VISUALIZATION OF DATA FROM TRANSPORTATION SIMULATION SYSTEMS

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ABSTRACT

Information visualization, as a way of presenting different data types in an understandable form, has the potential to support the analysis of transportation data. Visualization can often help decision makers to efficiently analyse large amount of information. One application area of information visualization is to support the analysis of the transportation data and thus facilitate the decision-making process. Most of the previous studies in this area have focused on visualization of transportation infrastructures such as roads, bridges in order to enhance the public awareness regarding upcoming projects which makes it easier to reach a consensus on the high-level decisions. However, the main focus of this article is on methods for visualization of data generated by transportation simulation systems to support analysis of the consequences of applying different transport policy measures, such as the introduction of road user charging or investment in new infrastructure. In this work, we investigate how visualization techniques could address the challenges of transportation simulation data analysis in order to facilitate the decision-making process. For this purpose, we have applied the visualization methods to a real implemented agent-based transportation simulator called TAPAS. In this case study, we have analysed the visualization related requirements of users using a user-centric approach and the visualization tool has been designed and developed based on the identified requirements.

Keywords: Transportation simulation visualization, decision support system, policy impact assessment, logistics, transport planning, usability.

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1. INTRODUCTION

There is a growing use of simulation in transportation and there have been established national and international models which can predict future flows in freight transport network (De Jong and Ben-Akiva, 2007; Brunner et al, 1998). The main idea is resting in the attempt to simulate the real system characteristics in a computer system and observe how applying different scenarios will affect the behaviour of the transportation system (Holmgren et al, 2012a). Simulation has a potential to assist in planning processes where the decision makers wish to be aware of the consequences of a specific decision on the whole system (Fishburn et al, 1995). One of the key applications of simulation in the transportation context can be related to the cost reduction and the increase of the quality of service provided (Fishburn et al, 1995). However, not all the transportation simulation systems are necessarily successful regarding reducing costs and increasing quality. There are some factors which determine the degree of success of simulation models. One important factor is the "Ease of use" of the simulation system by different types of potential users (Brunner et al, 1998). Typically, a simulation system generates a large amount of data as output. This data often need to be processed and analysed in order to be useful. Hence, the way of analysing and presenting the output data to the stakeholders, can be a challenging task. As individuals acquire more information through their sense of vision than through all the other senses (Ware, 2012; Chen, 2004), visualizing the output data of transportation simulation systems could help to overcome the complexity of data presentation and analysis.

This research seeks to investigate how visualization techniques can address the challenges of transportation simulation data analysis in order to facilitate the decision-making process for transportation simulation users. To achieve this goal, the paper explores a multi-agent based simulation model for transportation and production called TAPAS (Holmgren et al, 2012) (Transportation And Production Agent-based Simulator). TAPAS is a micro-level simulation tool which aims to reveal the effects of applying different measures including governmental policies like taxes, and infrastructure investments and business strategies (Ramstedt et al, 2007). It can also act as a decision support system for public authorities and policy makers by predicting what the effects are when applying a specific set of production and transportation measures and whether it contributes to the government goals of sustainable economic development (Bergkvist et al, 2005). Furthermore, TAPAS can assist enterprises to make both operational and strategic decisions, for example, decisions regarding consignment size and storage locations and similar (Davidsson et al, 2008).

The process for designing the visualization tool is based on the "Systems Engineering" process (Wymore, 1993). The study followed the "System Development Life Cycle (SDLC)" as a life cycle of system development; in which there are Analysis, Design, Implementation, Testing and Evaluation phases (Post and Anderson, 2002). Furthermore, the "Spiral Model" is used for the migration from requirements to design solution (Boehm, 1988). This selection is made due to the fact that prototypes of the system are created so as to obtain user feedback during the development process. This method has an iterative nature and each iteration is repeated until the final product is made. Before implementing the visualization options, sketches for the proposed system are prepared. These sketches are presented to the users to obtain the approval and their feedback on design alternatives and further

options. This may be seen as a type of an iterative process that is continued until a positive feedback is received from the users.

The rest of this paper is organized as follows. Section 2 introduces a literature review on information visualization. In section 3 we describe the core of our contribution by introducing the TAPAS visualization tool and its key design features and functionalities. Section 4 represents the evaluation of the proposed visualization tool. Section 5 concludes the paper by presenting our findings.

2. RELATED WORK

2.1 Information Visualization

It is crucial to understand the concept of visualization in order to develop a usable interactive tool for data visualization. Information Visualization is a relatively new area which is increasingly acquiring more and more attention in both academic and industrial environments. Here we explore the use of computer-supported interactive graphical representations for explaining data and amplifying cognition.

