TRANSPORT
2008
23(1): 16–20

ASSUMPTIONS OF SMALL-SCALE INTERMODAL TRANSPORT

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Received 16 May 2007; accepted 20 November 2007

Abstract. The aim of the article is to present the alternative to the very well known hub and spoken approach to intermodality when freight scale is small. When usually the blocked trains operate between two big intermodal hubs, here the concept of on-line blocking of intermodal transport units (ILU) is presented. The article investigates functional interrelations between the carriage of on-line blocked ILU and the structure of transport network. In order to forecast the flows of on-line blocked ILU the indirect model has been chosen which enables us to evaluate two important aspects: the first one is the evaluation of the structure of the ILU origins in terms of production and consumption regions as well as the other factors determining the formation of flows of goods. The second one is concerned with the structure of the transport network. Assumption of small-scale intermodal transport along Berlin–Baltic intermodal axis is presented.

Keywords: intermodal transport, terminal, transhipment.

1. Introduction

The term "intermodal" is understandable as door to door transportation of goods by view modes of transport within intermodal loading units (ILU) and ILU are not recharged during the transportation process. The containers, trailers and swap bodies are called intermodal transport units here according to ECMT Terminology of Combined Transports (2001). Intermodal transport is the well known way to reduce transport costs, pollution and congestion. The EU policy is strongly focused on reducing road transportation using intermodal decisions. It is strongly highlighted by Love (2005) and could be found also in the White Paper (2001). However, intermodal decisions need to be supported by economical reasons as said in IRU Statement 'Combined Transport: A Viable Solution' (2003). Economies of scale is one of the main driving forces of intermodality. One train may move 50 and more ILU and it is cheaper than 50 road trucks. This is just a first opinion. Transhipment of ILU has a need for infrastructure and equipment. Large-scale intermodal terminals may reimburse the investment due to the huge flow of ILU transhipped. The small-scale intermodal solutions as the practice shows are mostly temporary. The last example may be here the intermodal shuttle in Denmark Esbjerg-Fredericia, where the intermodal train concept was cancelled in the year 2006 and transhipment facilities were finally sold out.

The aim of the article is to present the alternative to the very well known hub and spoken approach to intermodality when freight scale is small.

2. Conceptualisation of hub alternative

In order for European intermodal transport to be competitive over short and medium distances, regional systems must be designed to adapt to local preconditions rather than to any general preconditions prevailing in all of Europe. According to Woxenius (1998) network modules are also likely to succeed only if the trafficking of direct connections is abandoned because of more advanced principles of operating the rail network.

Classical intermodal hub concept presented by Rodrigue (2007), Haynes (1998) and Baird (2006) is aimed at large flows over relatively long distances. For natural reasons, these services are most economically provided with direct full trains between end terminals. The terminals employ well proven large-scale transshipment technology. This part of the transition is well under way since measures for improving productivity imply that the current networks are split up, focusing on profitable direct connections (Fig. 1).

Alternative concept is for transport over short and medium distances – 200 to 500 kilometres according to Woxenius (2005), Trip, Bontekoning (2002) and Ballis, Golias (2004). It aims for the part of this market that involves densely populated areas generating freight flows. This market may be approached by introducing intermodal on-line blocked trains. The trains will cross all over Europe along such corridors and make frequent but short stops at road-rail transhipment terminals (Fig. 2).

Although the total of these flows are of significant magnitude in Europe, the dispatched volumes might be

ISSN 1648-4142 print / ISSN 1648-3480 online
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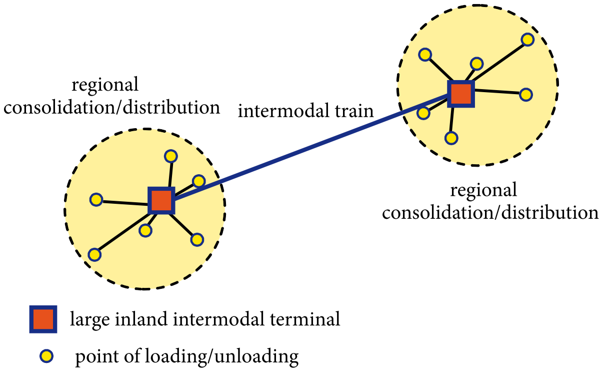

