation of co-modality, research focus needs to be directed towards the networks' co-modal nodes and their capability to accommodate coordination, access and modal shift. A node in this context is a geographical location i.e. city or region, that attracts goods due to its centrality or immediacy in the global or regional transportation network (Fleming and Hayuth, 1994). Inherent to the co-modality of the node, it cannot be considered as synonymous with a single terminal facility, rather it is a cluster of uni-, inter- and multimodal terminals that in concert accomplishes the mentioned functionality.

Existing literature regarding the function and performance of nodes either lacks the perspective of co-modality e. g. Notteboom (2010), Rodrigue and Notteboom (2010), Gardiner and Ison (2008), de Langen and Visser (2005) etc. or focuses on specific terminal facilities e.g. Van der Horst and De Langen (2008), Notteboom and Rodrigue (2009), Rosso (2009) etc. The principal deficiency of the first approach is that there needs to be an assumption about the overwhelming importance or impact of the chosen mode on the entire system. The second approach on the other hand, simplifies too much of the complexity of the real system.

Most of the literature examined that study the node is concerned with ports, airports or other single modes/facilities. There is however a tendency in recognizing that studying ports/airport in isolation is insufficient due to the fact that the nodes studied are a part of a transportation network and the goods that flow though the network are parts of specific supply chains (Tongzon, 2009). A rich body of literature regarding intermodal transportation is also compiled. This however does not address the deficiencies pointed out based on the fact that studies on intermodal transportation is by default directed to unitized transportation and often with focus on single facilities e.g. Roso (2009). One way to come to terms with these shortcomings in the study of co-modal nodes is to view the entire cluster of terminals as a single complex entity with interdependent parts that are not under central control; a sort of complex meta-terminal on the global or regional levels of abstraction.

Utilizing the terminal metaphor for the study of this entity, here to forth named Co-modal Terminal Cluster (CTC), in order to explain the emergent flows of goods and subsequently evaluating the performance of the node in its entirety is the approach adopted here. Therefore a natural first step in studying such an entity is to pursue a model for the description and explanation of its purpose, function and impact on the transportation network, operations and goods flow.

Based on the discussion above, the purpose of this paper is to develop and empirically validate a model of a CTC in order to create a tool for explaining and evaluating the patterns of co-modality emerging from/to/through a node.

2. Frame of reference

In the studied literature, and with regards to the deficiencies of studying modes or facilities in isolation, two trends can be identified. One is regarding the geographical clustering of hubs of different modes and the importance of the cluster as opposed to the singular facilities (Bowen, 2004, Tongzon, 2009). The second pertains to the impact of the quality of hinterland access and the effectiveness of the cluster on the attractiveness of the node (de Langen and Visser, 2005, Rodrigue and Notteboom, 2009, van Klink and van den Berg, 1998).

2.1. Transportation and logistics clusters

The relation between economic development of a region and transportation is well established to be a positive one (Bergqvist, 2007). A region can be viewed as formal or functional region. Formal regions are temporally stable and easily defined whereas functional regions refer to functionally integrated system of relations, often around a node (Rodrigue and Notteboom, 2010). In the study of a cluster the formal region is of less interest and the identification of a functional region is necessary but ambiguous. The attractiveness of a region as a node in the transportation network is impacted by the nodes centrality and immediacy. Regardless of whether a supply or demand driven approach is adopted, the centrality and immediacy of region is mutually reinforcing (Fleming and Hayuth, 1994).

The development of economic activity in region in relation to the access to transportation services can both pertain to companies who create the demand for transportation as well as companies for fulfilling that demand and providing related services. For examples Button and Taylor (2000) put forth that there exists a positive relation between the existence of an airport and the range of its service and the establishment and growth of firms in the surrounding area. At the same time Bowen (2004) notes that cities hosting major airports also are home to logistics parks offering specialized and customized third party logistics services.

The clustering phenomenon is also present regarding different modes of transport in the same gateways/hubs. Gateways make up the fundamental interface between regional and global transport systems (van Klink and van den Berg, 1998). Even though hubs and gateways are different concepts, there exists a considerable overlap between the two especially on the global scale (Rodrigue et al., 2006). Wang and Cheng (2009) propose the concept of multi-layer trade hub defined as a global/regional hub supported by the four activities: global maritime transport, effective hinterland links, regional air transport hub and non-physical logistics and value adding activities. The clustering in hubs creates economies of scale for freight forwarders. This in turn is reflected in the development of goods flows and transportation demand for the entire area across all modes (Bowen, 2004).

