ABSTRACT

Water transport could be the backbone of the future European combined transport system. Unfortunately, risks in water transport are perhaps an under researched area and consequently, this article outlines a rationale, why it is necessary to develop competence about risk in water transport. The development of the cargo transport in river traffic depends directly on technical-exploitative characteristics of the network of inland waterways. Research of navigational abilities of inland waterways always comes before building ships or making a transport schedule. It is known that the size of the vessel’s draught (T) is usually the limiting value in project tasks and it depend on the depth of the waterway or certain ports condition. This is the reason why navigation characteristics of rivers have to be determined as precise as possible, especially from the aspect of determination the possible draught of vessels. River transport due to their operational business and environmental conditions faced with several risks having different degrees of consequences. Current risk assessment methods for water transport just consider some dramatic events. We present a new method for the assessment of risk and vulnerability of water transport where river depth represents a crucial part.

Keywords: river depth, risk management, water transport

1 INTRODUCTION

A logistic chain comprises all the entities and activities required to deliver final products to end customers – encompassing procurement, transportation, storage, conversation, packaging, etc. In recent years, due to increasing competition and tightening profit margins, companies have adopted a number of strategies to operate more efficiently and reduce transport and logistic costs. In general, lower cost and higher efficiencies are accomplished through a globalized logistic chain, higher capacity utilization, lower inventories, and just-in-time activities. However, there is always a trade-off between efficiency and some kind of vulnerabilities. Hence, there is a clear need for enterprises to manage logistic risks and reduce vulnerabilities so that they can respond and recover from disruptions promptly and efficiently [1]. According to this, we can conclude that risk management has become imperative for today’s complex transport and logistic chain.

Inland water transport (IWT), as a crucial transport mode, could be the backbone of the future European intermodal transport chains, due to the fact that it can ship heavy as well as a large amount of commodities in combination with price advantages. Besides, inland waterways have still free shipment capacities. In Europe around 14,000 km of approximately 29,000 km of inland waterways are used for freight carrier. Also, IWT represents the only means of land transport which does not suffer congestion problems like that of rail or road within Europe. In general, inland waterways are underused, but inland navigation is not considered as a truly competitive alternative to other means of land transport. Estimates suggest that inland navigation would carry up to 425 million tons per year, including the
accession countries, in the European inland waterway network, if the necessary action towards an integration of IWT into managed intermodal logistics chains were undertaken [3].

In order to develop and implement an advanced European concept to manage intermodal transport chains with IWT as a core transport mode, we need to develop effective risk management tool for proactive management of disruptive events in IWT. Unfortunately, risk in IWT are perhaps an under researched area and consequently, this article outlines a rationale for why it is necessary to develop competence about risk and risk management in IWT. Hence, in this research we examine inland waterways logistic chains with respect to risks and accordingly disruptive events which can occur at the nodes as well as at the links of the logistic chain. The aim is to develop framework for generating an extensive risk catalogue for all associated logistic chain members. Briefly, risk management framework proposed in this article consists of the following steps in sequence: risk identification, consequence analysis, risk estimation, risk mitigation, risk assessment, and risk monitoring. This article focuses on the risk identification and risk estimation steps. In addition to that, we estimate the risk of inappropriate river depth according to their probability of occurrence and their business impact.

2 COPING WITH RISK IN INLAND WATER TRANSPORT

There are many different definitions of risk in the literature, and we will not attempt to list them all. Some of those definitions assumed connections between risk and uncertainty, and their definition of risk is “the possibility of suffering harm or loss”. From a more technical perspective, risk can be defined as the probability of an event multiplied by the (negative) consequences of the event. Kaplan [6] suggests that risk is defined by the answer to the three fundamental questions: (1) “What can go wrong?”, (2) “How likely is that to happen?”, and (3) “What are the consequences?”. Also, risk can be defined as the potential negative impact that may arise from an adverse situation. In our context, IWT as part of intermodal logistic chain, the adverse situation is disruption to logistics operations. Disruption is defined as any event or situation that causes deviation from normal or planned logistic operations. Disruptions bring about adverse effects such as blockage of material and information flows, loss of ability to deliver the right quantity of the right product to the right place and at the right time, loss of cost efficiency, inability to meet quality requirements and process shutdown [1]. According to all above mentioned, we can conclude that risk represent exposure to circumstances with potentially damaging effects arising from an event that is not handled appropriately. So, risk is defined as product of probability of accidental event occurrence and its consequence, and risk management needs to address both sides of an accidental event, the sources leading up to it and the consequences arising from it [8].

