This paper deals with intermodal operations optimization methods to be implemented by the Block Train Operator upon cargo flows asymmetries at the hinterland. The algorithm of containerized cargo flows analysis and mathematical model were developed based on the relevant intermodal operation system.

Inland leg of inbound containers from seaport to customer door arranged by truck is dominating within the emerging markets environment. Also imbalance in in- and outbound container flows as far as volumes, container size and payload is the case for largest inland destinations. Hence, the issue of rail-road transport prioritization and operational manageability is becoming of utmost importance. Centralizing those operations under a holistic service company – block train operator has been proven feasible.

Last mile deliveries prioritization approach is offered to achieve the highest number of inbound containers processing with their further utilization for outbound export shipments. Mathematical modeling was conducted for distinct sets of operational scenarios that might take place. The scenario that allows the block train operator to achieve the highest revenue numbers and emptied inbound containers utilization for exports was selected. The number of truck heads, chassis and truck driver mitigation has become a secondary objective. The optimal scenario selected helps to reduce the overheads risk at the time of weekly cargo volumes fluctuations.

The optimization approach represented can be applied to intermodal operations within markets where volume imbalance is rather possible

Keywords: intermodal transportations, block train operator, block train, cargo flows imbalance, agile management, service level

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DEVELOPMENT OF AGILE MANAGEMENT APPROACHES TOWARDS INTERMODAL OPERATIONS UPON CARGO FLOWS IMBALANCE

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1. Introduction

These days the development of intermodal transport connections is one of the key strategic initiatives in most of the countries taking part in global trade. The major feature of this type of transportation is the use of the Intermodal Transport Unit (ITU). Predominantly container unit that is moved from the origin to destination combining different transport modes. Cargo loaded remains within the ITU for the period of the entire trip, not being offloaded or trans-loaded in transit. This vastly increases the possibility of standardization of handling operations and ensures higher bandwidth of the supply chain. Also, intermodal transportation eliminates the necessity of any touch to the cargo itself by transportation companies involved and helps to decrease the loss event probability.

There are 2 alternate combinations of transport modes being used for inland portions of intermodal transportation: cargo moved by truck or by railroad. The choice between those two determines the extent of economic effectiveness of the entire transportation considering pros and cons of each of the options. Trucking ensures higher responsiveness of the supply chain and flexibility in route selection. Railroad transportation involving block trains allows moving cargo under a fixed schedule and projected transit time within the 24–72 hour time window. This type of intermodal connection replaces connections done by trucks in conjunction with environmental initiatives, as well as in order to reduce loads on national and international highways caused by heavyweight trucks. Mid and long-haul container moves from seaports to inland terminals have an economy of scale advantages. Hence, the issues related to intermodal transportations development, design of efficient block train management systems including strategical recourse allocation and tactical planning of day-to-day operations are relevant to nowadays agenda.

2. Literature review and problem statement

Management of intermodal transportations, approaches to process design and transportation participants interaction, determination of economic performance indicators of cargo deliveries are the major fields of the study for a number of scientists and researchers worldwide. [1] identifies intermodal transportations as a new field of scholarly studies of a decent potential. Considers key operational principles of designing inland terminals, creating pools of container trucks, trucking companies (further, drayage carriers) cooperate towards a mutual goal. [2] applies linear programming modeling to 5 essential strategic issues. The authors prove that the competitiveness of intermodal transportations is less sensitive to the terminal related component, but more sensitive to the bottom line cost of transportation paid by the cargo owner. A significant result of this study is finding of the rail-road based transportation competitive level relative to similar delivery done by trucks. [3] emphasizes that it is impossible to determine breakeven distance when intermodal transportation by rail that gains an advantage against transportation done by trucks. The authors concluded that the attractiveness of intermodal transportation involving railroad rather depends on the rail freight rate than the cost of terminal handling and last mile deliveries.

A number of intermodal transportation studies focus on subjective components. For instance, [4, 5] consider the concept of open cooperation between drayage carriers involved in containers last mile deliveries from the inland terminal to the customer door. [6] proved that it is viable to reduce the number of drayage carriers from 20 to 1, followed by fleet size increase for the latter. Thus, this hypothesis can justify the necessity of centralization of railroad and trucking operations under the aegis of a single provider. However, the organizational set up of such an operator remains uncovered.

Several studies uncover the issues related to intermodal transportation infrastructure and process optimization. [7] considers the design of various rail-road network combinations in the context of the European Union intermodal infrastructure. Terminal operations hold the potential of significant enhancements dealt with the increase of reloading equipment utilization accompanied by the reduction of processing time of a single transport unit. At the same time, the market level of terminal handling charges is barely covering the prime cost of the operations, which vanishes the investment potential of equipment renovations and new technologies implementation. The authors outline the necessity of expert based micro-model implementation for terminal operations and last mile scheduling systems automation. The optimization model for terminal infrastructure design has been suggested in [8]. The authors point out that investments' reduction and terminal productivity increase directly depend on container dwell time available for processing. Dwell time might be significantly reduced as a result of correct placement of terminal cranes, reduced operational cycles, selection of correct processing sequences and number of rail-road lanes involved at the terminal. The aspect of door deliveries of the chain will require deeper analysis going forward.