2.2. The competitiveness of a transportation node

One of the major factors for the choice of port for freight forwarders is the efficiency of the port (Tongzon, 2009). However, the concept of port efficiency is expanding beyond the physical boundaries of the terminal facility to include the quality of hinterland access and co-modal movement of goods through the node. Also direct monetary costs alone do not determine the competitiveness of a port. All cost relevant for bridging the distance such as costs related to risk and time etc. need to be taken into account (van Klink and van den Berg, 1998).

In maritime transportation the significant potential for efficiency improvements are to find on the inter-terminal movements (Rodrigue and Notteboom, 2009). Ports are no longer viewed in isolation but are viewed as an element of the supply chain (Tongzon, 2009) and competition is not limited to ports rather the entire co-modal transport chain from source to destination (De Langen and Chouly, 2004). Synchronization of terminals, both within and between different modes is where the biggest potential for improving the efficiency of the transport system lays. This is true especially where the infrastructural capacity is kept constant or in saturated or complex transport systems (Rodrigue, 1999). Increased hinterland access for the same generalized transport cost improves the nodes attractiveness (van Klink and van den Berg, 1998). This highlights the importance of the entire cluster of terminals spanning all modes of transportation as opposed to the port viewed as an isolated entity. The effectiveness and attractiveness of a port cluster are complementary where one reinforces the other (de Langen and Visser, 2005). The competitiveness of a cluster or its comprising parts is not independent of one and other (de Langen and Visser, 2005). This reasoning ought to be as valid to apply to a co-modal cluster, as a cluster of seaport terminals.

2.3. Terminal function and the definition of CTC

Hultén (1997) presents the generic terminal model below (Figure 2.1). In the model (C) denotes capacity, (T) time and (F) frequency.

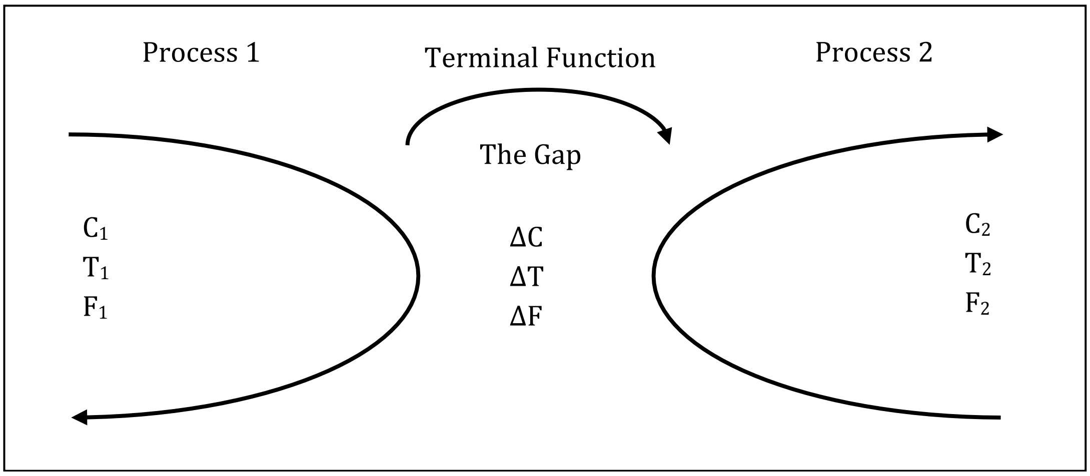

Figure 2.1 The generic terminal model presented by Hultén (1997).

The model illustrates that the transport processes that meet in the terminal will have a gap in these dimensions that the terminal needs to bridge with its functions. The model is applied on terminal facilities and as such can be viewed as starting point rather than readily applicable on a cluster of terminals.

The use of the terminal metaphor for modelling CTC is not without complication due to a number of factors. Firstly, terminals are usually in control of a single actor and are included in said actor’s organization as a unit. Approaching an entity that consists of several such facilities with disperse owners, operators and customers as one is not unproblematic. Secondly, the efficiency of a terminal facility is easily determinable because of an identifiable goal function. This would not be the case for a CTC as the goal function of the multitude of actors and stakeholders involved differ. In addition to the first two points, the required functionality of a terminal facility is a priori determined and designed into the configuration of its operations. An CTC in most (all?) cases is an emergent phenomenon, meaning that it is the result of the unconferred decisions of many different, though interdependent, actors and stakeholders over a long period of time and not designed for a specific purpose. Thirdly, as opposed to a terminal facility, the allocation of resources in a CTC is accomplished through market mechanisms, policy and other coordination mechanisms. This adds to the complexity of the CTC in its function as a terminal.