\[
\text{Risk (R)} = \text{Probability (P)} \times \text{Consequence (C)}
\]  

Risk management is the systematic approach to identifying, analyzing, and acting on risk. It incorporates all steps from the initial identification of risks to the final decision on risk-reducing actions and risk monitoring. The basic framework for risk management is illustrated in Figure 1 and follows a structure similar to [1]. The major steps are:

1. Risk identification: The first step is to recognize uncertainties and possible sources of disruption event. A wide array of methods exists for identifying sources of risk, e.g. comparative methods, fundamental methods, and logical diagram methods. Another way to identify potential risk factors is through historical analysis, which examines historical events to gain insight into potential future risk. Nevertheless, the identification or risk sources appear to be the least-
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mentioned risk technique, despite the fact that it is seen as the most important step.

2. Consequence analysis: Once the risks have been identified, their consequences have to be analyzed. The disruptions due to one particular risk or a combination can be simulated and consequences propagated through the business model to identify all likely effects.

3. Risk estimation: Risk is usually quantified in financial terms and/or ranked according to some pre-defined criteria. Two different dimensions need to be considered: its frequency/probability and its severity/consequences, taking into account the effects of mitigating actions and safeguards, if any.

4. Risk assessment: The risk management team decides whether the risk quantified in the previous step is acceptable based on experience, industry standards, benchmarks or business targets.

5. Risk mitigation: Mitigating actions and safeguards such as emergency procedures and redundancies have to be developed, based on both the business model and inputs from the risk management team or relevant personnel.

6. Risk monitoring: the business structure and operation do not remain stationary but change regularly, for example due to changes in suppliers, regulations, operating policies, products, etc.

Figure 1: Basic framework for risk management

The key research question in this paper was how to engineer this basic framework for risk management in IWT in general, given the different scope of different IWT chains. That is achieved by applying the framework for categorizing logistic risk and risk management used in [7], but adapted to an IWT setting, as the Figure 2 shows. This three-dimensional approach captures the different types of risks, the managerial context and the unit of analysis along three perpendicular axes.
Figure 2: The proposed framework for categorizing risk in IWT chains

In the next section we will use proposed framework for identification and estimation one kind of infrastructure risk – river depth as crucial navigation characteristics of river.

3 THE RIVER DEPTH AS RISK FACTOR IN TRANSPORT PROCESS

The river depth risk is a product of the probability of the physical event occurrence as well as losses that include damage, loss of life and economic losses. Shallow water or restricted river depth can expose vessel owners and operators as well as the public to the possibility of vessel or cargo damage, injuries, environmental damage, etc. Complete risk modelling requires frequency estimation and consequence quantification. In the next section, based on proposed risk categorizing framework, through the appropriate case study, we will analyze frequency estimation of restricted river depth. Our case study covers only river depth risk, as one kind of infrastructure risk, and its identification in one part of IWT chain (unit of analysis is port to port), as is shown in the Figure 3.

The river depth, as a variable in time and space, depends on the characteristics of the river bed and water level fluctuations. The river depth is a variable factor with stochastic character, but it is possible to observe its seasonal disorders [4]. On all navigable rivers, there are sections with favourable and unfavourable navigational conditions. The risk analysis first determines the critical sections, i.e. river sections with the most adverse navigational characteristics. The next step is a detailed analysis of conditions and seasonal disorders. An activity flowchart of the analysis of unfavourable river depths occurrence is shown in the Figure 4.
3.1 Case study: analysis of restricted river depths occurrence on the lower section of the Danube