Fig. 1. Intermodal hub concept

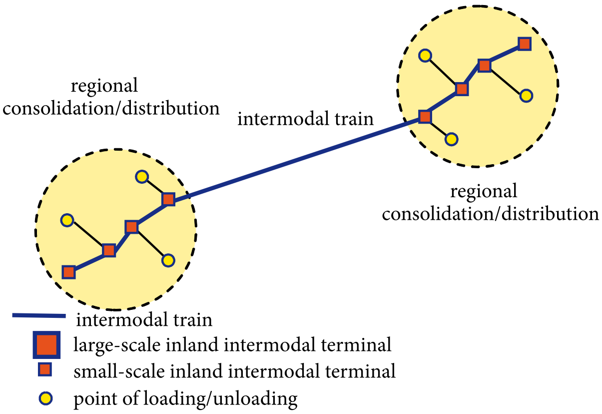

Fig. 2. On-line ILU blocking concept

small for each network module and each terminal, calling for small-scale technologies keeping investments and operating costs at a reasonable level. In order to secure a certain amount of freight, the network modules will collect and distribute ILUs connections with large-scale shuttle and corridor services. Another task for the small-scale systems is to take care of the small flows of ILUs and build them up for new large-scale direct train and corridor services.

3. The formulation of the conditions for the carriage of on-line grouped goods

Let us formulate the task of the need for the carriage of goods in the transport network. The similar modelling algorithm can be found in the works of Jaržemskis (2004) and Keršys, Jurkauskas (2001). Fig. 3 demonstrates our given network fragment G, consisting of links N and nodes M. Terminals as the nodes of the intermodal transport network are marked k_i. The nodes are intermodal terminals where ILU can be reloaded:

a) from rail into road transport means;
b) from road into rail transport means;
c) railway carriages can be reattached from one train to another one (in case of sorting out).

Let us now analyse the possibility of ILU grouping given in Fig. 3 fragment of the intermodal transport network.

Intermodal operators tend to have loyal clients and the flow of goods more stable because as the volume of goods fluctuates a lot, it becomes more difficult to organize the carriage and forecast the need for transport services. As the size of consignments is diminishing, there appears a possibility of minimizing volume fluctuations, i.e. grouping of ILU in accordance with the direction of the destination point. Thus, peculiar chains of grouped ILU (e.g. blocked train) goods are formed. For example, a transport intermodal operator moves goods from k_1 to k_6, knows about the need for transport goods from k_2 to k_5 and from k_4 to k_6.

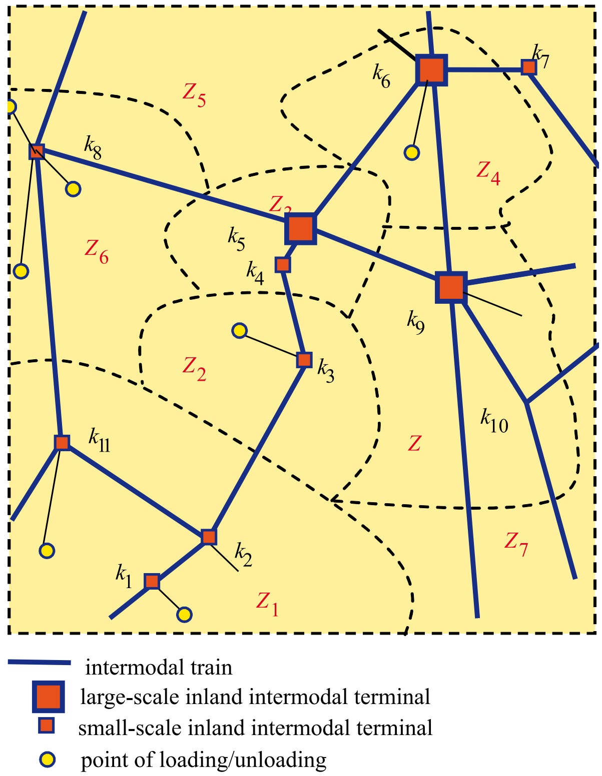

Fig. 3. A fragment of the transport network

Let us mark single carriages of the goods $\Omega_j(k_1, k_6)$, $\Omega_j(k_2, k_5)$ and $\Omega_j(k_4, k_6)$, where Ω reflects the amount of the goods, j – carriage. On-line grouping of goods should meet four requirements:

a) Adequacy of route:

$$(k_2, k_5) \in (k_1, k_6); \quad (1)$$

$$(k_4, k_6) \in (k_1, k_6); \quad (2)$$

b) Adequacy of time $\Theta(\Omega_j)$ of j-carrying of goods:

$$\Theta(\Omega_j(k_1, k_6)) \cong \Theta(\Omega_j(k_2, k_5)) \cong \Theta(\Omega_j(k_4, k_6)). \quad (3)$$

A possible time inadequacy error can be different in each separate case and it has to meet the needs of goods consignors and consignees.

c) Volume adequacy condition:

$$\Omega_j(k_1, k_6) + \Omega_j(k_2, k_5) + \Omega_j(k_4, k_6) \le \Omega_{a/m}, \quad (4)$$

$\Omega_{a/m}$ – the capacity of a blocked train for carriage.

d) The condition ensuring the adequacy of legal means.

Having met the above mentioned conditions, goods can be grouped by routes. In the long run, having the routes settled, we can also form a fixed route for carrying on–line grouped goods. For the sake of simplicity in our further modelling we will sign the logistical functions between adjacent terminals (k_i, k_{i+x}) as l_j.

4. The task of forming an intermodal network for carrying on-line blocked ILU

Let us assume that we have a fragment of the transport network $G[K; L]$. We are going to evaluate a possibility of building a logistical chain (k_8, k_5, k_9, k_{10}), for carrying on–line grouped goods. Its building will create a possibility of on–line grouping of goods at terminal k_5 (by combining directories north-south and east-west) as well as a possibility of delivering smaller blocks of ILU by grouping them into consignments at large terminal k_9, where goods further are carried by large blocked trains.

When forecasting the carriage of goods, it is expedient to identify the peculiarities of the territory being planned and investigated. The territory is being planned in the way which can provide us with possibilities of appearing of potential consignors and consignees. The territory under investigation is subdivided into trading regions. Fig. 3. illustrates the fragment of the transport network $G[N; M]$ with marked territories, i.e. trading regions Z_j. The size of a region is a very important criterion for establishing the interaction between the region trading subject located in this particular region and forecasting its future development possibilities.

A region can be described as a complete full set $X \times Y$. A complete set of regions $P = \{Z_1, ..., Z_{\text{p.max}}\}$ is called a territory under development, when the following requirement is met:

$$\forall_{1 \le i, j \le p.\max, i \ne j} Z_i \cap Z_j = \varnothing. \tag{5}$$

A complete set of trading regions $T = \{Z_1, ..., Z_{\text{t.max}}\}$ is called a territory under investigation, when the following requirement is met:

$$\forall_{1 \le i, j \le t.\max, i \ne j} Z_i \cap Z_j = \varnothing. \tag{6}$$

The structure and peculiarities of a territory are the main data to form the need for carrying blocked ILU. It can be argued that statistical data provide us with the peculiarities of the territory being investigated which in its turn encompasses the territory being planned.

The structure of a territory $S = (P, T, X, E, W)$ is composed of the following elements:

a) the territory being planned P;
b) the territory under investigation T, where $P \subseteq T$;
c) X: $T \to N$, i.e. a name granted to each trading region of the territory being researched;
d) E: $P \to N$, the number of enterprises attributed to each trading region of the territory being planned;
e) W: $P \to N$, The turnover (in ILU) of enterprises dispatched and accepted goods of each trading region located in the territory is being planned.

