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SCENARIO PLANNING AND ANALYSIS ON MULTIMODAL TRANSPORTATION IN METROPOLITAN HAMBURG SIMULATING A TERRORIST ATTACK ON RIVER ELBE TUNNELS

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Abstract. This paper presents a scenario planning and analysis embedding a simulation case study of an assumed terrorist attack on river Elbe tunnel to calculate the impact of the resulting bottlenecks on multimodal transportation in metropolitan Hamburg. A bottleneck-analysis is a process related approach used to identify shortages. In relation to transportation chains it is concerned with analysis of resource planes, depth of optimization of multimodal transportation, consideration of timeliness and concurrency while using resources, analysis of transactions in the network, etc. As a result the paper will evaluate the impact onto the multimodal transportation chains and show possible solutions based on the scenario analysis on how to overcome the bottlenecks.

1 Introduction

The term terrorism comes from the Latin terrere, which can be seen in the context of frighten. From the etymology point of view the term terrorism is related with the French word terrorisme. The English word "terrorism" was first recorded in English dictionaries in 1798 as meaning "systematic use of terror as a policy." (Douglas Harper, "Terrorism," Dictionary.com Online Etymology Dictionary). In general terrorism is the systematic use of terror. Most definitions of terrorism include only those acts which are intended to create fear (terror), and/or are perpetrated for an ideological goal (as opposed to a lone attack) and deliberately target or disregard the safety of non-combatants. Some definitions also include acts of unlawful violence and war (http://en. wikipedia.org/wiki/Terrorism#cite_note-1).

Terrorism is also a form of unconventional warfare and psychological warfare. The word is politically and emotionally charged, and this greatly compounds the difficulty of providing a precise definition. A 1988 study by the US Army found that over 100 definitions of the word "terrorism" have been used (Dr. Jeffrey Record, Bounding the Global War on Terrorism). Finally a person who practices terrorism, is a terrorist.

While acts of terrorism are criminal acts as per the United Nations Security Council Resolution 1373 and domestic jurisprudence of almost all countries in the world, terrorism refers to a phenomenon including the actual acts, the perpetrators of acts of terrorism themselves and their motives. There is disagreement on definitions of terrorism. However, there is an intellectual consensus, that acts of terrorism should not be accepted under any circumstances. This is reflected in all important conventions including the United Nations counter terrorism strategy, the decisions of the Madrid Conference on terrorism, the Strategic Foresight Group and ALDE Round Tables at the European Parliament (ALDE: Alliance of Liberals and Democrats for Europe (http://en. wikipedia.org/wiki/ Terrorism#cite_note-1).

2 River Elbe Tunnels

To analyze the consequences of a terrorist attack on river Elbe tunnels on the transportation chains in metropolitan Hamburg, a scenario analysis is essential. A scenario analysis can be performed to predict possible future events of a given entity considering alternative possible outcomes, assuming changing scenarios but inherently consistent framework conditions, for improved decision-making, that require as prerequisite a scenario planning, a method based on simulation games for decision making. This games combine known facts about the future, with plausible alternative trends that are key driving forces. The scenario analysis used in this paper is an improved decision making allowing consideration of outcomes and their implications on transportation chains through river Elbe tunnel tubes in metropolitan Hamburg. Hence the major facts of the tunnels concerning the transportation chain must be known:

- ☐ Built from 1968 to 1975, expanded 1995 to 2002
- ☐ Building costs for the first three river Elbe tunnel tubes are approx. 270 Mio €
- ☐ Building costs for the forth river Elbe tunnel tube are approx. 275 Mio €
- ☐ Tunnel entrances are in Waltershof and Othmarschen
- ☐ Part of interstate A7
- ☐ One of the longest under water road tunnels of the world
- ☐ Currently more than 150.000 vehicles per day
- ☐ Planned for 65.000 vehicles per day.
- ☐ Time of day dependent congestion → bottleneck

3 Terrorist Attack Consequences

Based on the aforementioned facts the consequences of a terrorist attack on river Elbe tunnels on the transportation chains in metropolitan Hamburg, can be assumed as follows:

- ☐ River Elbe tunnel tubes are destroyed
- ☐ Interstate route going compensatory through inner city in metropolitan Hamburg
- ☐ Assistance of this detour route through modified traffic light status
- ☐ Interstate speed limit with route in metropolitan Hamburg
- ☐ Max. speed due to road capacity approx. 30 km/h

Based on this consequences shortage identification is of great value for metropolitan Hamburg's multimodal transportation chains. Calculating shortages are done through the process related bottleneck-analysis approach. Concerning transportation a bottleneck analysis deal with

- Analysis of resource planes
- Optimization depth of multimodality transportation
- Consideration of timeliness and concurrency due to the used resources
- Analysis of transactions within the network
- Etc.