Analysis of the water level oscillation on a critical section is used to plan the navigation because low navigation levels limit the size of draught of all vessels. It is known that the size of the vessel’s draught (T) is usually the limiting value in project tasks and it is conditioned by the depth of the waterway or depths in certain ports. This is the reason why navigation characteristics of the Danube have to be determined as precise as possible, especially from the viewpoint of determining in reality possible draught of vessels. [5]

In this paper will analyze the oscillation of water level at the water level station in Giurgiu (Romania). To get even more precise condition of waterway on this section of the Danube, from the view point of navigation of vessels with large draughts, during research it has been started from the assumption that the possible draught of vessels is T=250 cm when water level on station Giurgiu shows H=44 (ENR) or T=250 cm when H<+44. By using the adopted principle research carried on to determine navigation condition for following draughts of vessels: for T<275 cm (H<+69); T≤300 cm (H<+94); T<325 cm (H<+119); T<350 cm (H<+144); T<375 cm (H<+169) and T<400 cm (H<+194). [11]

The research has been done for the period between 1 January 1987 and 31 December 2008. The results are presented below.
3.2 Results of analysis for water level station Giurgiu

Basic navigation characteristics of importance for determining vessels’ draughts in this period are:

- lowest navigation level determined in the observed period (1987-2008) is -142 cm;
- highest navigation level determined in the observed period (1987-2008) is +822 cm;
- average navigation level in the observed period (1987-2008) is $\bar{H} = 213$ cm with standard deviation from the average value $s = \pm186$ cm, which gives an interval of possible values of navigation level $H_{\text{min}}=+27$ cm and $H_{\text{max}}=+399$ cm, or draughts of vessels, average $\bar{T} = 419$ cm, minimal $T_{\text{min}}=233$ cm and maximal $T_{\text{max}}=605$ cm.

Probabilities of occurrence of adopted navigation levels, possible draughts and expected number of days for navigation in a year according to adopted levels for water level station Giurgiu in this period, as well as average annual number of days with water levels lower than adopted, expected beginning and ending of the periods, expected duration of period of restriction in navigation are shown in tables 1 and 2.

Table 1: Average probabilities of occurrence of water levels, possible draughts of vessels and expected number of days for navigation according to adopted water levels

<table>
<thead>
<tr>
<th>lower then adopted water level (draught)</th>
<th>higher than adopted water level (draught)</th>
<th>Expected number of days for navigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P(H&lt;+44) \rightarrow P(T&lt;250)=0.166$</td>
<td>$P(H\geq+44) \rightarrow P(T\geq250)=0.834$</td>
<td>$0.834 \times 365=304$</td>
</tr>
<tr>
<td>$P(H&lt;+69) \rightarrow P(T&lt;275)=0.214$</td>
<td>$P(H\geq+69) \rightarrow P(T\geq275)=0.786$</td>
<td>$0.786 \times 365=287$</td>
</tr>
<tr>
<td>$P(H&lt;+94) \rightarrow P(T&lt;300)=0.270$</td>
<td>$P(H\geq+94) \rightarrow P(T\geq300)=0.730$</td>
<td>$0.730 \times 365=266$</td>
</tr>
<tr>
<td>$P(H&lt;+119) \rightarrow P(T&lt;325)=0.324$</td>
<td>$P(H\geq+119) \rightarrow P(T\geq325)=0.676$</td>
<td>$0.676 \times 365=246$</td>
</tr>
<tr>
<td>$P(H&lt;+144) \rightarrow P(T&lt;350)=0.383$</td>
<td>$P(H\geq+144) \rightarrow P(T\geq350)=0.617$</td>
<td>$0.617 \times 365=225$</td>
</tr>
<tr>
<td>$P(H&lt;+169) \rightarrow P(T&lt;375)=0.441$</td>
<td>$P(H\geq+169) \rightarrow P(T\geq375)=0.559$</td>
<td>$0.559 \times 365=204$</td>
</tr>
<tr>
<td>$P(H&lt;+194) \rightarrow P(T&lt;400)=0.498$</td>
<td>$P(H\geq+194) \rightarrow P(T\geq400)=0.502$</td>
<td>$0.502 \times 365=183$</td>
</tr>
</tbody>
</table>

