DESIGN OF INTERMODAL BUNDLING NETWORKS FROM/TO THE HINTERLAND OF THE CZECH REPUBLIC

MODELOVÁNÍ INTERMODÁLNÍCH SDRUŽOVACÍCH SÍTÍ Z/DO VNITROZEMÍ ČESKÉ REPUBLIKY

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Abstract

Containerization transport systems to the inland have led to the reconfiguration and synchronization liner service schedules and associated hinterland networks of the market players. Market players in the maritime transport have identified inland logistics as one of the most important areas still left to cut costs and to increase profitability. One of the appropriate solutions could be a so-called complex bundling. The complex bundling allows applying a large vehicle scale, high frequencies and high network connectivity, despite of restricted flow sizes. The challenge is to identify promising directions of intermodal network development and to compare bundling concepts for a different design of networks. The paper will analyse and optimise the development of inland service configuration and bundling in the Hamburg - Rotterdam range with focus to the container bundling in rail networks to the central Europe, especially to the Czech Republic.

Abstrakt

Kontejnerizace přepravních systémů do vnitrozemí vedla hráče na trhu k rekonfiguraci a synchronizaci tras a jízdních řádů ve spojení s vnitrozemskou sítí. Hráči v námořní dopravě identifikovaly vnitrozemskou logistiku jako jednu z nejdůležitějších oblastí, kde je stále možno snížit náklady a zvýšit rentabilitu. Jedním z vhodných řešení by mohlo být takzvané komplexní sdružování. Komplexní sdružování umožňuje zavedení odlišných frekvencí spojení, zvětšit ložnou kapacitu dopravních prostředku (vyšší zatížení) a zlepšit síťovou propojitelnost. Výzvou je určení slibných intermodálních sdružovacích sítí a srovnání sdružovacích konceptů pro odlišná nastavení sítí. Článek bude analyzovat a optimalizovat přepravu kontejnerů po železnici mezi vnitrozemím střední Evropy, především ČR a severomořskými přístavy.

Keywords

Logistics, intermodal transport, bundling, container, terminal

Klíčová slova

Logistika, kombinovaná doprava, svazkování, kontejner, terminál

INTRODUCTION

Regarding the economic performance of the member countries of the European Union, fast, efficient and high-quality transport routes are the potential source for sustainable development of the society, and the way how to ensure growth of living standard at the same time. Besides numerous benefits, however, there is a wide range of negative phenomena that such development may bring. On one hand, they include jumps in the passenger transport volumes, in particular volumes of individual car transport, and on the other hand, there is a growing demand for the transfer of goods causing that the capacity of road networks (and railway networks in some cases) gets exhausted and, as a result, congestions arise. All this leads to diminished reliability of the transportation processes, extended transport times and increase in transport energy demand as well as environmental drawbacks and other negative impacts that affect the communities. In the freight transport, the so-called joint form of the transportation of goods with the use of multiple modes of transport, i.e. intermodal freight transport can be considered to be one of alternative options aiming to mitigate or resolve the said negative phenomena. It interlinks the road, railway and water (inland/maritime) transport in order to form a single harmonious whole for the purposes of mutual collaboration instead of presumed competition by harmonizing the advantages of each mode of transport to the benefit of the whole. This transport segment has been experiencing a turbulent development for several decades owing to the growth of the Asian markets and the exchange of goods with the use of containers as the unified transport units. There are, however, numerous problems and issues associated with such rapid development, which require prompt resolution. One of these issues is the transportation of containers by rail between the container terminals of the ports and those situated in the hinterland.