Here:

$$P = (Z_6, Z_3, Z_8), \tag{7}$$

$$T = P \cup (Z_1, Z_2, Z_4, Z_5, Z_7). \tag{8}$$

The network of chains carrying goods in the fragment $G[K; L]$ of the transport network located across the territory being researched T can be described as follows: $G_R = (K, L, L_R, I, XY, Q, B)$. This fragment consists of:

a) K – a complete set of transport terminals belonging to the chains along which grouped goods flow.
b) L – a complete set of links defined as $l \in L$, $l = (M, t, B)$ and consisting of the route of the logistical chain carrying blocked ILU $M[k_1, ..., k_n]$, where $\forall_{1 \le i \le n}\, k_i \in K$; the time period of carriage t: $\{1, ..., n\text{-}1\} \to N$ between two terminals, the length of the links B: $\{1, ..., n\text{-}1\} \to N$.
c) A set of connections between non-oriented trading regions and transport terminals $L_R \subset T \times K$. Thus, each trading region is connected: $\forall_{Z \in K} \exists_{k \in K} (Z, k) \in L_R$.
d) The numbers of terminals I: $K \to N$.
e) The coordinates of terminals XY: $K \to N \times N$.
f) The kind of transport and their combinations Q: $L \to \{road, railway\}$.
g) The length of distances between terminals and links B: $L_R \to N$, m.

Let us sign link l_1 between k_1 and k_2, l_2 – between k_2 and k_3; l_3 – between k_3 and k_4; l_4 – between k_4 and k_5; l_5 between k_5 and k_6; l_6 – between k_6 and k_7; l_7 – between k_2 and k_{11}; l_8 – between k_{11} and k_8; l_9 – between k_5 and k_8; l_{10} – between k_5 and k_9; l_{11} – between k_9 and k_{10}.

The network $G_R = (K, L, L_R, I, XY, Q, B)$ in the given example before planning consists of a set of nodes $K^A = \{k_1, k_2, k_3, k_4, k_5, k_6\}$ and a set of links $L^A\{l_1, l_2, l_3, l_4, l_5\}$.

The network of the blocked train paths at the planning stage consists of a set of nodes (terminals) – $K^P = K^A \cup \{k_8, k_5, k_9, k_{10}\}$ and a set of links $L^P = L^A \cup \{l_9, l_{10}, l_{11}\}$.

The following sizes can be defined in the territory T being researched and the logistical network $G_R = (K, L, L_R, I, XY, Q, B)$:

a) A full list of trinominals consisting of two nodes (terminals) and links connecting them (logistical junctions) $m_r = [(k_1, l_1, k_2), (k_2, l_2, k_3), ..., (k_{\text{m.max-1}}, l_{\text{m.max-1}}, k_{\text{m.max}})]$ will be referred to as a logistical chain:

$$-\forall_{1 \le i \le m.\max} : k_i \ne k_j. \tag{9}$$

b) The route of blocked ILU $m_r = [(k_1, l_1, k_2), (k_2, l_2, k_3), ..., (k_{\text{m.max-1}}, l_{\text{m.max-1}}, k_{\text{m.max}})]$ can be referred to as logistical connections between consignments region of origin Z_s and the accepting region Z_a, if the following equations are true:

$$(Z_s, k_1) \in L_R; \tag{10}$$

$$(Z_a, k_{\text{m.max}}) \in L_R; \tag{11}$$

$$Z_s \ne Z_a. \tag{12}$$

c) A set of all the connections from Z_s (dispatching region) to Z_a (accepting region) is described as:

$$Mr(Z_s, Z_a) = \{m | m \text{ logistical conection from } Z_{si} \text{ to } Z_a\}. \tag{13}$$

d) The quality of carrying a single ILU from one terminal to another one (k_i, l_i, k_{i+1}), where:

$$\pi(l_i, M, d) = k_i \wedge \pi(l_i, M, g) = k_{i+1} \wedge d < g. \tag{14}$$

It can be interpreted as follows:

$$\lambda_f(k_i, l_i, k_{i+1}) = \sum_{d \le j \le g_i^l} \cdot t(j). \quad (15)$$

e) The quality of the route servicing intended for grouped goods $m_r = [(k_1, l_1, k_2), (k_2, l_2, k_3), ..., (k_{m.\max-1}, l_{m\cdot\max-1}, k_{m.\max})] \in M_r(Z_s, Z_a)$ can be expressed as:

$$\lambda_r(Z_s, Z_a, m) = \lambda_i(i, k_1) + \lambda_m(m) + \lambda_a(a, k_{\mathrm{m.max}}), \quad (16)$$

or in other words (in terms of time) can be evaluated as the total time needed for loading, transition and unloading.