Visualization plays an important role in human understanding by providing visual representations of large amounts of data. This is required in order for data to be more usable and understandable for users (Ware, 2012; Mazza, 2009). "Visualizations have a small but crucial and expanding role in cognitive systems. Visual displays provide the highest bandwidth channel from the computer to the human" (Ware, 2012). Owing to the importance of visualization in real world problem domains, it has been growing tremendously in different contexts (Card et al, 1999; Chen, 2004). Obviously, the nature of the data to be visualized is different in various application areas. The choice of selecting a set of visualization techniques and applying them to a data set is highly dependent to the context of the specific data set. As an example, in case of existing inheritance relations between the data elements, graphs can be used as a way of representing and visualizing information (Herman et al, 2000). Layout algorithms have emerged as a way to solve the problems of visualizing complex and large data displayed in a graph. Some of these algorithms are focused on aesthetics criteria in the context of Graph Drawing (Di Battista et al, 1998; Kaufmann and Wagner, 2001), while others are based on drawing conventions and constraints (Di Battista et al, 1998). In addition, other types of visualization techniques, such as displaying data through diagrams are also available (Brasseur, 2006). Given the nature of the data and the type of analysis that should be drawn from the data, a mix of these approaches and techniques can be applied to reach usability requirements of potential users of the specific context.

Furthermore, visual attributes should be utilized to display data elements in different colours and shapes in order to increase readability of a visualized graph. Colin Ware (Ware, 2012) describes an ability of human cognitive system called "Pre-attentive processing" in his work. He defines the concept of pre-attentive processing as a theoretical mechanism which causes some aspects of a visual model more highlighted or distracted. Ware argues that there are some visual attributes which can be pre-attentively processed in the human vision system. Examples of these attributes are colour, spatial position, movement and form. The discussion

above emphasizes the pre-attentive visual attributes as crucial assets of a visualization model.

This research focuses on visualization of data in the context of transportation. For visualizing a transportation network, special techniques for graph drawings are required. An important characteristic of transportation context is positioning the elements on the screen. Thus, the aim here is to investigate the techniques for visualizing a set of nodes and their relations.

There are some general approaches to positioning nodes and edges. The most important and commonly used approaches are listed below (Aris, 2008; Shneiderman and Aris, 2006):

- Force-base drawing algorithms: In this layout algorithm, the network of nodes and edges are simulated as an electrical system. There are attraction and repulsion forces between nodes and edges. These forces will apply to nodes and the position of nodes will change accordingly. The goal of this algorithm is to reduce the energy associated to graph layout. This algorithm has an iterative nature and it will be repeated until the energy system reaches a balanced state (Eades, 1984).

- Geographical approach: In this strategy, position of nodes is based on geographical attribute of nodes on a map (Becker et al, 1995).

- Circular topology: This layout algorithm tries to put nodes on a circle, so the edge crossings will be at the centre of the circle (Breitkreut et al, 2003).

The selection of which approach should be taken depends largely on the domain of data to be visualized. In this article, we rely on the Geographical approach as it meets the requirements of users in the transportation simulation context, where the position of the nodes should be as close as possible to their real positions on the map.

2.2 Transportation system visualization

Several research groups have targeted the transportation visualization field with different approaches. However, very little research is conducted on applying visualization methods to transportation simulation in order to support the analysis of simulation output data. The "Visualization in Transportation Committee", a sub-committee of the "Transportation Research Board" (TRB), focuses on visualization techniques for transportation issues. The majority of previous studies both in TRB and other research groups revolve around visualization of the physical infrastructures (e.g. a new road or bridge) and the impact that these infrastructure investments have on the transportation system. However, the emphasis of this article is on visualization of output data from transportation simulation systems, where the effects of applying transport policy measures on the whole transportation network are potentially predicted.

According to Hixson (Hixson, 2006), the main uses of visualization rest in the design process where the aim is to facilitate the work of designers and in obtaining the public approval to reduce the rework costs. It can also act as a complementary way in ensuring alignment of achievements with planned improvements (Richter et al, 2003). Although the approach of using visualization in transportation for design purposes is also a goal of TAPAS, this approach is relatively different. In the above direction, the use of visualization in the design

process is limited to showing the anticipated final product (e.g. a road or a bridge) with respect to architectural factors as the input. By contrast, the aim here is to visualize the impact of applying different measures in transportation process, such as taxes.

Although visualization has been used in transportation field for many years and several studies have been done for improving and customizing visualization techniques for transportation goals, there is still a significant lack of research directed at application of visualization during the planning process (Hughes, 2008). Use of visualization in a planning process takes into account human and environmental aspects of transportation projects as well as the economic impact factors. Hughes believes that the research conducted so far in this field, mainly concerns the involvement of stakeholders in the design process and investigation of effective ways to demonstrate design alternatives to different stakeholders. Hughes argues that there is a need to apply visualization techniques in transportation by considering environmental perspectives in the planning process (Hughes, 2008).