BUNDLING MODEL

The bundling (sometimes also referred to as consolidation) is, in general, a process of generating sufficient volume of freight flows, i.e. organizing transport units or load units into a single unit with the required level of services (Kreutzberger, 2010). The theoretical background of the term “bundling” dates back to the '90s, when it was used in many scientific publications and papers, and practical guides as well. There were several similar models set up in the past, which were aimed at bundling the freight flows in the intermodal transport, however, the vast majority of them has never been put into practice or was cancelled as early as in the initial stage of the implementation process. The main cause lied in the reluctance of the intermodal operators to transport containers between the terminals (both inland and seaport terminals) with the use of indirect trains. As a matter of fact, direct trains keep the freight costs at low levels, which the intermodal operators are forced to offer to be able to beat the competitors. Nevertheless, the operators have failed to realize so far what advantages the bundling model can bring to them. After the boom in the '90s, the bundling networks have experienced a renaissance in recent years again. The bundling model allows finding of intermodal solutions which are relevant to different situations and helps increase the competitiveness of the intermodal transport at the same time. The directional bundling is divided in two categories, namely the direct bundling and complex bundling. The direct bundling (hereinafter referred to as the direct connection) is the best solution for voluminous freight flows which allow loading the train with freight to meet the required level and frequency. The networks of direct connections, however, do not serve intermediate terminals, and therefore they feature shorter transport distances and lower costs in comparison with the complex bundling. For the low-volume flows, direct bundling is not convenient due to low loading of the trains, which results in higher freight costs per load unit (container), and therefore, the complex bundling should be used instead.

The complex bundling is an operation during which the goods with different places of origin (begin terminals) and (or) different places of destination (intermediate and (or) end terminals) are transported by the commonly used means of transport and transport units (containers in this particular case) during the whole route (or a part thereof). The principle of the complex bundling is used mainly where the size of the containerized freight flow is not sufficient enough for operating the direct connection between the begin terminal and the end terminal (see Fig 1). Fig. 1 presents in its first section a comparison of two trains going from terminal A or B to terminal C or D. Each of the trains is only partially loaded and goes directly from its begin to its end terminal (i.e. from A to C or from B to D, respectively). In this case, the trains do not make stops at any intermediate terminals, and therefore this is what we call the direct bundling. If the main part of their route is bundled or consolidated into a single train instead transporting containers in the direct trains, it is possible to reach higher capacity of the train (it results in a higher loading degree as shown in the middle section of Fig. 1) or the transport can be optimized by increasing the number of frequencies (see the right section of Fig. 1).

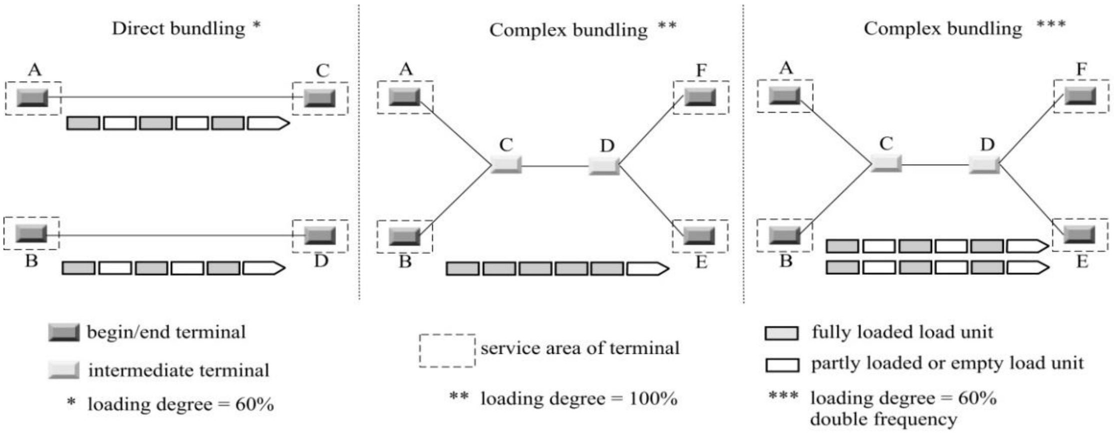


Fig. 1 Principle of the direct and complex bundling

The advantages of the complex bundling include:

- increase in the transport frequency, resulting in shorter waiting times of the containers in the begin terminal,
- increase in the number of final destinations (end terminals) from each begin terminal, which means that the serviced area can be expanded,
- reduced distance of pre- and post-haulage (=PPH), this applies to some specific cases,
- higher profitability due to higher loading degree of the transport units and load units,
- balancing the transhipment time at the terminal (reduced waiting times), this applies to some specific cases.