The original model of Hultén refers to the bridging of the identified gaps as the function of the terminal. It is argued here, that this is closer to the purpose of terminal than its function. Traditionally the functionality that terminal provides is exemplified by e.g. transhipment, consolidation, sorting, sequencing etc (Lumsden, 2006). These functions are the composite of a number of operations that together achieve the functionality whereas the bridging of the gaps is on a higher level of abstraction i.e. the purpose of a terminal, and need to be distinguished from simple functions (Figure 2.1).

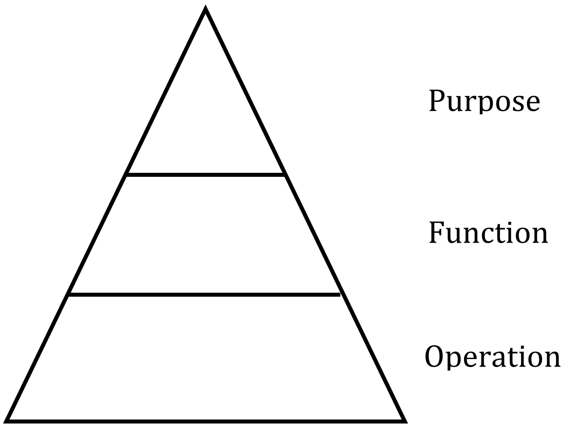

Figure 2.2 Hierarchy of the terminology.

Co-modal Terminal Cluster (CTC), which is introduced by the author as the concept that encompasses the entity that is the object of this study, is defined as an informal geographical region containing a cluster of terminals encompassing all modes of transportation providing transportation access at the regional/global level. By default, a CTC is a global/regional hub in the transportation network, serving a fore-/hinterland. The generic terminal model above is to be developed and empirically validated for it to describe a CTC as opposed to a single terminal facility.

3. Methodology

For the purpose of development and validation of a CTC model, a single case study is undertaken. The rationale for a single case study is based on representativeness and revelatory rational (Yin, 2003). The revelatory rational stems from the fact that drawing the system boundaries in a way to encompass the entire co-modal cluster is a novel approach which inherently supports the revelatory rational. This case is also argued to be representative even though it has some unique characteristics (3.2).

Representativeness of the case for the studied phenomenon is the necessary condition for selection. However, the importance of access for choosing to study this particular CTC should not be underplayed. The particularities of the selected case will likely not have any limiting implications for the external validity of the resultant model.

The predominantly qualitative data has been collected from semi-structured interviews and site visits. Secondary data in the form of official statistics, legislative documentation and entity specific archival records, official documentation and quantitative data has also been employed in the analysis. The quantitative data is however not used for any statistical analysis.

The resulting model is conceptually derived. However, the empirical evidence from the single case study is employed in validating and refining the conceptual model. The interplay of theory, conceptual modelling and empirical material is combined as inspired by Dubois and Gadde (2002). This is reflected in the presentation by structuring the paper so that the empirical illustration is introduced after the model, which in itself is a major result of this paper, in order to enhance the reader's understanding of the model.

3.1. Validity and reliability

To ensure construct validity triangulation of data, follow up interviews and feedback from key informants have been employed (Ellram, 1996). The triangulation of data is partially embedded in the cases study design due to the fact that many of the informants have access to the same information though from different sources and perspectives. The involvement of other investigators aside from the author (a total of 11) has been organized in way that does not limit any single investigator's contribution to one actor or segment alone.

A semi-structured interview protocol has been developed for conducting the interviews (Stuart et al., 2002) which helps strengthen the study's reliability. Particular care has been taken in this step due to the fact that multiple investigators have been involved in data collection and analysis. Furthermore, the interview data has been documented via transcriptions, summaries and partial case write-ups along the way, as well (Eisenhardt, 1989).

3.2. Case description

The organizational entities that have been included in the case are presented in Table 3.1. The case is a CTC that is peripherally situated with regards to major trade routes and thus has become a CTC more due to its centrality than its immediacy. Furthermore, the CTC is situated in area with a heavy presence of industrial activity. The captive hinterland of the CTC is geographically relatively large and sparsely populated. The contested hinterland of the CTC varies considerably in distance depending on i. a. the availability of high capacity modes and the ability of competing nodes to access these parts.

The CTC handles intercontinental, continental, regional and national flows of goods via direct relations as well as via other hubs. Some transhipment volume is also routed through the CTC. All four modes of transportation are present in the cluster and the functionality provided is assumed to not differ significantly from other CTC, even though the scope or balance of functionalities quit possibly does. The CTC lacks the capability to process bulk ships and no barge transport operations are present even though inland waterway transports are available.

