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ORIGINAL PAPER

ANALYSIS OF AUSTRIA'S LAND AND MULTIMODAL TRANSPORTATION

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ABSTRACT. **Background:** In the last decade, the total volume of freight transport has grown, partly due to the transportation of consumer goods. Multimodal transportation has been named in various publications as a solution. As a landlocked country in the middle of Europe, Austria has to bear more negative consequences of freight transport than other European countries. This study analyses the present situation of Austria's freight transport systems and compares it with the other 27 EU countries. This paper also looks for new methods in logistics, to get the problem of increasing demand for transport under control. On this basis, this paper tries to make recommendations for strategic future transportation development in the country.
Methods: This study is based on the analysis of both scientific literature, and on official publications of the logistics sector in Austria. Publications of European and Austrian statistical material have been used to compare the transport situation in the other European Union member states and Austria.
Results: Austria's usage of railways is already above average in the EU. On the other hand, waterway transport is below average. Intelligent exploitation of the River Danube could induce an important shift from road transport to cheaper and more environmental friendly river transport. New ways of managing traffic flow and increasing road safety are under development in logistics, although their implementation depends on the costs incurred.
Conclusion: By shifting a proportion of road transportation onto Austria's main waterway, the River Danube, pressure on the environment and traffic flow could be improved to a certain extent. The digitalization of logistics and the introduction of computer-driven road transportation systems, such as platooning and autonomous driving, and multimodal transportation may be useful ways to relieve the situation on the main roads, and to prevent an increase in traffic jams, exhaust emissions and the risk of accidents. Further research and practical tests will be necessary to reach market readiness and cost efficiency.

Key words: multimodal transportation, Austria, River Danube, platooning, autonomous driving.

INTRODUCTION

Globalization has increased, and continues to increase, the volume of international transportation. One of the most important aspects of an economy is global trade [Gopal, 2006]. Alongside traditionally traded goods, such as raw materials, wholesale goods and agricultural produce, the current increase in the need for international transportation has been brought on by the growing online trade in consumer goods. Packaging sizes and quantities are small, but the number of parcels has been growing rapidly, and all require transportation. At the same time, raw materials and semi-finished products for final manufacturing and assembly have to be transported within countries, over borders, and globally. The choice of the most effective mode of transport often decides the economic success or failure of a company. Hammadi and Ksouri [2013] define multimodal transportation networks as paths, different means of transport and interaction points or interchanges between networks, and describe the objectives in designing a system which is integrated into the existing infrastructure

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environment and fulfills the expectations of the users, while minimizing costs and waiting times. Whereas the book from Hammadi and Mekki focuses on passenger transportation, this paper will focus on the multimodal transportation of goods and its impact on Austria. For a small country in the middle of the European Union, transportation is an important economic factor but causes also serious ecological and political problems. In this paper, Austria's modal split in freight transport will be considered and compared with the modal split of the European Union to work out possible solutions.

GENERAL REQUIREMENTS FOR LAND AND MULTIMODAL TRANSPORTATION

The driving forces of a country or region are its transport infrastructure, the power of innovation and communication technology [Kummer, Badura 2010]. International or global transportation is reliant on many factors. These can be current political situations in the respective countries, security regulations, trade compliances and trade regulations and commercial terms or regulations about commodity responsibilities [Cook, 2012]. The main issues relating to mobility in freight transport are; the level of production and trade of the nation, the distance between the source of the raw materials, the site of production and the area in which it is sold, the intensity of foreign trade, the quality and quantity of infrastructure, the costs of transportation and, especially for transit countries, the geographical location of the country [Kummer, Badura 2010]. For a fast, functional global transport chain, a multiplicity of facilities is necessary. This includes roads, railways, sea and water routes, in particular air and water harbors, freight depots, transshipment hubs which are equipped with cranes, container terminals and efficient electronic software and communication systems. To run this infrastructure, including the means of transport, different sources of energy, such as electric power, gas, oil or water, have to be supplied.

MODES OF TRANSPORT

To transport commodities from one place to another, different means of transport are used. Means of transport operate on the road (trucks), on railway lines, on water (ships) or in the air (planes). Other possible modes of transport are pipelines, where oil or gas can be transported. In literature, modes of transport are categorized as monomodal, unimodal and multimodal traffic. Goods on monomodal transportation go directly from origin to destination without changing the means or mode of transport. Unimodal transport is based on general cargo with a single mode of transport. Multimodal transport is carried out on at least two modes of transport, for example road and railway. Intermodal transport is a sub-category of multimodal transport and focuses on the optimum and most economical method of transport [Kummer, Badura 2010]. The majority of transported goods are transported by road. The advantage of this method is flexibility, and the possibility to deliver quickly and directly between two points. The disadvantages are the high costs and the high risk of accidents. Actually, it is the most expensive method of transport for the national economy when external costs are taken into consideration, such as precautions for public safety, environmental protection and road maintenance. The longer the distance between origin and destination, the cheaper other transport modes and multimodal transport are compared to road transport.