Hughes also reviews current trends and approaches in visualization of the transportation data and argues that two techniques of visualization are mainly used in the context of transportation (Hughes, 2010):

- Map-based visualization: the nature of data in the context of transportation often is based on geographical information where using map as a background and visualizing transportation data on a map can be considered as a promising design solution. Typically, the transportation-related information consists of source, destination and routes between them. Thus, based on the characteristics of the transportation data, it appears to be more meaningful to rely on maps for visualization of freight data. An example of map-based visualization is illustrated in Figure 1 below.

- Using "Score Cards" and "Dash boards": These techniques can be used with the aim of tracking Key Performance Indicators (KPIs) of a system and also system level variables for users.

Figure 1 – A sample map-based visualization of freight data (Hughes, 2010)

P.J. Hoen, et al have conducted a research into developing a software system for visualizing a multi-agent model of logistics management (Hoen et al, 2004). Their proposed software features consist of visualizing the simulation process, routes, the appearing of loads and truck movements. The focus of the software is on the visualization of how the simulation system works (e.g. illustration of object movements) rather than visualization of the output results of the simulation. Therefore, in this paper we try to study the methods for visualization of the aggregated results of the simulation as opposed to the previous approach to visualize the events when they occur during the simulation. As the scope of this article is investigating of visualization techniques for a multi-agent based transportation simulator, where monitoring the effects of applying measures is the goal of simulator, it is very different form the research which conducted in this field so far.

3. TAPAS CASE

TAPAS is a Multi-Agent-Based Simulation (MABS) model of a transportation and production system including the operational and logistical decision simulators. TAPAS can be used to predict the consequences of various measures for decision and policy makers, before making any decision. Some of these measures are listed below (Bergkvist et al, 2005; Ramstedt et al, 2007; Holmgren et al, 2007):

- Governmental control policies, such as taxes and fees,

- Infrastructure investments, such as investments in a new road or railway,

- Strategic business related strategies, such as changing the location of a factory

Each TAPAS simulation scenario studies the effects of a certain set of measures on the supply chain. The output of TAPAS shows how supply chain actors are assumed to react to the above measures. Thus, the users of TAPAS can interpret the results and make more informed decisions and consequently avoid undesired effects. The main outputs of TAPAS simulation are described below (Davidsson et al, 2008; Holmgren et al, 2007):

- Economic effects, such as costs for fuel and taxes

- Logistic effects, such as route and mode choices

- Environmental effects, such as different types of emissions

The selection of TAPAS as the study case is made due to the fact that TAPAS is an implemented transportation simulation system without any visualization. Thus, it is possible to study how difficult and time-consuming the interpretation of the results can be without visualization especially for non-expert users. The idea is to explore the obstacles such users

face in interpreting the results of simulation, and how the visualization can help overcome the challenges of data analysis.

There are some terms often used in the TAPAS documentation, and therefore in this research as for example (Holmgren et al, 2012a):

- Node: A node represents different kinds of actors in the transportation chain, for example: customer, producer (a factory), or a connection point (terminal)

- Transportation mode: A transportation mode indicates the type of transportation (e.g. road, rail, or sea)

- Link: A link is a directed connection between two nodes. A link can have exactly one mode of transportation. However, several links between two nodes which differ in their transport mode can exist.

3.1 Requirements analysis

This section examines the requirements of users who want to view the results from a transportation system simulator in a visual representation. The first step seeks to understand the problems users experience regarding readability and usability of TAPAS output, and how a visualization tool could help them. In addition, we need to know the type of target groups which potentially can use TAPAS, because their needs are considered in the design process of the visualization tool of TAPAS. This can be achieved through conducting interviews with TAPAS users who are mostly expert in the field of transportation.

TAPAS can have two types of users. The first group relates to public authorities, which are interested in predicting the impact of their decisions whilst fulfilling the governmental goals, e.g. emission targets. The second group concerns the private companies and other stakeholders of transportation and production, which wish to enhance their profit. As a result, different type of users may intend to apply different measures. For example, public authorities are more interested in the first group of measures (i.e. governmental control policies), while enterprises are more eager to predict the effects of their business related decisions (i.e. changing the location of a factory) for profit related purposes. However, enterprises might be also interested in monitoring the effects of a new transport policy (Holmgren et al, 2012).

For purposes of this research, in addition to the previous user groups, transportation simulation experts (e.g. developers of TAPAS) are considered as users. They can also be seen as TAPAS users, because of the fact that they enter various scenarios to the system and run simulation several times to generate simulation results.

Hence, we can categorize TAPAS users from a different perspective:

- Expert users, usually the analysts and researchers which run the simulation system and analyse the simulation results.

- End users, usually decision makers in both public authorities and companies.

