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# INNOVATIVE MEANS OF CARGO TRANSPORT: A SCALABLE METHOD FOR ESTIMATING REGIONAL IMPACTS

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**Abstract**

The integration of innovative means of transport, like the Hyperloop concept, cargo drones and cargo zeppelins, into existing transport networks presents a challenge not only from a technological point of view, but also has various economic, social, and ecological impacts. Therefore, this work estimates regional impacts of a connection utilizing innovative means of transport. The presented scalable method is not limited to a specific type or number of regions, but capable to estimate the impacts of large-scale transport networks covering a great number of diverse regions. The work contributes to quantitative transport network modelling, as it provides a method for the quantification of essential regional impacts, which can be incorporated into comprehensive transport network models. The applicability of the method is demonstrated with a real-life example. As a result, values of an impact indicator for selected international regions are available for a set of innovative means of transport.

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*Keywords:* transportation network analysis; regional impact; cargo drone; Hyperloop; cargo zeppelin

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## 1. Introduction

Transport logistics is subject to constant change and has to react to transforming business requirements and environmental challenges. In addition to the need to reduce greenhouse gas emissions, various trends in transportation and supply chain management require new solutions for cargo transport (Speranza, 2016). In the last years, new transportation technologies have been developed, which promise new solutions for cargo transport. Cargo drones and cargo zeppelins open new possibilities for air transport (Bambury, 2015, Prentice and Knotts, 2014). At the same time, there are advancements with respect to land-borne transportation technology, like the Hyperloop concept presented by SpaceX (Hyperloop One, 2017) or the Cargo Sous Terrain concept, which might be implemented in Switzerland until 2030 (Cargo Sous Terrain, 2017). At the moment lots of research is devoted to technical aspects. However, the integration of new transport systems into existing transport networks presents a challenge not only from a technological point of view, but also has unknown economic, social, and ecological impacts on our living spaces (Berechman, 1994, Nijkamp and Blaas, 2012). Before new technologies and infrastructures can be integrated into the existing transport networks, potential impacts should be determined on a scientifically sound basis. Infrastructure investments often revive regions as they provide a better foundation for attractive industries, leading to more jobs and population growth (Aarhaug and Gundersen, 2017). Besides economic effects, a variety of socio-environmental effects should be considered as well (Amiri-Khorheh et al. 2015). For instance achieving transportation equity, i.e., a fair distribution of the benefits and costs of transportation investments over all members of society, is an ongoing challenge (Karner, 2016). Thus, this research aims to answer the following question: How can regional impacts of a connection utilizing innovative means of transport be estimated? This paper presents a scalable method, which is not limited to a specific type or number of regions, but capable to estimate the impacts of large-scale transport networks, which cover a great number of diverse regions. The work directly contributes to quantitative transport network modelling. It provides a quantification of essential regional impacts, which can be incorporated into comprehensive transport network models.

## 2. Method

This work develops a method to support a solution to the aforementioned problem in the field of freight transportation and demonstrates the applicability with a real-life example. The estimation of the regional impact of a transport connection which utilizes new means of transport follows the logic of a simple model (see Figure 1). The model describes a transport network consisting of nodes linked by edges. Traffic flows along an edge by employing a means of transport. Each edge is assigned to a region, i.e., a geographical area with a set of characteristics. An edge has an impact on its region, which is dependent on the edge's means of transport and the region's characteristics. This reflects the assumption that general strengths and limitations of an innovative means of transport should be considered in a regional context to evaluate regional impacts. This work does not address other related aspects, such as technical feasibility, costs in relation to benefits, and risks.

The developed method comprises four steps. In the first step effects on the elements of a transport system, when integrating innovative means of transport and related infrastructure, are identified. These effects, not yet quantified, can generally explain impacts of a transport connection, i.e. of a transport network's edge. In the next step information about innovative means of transport is compiled. A group of experts in the field of transport innovation assess relevant capabilities for promising means of transport. This information is used to estimate indicators for the effectivity of different means of transport in supporting the identified effects of integration. The following step determines region-specific characteristics, derived from an analysis of publicly available statistical data. Based on this information indicators for the region-specific potential of the effects of integration are estimated. In the last step, a multidimensional impact analysis is conducted to evaluate economic, social, and ecological impacts. Based on the effects identified in the first step and under consideration of the indicators estimated in the second and third step a quantitative estimation of the impact of a transport network's edge using innovative means of cargo transport is conducted. Figure 1 illustrates the described framework for estimating regional impacts.