Table 3.1 Detailed case components

Actor	**Units/informants /site visit**	**Actor**	**Units/informants /site visit**
Port	1/3/N	Train operator	1/1/N
Port terminal	3/3/2	Forwarder – Air freight	2/4/N
Airport	1/3/N	Forwarder – Ocean freight	2/2/N
Airport terminal	2/3/2	3PL	2/3/N
Intermodal terminal	2/2/2	Trade Union	1/1/N
Truck terminal	1/2/1	Branch association	3/3/N
Shipping line	3/4/N	Trade Association	2/2/N
Air line	2/2/2	Authorities	5/7/N
Trucking company	5/5/3		
Total			**38/51/12**

Note: (N) denotes that site visit has not been undertaken/not applicable.

4. Developing the conceptual model

The CTC can be modelled with a generic terminal model. This generic terminal[1] provides the capability for bridging the gaps in capacity, frequency, time and mode between the incoming and outgoing flows to/from the node. Imbedded in the terminal function of the CTC, is the coordination function it produced for the flows that run through it. The terminal function comes at a cost (time, energy, resources etc.) but also creates values as well as opportunities for additional value adding functionalities. The costs for bridging these gaps compared to the benefits provide a basis for the evaluation of the effectiveness and efficiency of a CTC. The functionality and performance of a CTC is dependant of a number of constraining and enabling factors.

In the following the composing parameters of the model are discussed. The original source from where the idea for the model is generated does not elaborate on the model and its components. The empirical data has been used for the validation and refinement of the model. The result is a generic terminal model of a CTC (Figure 4.1).

4.1. Coordination function and added value opportunity

The CTC fulfills its purpose of bridging the gaps by enabling the coordination of transport processes. The coordination is achieved by providing the functionalities traditionally referred to in the textbooks and literature e.g. transshipment, consolidation, short term storage, sorting etc. In the CTC model the term coordination is employed as an umbrella expression so as to take away the focus from the operations involved for achieving the coordination function, rather that the transportation processes and goods that flow through them are coordinated by the CTC in order to bridge the identified gaps. Combinations of different operations create functionalities that can be employed in the different parts of the CTC to achieve coordination. The point highlighted in the model is the fact that these gaps exist, the purpose of the CTC is

[1] Note that this does not refer to a terminal facility, rather the entire cluster of terminals modeled as one entity.

to bridge them and that this is done by coordinating the processes. Coordination, achieved through a number of functionalities, is in some sense the decoupling of the two processes i.e. allowing for the gap to exist and bridging it with the terminal functionalities; as opposed to coordination of the flows and processes in order to eliminate the gap. In principle the gaps can also be bridged by the introduction of overcapacity. A base assumption for the models is that the gaps are sought to be bridged in the most efficient manner possible wherefore the overcapacity solution is not highlighted here.