Henceforth, identifying shortages on the one hand deal with discovering the dependencies within a sequence of actions, and on the other hand showing the dependencies through which the different components are conditional with their related actions. But identified shortages may show different intensive impacts – optimal or sub-optimal – on the transportation process. Thus the main advantage of a bottleneck-analysis is the possibility of shortage identification and, if possible, rectification on the very spot to achieve optimized transportation chains. In general, the results obtained from a bottleneck analysis distinct between best -, worst -, und real case results, based on their respective approach. Assuming that a bottleneck-analysis in transportation deals with the calculation of the adequate availability of resources, the three different cases are:

- **Best Case Analysis**: resources for multimodal transportation chain are available and no shortage will appear. This result in a high priced solution, basically the resources available can't be used in an optimal way, because there are more resource available than necessary.

- **Worst Case Analysis:** resources for multimodal transportation chain are not available in the required amount or at the worst only one component is available but several of which are needed. Henceforth, shortages will appear. Result is a cheap priced solution, basically resources available are not adequate.

- **Real Case Analysis:** real available resources for multimodal transportation chain have been taken into account. Basically the solution achievable is in between beast case and worst case because the results obtained by the real case analysis are sub-optimal.

Due to complexity, time and cost constraints, identifying shortages/bottlenecks in transportation chains are not trivial. Because identification and elimination of shortages is, from a general perspective, only a first step of finding the possible/optimal solution Because afterwards it can be discovered that the criteria based objective function is sub-optimal due to another shortage, identified after elimination of the first one. In general this will result in a specific iterative routine which the bottleneck-analysis has to pass through as long as the desired optimal transportation behavior is not achieved [1, 5].

4 Bottleneck-Analysis

A schematic sketch of several shortages that may appear as a result of a bottleneck-analysis is shown in Figure 1.

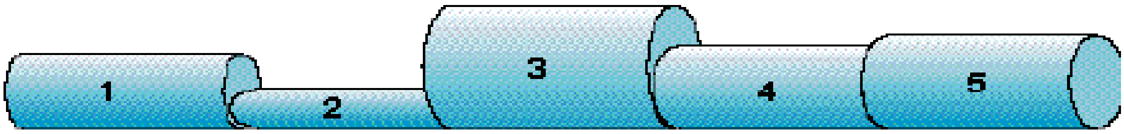

Figure 1. Bottleneck-Analysis with several shortages

The model approach behind the assumed shortages, shown in Figure 1, is a hydrodynamic one, that constitute a practical way calculating flows. In multimodal transportation flow can be assumed by way of example as trucks with containers, that have been load up at the container terminals Burchardkai or Altenwerder CTA) in metropolitan Hamburg. Flow means that trucks driving to the final destination. To gain an idea of this flow, some facts about container transportation to and from the container terminals, are of importance:

- 2006: 500.000 trucks are dispatched
- 2007: 550.000 trucks are dispatched
- 1999: 318 container ships with more than 13,50 m draft
- 2007: 1979 container ships with this draft.

- Let all river Elbe tunnel tubes be completely destroyed as result of the assumed terrorist attack. Henceforth, a resource shortage happen due to the impossible tunnel passage for vehicles from north to south and south to north, which is as sure as eggs is eggs.
- Let the resource shortage resulting from the assumed terrorist attack on river Elbe tunnels in metropolitan Hamburg require to detour more than 150.000 vehicles per day.
- Let the entire reconstruction of all river Elbe tunnels call on for a long time frame of at least 8 years with total cost of more than 1.100 Mio €.
- Let the interim solution being appropriate for a mid to long term usage.
- Let the amount of detoured vehicles through the inner city in metropolitan Hamburg be as low as possible.
- Let the detour be as fast as possible.
- Let the detour time be as good as possible.