Research in [9] gives recommendations for terminal space allocation and container storage arrangements in conjunction with terminal infrastructure elements operations. [10] studies the rail-cars allocation problem by modeling containers transshipment process optimization in a shunting yard. Several heuristic models are used for CPLEX modeling (Paris, France, 1998) in linear programming to determine the optimal shunting yard structure within the network, including hub-type. [11, 12] deal with the truck scheduling optimization problem pursuing all trucks enroute total operational cycle time minimization upon multiple container depots and large number of cargo senders and receivers in the network. The significance of this method rises towards a last mile distances increase along with its cost contribution growth into the entire intermodal transportation cost. The authors achieved high modeling and optimization results by determining the problem as an extension of the multiple traveling salesman problem with time windows (m-TSPTW). Those studies barely consider actual location, scale, and activity dynamics of the major inbound and outbound customers from the region.

[13] analyzes the handling problem of containers arriving by trucks to the inland terminal achieving lower reloading operations number and even cargo mass distribution within the block train. [14] considers the port access system that is restricted by the number of confirmed appointments for a particular dray carrier. The authors proved a significant correlation between drayage carrier productivity and even minor changes in the sequence of the port terminal entry. The results highlight that proper entry time selection and terminal turnaround time sufficiency are accountable for up to 8 % of service level increase and higher number of customers served by a dray carrier. The results of the study [15] evidence the reduction of the probability of container terminal entry lines as a consequence of efficient use of a centralized planning system by dray carriers. Also, the reduction of the operational cycles duration upon arranging trucker yards in the immediate proximity to the terminal. However, the issue of transportations effectiveness accountability remained uncovered.

A number of studies are dedicated to intermodal transportations management methods. For instance, the authors of [16] offered CPLEX modeling as a tool of daily container drayage cost minimization, routings design and distribution between trucks participating.

Research [17] developed block train loading optimization for the train length ranging from 416 meters to 652 meters when different size type and length rail cars being used taking realistic payload threshold of an intermodal unit into account. [18] deals with container repositioning for exports principles using gross profit maximization criterion. Research contains a number of approximations, namely: doesn't distinguish 20" and 40" container equipment, assumes that container equipment recourses and container terminal bandwidth are unlimited for 5 years to come. These assumptions make this research rather idealistic. This research results us fair to apply for inland moves exceeding 1,200–1,500 km distance and upon the balance between inbound and outbound cargo flows.

Regardless of substantial interest in intermodal transportations issues of research, some of their arrangements require deeper study. In particular, most recent studies haven't covered the holistic system of intermodal container deliveries using block train solutions upon inbound and outbound volumes imbalance. Finding a workable algorithm of operations set up involving all intermodal delivery chain participants accounting for intermodal infrastructure development constraints. Also systematic risks exposures of container equipment underutilization throughout import and export inland legs.

3. The aim and objectives of the study

The aim of the study is to elaborate approaches towards processes set up within the agile management system of intermodal transportations under the block train operator (BTO) umbrella for the emerging markets environment.

To achieve this goal, the following objectives have to be fulfilled:

– to complete inbound and outbound container transportations logistic system features involving ultimate cargo owners and determine preconditions of their switch to railroad deliveries using block train solutions;

– to determine target delivery parameters for inbound and outbound intermodal operations from transportation assets allocation, cost, responsiveness, intermodal service level and profitability perspectives;

– to elaborate an algorithm of operational system set up for the block train operator upon the relevant system of intermodal transportations technical backup.

4. Materials and methods of intermodal transportations management study

Statistics, analysis, synthesis, comparison methods are used for the purpose of the study along with linear programming Simplex LP (USA) modeling. Seaports operations volume data, emerging markets, logistics providers' data related to container transportations are used as initial data for this research. Research and approaches design towards intermodal transportation optimization in the paper rely on actual volumes, frequency and routings of containerized cargo.

5. Containerized cargo logistic services systems parameters research

There are two major problems that emerging states governments are trying to solve these days. The first is rapid wear of the domestic highway road surface caused by heavy loaded trucks, which causes multimillion spent for repair works annually. The second is environmental pollution with aged truck fleets that predominantly comply with EURO 2–EURO 4 pollution class. The most realistic way of solving these problems deals with the intermodal transportations development with inland portions covered by railroad transportation. From the international best practice, promising intermodal transportations, not multimodal, are used as a tool for cargo delivery to hinterlands from major ports. In turn, these transportations have to be economically and organizationally justified comparing to transportations by truck. From the cargo owner perspective, railroad based solution has to have a higher level of commercial attractiveness and prevent operational risks on the systematic basis. Heavyweight containers moved by road are an especially critical issue for most emerging states. Hence, for those, intermodal connection development is a nationally declared initiative. A number of countries are considering new legislation, related to subsidizing of multimodal terminal networks development supported by known tax exemptions for the enterprises that invest in infrastructure and necessary terminal equipment.

International practices of intermodal block train solutions involving seafreight containers are based on the following fundamentals:

– fixed departure and arrival schedules, voyages consistency;

– intermodal terminal transportation network located in close proximity to the importer and exporter that ensures a higher extent of inbound and outbound leg utilization;

– possibility of containers repositioning in case of surplus or shortage at one of the terminals within the network;

– decent turnaround time of container resources and equipment dwell time minimization at the terminals.

From railroad transportation perspective emerging markets are often characterized by inbound and outbound cargo flows imbalance in different regions and low level of container equipment re-distribution network between inland terminals. For instance, it is almost impossible to achieve inbound and outbound loadings matching when the central region of the country is accountable for 40–45 % of container imports.

One of the main operational constraints to further railroad based intermodal transportations development is considerably long container free time for offloading that is a drayage industry standard. This requirement is partially caused by the customer's own resources planning issues and possible internal conflicts in cargo handling prioritization. Eventually, a significant truck power is becoming immobilized and results in transportation assets return on investment (ROI) drop.