f) The route for carrying blocked ILU between two regions $Z_s, Z_a \in T$ can be defined as:

$$A_r(Z_s, Z_a) = Min\{\lambda_r(Z_s, Z_a, m) | m \in M_r(Z_s, Z_a)\}. \quad (17)$$

g) The route for carrying blocked ILU which is being planned $m \in M_r(Z_s, Z_a)$ from Z_s to Z_a, is considered to be the best one provided:

$$\lambda_r(Z_s, Z_a, m) = A_r(Z_s, Z_a). \quad (18)$$

The transport network of the territory being researched intended for grouped carriage of ILU will be marked G_B, where $G_B = (K, L, L_B, I, XY, Q, B)$. This fragment of the network is composed of:

a) K – a complete set of intermodal terminals located in the network fragment.

b) L – a set of links, defined as $l \in L$, $l = (M, t, B)$ and consisting of the path of blocked ILU $M[k_1, ..., k_n]$, when $\forall_{1 \le i \le n}\, k_i \in K$; the time period of carriage t: $\{k_1, ..., k_{n-1}\} \to$ between two terminals, the length of the links B: $\{k_1, ..., k_{n-1}\} \to k_N$.

c) A set of connections between non-oriented transport regions and transport terminals $L_B \subset T \times K$. Thus, each trading region is connected: $\forall_{Z \in K} \exists_{k \in K} (Z, k) \in L_R$.

d) The numbers of terminals I: $K \to N$.

e) The coordinates of terminals XY: $K \to N \times N$.

f) The means of transport and their combinations Q: $L \to \{road$, railway$\}$.

g) The length B: $L_R \to N, m$ of distances between terminals and links.

ILU can be transported by a generally established order in the given network fragment $G_B = (K, L, L_B, I, XY, Q, B)$ or blocked in the network fragment $G_R = (K, L, L_R, I, XY, Q, R)$. The supply of ILU can be expressed as $f(Z_s, Z_a\, \sigma, m) \in N$, where the dispatching region $Z_s \in T$, the accepting region $Z_a \in T$, a route $m \in M_B(Z_s, Z_a)$, when $m = B$ or $m \in M_R(Z_s, Z_a)$, when $m = R$, a way of ILU carriage $\sigma \in \{B, R\}$. The supply of ILU $\gamma_{sa\sigma m}$ will be a four-dimensional matrix of the total $f(Z_s, Z_a\, \sigma, m)$. The selection of the way of goods carriage $\gamma_{sa\sigma}$ will be a three-dimensional matrix $f(Z_s, Z_a, \sigma)$. The carriage of all ILU from Z_s to Z_a can be expressed as $f(Z_s, Z_a) = f(Z_s, Z_a, B) + f(Z_s, Z_a\, R)$. The matrix of all carriages γ_{sa} is the matrix of all ILU being sent and received. Carriages from the dispatching region Z_s are $f_s = \Sigma_{a \in T} f(Z_s, Z_a)$, i.e. the number of all carriages is related to the dispatching region. The expression of carriages $\gamma_s = (f_s(Z_s), ..., f_s(Z_{t.maz})$ of the dispatching region Z_s is a vector of all the carriages related to the region. Carriages $f_a = \Sigma_{i \in T} f(Z_i, Z_a)$ occurring in the accepting region Z_a are the number of carriages related to the dispatching region. The expression of carriages $\gamma_a = (f_a(Z_a), ..., f_a(Z_{t.maz})$ of the goods received in region Z_a is a vector of all the carriages related to this region.

The analysis and forecast of the matrix of carriages across all the regions enables us to optimize the process of planning of the routes for blocked ILU carriage.