General characteristic of the observed period is that restriction of river depth occurs two times a year (with the exception of water level $H<44$). For level $H<94$ the first period of restriction is expected to start on 23 August and to end on 24 October, while the start of the second expected period of restriction is on 13 January and the end on 10 February; for water level $H<119$ the first period of restriction is expected to start on 18 August and to end on 25 October while expected start of the second period of restriction is on 16 January and the end on 16 February. Identical claims can be made for other water levels $H<119$, $H<144$, $H<169$ and $H<194$.  

Table 2: Average number of days in a year with water level which is lower than adopted water level, expected start of the period, expected end of the period, expected length of the interval of the period and average duration of the period with limited water levels

<table>
<thead>
<tr>
<th>Water level</th>
<th>Average number of days in a year with water level which is lower than adopted</th>
<th>Expected start and end of the periods with water levels lower than adopted</th>
<th>Expected length of the interval of the period with water levels lower than adopted (days)</th>
<th>Average duration of the period with water levels lower than adopted (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H \leq 44$</td>
<td>63</td>
<td>from 14 Sep. to 4 Oct.</td>
<td>51</td>
<td>29</td>
</tr>
<tr>
<td>$H \leq 69$</td>
<td>78</td>
<td>from 23 Aug. to 24 Oct. from 13 Jan. to 10 Feb.</td>
<td>62</td>
<td>32</td>
</tr>
<tr>
<td>$H \leq 94$</td>
<td>100</td>
<td>from 18 Aug. to 25 Oct. from 16 Jan. to 16 Feb.</td>
<td>69</td>
<td>36</td>
</tr>
<tr>
<td>$H \leq 119$</td>
<td>120</td>
<td>from 23 July to 21 Oct. from 24 Jan. to 21 Feb.</td>
<td>89</td>
<td>49</td>
</tr>
<tr>
<td>$H \leq 144$</td>
<td>141</td>
<td>from 4 Aug. to 29 Oct. from 29 Jan. to 1 Mar.</td>
<td>86</td>
<td>47</td>
</tr>
<tr>
<td>$H \leq 169$</td>
<td>163</td>
<td>from 23 July to 18 Nov. from 9 Feb. to 14 Mar.</td>
<td>118</td>
<td>64</td>
</tr>
<tr>
<td>$H \leq 194$</td>
<td>185</td>
<td>from 12 July to 25 Nov. from 3 Feb. to 18 Mar.</td>
<td>136</td>
<td>76</td>
</tr>
</tbody>
</table>

Probabilities of occurrence of navigation levels that are lower than certain adopted navigation levels for every day of year (from 1 May to 30 April), are shown in the Figure 5.

It is necessary to state out that in observed period of water level monitoring draught of 250 cm (which must be guaranteed at ENR during whole year) cannot be achieved 61 days in a year for water level station Giurgiu.

Figure 5: Probabilities of occurrence of restricted navigation levels for every day of year
4 CONCLUSION

Risks are increasingly prevalent in complex transport and logistic chains. In addition to disruptions within each transport chain entity, the maze of interactions necessary for efficiently logistic operations can also be the origin for disruptions. Currently, there are no systematic methods to identify logistic risks in complex logistic chains. This is especially case in logistic chain where inland water transport presents one of the most crucial parts. Hence, in this paper, we propose a structured framework for characterizing risk in inland water transport chains. The first step of proposed risk management process is risk identification, and based on the proposed framework eight types of risks were identified in IWT chains: technology, infrastructure, political, economical, environmental, temporal, organizational, and legal. According to this, we analyze in detail river depth as one of the infrastructure risks and crucial navigation characteristics of river. The case study demonstrates the restricted river depth risk probability estimation as a first part on risk assessment process. This work provides a good platform for further extensions of risk assessment and management process. In the next step we have to analyze possible consequence of restricted river depth and measures for managing and monitoring this kind of risk, and on that way we will have completed process of risk management.

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