Extended container free time at the consignee also leads to a number of containers accumulation at the terminal with equipment turnaround time significantly exceeding one week. Upon these circumstances, the intermodal terminal is becoming flooded with abnormal volumes of container equipment that will cause its operations interruption.

Offloading free time standard for developed markets is 1–2 hours after the cargo is cleared at the customs and arrived to the final destination. In order to build effective block train operations within emerging markets cargo owners will have to achieve similar offloading times.

The key feature of emerging countries container transportations is a large number of stakeholders involved in the process: cargo sellers and buyers, steamship lines, rail-road companies, drayage carriers, inland intermodal terminals, container depots. In particular, a large number of steamship lines calling main sea gateways, operating with different volumes, various destinations and other specific container transportation parameters. Along with a number of transportations stakeholders' growth from steamship line and drayage carrier parties, the authors [1] outline the necessity of centralizing full set of inland operation under integrated stakeholder – Block Train Operator. This will allow to achieve required planning quality, transport resources, utilization and service level for cargo owners.

In this study, organizational and economic conditions of BTO operations are described. One of the key objectives of BTO activity is achieving the highest level of the revenue, lower delivery bottom line cost along with sufficient service level.

6. Block train operator organizational and economic activity parameters modeling

To simplify the statement of the problem and further research, we will set several pre-conditions required for service functioning:

– BTO is considered as a single company that centralizes rail and last mile drayage moves management;

– import customs clearance of goods is done at the port of arrival;

– overall inbound cost of rail haulage+last mile is restricted to 0.5 cost of pure trucking dray move to hinterland area that for heavy containers is set to USD 500/cntr for intermodal combined;

- according to rail-road technical requirements and expert's assessment block train capacity equals to 200 TEU (twenty-foot equivalent unit), 200 – 20" or 100 – 40" containers;
- system is closed to the following participants: inbound customers, outbound customers, block train operator;
- operations cycle is considered as 1 week accounting 1 vessel port call per week;
- number of allocated rail cars for weekly block train moves is limited;
- safety of the goods enroute is enhanced with additional GPS equipped security measures installed at the port;
- all chassis units at the destination inland terminal are tri-axle chassis allowing heavyweight container moves;
- based on modern international practices, the hinterland terminal has to have extended recourses of chassis trailer units to ensure truck heads utilization is a priority;
- all chassis units and truck heads are equipped with GPS loggers for smooth equipment matching and agile routes optimization. Meaning that the truck head returning to the rail depot can pick up de-vanned container on the way to optimize the cost;
- to optimize truck heads utilization within certain delivery zone containers might be dropped and picked up later the same day;
- all truck heads, chassis and containers have to return to the hinterland depo by the end of each day;
- no inbound containers conversion for export reversals in the inbound delivery region is considered;
- exporters located in different regions can accept containers loaded on railcars at their premises at any given working day;
- block train arrival is on the weekend. Cargo is derailed and available for collection by 6 a. m. Mon;
- hinterland rail terminal bandwidth for lift-on, lift-off and truck entering the terminal is available at any given time, with truck gate-in/gate-out turnaround time of 40 minutes;
- hinterland rail terminal operates 5 days a week, Mon-Fri, from 6am through 6 p. m.;
- with arrivals and last mile moves planning done in advance inbound customer can accept the entire weekly volume of containers within the week of arrival;
- all decisions on assets allocations, dray and rail moves management are done centrally based on max revenue achievement;
- in conjunction with the rail freight rates card, there is a cost of repositioning of the emptied inbound container to the exporter. Hence providing of empty equipment to the exporter is justified when this distance is shorter than the distance from the seaport to the exporter. The feasible distance can be considered as 300 km.

Being revenue oriented, BTO has to consider its dependency on the large scale of factors. Interaction with state-owned railroad and inland intermodal terminal at the destination and other stakeholders. Calculating the adjusted revenue of the BTO is based on rates accepted under study constraints. Weekly revenue maximization is resulted by combining loaded inbound container moves, the most efficient layout of intermodal terminal operations, the necessary number of last mile deliveries to an appropriate delivery zone. At the same time, the minimum quantity of truck heads and chassis units has to be utilized.

$$
\begin{aligned}
AdjRevenue_{\max} &= \sum_{PD} Q_{PD20}\cdot C_{PD20} + \sum_{PD} Q_{PD40}\cdot C_{PD40} + \\
&+\sum_{D}\sum_{K}\sum_{Z=1}^{7} \begin{array}{l} \partial_z \cdot Q_{DKZ}\cdot\left(L_{on}+D_{DKX}+L_{off}+CR/M_{DK}\right)- \\ -PE_{DP}\cdot\sum\limits_{DP} QE_{DP} \end{array} - \\
&-\sum_{n}\sum_{p} \begin{array}{l} \left(QT_n-QT_p\right)\cdot(A+S)- \\ -\sum\limits_{p}\left(QCH_{\max}-QCH_{\mathrm{m}}\right)\cdot CR+\sum\limits_{D}\sum\limits_{E} Q_{DE}\cdot C_{DE} \end{array}, \qquad (1)
\end{aligned}
$$