Nevertheless, the bundling model also has some disadvantages, which are:

- increase in the transhipment operations at intermediate terminals and increase in costs associated therewith; this can be handled by using an optimized transhipment technique for the transhipment of containers,

- increased transport distances compared to direct connection and increase in the total transport time (detour), which is not pertinent in every case,
- lower capacity/volume of the transport units on local routes of the networks (feeder routes), which is not pertinent in every case.

The bundling model uses different networks, in which the self-contained container trains move, see Fig. 2. These networks are the feeder networks (=F), line networks (=L) and the hub-and-spoke networks (=HS); direct bundling is designated as direct networks (=D). Each network has its specific features; they differ from each other in the number of main and local routes, number of intermediate terminals, etc. The D networks have the highest number of main routes, while the HS networks feature a medium number thereof and the remaining two bundling networks have only one route (connection). The D and HS networks consist of only main routes or parts thereof, on which the volume of trains between the begin terminal and the end terminal is constant in order to operate fully loaded trains. The F and L networks consist partially of local routes, on which the trains are shorter or have a lower loading degree (which may not be pertinent in every case). The D networks only have begin and end terminals and no intermediate terminals. The number of intermediate terminals is ranging from one for the HS networks (known as the hub) to two for the F networks (it is not necessarily the rule), and is variable for the L networks; it is, however, identical to the D networks as far as the number of transhipments is concerned. Every begin terminal and end terminal have a service area of their own, which means that the PPH is organized via road transport.

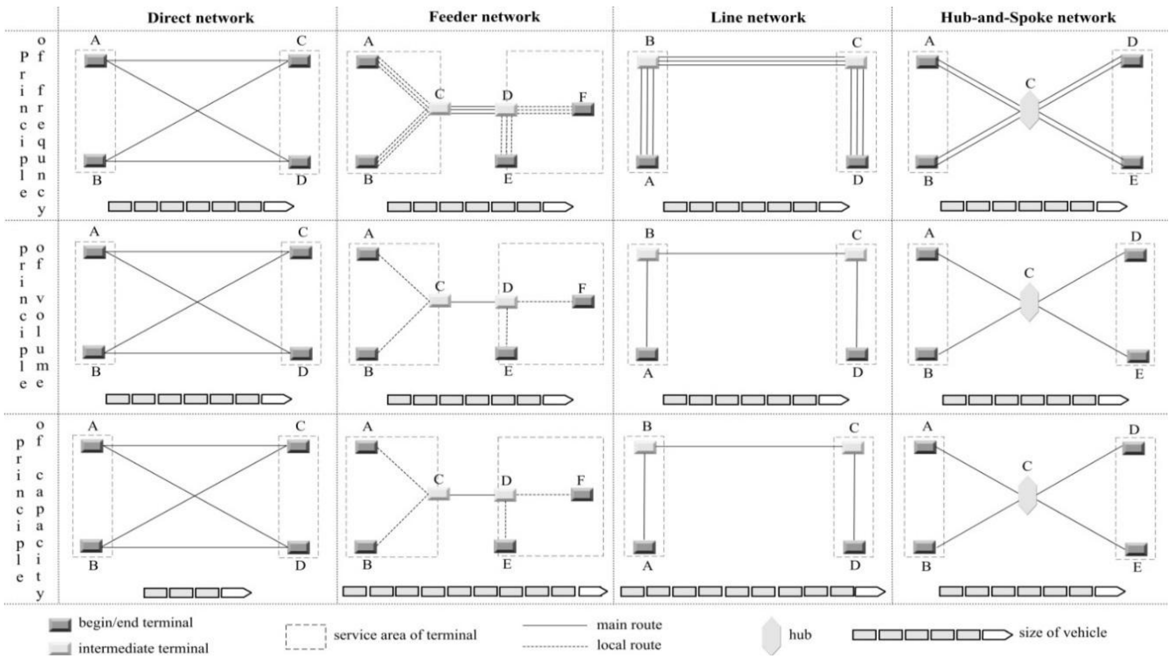


Fig. 2 Individual networks and bundling principles

PRINCIPLES OF THE BUNDLING MODEL

The heart of the bundling model are the so-called major variables, which primarily include the transported volume in the networks and number of connections as well as the size of transport units (trains) and number of frequencies. These interactions need to be differentiated in the bundling model and they can be collectively designated as the so-called principles of bundling (Kreutzberger, 2008), see Fig. 2:

- the principle of transport frequency - the cargo volume passing through the network and the capacity of the transport unit is the same in all networks; the transport frequency is variable,
- the principle of network volume (size) - the cargo volume passing through the network and the capacity of the transport unit is the same in all networks; the transport frequency is variable,
- the principle of transport unit capacity (effect of operational measures) - the cargo volume passing through the network and the transport frequency is the same in all networks; the transport unit capacity is variable.

There is a quantitative relationship between the three principles, which can be called the bundling triangle. Any change in one of these three principles (entities) will cause that at least one other principle will be changed. The quantitative relationship depends on the choice of the bundling principle and the number of the begin and end terminals. The above three principles are also shown in Fig. 2 in the so-called directed and separated networks with 2 begin and 2 end terminals on each side of the network. Each line between the terminals signifies connection per time unit and indicates the frequency. The sum of the lines represents the network volume; the length of the transport unit displayed in each of the rectangles at the bottom represents the capacity of the transport unit, i.e. the volume of trains in each network. In the principle of frequency, the network volumes and the capacities of transport units are constant, i.e., the D network has a frequency of 1, the F and L network has a frequency of 3 for the main route, and the HS network has a frequency of 2, which means that the number of departures from the begin to the end terminals is in a ratio of 1:3.2. In the principle of network volume, the volumes are in a ratio of 4:1:2 (D, F/L and the remaining HS network) and feature identical transport frequencies and capacities of transport units in all bundling networks. In the principle of transport unit capacity, the capacities of transport units are in a ratio of 1:3:2 (D, F/L and the remaining HS network) based on the identical network volumes and frequencies in all bundling networks.

MATHEMATICAL FORMULATION OF THE BUNDLING MODEL

The major variables of the bundling model include volume transported in the network, number of frequencies per connection and transport unit capacity, and compared to the above mentioned bundling triangle the number of main routes has been additionally introduced as another variable. These variables are characterized by unavoidable and flexible quantitative relationship within the same period. This relationship is unavoidable in any network and its simplified formulation for the bundling networks is as follows. The capacity of transport unit (trains) C in TEU on the major route of the connection is equal to the volume transported in the network V_n in TEU divided by the number of main routes of the vehicles R_v and the number of frequencies of services per unit of time (F) (see formula 1), or analogically expressed as a quotient of the volume transported on the route V_r and the frequency F. The capacity of transport unit shall not exceed technical maximum C_{max}, which represents the maximum length of the train (600-700 m in Europe) and the maximum axle load.

In the top-to-bottom decomposition of the system, the capacity of the transport unit is as follows:

$$C = \frac{V_n}{R_v * F} = \frac{V_r}{F} \leq K_{max} \qquad (1)$$

in which:

$R_v = N^2$ in D networks, 1 in F/L networks, N in HS networks (2)

In the bottom-to-top approach, the capacity of the transport unit is the product of the capacity C_{max} and the loading degree of the vehicle λ, see formulas 3 and 4.

$$C = C_{max} * \lambda \tag{3}$$

$$0 \leq \lambda \leq 1 \tag{4}$$

The above mentioned term "unavoidable relationship" means that if three of the four variables of the bundling model (C, V_n, F, R_v) are given, then the fourth of them is definitive. It also means that if the bundling options are compared, it is necessary to compensate the different number of the main routes in the bundling network by the value of at least one of the four variables. In such case, the aforementioned bundling triangle will change into a bundling square. The above mentioned term "flexible" refers to the fact that any of the bundling variables can be calculated at both the input and output. The choice of the variable is compensated by the number of the main routes R_v pertaining to the principle. In the frequency principle, the transported volumes and the capacities of transport unit in the compared bundling networks are identical and the number of frequencies per time unit F_B is dependent on the bundling and is varying (formula 5). The index $_B$ represents the value of pertinent variables in the bundling. In the network volume principle, the transport frequencies and the capacities of transport units are identical in all compared networks and require a network volume V_{nB} in TEU depending on the bundling, which is varying (formula 6). In the principle of transport unit capacity, the network volumes and the frequencies of services are identical in the compared networks; the capacity of the transport unit C_B in TEU is dependent on the bundling and is varying (formula 7).