5. Small-scale intermodal freight potential in Berlin-Baltic axis

In the year 2004 the European Commission approved the new list of TEN-T projects (2002). In the project No. 27 called Rail Baltica the railway connection Warsaw–Kaunas–Riga–Tallinn is foreseen. Today due to different width of gauges in the Baltic States (1 520 mm) and Western Europe (1 435 mm) freight transportation by railways practically does not exist. The freight is transported by roads. According to TEN-T plans, the line Warsaw–Kaunas will be constructed up to 2010, Kaunas–Riga – up to 2014 and Riga–Tallinn up to 2016.

As Warsaw and Berlin are well connected by rail, there will be a chance to create intermodal bridge between the intermodal network in Western Europe and the Baltic States.

Annual road freight in the so-called Berlin-Baltic axis is near to 3 mill tons and there are seeming tendencies for growing after Poland, Lithuania, Latvia and Estonia joined the EU, as is stated in the work of Jaržemskis (2007). It means 240 thousand trailers per year in both directions. It means 10 thousand one-way trailers per month as well. About 10 percent of this flow is loaded/unloaded in the so-called Berlin Region which could be defined as territory of three Federal Lands of Germany – Berlin, Brandenburg and Mecklenburg-Vorpommenrn.

Having in mind, that road haulers prefer daily intermodal service in western part of the EU as well as in the US, the trailers daily market potential in Berlin-Baltic axis is about 330 trailers, 33 of which are in the so-called Berlin region loaded and unloaded (Fig. 4).

Existing ILU potential is enough for a large terminal, but loading and unloading points of trailers are dispersed over geographical area.

The COWI consulting company prepared the feasibility study of Rail Baltica project, and suggested geographical pattern of the railway. However by the end of 2007 the first milestone of implementation of the project is not started. Decision makers in order to reduce budget of the project started talking about project reducing up to Kaunas.

In Figs. 5 and 6 the two intermodal possibilities are presented. If the line is constructed to Kaunas only – it will be possible to implement the classic hub concept.

When the line is build to Tallinn – it will be possible to implement the on-line ILU blocking concept.

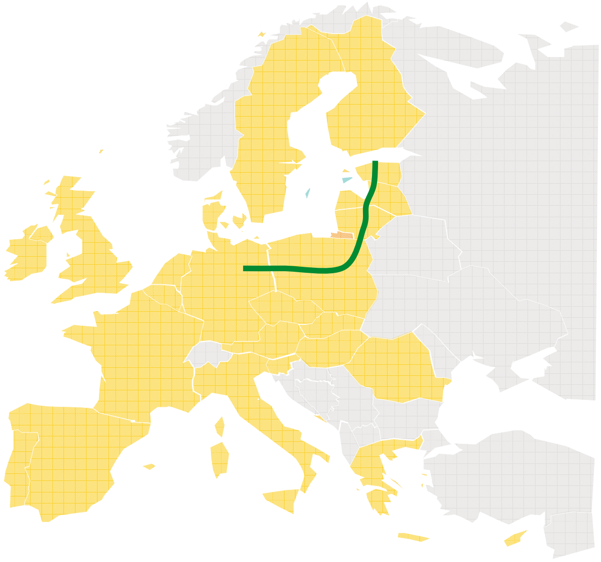

Fig. 4. EU context of Berlin–Baltic freight axis

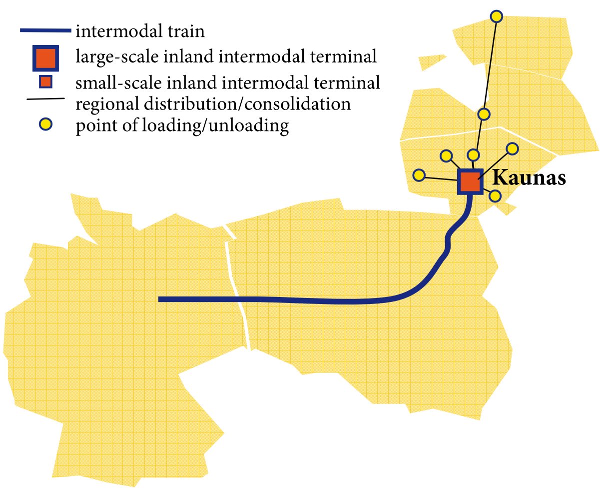

Fig. 5. Eastern part with a large intermodal terminal (hub)