where Q_{PD} – quantity of full inbound containers transported per week from sea port to inland terminal, 20" and 40", that are being transported from sea port to hinterland by rail-road, C_{PD} – cost of rail transportation of 1 full container from port to hinterland, ∂_z – 1, if there is demand for containers in zone Z, otherwise 0, Q_{DKZ} – quantity of full containers moved from depo D to customer K located in a specific delivery zone, L_{on} – lift on cost at the inland terminal, D_{DKZ} – drayage roundtrip cost to customer K based on the delivery zone with empty return to hinterland terminal, L_{off} – lift off cost at the terminal, CR/M_{DK} – chassis rental fee to number of trips within the zone ratio, PE_{DP} – penalty for containers returned empty to sea port, QE_{DP} – quantity of empty containers returned from hinterland to port, Q_{DE} – quantity of containers provided for outbound loading and further delivery to port by rail, C_{DE} – total cost of reversal container transportation from the depo to exporter and from exporter to port, QTn – q-ty of truck heads allocated at the inland terminal, QTp – q-ty of truck heads being in use on day p, A – daily administration and maintenance cost per truck head, S – daily truck head driver salary, QCHmax – max q-ty of chassis units required to cover daily necessity for the moves, $QCHm$ – q-ty of chassis units in use on day p.

Function constraints:

$$QE_{DP} \le Q_{PD40},\ \ \forall Q_{PD40},\ \ QE_{DP}\in N,$$

$$Q_{DE} \le Q_{PD20},\ \ \forall Q_{PD20},\ \ Q_{DE}\in N,$$

$$Q_{DKZ} \le Q_{PD20}+Q_{PD40},\ \ \forall Q_{PD20}, Q_{PD40},\ \ Q_{DKZ}\in N.$$

7. Block train operator operation processes set up

These days 3 major ports are operating in the country. Their 2019 annual stats according to [20] are represented in Table 1. Based on 2019 operational results, container terminals in Odesa Port are accountable for 60 % market share. This paper relies on "HPC-Ukraine" (Hamburg Port Consulting GmbH) terminal stats.

Container terminal "HPC-Ukraine" handles cargo flows brought by 11 steamship lines. Their monthly average portfolio of import and export operations along with steamship lines name codes are shown in Fig. 1.

According to the data displayed, each of the steamship lines operates with the different ratio of inbound and outbound containers of both types. Six steamship lines can be classified as relatively balanced, they are: MSC, HLC, ONE, OOCL, ZIM, ACOL, remaining five operating with substantial imbalance. This evidences the necessity of using floating weekly allocations for each of the steamship lines in order to achieve the highest financial yields from block train operations.

Table 1

2019 annual results of container seaports operating in Ukraine

Indicator		Cargo volume			Market share, %		
		Odesa	Pivdenniy	Chornomorsk Fish	Odesa	Pivdenniy	Chornomorsk Fish
Imports	Container tonnage, Mio tons	3.49	1.17	0.647	66	22	12
	Total containers q-ty	195,490	73,136	41,273	63	24	13
	20”	69,199	36,510	21,402	54	29	17
	40”	126,291	36,626	19,871	69	20	11
Exports	Container tonnage. Mio tons	4.01	1.72	1.13	58	25	16
	Total containers q-ty	181,967	67,688	50,735	61	23	17
	20”	64,380	37,527	23,460	51	30	19
	40”	117,587	30,161	27,275	67	17	16

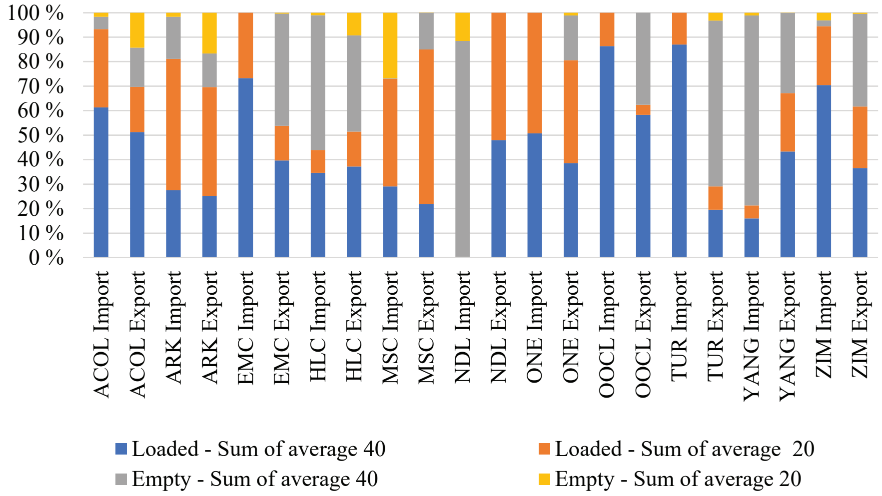

Fig. 1. Distribution of weekly average volumes handled by “HPC-Ukraine” terminal

In order to determine the prime strategy of BTO operations, container volume distribution of “HPC-Ukraine” has to be considered from gross mass and inland transport mode that is being used for on-carriage to Kyiv region at present. Those are shown in Table 2.

Table 2

Inbound container volume distribution for on-carriage done railroad and truck in conjunction with their gross mass

Mode share, %	Mode	Container type	Lading weight range, tons	Containers q-ty, 6 months	Average lading GW per container, kgs
4	RAIL	20	20–24	436	24.704
	RAIL	20	below 20	11	19.224
	RAIL	20	over 24	205	29.090
<1	RAIL	40	20–24	10	26.635
	RAIL	40	below 20	7	10.101
	RAIL	40	over 24	4	30.350
27	TRUCK	20	20–24	2,044	25.002
	TRUCK	20	below 20	1,835	14.831
	TRUCK	20	over 24	404	28.893
68	TRUCK	40	20–24	1,825	26.215
	TRUCK	40	below 20	7,010	14.123
	TRUCK	40	over 24	1,852	29.327

Table 2 shows that 20” containers moved by truck with gross mass under 20 ton are accountable for 57 % of the volume, 40” are accountable for 34 %, or averaged weekly volume 94 and 142 containers of each type, respectively. It is also important to take the existing volume of 25×20” containers moved by rail and add those to requiring block train allocation.