The principle of frequency:

$$F_B = \frac{V_n}{R_v * C} \tag{5}$$

The principle of network volume:

$$V_{nB} = C * R_v * F \tag{6}$$

The principle of transport unit capacity:

$$C_B = \frac{V_n}{R_v * F}$$

ANALYSIS OF THE CURRENT STATUS IN THE CONTAINER TRANSPORT

The busiest ports in Europe are currently (2013) those situated on the coast of the North Sea or the Atlantic Ocean, which have a percentage share of more than 70% in the total transhipment volume of 100 million TEU (Bartošek and Marek, 2013). It means in practice that the major share in the transhipment of containers is divided among the large ports of Rotterdam, Antwerp, Hamburg and Bremerhaven. One of the factors that favour these ports and their container terminals is their technical maturity that enables berthing and transhipment of large container vessels, which require sufficient maximum draught, long quaysides and automated transhipment, etc. The shipping lines also tend to favour those ports, since they have their parent terminals there, and last but not least, various political pressures and lobbying also play an important role. The so-called H-R port area is used mainly as the transport link between Asia and Europe in connection to the feeders to the Northern and Eastern Europe. During the service schedule (loop) of container vessels, the shipping lines always visit at least one of the said ports and further 3-5 regional ports in Europe. These container vessels may reach a capacity of up to 18,000 TEU (Marek and Bartošek, 2012). The mutual interaction between the seaports and hinterland is gaining intensity and plays an important role in the formation of logistics solutions of the providers of logistics services. The key factor that impacts on the competitiveness of the ports in the intermodal transport chain is primarily the ability of the ports to handle the flows of containers from/to the hinterland. The lack of interest in the reliability of transport to the hinterland was the reason that prompted the shipping lines and seaports to take over a more active role in the logistics chains. The choice of transport routes is strongly influenced by the conditions of transport to the hinterland and its reliability, which are the basic factors for the route selection process. The development of intermodal hinterland corridors has enabled deep penetration mainly due to shuttle trains and connection with the use of inland container vessels. The liberalization of railway transport that began in the '90s has proved to be a useful tool to increase the efficiency of the services provided on the corridors to the hinterland. Not only that the intermodality has stimulated the ports to expand in the hinterland, but also the hinterland itself has become within easy reach of the ports. The size of each serviced hinterland zone thus primarily depends on the number of frequencies of the services as well as the tariffs and services that are being offered.

Although the share of rail transport volume in the total transported volume has been declining since the 1970s (compared to road transport), this difference is not so much striking in the transportation of containers from/to inland. The transportation of containers by rail, or more precisely, intermodal transport was, particularly in the early stages, in the hands of state-owned carriers (until the end of the 1990s) who have been putting it out of their main area of interest over a long period of time. The leading role has been gradually taken over by the intermodal operators who have to face profitability issues in intermodal transport at their own risk. In the '90s, the intermodal rail connections based on the Hub and Spoke networks dominated, but they were gradually being abandoned due to liberalization of the railway transport in Europe and the growing volumes of transhipment operations in the ports. Presently, new connections are being introduced in the form of direct shuttle trains in the networks, in which the competitors have been already operating (example thereof is the introduction of shuttle trains by the intermodal operator TFG Transfracht between Hamburg and Lovosice in September 2013). Some intermodal operators, however, are gradually building their own Hub and Spoke network between the central hubs and local terminals (such Metrans with its hubs in Česká Třebová and Prague-Uhříněves and Rail Cargo Operator with its hub in Prague-Žižkov). The introduction of new railway connections and routes is very expensive, and because of strong competition between the intermodal operators and saturation of the market by road carriers, finding an optimized transport connection is a complicated task. Launching new services in the intermodal transport chain via railway connections in the major segment of transportation requires comprehensive analysis, involves higher costs and taking the risks to find appropriate critical transported volumes.