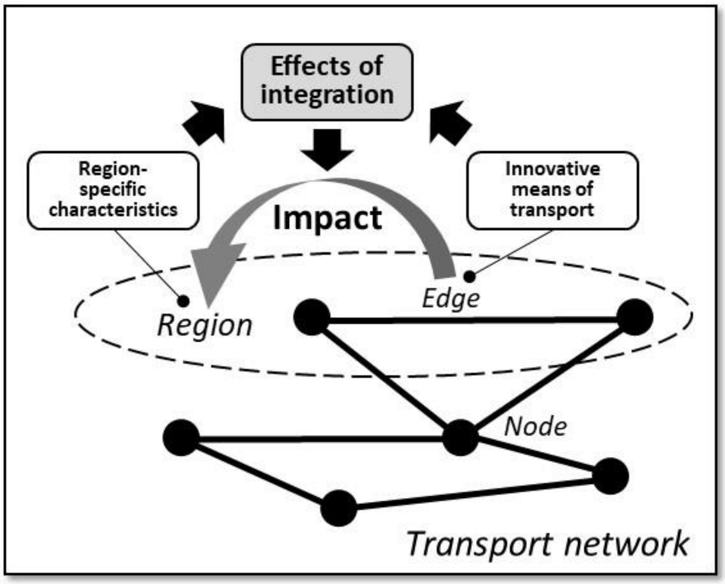


Fig. 1. Framework for estimation of regional impacts.

## 3. Results

Based on the Trans-European Networks, we selected international regions with particular relevance to Austria. For these regions, the impact of innovative means of cargo transport is evaluated following the method presented above. As a result, values of an aggregated impact indicator for a transport network including the nodes Bratislava, Brno, Budapest, Graz, Linz/Wels, and Vienna are available for the Hyperloop, cargo zeppelin, and Cargo Sous Terrain, as well as for combinations with cargo drones. In the following sections, the application of the four steps mentioned above is presented in detail.

### *3.1. Effects of integration*

The integration of innovative means of transport into an existing transport system will affect the system's elements. Following Holderied (2005) we define the major elements of a transport system (see Figure 2). Transport supply meeting transport demand results in transport performance, which is driven by technology and affected by environmental elements, such as economy, society, natural environment, and politics.

Based on literature and logical conclusions we identify possible effects of the integration of innovative means of transport on transport system elements (see Figure 2). Effects on the economy are caused by new transport opportunities, when they help to tackle the following three effects popular in transportation literature (Kummer, 2006, Aberle, 2009). The "goods structure effect", i.e., the decline of low-cost bulk goods in favor of high-value consumer and investment goods, leads to more individual transports with smaller units and higher value. The "logistics effect" is driven by modern logistics concepts, like synchromodality (Prandtstetter et al., 2016) and stimulates demand for generally more flexible and reliable transports, which are well integrated in the value chain's processes. According to the "quantity of goods effect", a lower depth of production leads to more division of labor and thus increases the demand for transport. Furthermore, the reduction of regional social disparities (e.g. differences in employment or income) can be achieved by a new transport connection bearing a consequent effect on society. Moreover, a shift to environmentally friendly modes of transport affects the natural environment positively (European Commission, 2011). New transport opportunities also allow to cope with the so called "integration effect", i.e., more transport performance resulting from a reduction of protectionist measures for production and sales markets (Kummer, 2006, Aberle, 2009). Facilitating international orientation and globalization, this clearly influences politics. Finally, the element technology is affected if a new means of transport can use digitalization as key enabler for the reliable and sustainable transport of goods (Kagermann, 2015). The choice of effects is considered sufficiently comprehensive covering aspects of economic, social and environmental dimensions. It is also justified by data availability, which allows efficient impact analyses for various regions.

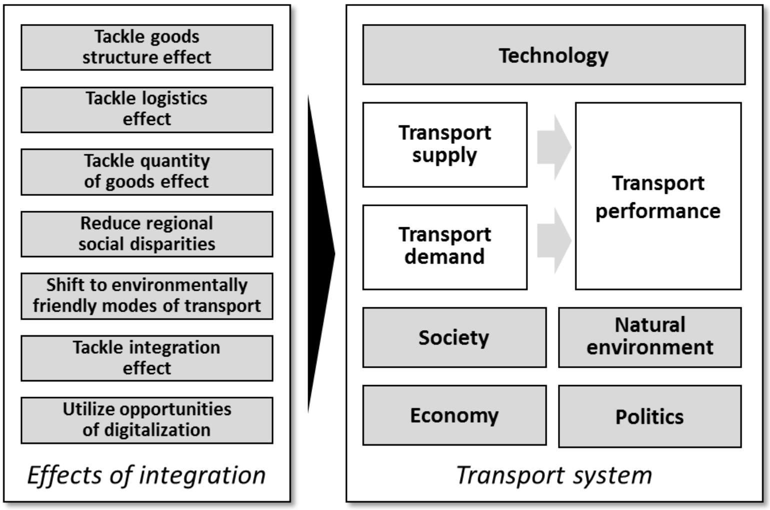


Fig. 2. Effects of integration on elements of transport system.