BTO has to account several constraints when operating with the entire pool of containers weekly. In particular, the risk of late vessel arrival to the port and the risk of the asymmetrical distribution of arrived containers at the terminal. Implementation success for the suggested logistics solution directly depends on a shrewd combination of containers with the gross mass exceeding 20 ton and non-heavy containers.

Based on data collected, imports and exports container volumes regional distribution according to the inland mode of move by truck or rail are shown in Fig. 2 and Fig. 3.

From Fig. 2, 3 it is easy to see that approximately 40–45 % of inbound customers are located in Kyiv and Kyiv region.

With the assumptions made concerning the upper intermodal transportation cost limit, it is viable to divide the entire inbound delivery region into zones. Also, the last mile delivery rates card has to be based on the number of door delivery cycles that one truck head can accomplish within one day and not the distance of actual voyage.

Designing the last mile delivery business model, it is wise to consider similar to the US drayage operations model that has been described in [1, 4, 5]. Each day of operations has to be planned upfront, taking actual container offloading times at the customer into account. Each container along with the chassis unit is being locked at the customer warehouse gate upon arrival. The truck head unit gets disconnected from the chassis unit and leaves to pick up the next inbound container for delivery. All forthcoming containers are being delivered either to the same customer or within the same delivery zone. The majority of the cargo are floor loaded, which requires extended free time for their discharge, BTO provides 2 hours free for offloading operations to be complete by the customer. Research of Kyiv region based inbound customers and actual road traffic according to [21] showed that the entire delivery area can be divided into 7 delivery zones (Z) as shown in Fig. 4. It is important to mention that the model contains customers with annual volumes exceeding 500 ton a year according to 2019 data.

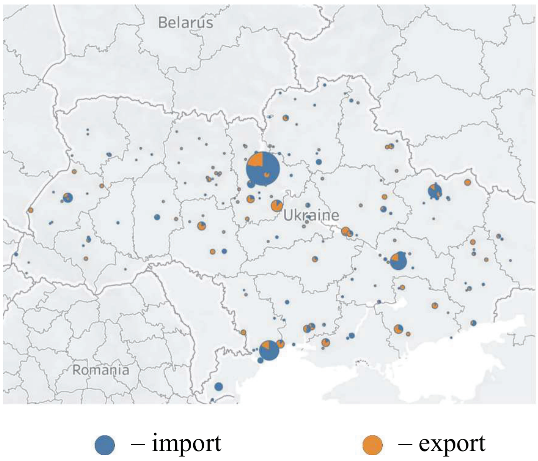

Fig. 2. Import and export containers moved by truck regional distribution

Inbound customers *q*-ty per zone, average weekly volumes of 20” and 40” containers are represented in Table 3.

The entire Kyiv and Kyiv region potential exceeds container quantity numbers sufficient to secure a high extent of block train utilization. Consequently, Kyiv intermodal terminal bandwidth and acceptable block train length according to rail-road technical regulations are becoming constraints.

2019 exporters operations stats showed that there are 7 outbound customers that operate with consistent weekly volumes. These companies can provide up to 206 containers per week in total. All these customers operate with 20” containers. Commodities shipped are raw sunflower oil, grains, flour, ore.

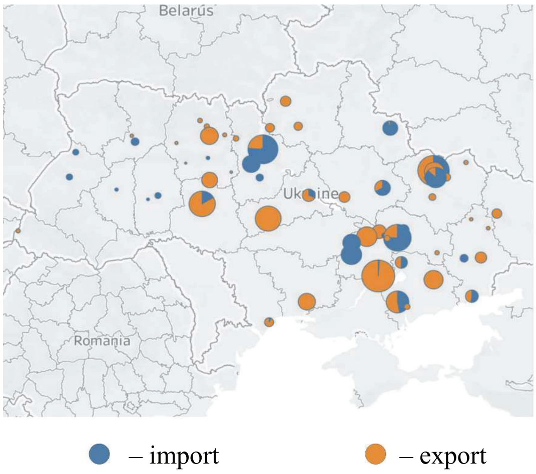

Fig. 3. Import and export containers moved by rail regional distribution

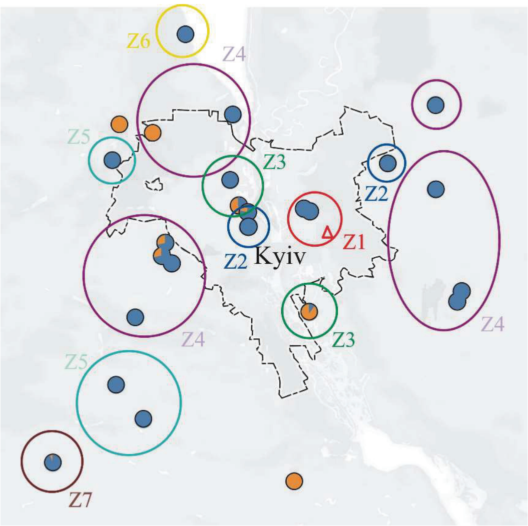

Fig. 4. Inbound container delivery zones for Kyiv and Kyiv region with the number of daily delivery cycles

