

Multimodal Transport of Humanitarian Relief Cargo from Western Europe to Ukraine: From Costing Modelling to Risk Modelling

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Abstract—This paper considers the operational aspects of humanitarian response to the Ukraine war which resulted in the mass displacement of several million people both internally and externally, and large-scale disruption the movement of goods along their traditional routes. An established model regularly used for mapping supply chain operations with an emphasis on cost, distance, time and modal choice in the first instance. This paper then suggests, following the same operations management approach, a risk-based analysis such that routes, transport methods, times and distances are used as a starting-point for evaluating reliability of freight transport by less orthodox modal combinations in volatile environments. The pioneering work of Banomyong and Beresford [1] was probably the first attempt to build the concept of risk into multimodal transport chains by means of employing a ‘confidence index’, but the study considered only stable commercial environments.

Design Approach: This paper is a desk-study, based on an interpretation of a real-time crisis which is ongoing. The invasion of eastern Ukraine precipitated the mass evacuation of populations over wide areas and the use of emergency transport solutions for both freight and human transport. Information has been obtained from secondary sources, primarily media coverage, and this is combined with factual data (e.g., distances) acquired from published sources. Sources include a complex mix of agencies, UN, UK government supported programmes and non-governmental, independent private suppliers of aid.

Findings: The extreme conditions prevailing in much of the Ukraine have necessitated the use of transport combinations which go as close as possible to ensuring the maximum rate of delivery is achieved. However, risks are substantial and intermittent which implies that at least two, and preferably more routes and modal combinations are employed. Risks are sufficiently high to suggest that an established cost-based model, widely used by academics, practitioners and UN agencies, could be redesigned in order to inform both observers and operators very positively.

Originality: This paper breaks new ground from, for example, the work of Banomyong and Beresford [1] and Choi et al [2]. It applies an established model to an unstable environment which implies that the model’s value could be high, as it informs practitioners of alternatives which maintain commercial robustness, but which carry the flexibility required adapt to extreme and unstable conditions.

Keywords—Humanitarian Logistics, Ukraine, Risk Modelling, Case Study

I. INTRODUCTION: INSTABILITY AND FRAGILITY

Following the invasion of the Donbas region of Ukraine in February 2022 by Russian military forces, the country became

involved in a defensive war to protect its territory. It is estimated that from the start of the invasion seven million Ukrainians have been either internally displaced, while five million have sought refuge in other countries, and more than ten thousand have been killed [3] [4]. The scale and intensity of the crisis is unmatched during the post-World War Two years.

Ukraine is now almost landlocked and if Russia were to annexe the Ukrainian Black Sea coast in its entirety, Kyiv would be at least 900 kilometres from seaports which are open and reliable such as Gdansk (Poland) or Constanta (Romania)[5]. Even at the stage of the crisis in July 2022 Ukraine was effectively landlocked due to Russia’s blockade of its ports. Ukraine’s isolation from most of its world markets affects its exports, imports, and economy. Not only is there the transport challenge itself but additional security challenges [6], created by the need to rely on passage through fragile regions and on newly established road-rail links which are themselves vulnerable to attack by Russian forces [7].

II. UKRAINE TRADE AND TRANSPORT

The economy of Ukraine relies heavily on exports of grain, and imports for its industrial needs (Table 1). The political history of Ukraine has had a major influence on both the orientation of its trades (largely to/from the Russian Federation) and on the structure of its transport network which is rail-dominated. International transport systems mainly use multimodal transport (truck – rail or truck - waterway) because of the advantages of achieving operational efficiency and cost-effective delivery of freight in the supply chain through integrated, combined transport modes [8][9]. Thus, the transport industry plays an important role in Ukraine’s successful ‘post-perestroika’ economic development.

TABLE 1. TRADING PARTNERS OF UKRAINE, 2021

Ukraine Exports to:	Value	Ukraine Exports to:	Value
China	\$7.99B	Egypt	\$1.91B
Poland	\$4.98B	Spain	\$1.64B
Turkey	\$4.00B	Hungary	\$1.58B
Russia	\$3.35B	United States	\$1.55B
Italy	\$3.24B	Romania	\$1.50B
Germany	\$2.79B	Belarus	\$1.46B
India	\$2.51B	Czech Republic	\$1.38B
Netherlands	\$2.13B	United Kingdom	\$1.05B

Rail is the basis of Ukraine's transport system and there is no real alternative for the transport of bulk cargo such as coal, ore, metals, and grains. Its reliable functioning is a prerequisite for sustainable economic development to create optimal routes meeting the needs of industry and increasing the transit potential of the country.