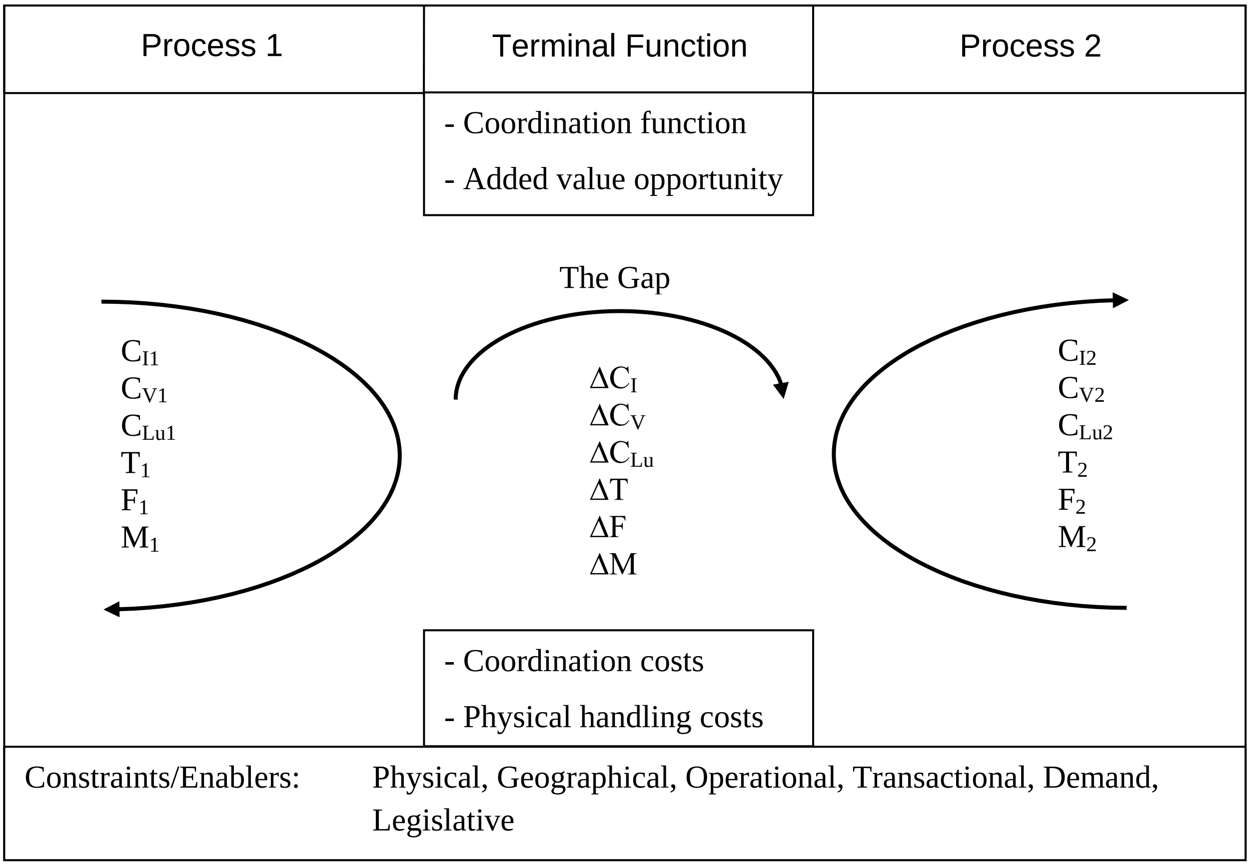

Figure 4.1 The generic terminal model; a model of a CTC.

An inherent drawback of using the terminal for modeling a CTC is the fact the term itself – Terminal – leads the mind awry. Terminal had the connotation of a closed system with clearly delimited functionality. On the other hand a CTC is an open system occupied by a wealth of different actors that enable, enhance or limit the effectiveness of the CTC. Many actors may not even physically perform transport services. The CTC creates opportunities beyond its main purpose of bridging the gaps in the transportation processes; as do many other clusters. The disparate resources and actors of a CTC benefit from partially overlapping goal functions at the same time as many are able to make use of the economies that the cluster provides e.g. economies of scope, presence, density, scale etc.

Much like, even perhaps to a greater degree than, a single terminal facility the function of CTC can surpass its basic purpose and create added value. "Added value" is terminologically indistinct due to the way it is used in the literature. The term "added value" in the literature refers to anything from physically alteration of the products that are being shipped to labeling or sequencing the goods being transported. Here, the term "added value opportunity" is employed to indicate that "value" in this context is subjective. This allows for the inclusion of any operation or service that creates an opportunity for any other actor along the transport chain i.e. from shipper to consignee or end customer, to benefit from additional value that surpasses the time and place utility created by the base service.

4.2. Bridging the gap

In the transportation process accommodating the flow of goods through a node in a transportation network, whether for the purpose of transhipment or final distribution, a gap in a number of parameters are displayed, the bridging of which is the primary purpose of a terminal. In this model, the terminal metaphor is applied to a CTC. The parameters of time, frequency, capacity and mode are where the gaps between incoming and outgoing flows arise and need bridging. Capacity can be subdivided into three constituting parts. The gap referred here regards the temporal and directional flow of goods and can be identified even in cases of perfect balance in the aggregate of each individual parameter.

4.2.1. Capacity

In the original model, Hultén (1997) includes only one parameter for capacity. A more apt approach would be to differentiate between different dimensions of capacity that the CTC needs to handle i. e. infrastructural (C_I), vehicle/vessel (C_V) and loading unit (C_{Lu}) capacity. All three dimensions of capacity are interdependent and hierarchical meaning C_I is limiting for C_V and C_V is limiting for C_{Lu}. The gap between incoming and outgoing C_V and C_{Lu} are inherent to the function of the node in the transportation network, whereas the gap regarding C_I, more often than not, arises from co-modality and the different characteristics of the different modes. This however is too simplistic of an explanation as capacity in transportation is time dependent and the gap could arise/be explained by the temporal and directional flow of goods through the node.

In a terminal facility in e.g. a distribution network, if the gap can be eliminated without detriment, then the need for passing through the terminal is effectively also eliminated in that respect. However, in the case of a CTC, even if this gap is eliminated thorough perfect balance of capacity, time and frequency, there still would be cases where it would be incumbent to pass though the CTC due to a need for modal shift. Furthermore, even if there exists perfect balance between incoming and outgoing capacity, the gap in capacity will still likely be present and require bridging due to the direction of the flows of goods. In that sense, the functionality of a CTC overlaps that of a hub, a gateway and a terminal.