Henceforth, the detour of more than 150.000 vehicles per day is the primary bottleneck in this scenario analysis. But based on the aforementioned assumptions the primary shortages may show a sequence of hidden shortages that one after each other will be discovered once the previous has been identified. The capacity for transit purposes through river Elbe tunnel tubes of 150.000 vehicles per day – which can be expressed by component 3 in Figure 1 –, has to be replaced by possible detours, the most critical one through the metropolitan inner city – which can be expressed by component 2 in Figure 1 –, and a second detour route to bypass river Elbe tunnels and the inner city detour – which can be expressed by component 1 in Figure 1 –, etc. As a result of this assumptions the primary shortages show a sequence of hidden shortages that one after each other will be discovered once the previous has been identified. However the shortage of component 3 is the primary one in the this scenario analysis, and the others are secondary shortages. Moreover, beside the set of shortages given by the used resources, weighting functions can be added to the components´, in order to calculate the respective output delay. In terms of an optimization of the resources' management, calculating the output delay as part of the transaction chain result in more sensitive parameters, compared with the pure identification of the shortage caused resources´. Based on the output delay as part of a transaction chain the calculated transaction time is characterized from the point of time starting with the detour up to the arrival at the final destination. In general the bottleneck analysis allow, as it is shown in Figure 1, the entire utilization analysis from sink to source, and concurrently the identification of opportunities for optimization. But rating an optimization has to consider the different views of stakeholders (carriers) and the quality of live of people in metropolitan Hamburg in case of detouring through the inner city as well as detouring in the more outer metropolitan domain. The views guessed can be local or global operating procedures, decision making processes, interpretation of data exchanged, optimization strategies, etc.

5 Multi-Criteria Approach

As soon as shortages can be allocated, their impact on the overall time delay due to the sequences of hidden shortages can be calculated. This procedure result in the multi criteria approach, which is based on the assumption that several occasions have to be taken into account for decision making purposes, meaning that a set of alternatives exist, e.g. $\mathbf{A \neq 0}$. As consequence of the multi criteria approach a weighting function $\boldsymbol{f}$ has to be solved by calculation

$$f : A \rightarrow R^q;\ q \geq 2$$

.

Let $f_k : A \rightarrow R$, with $f_k(a) = z_k$ $(k \in \{1;\ldots, q\};\ a \in A)$, whereas $f(a) = (z_1;\ldots; z_q)$ is essential, than the weighting function is a criteria of the so called objective function.

Let the objective function f_k, $(k \in \{1;\ldots, q\}$ be a maximum, than for each criteria a higher value will be preferred opposite a lower value.

Let the objective function f_k', be minimized, than the maximum criteria can be defined as a substitute for $f_k = -f_k'$.

6 Elbe Tunnels Scenario Analysis

Scenario analysis is a methodology that break down possible future events by considering alternative possible outcomes which are the so called scenarios. Hence scenario analysis enable an improved decision-making by allowing consideration of outcomes and their implications, which goes back to strategic military intelligence organizations, policy makers, and the business domains in the 1960s. For example using scenario planning and analysis in the military domain allow design war games so that policy makers obtain great flexibility and freedom to adapt their organizations “on the flight”, stressed by the scenarios as a game plays out.

In so far as pace of change and increased level of uncertainty is concerned, an enormous interest in scenario analysis and planning can be discovered. Because scenario analysis is seen as transform of scenarios into perceptions du to the identification of e.g.:

- Driving forces
- Predetermined factors
- Critical uncertainties
- Implications of different scenarios
- Indicators to monitor

.

But scenario analysis in general is no substitute for a complete and factual exposure of survey error in the respective studies under test. In commonly prediction, the data given are used to model the problem under test, with a reasoned specification and technique and the analyst in charge with the respective analysis feels in duty bound, within a certain percentage of statistical error, to state the likelihood of previous specified coefficients being within a certain numerical bound. To scale down this expectations it should be noted that this exactitude need not come at the expense of very disaggregated statements of hypotheses of a real scenario analysis., i.e. it has to be considered causal inference, as well as the evaluation of the counterfactuals.

Against this background the scenario analysis for the river Elbe tunnels contemplates the possible outcomes the simulation plays of for transportation in metropolitan Hamburg while river Elbe tunnel tubes are closed for

- Maintenance
- Reconstruction work
- Demolition through the assumed terrorist attack which may destroy all tunnel tubes.

Henceforth,

- Thinking about how to respond to each, of it
- What the consequences of the above mentioned hypothesis might be
- Playing with different scenarios and different responses, in order to consider the likelihood of each scenario

is essential for a real scenario analysis.