### 3.2. Innovative means of transport

Driven notably by the pressure to meet higher environmental standards and to increase efficiency and quality of transports, various concepts for future cargo transport have been suggested. In our analysis we focus on two land-bound concepts, the Hyperloop and the Cargo Sous Terrain, and two airborne means of transport, the zeppelin and the drone. The Hyperloop comprises evacuated tubes through which a pod transports people or goods with high speed. A prototype is currently under development in the United States of America (Hyperloop One, 2017). Cargo Sous Terrain is a visionary Swiss system for the automated transport of pallets and purpose-built containers through tunnels between hubs in urban areas and other production and logistics locations (Cargo Sous Terrain, 2017). The concept of zeppelins, i.e., airships with a rigid frame that are filled with gas to float, are not new, but current initiatives demonstrate the potential for commercial transport of heavy cargo and containers (Prentice and Knotts, 2014). Another innovative means of air transport is drones, i.e., unmanned aerial vehicles, receiving attention as possible transport solution, e.g. for parcel delivery (Bambury, 2015). As the typical range and load capacity of drones differ from the other mentioned means of transport, a direct comparison is not appropriate. Therefore, a combination of drones for the local distribution with the aforementioned means of transport will be considered in the impact analysis.

For the considered innovative means of transport the relative effectivity in supporting the effects defined in Section 3.1 is determined. It should be noted that an estimation of the efficiency is not intended. The evaluation is done by interviewing a group of three senior experts in the field of transport innovation. Asked questions are based on the indicators listed in Table 1. For the seven effects 18 points per expert are distributed among the defined three means of transport and three combinations of means of transport. After normalizing, the resulting indicator represents the effectivity of a means of transport in supporting the effects of integration on a scale from 0 to 100.

Table 1. Indicators for means of transport-specific effectivity in supporting effects of integration.

| Dimension | Effects of integration | Indicators for of transport-specific effectivity in supporting effects of integration |
|---|---|---|
| Economic | Tackle “quantity of goods effect” | Contribution to cope with increasing transport volume due to the “quantity of goods and integration effect” |
| | Tackle “integration effect” | |
| | Tackle “goods structure effect” | Contribution to meet changing requirements due to the “goods structure effect” |
| | Tackle “logistics effect” | Contribution to meet changing requirements due to the “logistics effect” and digitalization |
| | Utilize opportunities of digitalization | |
| Social | Reduce regional social disparities | Contribution to reduce regional social disparities |
| Ecological | Shift to environmentally friendly modes of transport | Contribution to a shift to environmentally friendly modes of transport |

### *3.3. Region-specific characteristics*

A region in the context of the impact analysis is defined as geographical area in which an edge, i.e., a traffic connection under study, is located. The geographical areas are composed by the corresponding regions according the Classification of Territorial Units for Statistics (NUTS) on level 2 (European Union, 2011). The selection of nodes in this work is based on the Trans-European Networks (European Commission, 2013), whereby the edges between the node Vienna (Austria) and its neighboring nodes, Brno (Czech Republic), Bratislava (Slovakia), Budapest (Hungary), Graz (Austria), and Linz/Wels (Austria), are considered. Three other edges (Linz/Wels - Brno, Brno - Bratislava, Bratislava - Budapest) are considered as well.

Region-specific characteristics are determined by using publicly available statistical data provided by Eurostat (2017). For each of the regions the potential of the effects when integrating innovative means of transport, as defined in Section 3.1, is rated on a scale from 0 to 100 based on suitable indicators (see Table 2). The relative increase of road transport, measured through the change of tonne-kilometer in four years, is used as indicator for the potential of the “quantity of goods effect” and the “integration effect”. The share of employment in the high-tech industry is used to describe the potential of the “goods structure effect”. An indicator for the potential of digitalization and the “logistics effect” is the share of companies having business processes automatically connected with suppliers and/or customers. Regional social disparities are quantified as absolute regional differences of unemployment rates. The share of road traffic based on tonne-kilometers explains the environmental unfriendliness of the modal split.

Table 2. Indicators for region-specific potential of effects of integration.

| Dimension | Effects of integration | Indicators for region-specific potential of effects of integration |
|---|---|---|
| Economic | Tackle “quantity of goods effect” | Relative increase of road transport, measured through the change of tonne-kilometre in four years |
| | Tackle “integration effect” | |
| | Tackle “goods structure effect” | Share of employment in the high-tech industry |
| | Tackle “logistics effect” | Share of companies having business processes automatically connected with suppliers and/or customers |
| | Utilize opportunities of digitalization | |
| Social | Reduce regional social disparities | Absolute regional differences of unemployment rates |
| Ecological | Shift to environmentally friendly modes of transport | Share of road traffic based on tonne-kilometres |

When a region consists of more than one NUTS-region, an average of the indicator value is calculated. Indicators are normalized with the respective maximum value of all NUTS-regions of the European Union.