The transportation of containers by rail in the area of H-R ports is serviced mainly by direct shuttle trains. A large part of these shuttle trains operate between the ports and logistics terminals/hubs in the hinterland of Germany, Switzerland, France and Italy. As regards connection with Central Europe, the most widely expanded connections can be found especially to/from Czech Republic (Prague-Uhříněves, Česká Třebová, etc.), Poland (Poznaň, Slawków, etc.), Austria (Wells, Vienna, etc.) and Hungary (Budapest, Sopron, etc.) as well as on the lines in the north-western direction (North Sea ports) and, to a lesser extent, in the direction towards the South (Adriatic ports), see Table 1.

Table 1 Selected shuttle trains between H-R ports and Central Europe (2014), (Selected intermodal operators, 2014)

Connection/Intermodal operator (Number of trains per week - export/import)	Metrans (GER)	Rail Cargo Operator (AUT/CZ)	Polzug (GER/PL)	TFG Transfracht (GER)	ERS Railways (DK/NL)
Hamburg - Prague Uhříněves	26/23				
Bremerhaven - Česká Třebová	4/10				
Rotterdam - Prague Uhříněves	5/5				
Koper - Dunajská Streda	14/14				
Hamburg – Prague Žižkov		10/10			
Koper - Bratislava		3/3			
Hamburg - Dabrowa			6/6		
Bremerhaven - Salzburg				3/3	
Hamburg - Lovosice				2/2	
Rotterdam - Poznaň					6/6

As regards the system of train connections used in the intermodal transport chain in the Central European space, it includes primarily the system of shuttle trains (direct connection) and the Hub-and-Spoke system that has been successfully applied in the transportation of containers between some terminals in the hinterland, which are used as node terminals/hubs. At shorter distances, feeder connections are also used to supply the large container terminals (hubs). The load flows are very intensive in these relations and the frequency of trains reaches at least one train per 24 hours. In other related directions, i.e. to other terminals within a country (continental transport), or to the neighbouring countries, the container flows are lower with train frequencies ranging from 2 to 5 trains per week. These connections can also be classified in some cases as feeder connection systems (an example thereof can be the connection operated by the Rail Cargo Operator between the terminal Prague-Žižkov and the terminals in Přerov and Paskov). In the Czech and Slovak Republics, the total transported volume between the European ports and the hinterland was around 847,000 TEU in 2013 (Hafen Hamburg Marketing, 2014), see Fig. 3. A noticeable trend in recent years is especially a successive decline in the Rotterdam port´s share, unchanged status of operations in the Hamburg port and increase in share of the ports of Bremerhaven and Koper. At present, the following companies can be considered to be fully fledged intermodal operators in the Czech Republic: Metrans, Rail Cargo Operator, Maersk Intermodal (former ERS Railways) and TFG Transfracht, see Fig. 3, which operate connection with the seaports as well as domestic connections.