Each type of users has their own concerns and expectations from the system. In order to identify specific user needs, interviews are conducted with expert users of TAPAS. The interviews aim to define the user requirements and discover probable problems which TAPAS users face without visualizing the results. The questions of the interview are listed below:

1. What is the specification of TAPAS output? Which data is important to visualize?

2. How do you get output data from TAPAS? Is there currently any visualized output or not?

3. What are the major problems in the process of monitoring the results of simulation which cause difficulties and interrupts your work?

4. How much time do you spend as an outcome of above problems?

5. Can visualization help you in understanding the results? If yes, what is your suggestion for design of a visualization model?

Furthermore, two web-based questionnaires for potential end users are used in order to understand their special needs and interests with respect to the transportation simulation visualizer. The aim of the first questionnaire was to demonstrate the idea and some initial mock-ups of the tool to the end users. The second questionnaire was sent to 12 potential end users, after a short demo of the semi-final version of the tool.

The interviews with expert users reveal that a major problem for TAPAS users without a visualization tool is that the whole process of designing visible outputs from TAPAS is quite time-consuming. The interviewees agree that visualization can help TAPAS users to have a better and clearer understanding of the results. They had also some suggestions for visualizing. Full details of the expert users' answers to the interview questions can be found in (Hajinasab, 2011). Based on the interests of users regarding visualization of output, the important outputs to be visualized can be categorized as below:

1. Route choices (e.g. percentage of different routes)

2. Mode choices (e.g. percentage of different modes)

3. Transportation per link (e.g. number of vehicles per link)

4. Amount of emissions per route (e.g. CO_2)

5. Transport cost (per route)

The interview study further suggests for a need that visualization in TAPAS facilitate the process of analysing simulation results. Furthermore, the interview provides an initial idea regarding the requirements of the users with respect to visualization of output.
In order to find out which type of simulation data the end users are interested in, we used the knowledge extracted from the previous studies and the interview with expert users to suggest

possible data which they may be interested in. Sample examples and mock-ups from our design solutions are used in order to obtain the interviewees' opinion regarding their preferences for the information of simulation and how the final visualization tool should look like. The aim of these questions is to gain the users' opinions on the importance of showing information related to each route or each link in the transportation network. The respondents appear interested to have information related to each route.

As a conclusion of the user studies, the requirements of users can be categorised as follows:

- Req1. Showing input and output of simulation: We can conclude from the interviews that both expert and end users are interested in a visualization tool and they believe such system could facilitate their work. Also, they prefer to see which input (transport policy measure) results in a specific output; just visualization of simulation output is not deemed meaningful for them. Thus, we conclude that visualization of the input related to each output is also important for users.

- Req2. Showing different scenarios concurrently: Both types of interviewees would like to be able to see several different scenarios at the same time. They found this to be useful when comparing various scenarios and their related output. They also believe that this feature can help them in evaluating the output results and facilitate the decision making process.

- Req3. Showing simulation information based on links and routes: Furthermore, interviewees had some suggestions for which output is more meaningful to be visualized and which not. We can also conclude that they need to see information related to both links and routes.

3.2 Design Features and Functionalities of TAPAS Visualization Tool

Due to the fact that the design decisions could not be discussed with users just by explaining theories, we have designed several mock-ups of the visualization tool. A mock-up helps users imagine the real system and facilitate the process of designing functions and features of the visualization tool. Thereby, the mock-ups are designed in several steps based on the spiral method in order to obtain the feedback from expert and end users. Some of the initial results of the tool are presented in (Hajinasab et al, 2012)

Based on the user studies, the proposed User Interface of the TAPAS visualization tool can have two Tab Views; Link-based view and Route-based view. A simple sketch is produced as the first step. The relevant information of each category can be displayed in their related tab. During the discussion with users and by presenting the mock-ups, we could make valuable design decisions, such as the way of demonstrating different transportation modes.

For displaying the route choice, the best solution based on previous work and user feedbacks is via the use of a graph. To put it simply, the proposed solution displays each origin and destination as a node of the transportation graph. For illustrating the percentage of using each route (e.g. the amount of ton/route), the solution could be drawing edges between nodes with different thicknesses. As a result of this visualization feature, the user of TAPAS can easily discover which route is used more frequently than others.

As the next step, based on these main features of visualization system, we designed a more complete sketch. We also used this sketch for preparing the end-users' questionnaire.

In order to provide the user with an ability to make a comparison between different scenarios, the user can select a specific scenario at first when the program runs; following which the information related to this specific scenario is shown.