While the transport infrastructure of Ukraine is evolving, transport systems viewed from logistics and supply chain management perspectives are brought into sharp relief by the country's heavy reliance on its Black Sea and Sea of Azov ports, notably Odessa, Mykolaiv and Chornomorsk [5]. Other Ukrainian ports such as Sevastopol in the Russian annexed Crimean region are currently closed to Ukrainian vessels. The three-month battle for control of the steelworks in the port of Mariupol during the spring of 2022 exemplifies both the importance of the country's Black Sea access and its vulnerability to aggressive action in a relatively limited maritime area. The blockade of Odessa's port, starving Ukraine of its primary multimodal grain outlet, the principal source of the country's foreign exchange, further emphasises the weakness of its southern border. Reducing Ukraine's international access options still further is the customs and military union between Belarus and Russia established in 2010 [10]. It became clear with the military build-up of troops and equipment in early 2022 that Russia and Belarus were clearly aligned in their desire to facilitate attacks on northern as well as eastern Ukraine.

Northern supply routes into / out of Ukraine are therefore limited to road or rail to/from Poland. The main maritime and land routes to Ukraine (Kyiv) are suggested in Figure 1. Alternative routes 1, 2 and 4 are presented as different line styles with short sea-land (Route 1) in solid type, shortest land distance (Route 2) in large dash and sea with transshipment at Istanbul (Route 4) in dotted type. Route 3 is a variation on routes 1 and 2 and not therefore shown.



Fig. 1. Suggested routes into Ukraine.

Of countries reporting data in 2018, Ukraine was one of the countries with the largest ratio of rail tonne-kilometres per unit of gross domestic product (GDP) reflecting the importance of freight transport by rail to economic activity [11]. This unusual modal split, heavily biased towards rail, points towards the historical origin of the Ukraine as a part of

the Soviet Union whose function was largely to provide the main soviet markets with food crops. It also points towards the nature of the cargo, which is itself unusually biased towards dry bulks and especially grain, and the distances over which the cargoes are transported [12].

III. HUMANITARIAN SUPPLY CHAIN MANAGEMENT AND RISK

There is a growing literature focused on risk in commercial environments [6][13] and a separate literature on risk evaluation in a humanitarian context [2][14][15], but the two areas have rarely, if ever, been considered together in an adaptive model. This paper is presented as a work-in-progress study of emergency freight transport during the second phase of the Russian invasion of eastern Ukraine. During this period Russia refocused its major military effort on the Donbas and Luhansk regions, having suffered significant military setbacks in central Ukraine around Kyiv [16]. The research adopts an operations management approach following the methodology first published by Beresford [17] and Banomyong and Beresford [1] and adopted by UNESCAP during the early 2000s [18]. The methodology was first applied to transport in volatile conditions in East Africa by Choi et al [2] and by Beresford and Pettit [19] to post-disaster conditions in examining response structures immediately following the May 2008 Wenchuan earthquake.

Here, we seek to demonstrate how traditional key performance indicators (e.g., cost, time, wastage, resource utilisation) are often re-ordered in terms of relative importance at times of crisis. This paper also seeks to highlight that the established or widely accepted operational facts underpinning the effectiveness of the respective modes often cease to apply in volatile, crisis or emergency situations. By its nature, this research relies upon some information which is either sensitive or confidential; the authors have therefore omitted some detail to protect the anonymity of individuals, organisations or companies which cooperated in providing information or insights for the compilation of this paper. However, from a range of sources including the Confederation of British Industry, Polish Government Strategic Reserves Agency; Oakland International (food distribution); Ukrainian Agricultural Council; Mail Force Ukraine Refugee Appeal; and the Daily Mail and General Trust, a synthesis of factual information has been compiled by combining the information from those sources with factual data collated from Lloyd's Maritime Atlas [20] and Abdugaliyev [21].

Table 2 presents a collated range of transport solutions, including a future possible solution for the movement of aid cargo from the UK (Central England) to Ukraine (Kyiv), taking account of operation and practical constraints, reliability, distance and time. The table is completed by a summary column which lists risk or threat for respective transport segments where relevant. Three routing alternatives are tabulated and the table concludes with a speculative solution routing goods via by sea via transshipment hub at Istanbul.