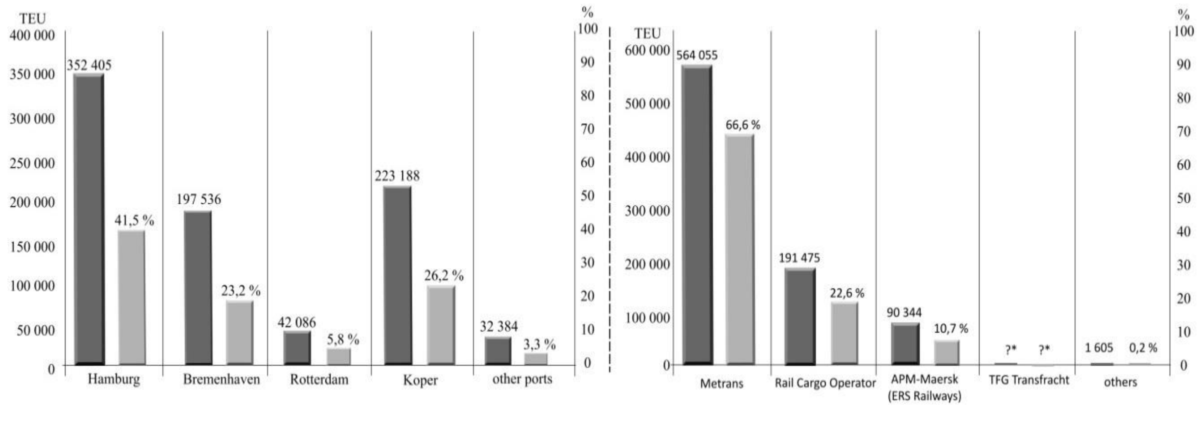


Fig. 3: Share of individual container transports between Czech/Slovakia and European ports 2013 (Hafen Hamburg Marketing, 2014)

IDENTIFICATION OF PROMISING BUNDLING NETWORKS

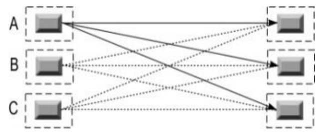
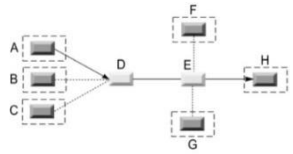
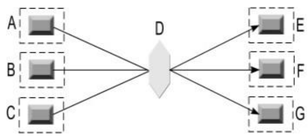
In order to be able to identify promising and suitable bundling networks, which can be applied in practice (simplified networks), it is necessary to make a comparison of the networks. The maximum possible number of terminals that can be bundled in practice is ranging from 2 to 4 terminals. The incorporated networks should be comparable in particular in the following aspects: the same number of the begin and end terminals, if possible, approximately identical distances between the terminals and a comparable transported volume between the begin and end terminals (the principle of volume) and/or comparable number services per begin terminal (the principle of frequency).

A simple comparison of the internal mechanisms between the bundling concepts in terms of the principles of frequency, volume and transport unit capacity, and identification of promising bundling networks are shown in Table 2. The table includes all bundling networks shown in Fig. 2. The trains in the presented networks have a capacity of 89 TEU, or only 44 TEU if the principle of transport unit capacity is applied. The loading degree is 90% (which means 80 TEU or 40 TEU per train respectively after conversion) and the train length is 600 m. These input data are fully verified since they come from the intermodal operators (Question forms for intermodal operators, 2014). The number of the begin terminals and end terminals in this comparison is either $N = 1$ or $N = 3$ on one side of the network. The number of main routes is in a ratio of 3:1/3:1/3:1 or 9:1:3. As regards the principle of volume, the annual volume of the network totals to 49,920 TEU; each begin terminal or end terminal has an annual transhipment volume of 16,640 TEU and approximately 12,480 TEU in the D networks. This amount of transportation enables the use of the following frequencies:

- once a week from each begin terminal or end terminal in the D network,
- twelve times a week from each begin or end terminal in the F and L network,
- four times a week from each begin terminal or end terminal in the HS network.

The above mentioned investigation clearly shows that the complex bundling enables offering of more frequented connections compared to the D networks, thus confirming the premises as mentioned in Section 2. In the frequency principle in Table 2, it is assumed that each begin terminal has a weekly frequency of 4 trains sent to each end terminal. In the D network, each destination must serve separately, i.e. there are 9 branches with a total annual volume of 149,760 TEU and annual volume of 49,920 TEU between the begin terminal and end terminal. In the F and L network, this volume amounts to 5,547 TEU, implying thus that a specific frequency can be achieved in the complex bundling with a relatively small number of begin terminals and end terminals in comparison with the D networks. In the HS network, terminals can be operated jointly, i.e. there are 3 branches, which show that the required volume between the begin terminal and end terminal amounts to 16,640 TEU per year. As regards the last principle (the principle of transport unit capacity), the frequencies and volumes of the networks are the same, the capacity of transport units, however, is different. The capacities of transport units for the D, F/L and HS networks differ in a ratio of 1:12:4. The quantitative relationship for the directed, separated and balanced networks can be expressed in general terms so that the capacity of transport units of the HS network is N multiple of the D network value, where N is the number of the begin terminals and end terminals on each side of the network, i.e. in parts of the major route of the other networks the capacity is N^2 of the D network.