In the light of user requirements, we propose to visualize information of each main output (Cost, CO_2, Transport work) and allow users to select the desired information from the right side bar in the Figure 2. In link-based view, the cost (or CO_2, load) information for each link is shown above each link. In addition, different edge styles are used to exemplify the various transport modes of links, while, the cost (or CO_2, load) information of each route is illustrated in route-based view. We can also, highlight the selected route. We have a graph in the right bottom corner of the Figure 2, which shows and compares the cost related to all routes. A set of final mock-ups of the proposed design is shown in Figure 2.

In general, main functionalities of the system, regarding user requirements and based on the previous studies in information visualization are designed as below:

- Show as a graph: Using colour, edge thickness, edge styles to differentiate links and routes; to show the simulation results.

- Draw charts: to illustrate data and make comparison between different scenarios.

- Link and route-based information on Graph: Showing information of cost, emission and amount of transport work on each link and route.

- Interactivity: The interactivity of the visualization toolkit empowers users to explore implications of different simulation scenarios and engages them in what-if- reasoning.

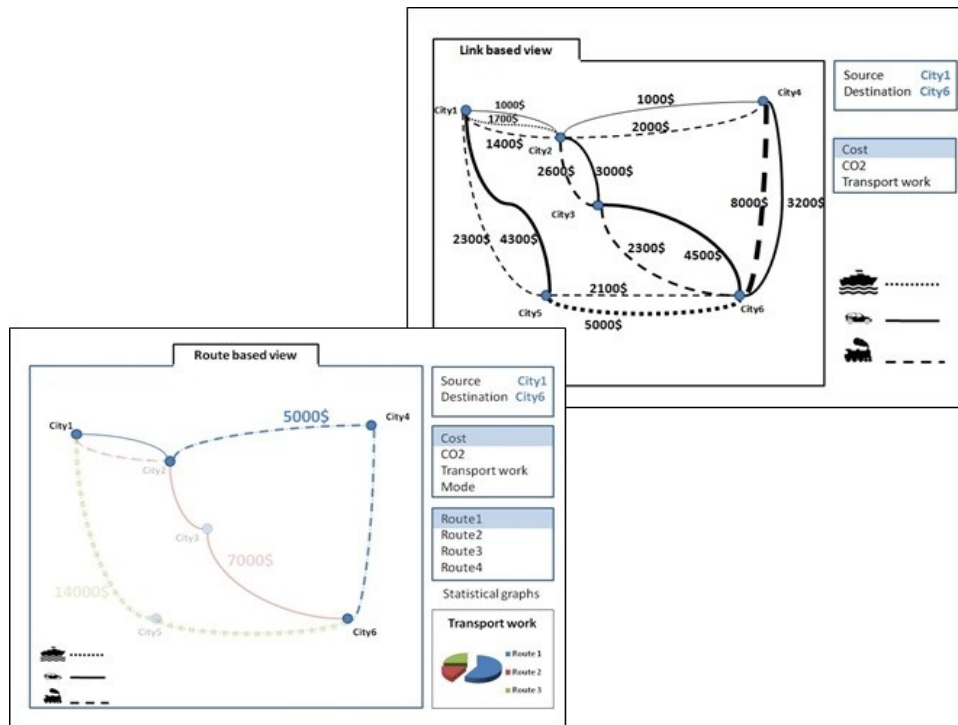- Add a map as background: to increase usability and readability of the transportation data.

Figure 2 – Final mock-ups of the link-based and route-based view in the proposed design of the interface

3.3 Development of visualization module

TAPAS is implemented using the Java language, so it would be more integrated to use the same language for developing this tool. We have used Swing technology as an Application Programming Interface (API) for designing the user interface.

Another option would be to develop the tool on the top of the Google Maps API. The advantage of Google Maps API is that it can locate nodes on their spatial locations automatically so that we do not need extra classes and relations with graph drawing libraries to place nodes. However, the main issue is that we cannot use real positions in a real map for this tool. Because in some cases the positions of two nodes are very far from each other while some others are relatively close to each other, so if we use real coordinates in a real map it will decrease readability of the graph to a high extent. Thus, we need to customize the map and adjust the positions of the nodes either manually or automatically in order to increase usability and readability of the transport graph. Another problem of using Google maps API is that it contains too much information. This in turn makes it difficult for users to see the simulation results on the map. Furthermore, there are some limitations in using Google Maps API for this tool. For example, we need to use other classes and libraries to draw charts and other parts of the tool, which is not possible by using Google Maps API.

For implementing the graph drawing part of the tool, the JUNG library[1] is regarded as the most suitable solution. JUNG library, Java Universal Network/Graph Framework, is a software library that provides a common and extendible language for the modelling, analysis,

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[1] "JUNG - Java Universal Network/Graph Framework" Internet : http://jung.sourceforge.net/

and visualization of data that can be represented as a graph or network. This selection is motivated due to the fact that JUNG is well-documented, easy to use, and well-supported.