Based on what is perceived would be the outcome of each and the basis to plan the next step, which finally require testing to perceive a good scenario that is:

- Plausible to decision-makers/stakeholder
- Internally consistent
- Relevant to topic or issue of interest
- Recognisable from data/signals
- Challenging,
- Surprising or novel.

For this reason the scenario planning is necessary to understand as best as possible likely future trends to make strategic decisions based on an analysis of the consequences of the most likely scenario. Such contemplation at least result in the following topics that have to be taken into account such as:

- Key questions
- Time and scope
- Stakeholders
- Uncertainties
- Extremes of possible outcomes
- Disaggregated statements.

As result of this topics a traffic network model was developed, based on modifying VITS (Virtual Intermodal Transportation System), that support multi-modal traffic and provides reasonable tradeoff between macroscopic computational efficiency and microscopic/agent-oriented accuracy, but require data nearly impossible to obtain [2].

The traffic network consist of nodes and links. For the road mode vehicles can be modelled individually, attributes including current location, speed, and destination. Vehicles stochastically appear at any node (inter-arrival time exponentially distributed) and traverse fixed routes, i.e. sequence of road links, reaching destination. Each vehicles´ speed on link i currently traversed is sampled from a normal distribution with which the expected link travel time $\hat{t}_i$ amounts to

$$\hat{t}_i = t_i \left[1 + \alpha \left(\frac{x_i}{C_i} \right)^{\beta} \right]$$

and is subject to free flow travel time t_i (depending on speed limit), link capacity C_i, and flow during the last period x_i. Flow x_i and link capacity C_i are measured in terms of cars, using an equivalence factor of 2.5 cars per truck. The non-freight car traffic flow x_i is chosen such that trucks account for 25% of overall traffic. All Vehicles´ speeds are updated every 7.5 minutes.

The traffic simulators application area was developed for, but not limited to, metropolitan Hamburg, providing a tool for scenario analysis evaluating the impact of shortages due to the real situation of the tunnel tubes. Such investigation typically includes performance measures like vehicle travel times, link speeds, or throughput, yielding a valuable decision support tool by offering judgement whether solutions, as part of the scenario analyzed, are sufficient with respect to given target performance measures for further enhancement.

Figure 2 depicts the metropolitan Hamburg bottleneck network, consisting of the assumed 16 nodes – seven of which are network boundaries – and 18 of which are links. Most of the nodes denote interstate junctions or exits; in this topology – that does not claim to reflect a level of detail sufficient to produce valid results–.
The bottleneck analysis is based on the following specific assumptions:

- River Elbe tunnels destroyed by a terrorist attack
- Interstate alternate through inner city of metropolitan Hamburg
- Bridge over river Elbe
- Alternative solutions for metropolitan Hamburg