Table 3

Main inbound customer analysis in Kyiv and Kyiv region divided by zones

Zone	Distance from the terminal, km	Number of import customers	Average *q*-ty of containers per week, total	Demand *Q*-ty of 20” per week	Demand *Q*-ty of 40” per week	Number of deliveries per day, MAX	Chassis allocation, units
Z1	0–5	6	32	0	32	4	2
Z2	5–10	206	858	215	644	3	2
Z3	10–15	24	94	24	71	2	1
Z4	15–30	28	158	40	119	2	1
Z5	30–40	6	43	11	32	1	1
Z6	40–50	3	11	3	8	1	1
Z7	50–100	23	137	34	103	1	1
Total	–	296	–	325	1,008	–	–

Since BTO has fixed limited number of rail cars in operation, the target conversion rate for inbound rail cars into outbound is set to 50 %. After inbound containers arrival and de-railing, 50 % of idle rail-cars will remain at the inland terminal premises pending necessary quantity of 20” containers emptied from imports. Obviously, BTO will be seeking for prompt dispatch of emptied container portions for exports in order to minimize rail cars detention [13, 14]. This creates 2 additional constraints:

1. BTO has to ensure the necessary quota of 20” import containers emptied daily with their following repositioning and logistic solution enhancement in general.

2. Deliveries to Zone 2 located customers have to be prioritized for 20” containers. Zone 1 doesn’t contain any of 20” container importers. As a planning process target BTO has to achieve 100 loaded inbound container deliveries within first 2 business days of weekly operations.

All deliveries will be accomplished in a drop-pull manner according to the following timings:

– rail terminal entrance and lift-on – 40 min;

– container drop at the customer warehouse gate – 40 min;

– empty container lift-off at the terminal – 40 min.

Using Simplex LP (USA), linear programming solving method [16] is done upon the following constants and service level requirements:

– C_{PD20}=USD 300;

– C_{PD40}=USD 400;

– PE_{DP}=USD 150 and is applicable to each 40” inbound container;

– C_{DE}=USD 300 and is applicable to each 20” inbound container that is delivered and discharged within the weekly time frame;

– 60% of the rail cars will be utilized under 20’, 40 % of the rail cars under 40”;

– max quantity of 20” Q_{PD20} have to be delivered within the first 2 weekdays to maximize rail cars with empty 20” to outbound customers on Day 1 and Day 2 of operations. Meaning that 100 % of Zone 2 inbound deliveries will have to be complete.

– For the purpose of the study and in partial conjunction with actual weekly volume allocations will set the following volume distribution per delivery zone:

– 20”: Z1 – 0, Z2 – 66 %, Z3 – 10 %, Z4 – 5 %, Z5 – 5 %, Z5 - 4 %, Z6 – 4 %, Z7 – 10 %;

– 40”: Z1 – 50 %, Z2 – 30 %, Z3 – 10 %, Z4 – 3 %, Z5 – 3 %, Z6 – 0, Z7 – 4 %;

– as a minimum service level for each zone where allocation is greater than 0, we will set up a minimum delivered *q*-ty as 50 % of the volume assigned to a delivery zone, but not less than 1 container;

– to ensure the earliest 20” equipment discharge and availability for exports, minimum service level for Z2 has been set to 66 % of the entire 20” weekly inbound volume to be delivered to customers on Day 1 and Day 2. Also, this minimizes rail cars related demurrage that might be charged by the rain-road for keeping them at Kyiv depo;

– chassis (container platform) rental fee is set to USD 20/day. Due to the number of haulages a day for Z1 and Z2 being greater than 2, allocation of 2 chassis units per truck head was made;

– due to spike in volumes, the block train operator will have to overcome in Day 1 and Day 2 of operation, we foresee that not all truck heads might be utilized Day 3 through Day 5 of inbound operations. Daily penalty of non-using the truck head is set to USD 144, this includes truck driver daily wage, maintenance and admin fees USD 80/truck head per business day;

– Adjusted Revenue parameter will have to be introduced for the sake of the modeling results analysis, Adjusted Revenue=Revenue – Drayage power underutilization penalty.

In order to determine the maximum value of Block Train Operator weekly revenue 9 operational scenarios of base approach modeling will be performed using Simplex LP (USA), linear programming solving method. Modeling will be done relying on the hypothesis that 100 % of delivered and emptied 20” containers will be converted to exports.

Operational scenarios of base approach modeling results are shown in Table 4.

Table 4

Operational scenarios of base approach modeling results

Indicator	Scenario								
	1	2	3	4	5	6	7	8	9
Rail cars total	120	120	120	100	100	90	85	80	80
Truck heads *q*-ty	30	25	20	20	15	15	15	15	10
Containers target, 20”	144	144	144	120	120	108	102	96	96
Containers served, 20”	137	137	135	116	106	98	95	84	57
Containers target, 40”	48	48	48	40	40	36	34	32	32
Containers served, 40”	48	48	42	40	36	35	33	32	20
Drayage power underutilization penalty, USD	10,452	6,852	3,712	4,576	2,796	3,288	2,592	3,396	2,064
Total revenue, USD	120,924	120,924	116,964	102,232	93,012	86,486	83,646	74,816	50,480
Total chassis, units	40	40	36	34	28	28	26	24	20
Adjusted revenue, USD	110,472	114,072	113,252	97,656	90,216	83,198	81,054	71,420	48,416
k, chassis/truck heads	1.33	1.60	1.80	1.70	1.87	1.87	1.73	1.60	2.00
Satisfaction score 20”	0.95	0.95	0.94	0.97	0.88	0.91	0.93	0.88	0.59
Satisfaction score 40”	1.00	1.00	0.88	1.00	0.90	0.97	0.97	1.00	0.63
c, truck heads to rail cars	0.25	0.2083	0.1667	0.2	0.15	0.1667	0.1765	0.1875	0.125

Easy to see that BTO achieves the highest financial adjusted revenue results upon scenario #3 realization, however, the highest service level is achieved upon scenario #2. Two alternate sets of scenarios will also have to be studied. The major change is the reduction of daily delivery cycles for Zone 1–Zone 4 located customers by (1). Also, chassis unit allocation will be reduced accordingly. The results of the first alternate set of scenarios modeling are shown in Table 5 and visualized in Fig. 6.