More often than not, the gap in capacity is bridged by modification of the other parameters of frequency, time and/or mode. The gap in infrastructural capacity can, in the short term, only be remedied by underutilization and in the long run by capacity increase in order to eliminate the gap.

4.2.2. Mode

The inclusion of mode as a parameter here is not self-evident. For one, it is somewhat redundant because the characteristics of the different modes can be captured by the other three parameters, i. e. capacity, frequency and time to a satisfactory degree. Furthermore, where time and frequency are continuous and capacity, ranging from infrastructural to load unit here, is pseudo-continuous, mode is discrete i.e. road, rail, air and sea. However, as discussed above, the inclusion of in this model is imperative in order to capture the co-modality aspect of CTC.

The parameter of mode illustrated two neighboring but different facets. For one, a prerequisite for a CTC is the ability to accommodate modal shift. Secondly, modal shift can be one of the consequences of/measures to bridging the gap in any or combinations of the other parameters. This is in part due to the fact that different modes display vastly different ranges of value regarding the other three parameters i.e. frequency, capacity and time. Furthermore, even modes with similar characteristics with regards to these parameters; operationally still provide different possibilities for achieving the same functionality.

4.2.3. Time

The time gap denotes the difference in the time of arrival and departure of goods to the node. Time here denotes real time. The gap in time is most commonly bridged by storage capability. Even though handling the gap in this parameter is one of the purposes of a terminal, the discrepancy itself is a necessity to some degree for the terminal to be able to fulfill its other functions. Bridging the gaps in frequency, capacity and mode in many cases necessitates modification in the time gap i. e. storage capability or speedy transshipment. Capacity to store and speed of transshipment are the two indicators with witch the effectiveness of a terminal in bridging the time gap can be measured.

4.2.4. Frequency

Transport frequency and capacity are both functions of time, which makes them closely interdependent. The simplest way to illustrate the interdependence would be to point out that formulating the gap of frequency is meaningless unless one considers capacity at the same time. For a terminal to successfully fulfill its purpose it is to accommodate a match between the product of capacity and frequency regarding in- and outgoing flows. Here, it is not of primary interest which of the two parameters is the driving one. Rather that the terminal function need to bridge the discrepancy to a satisfactory degree.

The characteristics of the different modes regarding frequency and capacity differs considerably which makes the inclusion of this parameter all the more important when modeling a CTC. Furthermore, the trade-off of capacity and frequency is central for transportation network theory and is a significant indicator for the role of the node in the network.

4.3. Physical handling and coordination cost

Cost referred here does not primarily concern monetary cost, even though ultimately any physical measure of cost can be translated to monetary ones. A more suitable unit for indicating the cost that a CTC induces in performing its function would be time or energy or capacity utilization especially regarding critical (scares) resources. The inclusion of cost in this way is a way of enabling the use of the model for conceptualization and measurement of the efficiency of the CTC.

The coordination function that the CTC provides is accomplished by execution of a number of operations. These costs are categorized in the “physical handling cost” indicated in the model. These costs also include costs that are not directly incurred by the physical handling e.g. cost for information transfer and handling etc.

The costs denoted “coordination costs” refer to the cost related to the coordination function of the node (Kalantari and Lumsden, 2007) and hence the existence of the gaps to be bridged. For instance the time delay induced by consolidation is partially due to the physical handling (cfr. active node time) of the goods (Lumsden, 1995) and partially (the lion’s share in most cases) due to the “faster” goods inactively waiting for “slower” ones (cfr. passive node time). The latter portion of the cost is categorized as coordination costs in the model.

4.4. Constraints and enablers

There would be many viable ways to categorize constraints and enablers in a terminal model. However, this generic model is meant to be applied to a CTC and the categorization must be at an appropriate level of abstraction for it to match well with the complexity of CTC as compared to a single terminal facility. The six attributes included in the model will be briefly mentioned in the following. This portion of the model is not treated in comprehensively here due to lack of space. What is sought here is to in short distinguish the categories of attributes from one and other.

Geographical: The *geographical* position of a CTC relative to major trade routes and centers of production and/or consumption is a major enabler/constraint for the potential of the CTC (cfr. Fleming and Hayuth (1994) regarding centrality and immediacy). The demand for transportation is strongly influenced by the position of the CTC. The centrality and immediacy of a CTC tend to be mutually reinforcing attributes and are not temporally static.

Physical: The enabling/constraining *physical* properties of the CTC is related to available land for exploitation, make up of facilities and infrastructure etc. Some of these properties are closely interrelated to the geography of the CTC and cannot be easily altered such as depth of maritime ways or available land for expansion, whereas others are more accessible for change such as facilities and infrastructure.