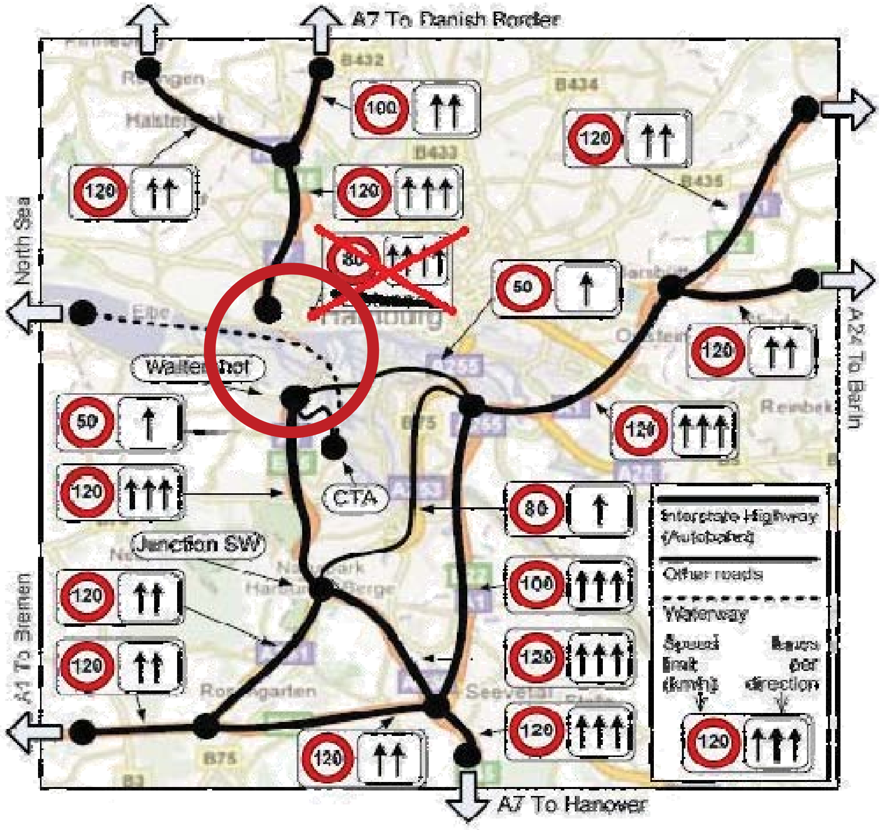

Figure 2. Hamburg Network without river Elbe tunnel passage

The most ineffective but easily manageable solution is detour of interstate A7 at exist Othmarschen through the inner city of metropolitan Hamburg via river Elbe bridges and afterwards via Köhlbrand bridge back to interstate A7.

This interstate alternate could be additionally supported by modified traffic light cycles – adjusted green phase for substitute conjunction –. This possible substitute conjunction is shown in Figure 3.

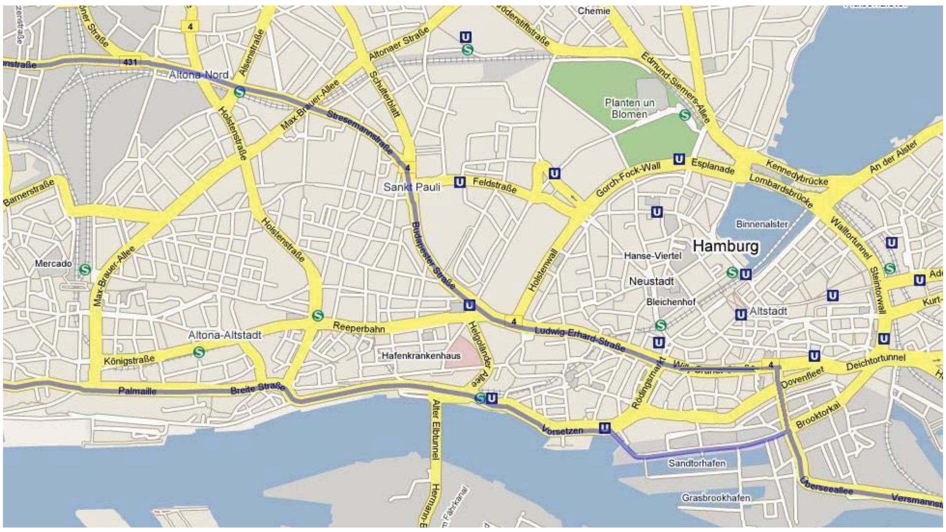

Figure 3. Substitute conjunction of metropolitan Hamburg

An intermediate feasible solution would be a bridge over river Elbe close by the area of the destroyed tunnel tubes, which can be build up in a few years with minor costs than tunnel tubes, as shown in Figure 4. But several serious reasons can be found against such a solution:

- At least 80m over NN
- Due to this height extremely vulnerable to whether conditions
- As regards urban development such height is not suitable because the height of this bridge would 25 m over the major road Elbchaussee
- Maybe the bridge embarrasses the progress of the harbour development

All these reasons have been previously analyzed in the early sixteen's of the former century when western ring road was discussed in metropolitan Hamburg, including a bridge. But the decision was against it and in favour of the tunnel.

Another feasible solution are ferries. The reason against ferries was that such much ferries are needed that shipping traffic would not be possible. Henceforth, this is not any real alternative.