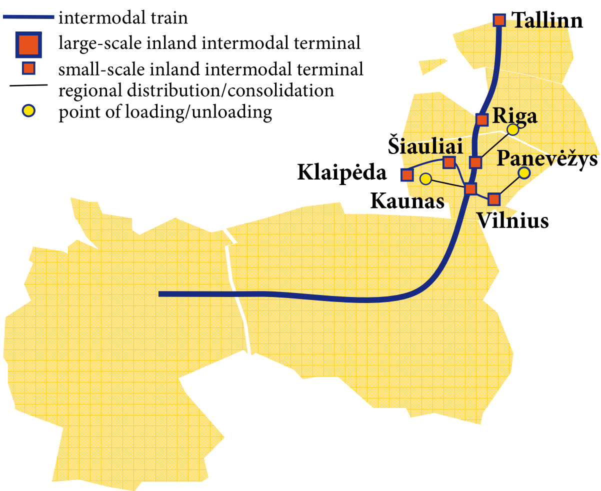

Fig. 6. Eastern part with on-line blocked train

The problem arose because of uncertainty. It needs to be clear about the end point of the line – Kaunas or Tallinn, because on this it depends whether small-scale or large-scale intermodal terminal should be built in Kaunas.

6. Conclusions

1. It is reasonable for long but dispersed flows connecting Eastern part of the EU with the Western part, to develop corridor trains at high frequencies according to strict schedules with short and frequent stops at terminals.
2. The technological tool permitting us to optimize ILU carriages is the design of stable paths for carrying blocked ILU in accordance with the forecast of the indirect demand and supply of the ILU market. This is particularly urgent as the size of shipments (ILU calls) in the European Union and Lithuania is gradually diminishing, the number of shipments and need for delivery frequency, however, is increasing.
3. The analysis and forecast of the matrix of goods carriage among all the regions enable us to optimize the process of planning routes for carriage of on-line grouped goods.

References

Baird, A. 2006. Optimising the container transhipment hub location in northern Europe, *Journal of Transport Geography* 14(3): 195–214.

Ballis, A.; Golias, J. 2004. Towards the improvement of a combined transport chain performance, *European Journal of Operational Research* 152: 420–436.

Combined Transport: A viable solution. 2003 Geneva: IRU. 5 p.

European Commission. Trans-European transport network, TEN-T priority projects. 2002. Office for official publications of the European Communities, Luxembourg.

European Conference of Ministers of Transport. 2001. Terminology of Combined Transport, United Nations, Geneva.

European Union – White Paper "European transport policy for 2010: Time to decide". 2001 Office for official publications of the European Communities, Luxembourg.

Haynes, K. 1998. Intermodalism, *Journal of Transport Geography* 5(1): 21–22.

Jaržemskis, A. 2004. The modeling of the logistical network of on-line grouped goods, *Transport* 19(2): 82–85.

Jaržemskis, A. 2007. *The feasibility study of goods transfer between ports of Klaipeda and Swinoujsce*. Report of the Research. Vilnius. 27 p.

Keršys, A.; Jurkauskas, A. 2001. Prediction and modeling of communication needs, *Transport* 16(2): 70–76.

Lowe, D. 2005. *Intermodal freight transport*. Oxford: Elsevier. 276 p.

Rodrigue, J.-P. 2007. The geography of transport systems. NY. Available from Internet: <http://people.hofstra.edu/geotrans>.

Trip, J. J.; Bontekoning, Y. 2002. Integration of small freight flows in the intermodal transport system, *Journal of Transport Geography* 10: 221–229.

Woxenius, J. 1998. *Development of small-scale intermodal freight transportation in a systems context*. PhD. Thesis. Depart-