A part of the visualization tool, consists of drawing charts and diagrams which has been implemented using the JFreeChart library.

Both input and output (i.e. simulation results) from TAPAS sit in a database. In order to access this database and retrieve desired data from the database, we used PostgreSQL and SQL queries. To explore the database, we have used pgAdmin III, which is a PostgreSQL administration and management tool.

The procedure of developing the functionalities of the visualization module is described as follows:

In order to show data in a graph, we use JUNG library and we draw the graph based on the information from the database. Several queries have been designed to obtain the desired data and draw the graph based on the retrieved information.

We have designed the first form of this tool in a way that the user can open several windows for each scenario. It means that, at the first stage of visualization tool, the user can select the scenario name, and then the second stage which contains the related scenario will open. This enables users to go back to the first form and select another scenario, while the first selected scenario is still open, and thereby draw a comparison between the charts of two or more scenarios.

For illustrating the information on each link, we retrieve different information (cost, CO_2, and load) related to the links from the database. Then, we send this data to the Graph Listener to present them in the graph. This Listener will activate whenever the user pushes the related button of each data to show related information on each link. It can support interactivity of the visualization module. A sample screenshot of the link-based view is shown in Figure 3. The figure illustrates the amount of CO_2 emission related to each link in the transport network. The data which is presented in the following diagrams is coming from the EastWest Transport Corridor II[2] project (Holmgren et al, 2012b).

For the purpose of illustrating the route-related information in the route-based view, more complex queries have been designed. Furthermore, a chart is drawn to compare the information for all routes of a scenario with each other.

One screenshot of the route-based view is shown in Figure 4. The charts are drawn in the route-based view, because the charts are supposed to compare the information for all routes of a scenario to each other.
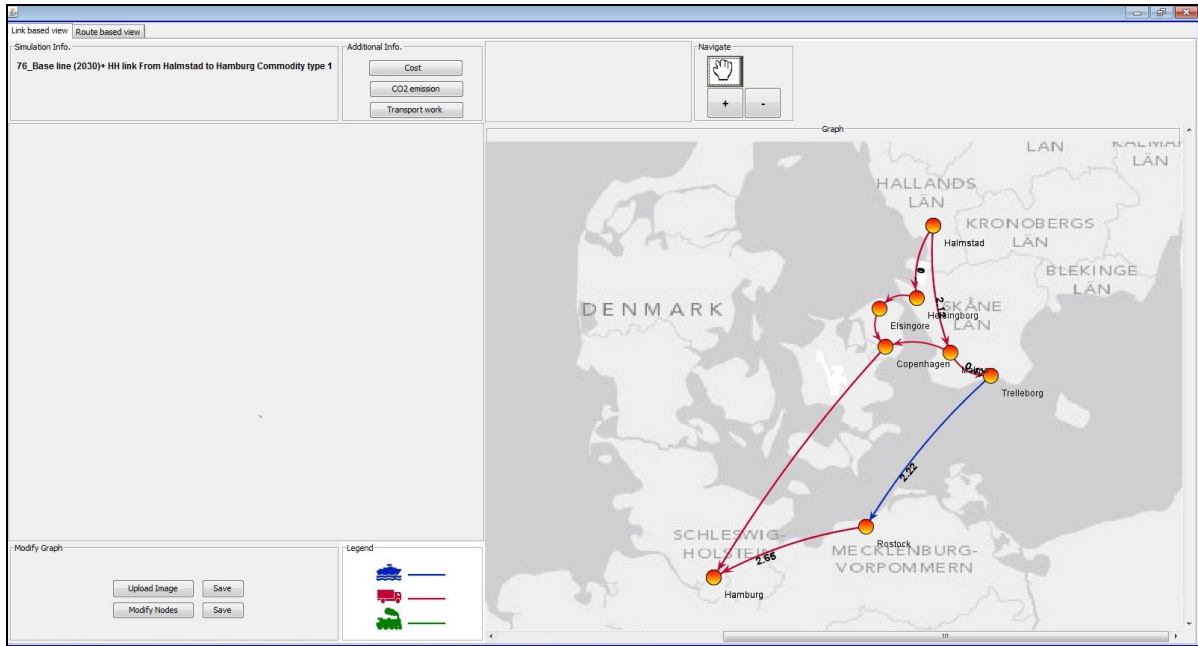
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[2] http://www.ewtc2.eu/