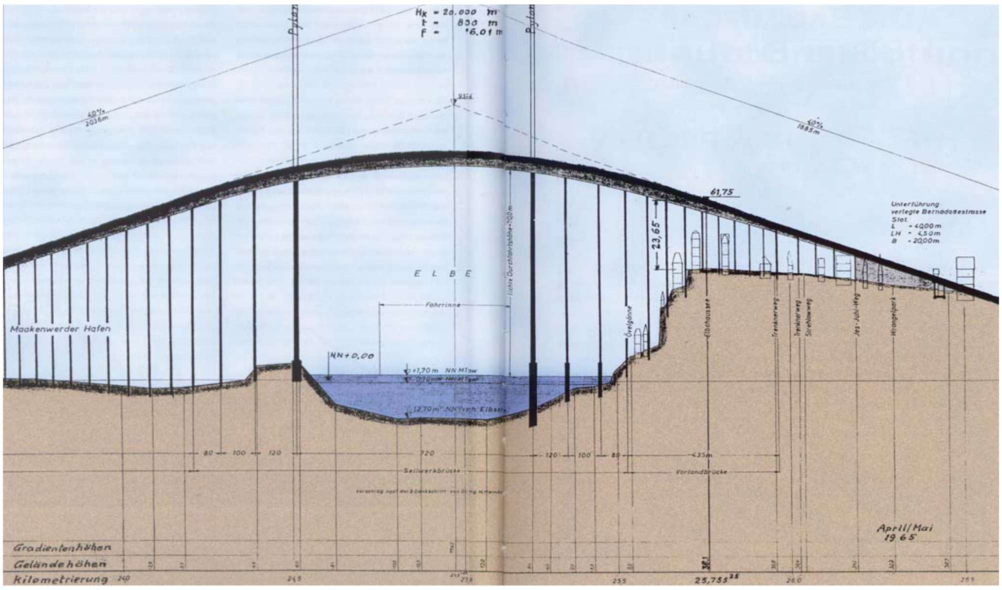

Figure 4. Substitute conjunction via a bridge over river Elbe

Furthermore, seeking for dodge ports as alternative for Hamburg's harbour, could be an temporary solution, as shown in Figure 5.

Possible temporary dodge ports are:

- Cuxhaven
  - Sea port at the estuary of river Elbe
  - Since 1997 deep water harbor
  - Handling 2006 approx. 32.900 TEUs
- Container Terminal Bremerhaven
  - Handling 2006: approx. 4400.000 TEUs
  - Sprawl tidal quay
- Rotterdam, Netherland
  - Biggest European port
  - Handling 2006: approx. 9286.757 TEUs