With the truck heads quantity remaining unchanged BTO will be achieving significantly lower weekly revenue. Upon scenario #2, the weekly revenue is reduced by 7 %. Also, satisfaction score drops for both types of containers, hence the number of containers available for exports will also decline.

The results of the second alternate set of scenarios modeling are shown in Table 6 and visualized in Fig. 7.

Upon further reduction of daily door delivery cycles for customers from Zone 1 and Zone 2 and truck heads allocation unchanged, the model becomes unstable. In order to perform modeling and fulfill deliveries quota for the week, significant truck heads allocation increase is required.

Table 5

Modeling of the first alternate set of scenarios (upon daily delivery cycles number reduction by 1)

Indicator	Scenario								
	1	2	3	4	5	6	7	8	9
Rail cars total	120	120	120	100	100	90	85	80	80
Truck heads *q*-ty	30	25	20	20	15	15	15	15	10
Containers target, 20”	144	144	144	120	120	108	102	96	96
Containers served, 20”	139	126	106	100	80	82	82	83	61
Containers target, 40”	48	48	48	40	40	36	34	32	32
Containers served, 40”	42	42	42	36	36	33	31	30	20
Drayage power underutilization penalty, USD	6,572	4,072	2,464	2,992	1,240	2,076	2,076	2,220	1,696
Total revenue, USD	120,192	110,076	95,916	88,596	74,436	73,902	73,186	73,056	53,648
Total chassis, units	54	48	38	38	28	30	30	30	20
Adjusted revenue, USD	113,620	106,004	93,452	85,604	73,196	71,826	71,110	70,836	51,952
k, chassis/truck heads	1.80	1.92	1.90	1.90	1.87	2.00	2.00	2.00	2.00
Satisfaction score 20”	0.97	0.88	0.74	0.83	0.67	0.76	0.80	0.86	0.64
Satisfaction score 40”	0.88	0.88	0.88	0.90	0.90	0.92	0.91	0.94	0.63
c, truck heads to rail cars	0.25	0.2083	0.1667	0.2	0.15	0.1667	0.1765	0.1875	0.125

Table 6

Modeling of the second alternate set of scenarios (upon daily delivery cycles number reduction by 2)

Indicator	Scenario				
	1	2	3	4	5
Rail cars total	120	100	100	100	100
Truck heads q-ty	30	30	40	50	25
Containers target, 20”	144	120	120	120	120
Containers served, 20”	92	86	106	119	76
Containers target, 40”	48	40	40	40	40
Containers served, 40”	42	36	36	40	36
Drayage power underutilization penalty, USD	4,712	6,800	12,320	18,212	4,060
Total revenue, USD	86,832	79,644	93,804	104,524	72,192
Total chassis, units	54	54	74	92	45
Adjusted revenue, USD	82,120	72,844	81,484	86,312	68,132
k, chassis/truck heads	1.80	1.80	1.85	1.84	1.80
Satisfaction score 20”	0.64	0.72	0.88	0.99	0.63
Satisfaction score 40”	0.88	0.90	0.90	1.00	0.90
c, truck heads to rail cars	0.25	0.3	0.4	0.5	0.25

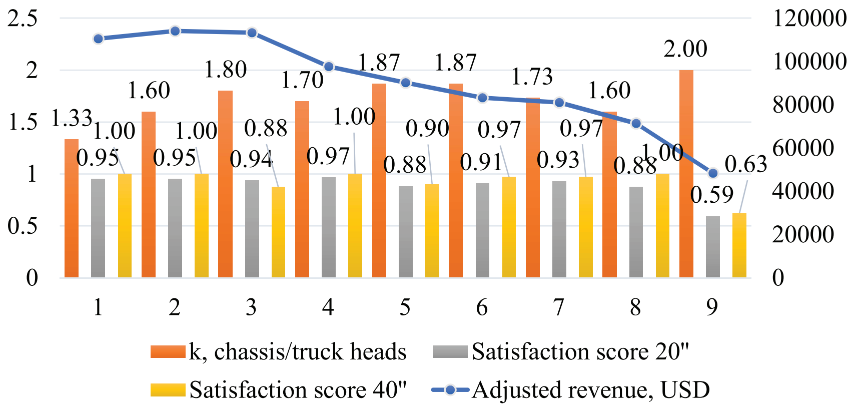

Fig. 5. Results of main service satisfaction indicators calculation

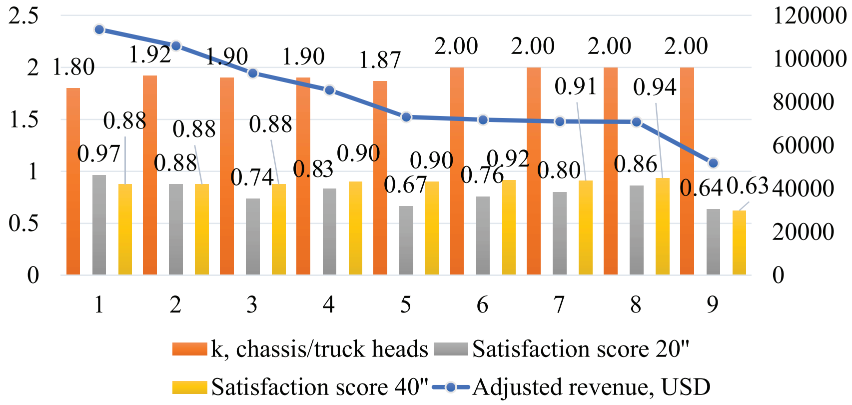

Fig. 6. Results of the first alternate set of scenarios (upon daily delivery cycles number reduction by 1)