Operational: The *operational* attributes regards both how activities are organized and executed. In some cases a certain type of operation is viable, but my not be realized because of the reluctance of the actors involved based on their respective goals or business models. On the other hand, there are instances where the efficiency or even feasibility of the execution of a certain operation is what is included in this category.

Transactional: *Transactional* properties and the operational one can be viewed as subsets of the same higher level category of attributes. The differences are that where operational attribute can regard single or multiple actors, the transactional ones always include interaction between more than one actor and do not necessarily regard physical movement or activity. Transactional properties include i. a. information exchange, formal/informal cooperation and relationships between different actors.

Demand: The volume of *demand* is important but not what is meant here. Shippers demand impacts the outcome e.g. mode choice, control, consolidation etc. Demand here refers to aspects of customer demand that impacts the operations and transactions in the transportation process.

Legislative: The *legislative* attributes of a CTC impacts the landscape of what can be done, how and to what cost. Anything from environmental requirements to labor laws and taxes that impact the ability of the CTC to perform its function is considered here.

5. Empirical validation

The case study in its entirety is too vast to be presented here. However one example is in part presented below for illustration purposes. Air freight is selected because, in this case, much like an entire CTC, the terminal function surpasses that of the simple facilities. The drawback is off course that this is just one part of a larger system that was meant to be captured by the model. However, the generic character of the model allows for this type of scalability. By this reasoning the inclusion of this example as illustration is warranted.

5.1. Illustrating case description

The air freight market in the studied case is highly segmented. The degree of segmentation is so high that the top 5 largest air freight forwarders do not even account of 10% of the total market. The lone airport in the CTC that handles air freight is the largest air cargo airport in the country. In numbers this means that the airport is visited by 2-3 air freighters per week in addition to express freighters and the belly-pax flows. Furthermore the majority of the total air freight volume actually leaves the country on trucks to larger air freight hub in continental Europe where the goods after consolidation actually get on airplanes. The airport is situated in an area of high industrial and relatively large population density. Geographically, this airport is the closest to the regional and national economical points of gravity than any other comparable airport.

The physical handling of the cargo is done in two fiercely competing terminals adjacent to the airport. However, the position of the terminals relative the tarmac and their mix of customers forces the two terminals to exchange significant amounts of goods on regular basis. The facilities and the services offered are very similar. The services include but are not limited to, short run storage, information and goods handling services etc.

Heightened security concerns surrounding air freight has led to legislation that considerably limits the opportunity to consolidate air freight cargo with other types of cargo as air freight is to be handled in a closed system. Failing that, goods need to be security checked e.g. via scanning upon entering the airfreight terminal. This procedure is costly and time consuming and also not available universally which has led to air freight cargo being transported to the airport in dedicated trucks. This means that large operators with access to terminal network for road freight have little use of this asset when handling air freight.

This has led to the emergence of hauler companies that mainly specialize in collection and delivery of air freight cargo to and from the airports. In this case, the largest such company handles roughly 80% of the air freight volumes handled by this airport which amounts to a near monopoly. The 20% that is not handled by this company consists mainly of shippers that buy capacity directly from the airlines and care for the transport to the airport themselves. Almost all of the air freight forwarders elicit the services of this hauler when shipping through this airport. Even though more than half of the air freight volumes are transported by trucks to larger hubs in continental Europe, the point of entry for the goods are still the airport in the hinterland of which the shipper is situated. Many airlines offer services from airports that they do not actually fly to.

5.2. Applying the model

At first glance, the airfreight volumes that are transported between airports on trucks, in total appear to be great enough to motivate both higher frequency and capacity of air freighter services. However analyzing the air freighters that actually fly to this airport and the distribution of the cargo’s destination reveals the rationale behind the present modal split. Breaking down the current demand, few routes for any single airline have the volumes that would warrant a direct service. Adding in the need for further deconsolidation/consolidation at a larger hub on the continent, the tradeoff between the cost of administration and handling i.e. building airplane pallets, favors the use of alternative modes (in this case almost exclusively trucks). On the other hand the air freighters that traffic the airport all fly to destinations far away e.g. Middle East, Asia etc. The long distances create a balance in the tradeoff that favors the use of air traffic even between hubs.

Applying the model to this illustrating case yields the following results (summarized in Table 5.1). The gap in infrastructural capacity (C_I) is not really an issue in this case. Generally, a gap in this dimension is best handled by elimination i.e. long-term increase (or decrease) of capacity in order to reach balance. In the short term, gap in C_I can be mitigated by altering the time or frequency of the transportation processes so as to allocate capacity when possible. Modal shift can also be an option though this approach in part is contingent on the different characteristics of the different modes. Meaning, shifting volumes between modes in part achieves allocation to where capacity is available and in part changes the other dimension due to the inherent difference in characteristics between different modes. Where C_I gap is an issue in this case here, it is mostly the result of local, temporal congestion which is handled in part altering the dimensions of time and frequency using short-term storage and temporal relocation of transshipment operations. Operationally, this is achieved without central control.