TABLE II. UK – UKRAINE MULTIMODAL TRANSPORT SOLUTIONS FOR AID CARGO

<i>Routes</i>		<i>Distance</i>	<i>Time</i>	<i>Risk</i>
Route 1				
Leg	Mode	Km	Nm	Hours
Leicester – Felixstowe	Rail	217		7
				Road – Rail Delay
Felixstowe – Rotterdam	Sea		150	10
				Port Shipping Delay
Rotterdam - Gdansk	Sea		1058	100
				Maritime Delay
Gdansk – Kyiv	Road	1190		24
				Military Attack (In Ukraine)
Route 2				
Leicester – Dover	Road	292		5
				Road delay
Dover - Zeebrugge	Sea (Ro-Ro)		70	5
				Port Shipping Delay
Zeebrugge – Wrocław	Road	1103		50
				Road delay
Wrocław - Kyiv	Rail	1184		80
	Road	1158		24
				Military Attack (In Ukraine)
	Rail	1216		85
Route 3				
Leicester – Felixstowe	Road	220		5
				Road delay
Felixstowe - Hamburg	Sea		410	20
				Port Shipping Delay
Hamburg - Kyiv	Road	1629		60
				Road delay
	Rail	1442		100
				Military Attack (In Ukraine)
Route 4 (Hypothetical)				
Leicester – Felixstowe	Road	220		5
				Road delay
Felixstowe – Rotterdam	Sea		150	10
				Port Shipping Delay
Rotterdam – Istanbul	Sea		3542	240
				Port Shipping Delay
Istanbul - Odessa	Sea		310	20
				Mines, Marine and Airborne attack

IV. SUMMARY AND CONCLUSIONS

This study highlights alternative multimodal routes from the UK to Kyiv using data from Lloyd’s Maritime Atlas and Commercial sources as an initial framework. Various combinations of sea, rail, and road transport were presented. First, where the sea leg is from Felixstowe to Rotterdam, then to the port of Gdansk or from Felixstowe to Hamburg and then onwards by road. Using the port of Dover, there is a similar combination of sea, rail, and road but the sea leg is minimised; An additional postulated route using sea from Felixstowe to Istanbul where transshipment takes place prior to short-sea transport to Odessa. Inland transport from Odessa by road (or rail) then would complete the aid cargo delivery.

This research suggests a potential future direction for developing an established and widely used cost model into a ‘risk model’ suited to emergency and crisis logistics conditions [22][23] such as those in evidence following Russia’s invasion of Ukraine in February 2022. More generally, reforming the original cost-oriented model into a risk-focused formulation, capturing abnormal logistics conditions experienced during natural disasters or war

conditions would widen the model’s reach and increase its value.

All of the alternative routes presented use the combination of sea, rail, and road transport, instead of the current all road solution for transport of mining equipment from Hamburg to Aktogay and all alternatives could achieve cost savings even the most complicated and longest option through Istanbul. Table 7 compares all alternative routes presented in the study and shows average costs per kilometre for each route. When comparing the average costs per kilometre on these routes, sea is the cheapest, rail is intermediate, and road is the most expensive as expected.

Overall, cost savings on one route against another are far less important than risk minimising and success maximising.

As Al Hashimi et al. [24] state, the multimodal solution could be a complex mix of different criteria such as cost effectiveness, time efficiency and reliability of the system. This study has demonstrated that in the case of war conditions, loss of lower value cargo (e.g. tents, rice, building equipment) may be acceptable, but loss of vehicles, ammunition and trained personnel is not.

Following the brokering of a deal involving Ukraine, Russia, Turkey and the UN for the safe passage of grain exports via a maritime route (albeit mined) into / out of Ukraine via Odessa with transshipment at Istanbul would seem to be feasible in the future if safety and security conditions are deemed acceptable. This, in turn, suggests that a ‘sea-maximising’, ‘risk-minimising’ model should be pursued rather than a purely mode focused ‘land-multimodal’ solution, which would be medium to high risk.

This paper, therefore, offers a clearer understanding of the potential need to take a mixed-modelling approach in a humanitarian context, such that both modal choice and risk and uncertainty are taken into account; this mixed approach is potentially extremely important in volatile conditions created by ‘special military operations’, more commonly perceived as war fighting or invasion. From the point of view of academic research the field of risk management appears to offer a number of opportunities for applying well documented concepts taken from stable commercial environments and applied to unstable humanitarian and emergency relief fields. The early work of Banomyong and Beresford [1] was the basis for more sophisticated studies carried out more recently [6]. One of few case-based studies in an emergency context was compiled by Choi et al [2]. That study did however lack analytical content, in particular it did not attempt to model the inputs or outputs which could have provided a deeper understanding of the relationships between fundamental logistics requirements (transport, storage, documentation, cross-border protocols etc.) with the crisis environment prevailing at the time [14][15].

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