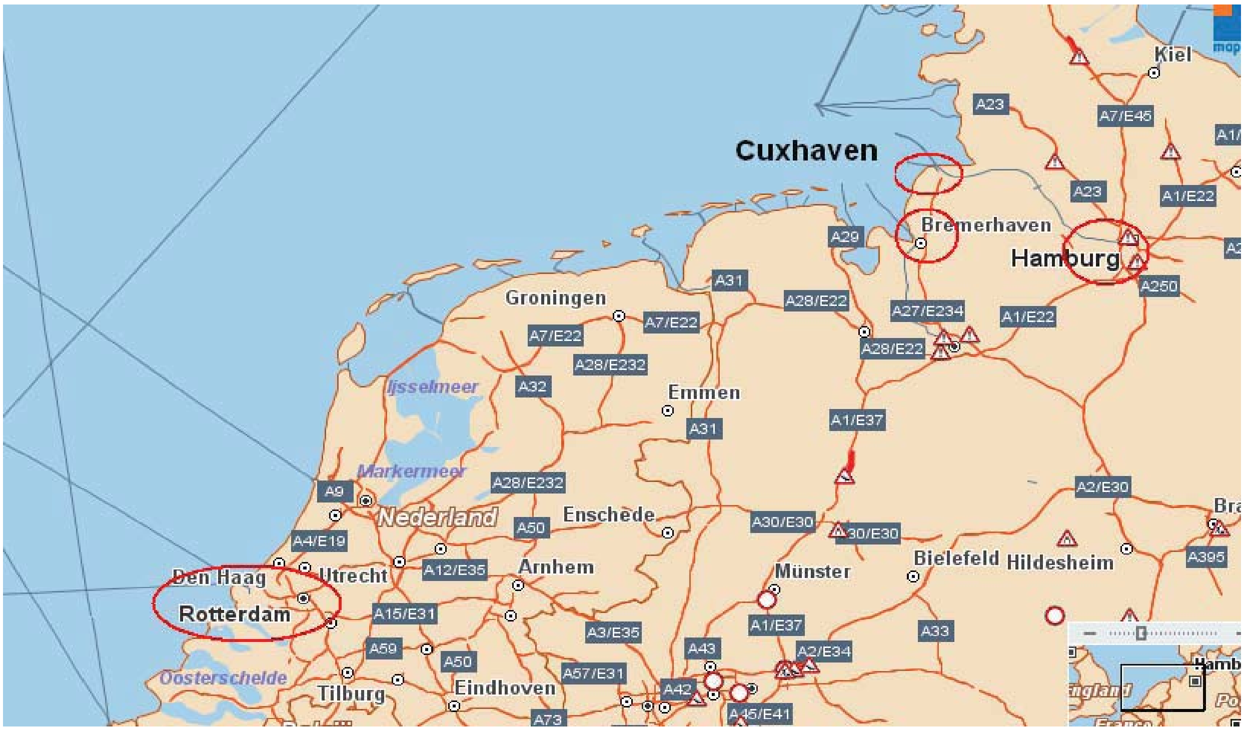

Figure 5. Alternative dodge ports for Hamburg's harbor

7 Simulation Study

As simulation platform the software ProModel was used with a modified VITS traffic network model. The scenario analysis is based on the road network shown in Figure 2, for which the simulation show the following results:

#vehicles travel from note _nach Flensburg_ to node _nach Hannover_" 8425
#vehicles travel from note _nach Hannover_ to node _nach Flensburg_" 8539

mean travel time from node _nach Flensburg_ to node _nach Hannover_" 0.41 h
mean travel time from node _nach Hannover_ to node _nach Flensburg_" 0.42 h

Another simulation run for the scenario analysis show that this distance can be traveled within 25 min. so far the road can be assumed as clear.

To continue the scenario analysis the road network of metropolitan Hamburg was modified by introducing four new nodes:

<Node ID="20">Kr_Behringstraße_Hohenzollernring</Node>
<Node ID="21">Kr_Hohenzollernring_Elbchaussee</Node>
<Node ID="22">Kr_Kajen_Rödingsmarkt</Node>
<Node ID="23">Köhlbrandbrücke_West</Node>

with their resulting connections

<Link From= "16" To= "20" Type="1" Length= "2" Speed= "50" Lanes="1" Cap="2000">Behringstraße</Link>
<Link From= "20" To= "21" Type="1" Length= "1" Speed= "50" Lanes="1" Cap="2000">Hohenzollernring</Link>
<Link From= "21" To= "22" Type="1" Length= "5" Speed= "50" Lanes="1" Cap="2000">Elbchausee_bis_Vorsetzen</Link>
<Link From= "22" To= "23" Type="1" Length= "9" Speed= "50" Lanes="1" Cap="2000">über_Elbe_bis_Köhlbrand</Link>

<Link From= "22" To= "5" Type="1" Length= "9" Speed= "50" Lanes="1" Cap="2000">über_Amsinckstr_bis_A1</Link>
<Link From= "23" To= "2" Type="1" Length= "5" Speed= "50" Lanes="1" Cap="2000">Köhlbrand_bis_A7</Link>

Last but not least the route has to be modified:

<Vehicleroute Mode="0" From="10" To= "13" Via="3;16;20;21;22;23;2;4;6" VehicleCap= "1"></Vehicleroute>
<Vehicleroute Mode="0" From="10" To= "14" Via="3;16;20;21;22;23;2;4;7" VehicleCap= "1"></Vehicleroute>
<Vehicleroute Mode="0" From= "9" To= "12" Via="3;16;20;21;22;5;8" VehicleCap= "1"></Vehicleroute>
<Vehicleroute Mode="0" From= "1" To= "9" Via="2;23;22;21;20;16;3" VehicleCap= "1"></Vehicleroute>

Furthermore for this new scenario analysis an additional scenario panning was conducted without the possibility of river Elbe tunnels passage and therefore the detour through the inner city in metropolitan Hamburg. The simulation run for this scenario analysis results in:

#vehicles travel from note _nach Flensburg_ to node _nach Hannover_“ 8209
#vehicles travel from note _nach Hannover_ to node _nach Flensburg_“ 8561

mean travel time from node _nach Flensburg_ to node _nach Hannover_“4.64 h
mean travel time from node _nach Hannover_ to node _nach Flensburg_“3.42 h

The simulation results for this scenario analysis show that this distance can be traveled by vehicles only with a 10 time higher travel time.

8 Conclusions

From the simulation runs it can be seen that a potential terrorist attack on the river Elbe tunnel system in metropolitan Hamburg will have a huge impact on the overall transportation chains. Based on scenario planning and scenario analysis simulation studies can be conducted to estimate the effect of possible detours in order to overcome shortages. Henceforth, scenario planning and scenario analysis can be introduced as important part of performance management in multi-model transportation.

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