Figure 3 – Sample screenshot of the link-based view for a specific scenario

We also enhance the module with an ability which enables user to select an image and upload it as background for a specific scenario. Then for the next run of the visualization tool, the tool shows the right background which is selected and uploaded by the user for each scenario. The benefit of this feature is that in case of existence of two nodes which are too far from each other, the user can customize the map and cut the empty gaps between the nodes and upload it as a new background for the current scenario. This tool also has the capability to move the nodes and change their location on the map. In this case, the user can upload a map and check if the positions of nodes on the map are suitable or not. Then, he/she can adjust the nodes' places by moving nodes until it reaches a desirable position.
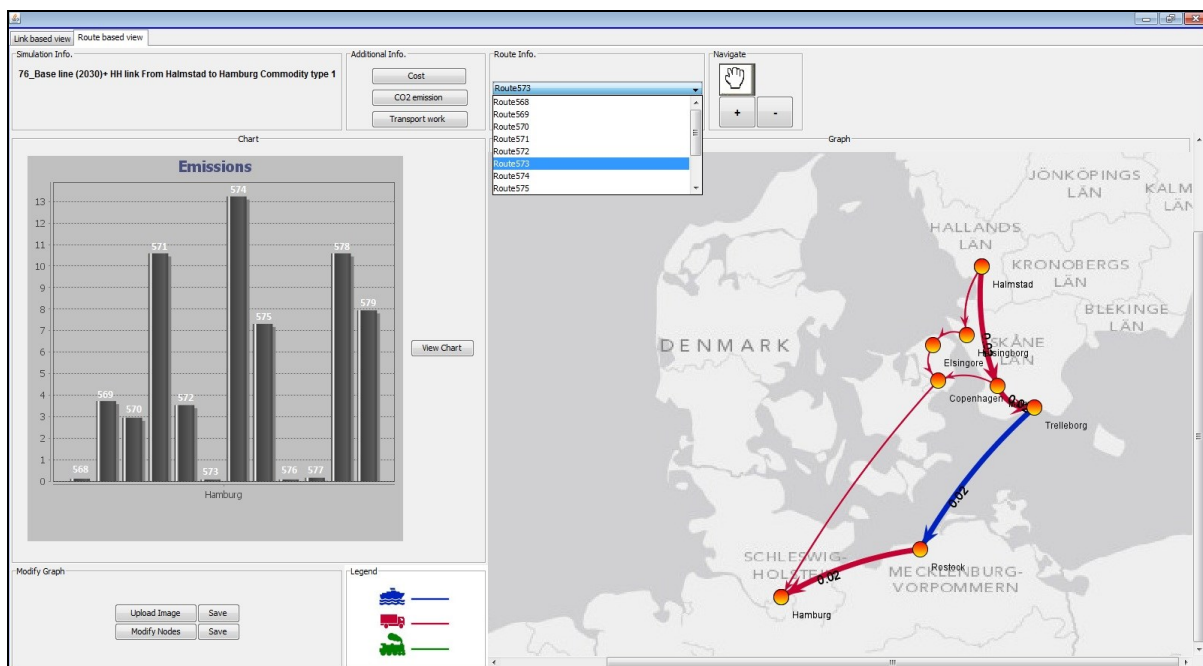

Figure 4 – A screenshot on the interactive tool for visualization of transportation simulation data, showing route-based view of a specific scenario

13th WCTR, July 15-18, 2013 – Rio de Janeiro, Brazil

Based on the feedback from the users, we also designed a set of complementary diagrams, illustrating the aggregated results of several simulation runs of each simulation scenario. In this example simulation study, we have 5 different simulation scenarios and for each scenario there are more than 25 simulation runs. In the below diagrams (Figures 5a, 5b), the aggregated simulation results for two sample scenario are illustrated. The diagrams show how transport work distribution over the transport corridor will change in different simulation scenarios. Figure 5a illustrates the current situation (2010) scenario, while Figure 5b is showing the Base line (2030) scenario where a distance-based road charging of 0.15 Euro/km for heavy trucks in the EWTC region is introduced (Holmgren et al, 2012b). The user can understand from the diagrams that by applying the specified distance-based road charging in 2030, how the amount of transport work will change, e.g. the load on the truck link between Kaunas-Klaipeda will considerably increase or the load on ferry link between Trelleborg and Rostock will slightly increase.
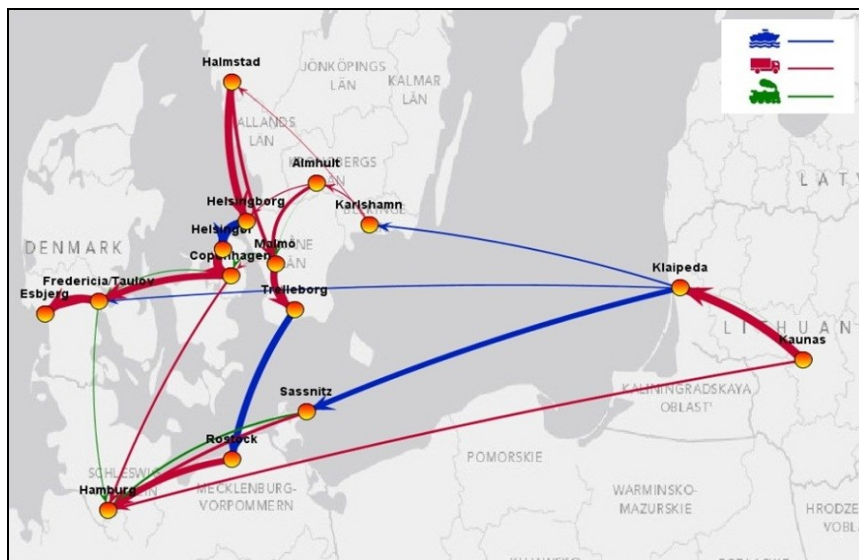