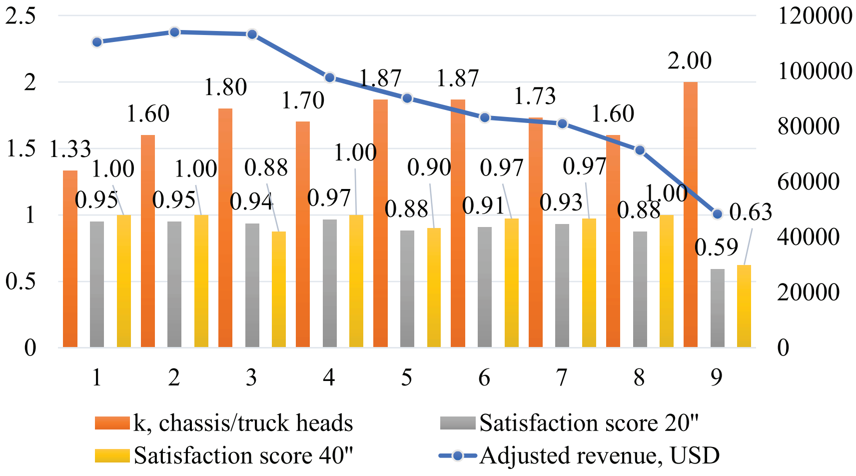

Fig. 7. Results of the second alternate set of scenarios (upon daily delivery cycles number reduction by 2)

8. BTO operations modeling results discussion

The designed model of operational processes optimization for the block train container deliveries management system is versatile within the emerging markets environment. The proposed model is focused on BTO revenue maximization considering primary realities of inland logistics processes. It gives a holistic concept and specific actionable items.

The results of the study upon the base approach and main scenario are shown in Table 4 and Fig. 5. The highest weekly adjusted revenue generated by BTO is achieved when 120 rail cars are used to form the block train and 25 truck heads to accomplish door deliveries at the inland terminal. Also, this assets allocation layout secures the highest door deliveries satisfaction score, which equals to 0.95 and 1.00 for 20” and 40” containers.

An important metric of the study is the Drayage power underutilization penalty that reflects BTO systematic risks exposure upon weekly volume drop. Local optimum is achieved when 100 rail cars and 15 truck heads are utilized.

Alternate sets of scenarios modeling results that are shown in Tables 5, 6, emphasize a significant weekly adjusted revenue drop upon daily door delivery cycles reduction. With transport assets allocations remain unchanged door deliveries satisfaction score does not exceed 0.9 for both container types.

The proposed intermodal operations set up has several constraints that exist in practice. Import customs clearance of goods has to be complete at the port of arrival. Customers that are not capable to fulfill this requirement can barely benefit from block train advantages. Container portions consolidation at the port will require several business days. Hence customers will be losing the opportunity to use the port terminal for long-lasting cargo storage, which can affect actual block train utilization. The block train will have to be operated with a fixed number of rail cars from the pool, and minor possibilities of additional rail cars involvement.

The described logistics solution is based on constant drayage power availability at the inland terminal, ready for intensive operations. The designed set up is also highly dependent on the operational efficiency of the containers discharge process and customer planning level. Eventually, this leads BTO to have a selective approach when choosing customers and cargo traffics, which might affect high % of heavyweight containers coverage.

Further research perspectives are related to cargo safety enhancement in transit on the railroad. In particular, GPS container and chassis tracing technologies implementation feasibility study. Clean real-time data collection and interpretation will allow deeper processes optimization. Especially higher yields might be expected from real-time empty containers recovery after offloading at the customer coordination.

9. Conclusions

1. Key features of container deliveries from seaports that characterize the emerging market environment are: cargo flows imbalance and on-carriage of goods by truck. In order to decrease highways loading, reduce annual road surface repair works and offer more beneficial inland delivery options, block train deliveries gain more sense. Block train solution has to be consistent and operate towards frequent reliable schedule accompanied by accurate planning and logistics processes operational efficiency. A large number of steamship lines, cargo owners and freight forwarders involved in the transportation process is the key factor of the entire process centralization under Block Train Operator as an institution.

2. The main objectives of BTO integration are high revenue and decent service level achievement. These objectives can be fulfilled through systematic operational risk mitigation the truck detention reduction and transport assets utilization maximization. Cost attractiveness of container deliveries using the block train can be achieved upon its relative cost of 50 % against similar delivery cost done by truck.

The proposed solution has to take a systematic exporter interest into account that can foster outbound containers utilization regularly.

3. The main suggestions also deal with actual weekly container volumes allocation that come from each of the steamship lines. They include volume information supply at the time of vessel departure from origin, drop/pull mode container deliveries with systematic offloading time reduction, export operations weekly planning. The highest adjusted revenue numbers are achieved upon 120 rail cars and 25 truck heads at the terminal layout.

A significant weekly adjusted revenue drop might be caused by daily door deliveries number reduction.

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