### *3.4. Regional impact*

Finally the regional impact of a transport connection is estimated. The impact is generated by the identified effects of integration. The transport connection runs through a specific region and utilizes a particular innovative means of transport. The characteristics of the region determine the potential of the effects of integration. The realization of the potential is dependent on the capabilities of the means of transport, which determine the effectivity in supporting the effects of integration. For each of the seven effects (identified in Section 3.1) the actual impact on the region is calculated as product of the effectivity of the means of transport in supporting the effect (indicator from Section 3.2) and the region-specific potential of the effect (indicator from Section 3.3). The average of all effects is calculated and normalized, so that the resulting value indicates a positive regional impact of an edge for a given innovative means of transport or combination of means of transport on a scale from 0 to 100.

Figure 3 shows the results of the impact analysis. It can be seen that the same means of transport has a different regional impact dependent on the region it operates. It is also worth mentioning that in most cases a combination of Hyperloop, zeppelin or Cargo Sous Terrain with drones lead to a higher positive regional impact. This reflects the assumption of experts that a transport connection may benefit from utilizing drones for local distribution.

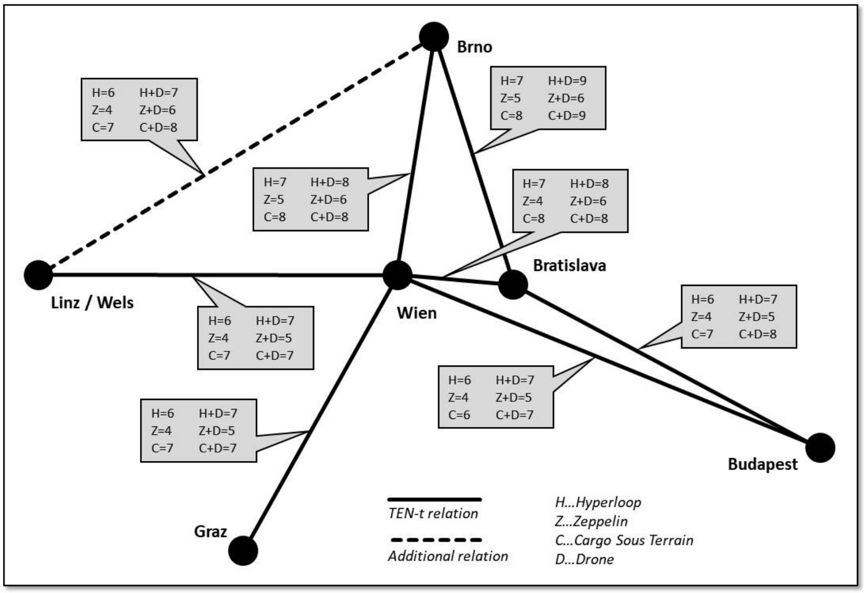


Fig. 3. Results of impact analysis.

## 4. Conclusion

The work presents an approach to evaluate the impact of innovative means of cargo transport, i.e., Hyperloop, cargo zeppelin, Cargo Sous Terrain, and cargo drone, on regions with particular relevance to Austria. The evaluation takes various effects into account and is based on statistical data and expert appraisal. Results should not be understood as recommendation for implementing such visionary means of transport in one of the regions under study nor for rejecting them. Clearly, for a comprehensive evaluation many other factors should be considered including economic, technical and legal aspects for instance. However, the presented approach can support two important activities. Firstly, it can play a role for the preselection of scenarios subject to detailed analysis. Secondly, the work can contribute to quantitative transport network modelling and provide a quantification of essential regional impacts as decision-making parameter. This work illustrates the practicability of the approach. A significant advantage is that the applied statistical data is available for virtually all European regions (and similar data for other world regions), allowing an easy application. For that reason the approach is scalable, i.e., not limited to a specific type or number of regions.

Despite the relevance and practicability of the approach, it has its limitations. Expert estimation of the effectivity of innovative means of transport is subjective, i.e., different experts do not necessarily come to the same or similar results. Moreover, it must be guaranteed that the choice of effects on the elements of transport system is appropriate and does not neglect relevant effects. Ideally, the results of the impact analysis should be empirically validated. However, possibilities are limited because of the lack of real-life implementations for the time being. As always, limitations may lead the way to further research.

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