The gaps in load unit capacity (C_{Lu}), time (T) and mode (M) cannot be mitigated in any significant way by altering any other of the dimensions. Here, mitigation of arisen gaps is achieved only by altering the same dimension. It should be reiterated that mitigation is seldom sought after and the primary purpose of a terminal is to bridge the gaps. In the case of (T), too narrow a gap (mitigation) would constraint the ability to perform necessary activities or even render the point of entering the node moot.

Modal shift can actually mitigate the frequency gap in some cases. This is due to the fact that the different modes have vastly different characteristics with regards to e.g. capacity and frequency. Load unit capacity (C_{Lu}) is also in part constrained by the capacity of the vehicle[2] wherefore it is included here as one of the dimensions to alter in order to mitigate the frequency gap. In reality, the alteration of C_{Lu} is likely the result of change in vehicle or modal shifts.

Finally, the vehicle capacity (C_V) is mitigated by alteration of mode or frequency of either transportation process that connected to the terminal. The rationale behind modal shift for adjustment (C_V) gap is the same as above; namely that different modes have different rages of capacity. The relation of capacity and frequency is based on the same argument in (4.2.4).

Table 5.1 Functions and parameters involved in mitigating/bridging the gaps.

Gap	**Alter to mitigate**	**Function for bridging**	**Deciding cost**
ΔC_I	C_I, F, T, M	Storage, transshipment	Coordination
ΔC_V	C_V, M, F	Consolidation, transshipment, storage	Physical handling
ΔC_{Lu}	C_{Lu}	Sorting, consolidation	Physical handling
ΔF	F, C_V, C_{Lu} (M)	Storage, transshipment	Coordination
ΔT	T	Storage	Coordination
ΔM	M	Transshipment	Physical handling

[2] Vehicle here is used in a broad sense including vessels, airplanes, trains and road vehicles.

Coordination, achieved through a number of physical handling operations and control functions, is in some sense the decoupling of the two processes i.e. allowing for the gap to exist and bridging it with the terminal functionalities; as opposed to coordination of the flows and processes in order to eliminate the gap. As argued above, a gap in a dimension can be mitigated by altering some of the other ones which would be an example of the opposite of the decoupling approach mentioned here. Mitigation is suitable to employ in cases where the existing gap is too costly to bridge in relation to the expected benefits. This way, the mitigated gap may turn out to be more feasible to bridge in an economic way as illustrated in the case here.

6. Discussion and future research

It is clear that there exists a clustering effect that is mutually reinforcing across modes and additional services. This is evident both in the review of the literature as well as in the empirical evidence. This is phenomenon in not unique for CTC either. Furthermore, the importance of the node's ability to access its hinterland is also plainly evident. However, evaluating the attractiveness of a Co-modal node as operationalized here, in all its necessity, is not easily accomplished. The issue is in some sense an "ownerless" problem, where no single actor or group of actors can control or be responsible for the entire system. The fact is that the overlap of the goal function of different actors is not insignificant where their their interest in many cases may be.

Where de Langen and Chouly (2004) introduce the concept of collective action problem (CAP) or de Langen and Visser (2005) approach the issue with hinterland access regimes (HAR), neither would be readily applicable to this setting i.e. Co-modal terminal cluster. The similarities between the entities included in these clusters, and the similarities between the direct impacts of any measures on all are not present in the case of the CTC as opposed to a uni-mode or intermodal cluster. The allocation and analysis of costs and benefits, as well as the formulation of a goal function, for the cluster as a whole, and its comprising members are more feasible in the case of the more homogeneous clusters.

The decisive impact of scale economies of the transportation processes (Hultén, 1997) in itself can warrant the borderline trivial conclusion that the increase in transportation demand to/trough a geographical node would create opportunities for rationalization. This is also confirmed by basic network theory and the empirical observations in this study. This however, only makes the point that it would be of interest for all members of a CTC to increase the attractiveness of the entity as a whole. The bedrock assumption of this study lies in the notion that with the development of theory based on the entire system being modelled and evaluated as a single entity, then measures or opportunities for improvement may be identifiable in a way where it would become clear where the costs and benefits would lie for individual members of as well as the whole of the CTC.

This paper presents the first step by providing an empirically validated conceptual model that would enable the further study and evaluation of a CTC as en entity. The most appropriate future study, at this stage, would be to further develop this model in an attempt to lay bare the relationship between the function of a CTC and its attractiveness.

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