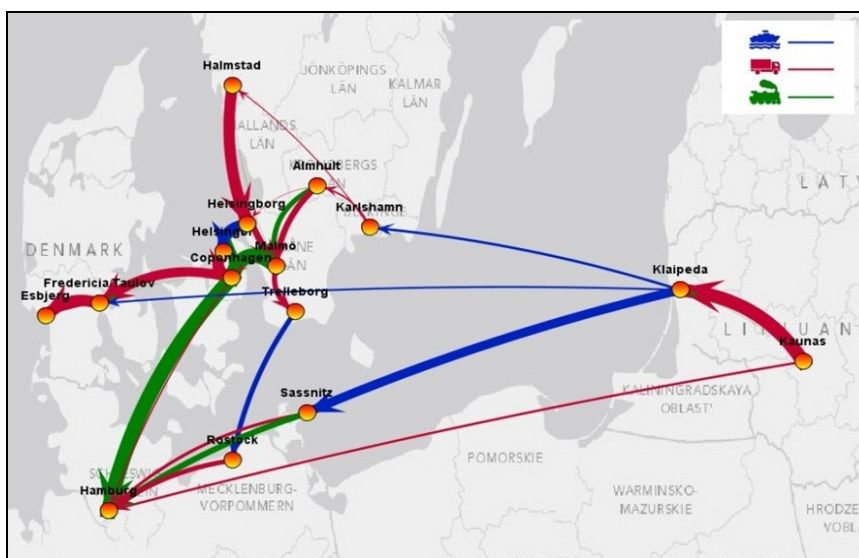Figure 5a – Visualization of simulation results for "Current situation" scenario

Figure 5b – Visualization of simulation results for Base line (2030) scenario with a distance-based road charging

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4. EVALUATION AND USER FEEDBACK

To investigate how the system can help decision makers to use simulation results more effectively, we did an evaluation by presenting the system to the users and asking for feedback through a questionnaire. According to the results of the questionnaires, the users found the diagrams showing aggregated results related to all simulation scenarios very useful. They are also more interested to see the simulation results for each route rather than links; even though they expressed that link-based data can also be useful in some special cases. All the respondents think that a visual representation of simulation data is definitely more useful than the current non-interactive and paper based solutions (e.g. tables and Excel sheets) for communicating the simulation results. Furthermore, the participants were mostly satisfied by the organization of the information and the interface of the visualization toolkit. They have also some suggestions for improving the visualization toolkit e.g. the use of colours in the bar charts and the possibility to make the scenario of their own by using the visualization toolkit.

Based on the positive feedbacks received during presentation of the module for users and from the questionnaire, we believe that the results from this study and the preliminary version of the visualization module can lead to future developments of visualizing the transportation simulation data for related stakeholders.

To increase the validity of research we have selected different methods to collect data and observe facts. Several interviews with users, experts, and the TAPAS development team are also conducted. In addition, the published documents of TAPAS; including the real data of database are reviewed and triangulation is used in this study's quest to discover relevant facts.

5. CONCLUSION

Visualization techniques can be used to increase the readability and usability of transportation simulation systems. To investigate how visualization can be applied to transportation context, we studied TAPAS as a real case and tried to specify user requirements related to visualization, design appropriate functionalities, and develop a visualization tool for TAPAS.

As an overall conclusion and in the light of our findings from the TAPAS case; firstly, visualization related requirements of users are identified and analysed for each group of users. Then the visualization capabilities are applied to each requirement. In the next step, the main features and functions to visualize outputs of system are designed. Finally, visualization tool is developed and is evaluated by system users to ensure that the developed tool can satisfy user's requirements.

In future, we plan to further evaluate functionality and usability of the tool to find out if the visualization tool can contribute to readability and usability of results.

A possible future improvement of the visualization tool can lie in investigating methods and techniques for visualizing input of TAPAS in order to be able to design the simulation scenarios using the visualization tool.

Furthermore, we can complement this user study further by investigating different decision-making methods in transportation field to understand how decisions in the transportation context are usually made. This has the potential to help design more effective and usable visualization models.

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