Table 2 Promising bundling networks in terms of transport unit capacity, frequency and network volume principles

	Bundling network	The capacity of transport unit	Frequency per week	Connections x weeks	Transport volume
P		80 TEU	1x per week	3x52	12 480 TEU
		80 TEU	4x per week	3x52	49 920 TEU
		40 TEU	1x per week	3x52	6 240 TEU
		80 TEU	1x per week	9x52	37 440 TEU
		80 TEU	4x per week	9x52	149 760 TEU
		40 TEU	1x per week	9x52	18 720 TEU
F		80 TEU	12x per week	1/3x52	16 640 TEU
		80 TEU	4x per week	1/3x52	5 547 TEU
		40 TEU	12x per week	1/3x52	8 320 TEU
		80 TEU	12x per week	1x52	49 920 TEU
		80 TEU	4x per week	1x52	16 640 TEU
		40 TEU	12x per week	1x52	24 960 TEU
L		80 TEU	12x per week	1/3x52	16 640 TEU
		80 TEU	4x per week	1/3x52	5 547 TEU
		40 TEU	12x per week	1/3x52	8 320 TEU
		80 TEU	12x per week	1x52	49 920 TEU
		80 TEU	4x per week	1x52	16 640 TEU
		40 TEU	12x per week	1x52	24 960 TEU
HS		80 TEU	1x per week	1x52	4 160 TEU
		80 TEU	4x per week	1x52	16 640 TEU
		40 TEU	4x per week	1x52	8 320 TEU
		80 TEU	1x per week	3x52	12 480 TEU
		80 TEU	4x per week	3x52	49 920 TEU
		40 TEU	4x per week	3x52	24 960 TEU
	begin/end terminal; intermediate terminal	service area of terminal		hub	

It can be concluded from the above results that the comparison shows in some cases values that are not suitable for practical use. It can be stated within the validation of the results that the resulting volume corresponds to 80 TEU, i.e. the average loading of trains lies between 72 and 92 TEU, which corresponds to the standard volume transported by container train in the Czech Republic (Question forms of intermodal operators 2014). Also the annual transported volume of 49,920 TEU corresponds in practice in rough figures to the annual volume transported by the intermodal operator Rail Cargo Operator on the relation Prague - Bremerhaven. It is necessary to take into account the limitations of technical nature (max. capacity of the transport unit, maximum length of trains in the networks, clearance profiles, elevation profile of the route, etc.), which should be fully considered in the calculation when conducting an investigation in practice.

CONCLUSION

The bundling model offers good utilization potential mainly where the size of the containerized freight flow is not sufficient enough for operating the direct connection between the begin terminal and the end terminal. The model offers different networks (systems of train connections, i.e. bundling networks) for the transport purposes, in which the container trains can move. As far as the individual networks are concerned, important role is played by the bundling principles, upon which the frequency of services, volumes of networks and capacities of transport units are being changed. Each of the networks has different characteristics relating to the use, length of connections (detours), time-based evaluation, number of transhipments in the intermediate terminals, etc. The best bundling concept for each particular situation is the one that establishes an optimum balance between the advantages and disadvantages of the complex bundling. There is, however, no best bundling concept that would be generally applicable, but only the one associated with specific network volumes and performance values. For example, option suitable for the defined volume and frequency, if the principle of network volume is applied, will be either the D network and HS network, or the F and L network. Additional costs which arise if complex bundling is used (not pertinent in every case) should be compensated by the benefits resulting from the introduction of new transhipment techniques. The optimum value will vary depending on the network, minimization of both the operational and logistics costs or maximized expansion of the serviced area. Nevertheless, it is obvious that larger capacities of transport units, higher frequencies or identical performance levels for lower transported volumes represent the extent and scope of economic benefits.

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