ELECTRONIC SYSTEMS IN TRANSPORT

Digitalization in transport is already state-of-the-art. For cost calculation and evaluation of transportation, so called transport demand models (TDM) are used. These models have four priorities [Möller, Schroer 2014]:

- To generate the ideal trip (using demographic data of the countries and the quality of their transportation system, and the distance between origin and destination)
- Focusing on the distance between different pairs of zones
- Focusing on available transport modes
- Route assignment for using specific transport infrastructure.

New methods in multimodal transportation systems use communication technology and computer animated analyzing tools for traffic forecast and simulation. These programs are able to support four main components [Nuzzolo & Lam, 2017]:

- Real-time supply (based on costs, real-time and historical data)
- Real-time origin-destination flows (based on traditional models and real-time data)
- Real-time transit vehicle loads (based on a simulation of demand and supply)
- Origin-destination matrix (based on historical and real-time data)

Those intelligent transit systems should be able to shift passengers as well as commodities between different means of transport and transport routes in the shortest possible time in the near future. This is only possible with a comprehensive database, which includes routes, available means of transport with their particular capacity, costs, real-time data of the traffic situation and many other parameters.

LAST MILE CONCEPTS

For customers, reducing the cost of transport and increasing delivery speed is important. Because of the increase in online trading, traffic in urban areas is also rising. The so-called "Last mile" is a short but expensive part of transportation, especially if the receivers are end consumers. Logistic companies have to think about "last-mile" concepts, such as building decentralized local distribution centers where minimum quantities with short processing times can be ensured. Freight has to be separated into single parts, packed in parcels and addressed to different recipients. For this reason, high speed data infrastructure is also necessary, to provide all required data for every single parcel just in time. The distribution centre has to provide a suitable vehicle fleet. An optimum density of population in this area is 3000 to 5000 inhabitants, to keep costs to a minimum and ensure fast delivery times. Important characteristics for customer satisfaction are fast and flexible delivery, the possibility to return goods easily and a secure delivery procedure [Macharis, Melo 2011].

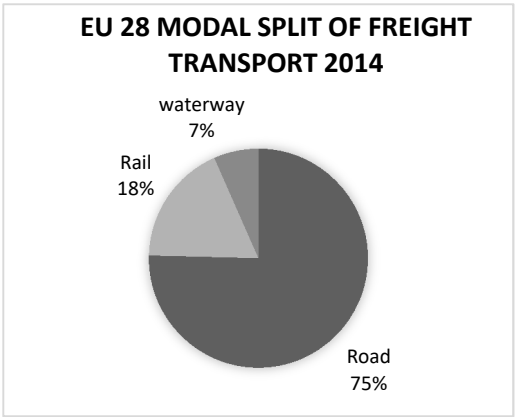
CRITICAL ASPECTS OF TRANSPORT

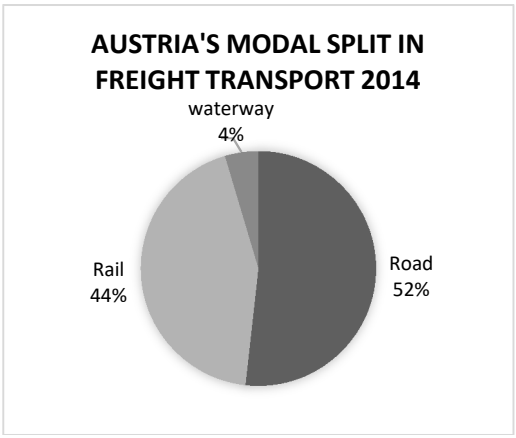
Critical aspects of transport, aside from the availability of the necessary infrastructure for affordable and competitive costs, are the fulfillment of legal requirements in the relevant country and environmentally friendly methods of delivery, to minimize the impact on the local population. Impact factors include traffic noise, exhaust gases or damage to transport routes. The transportation of dangerous substances such as chemicals or gases must be handled with particular care and requires specific equipment. Some food has to be transported refrigerated without interruption. Some countries have temporal bans on driving, to protect the population against noise at night or at weekends. Apart from technical and legal restrictions and requirements, the cost of transportation for the customer as well for the national economy should be as low as possible. A study commissioned by the German "Wasser- und Schifffahrtsdirektion Ost" [Planco Consulting GmbH, 2007] compared different transportation routes, and discovered that, in most cases, inland waterway transport is the least expensive form of transport, followed by rail, when only the business-driven performance is considered. When the national economic perspective is also considered, in every case waterway transportation is the cheapest. The primary energy consumption of railway transportation is about 50 percent lower than road transportation, compared to about 67 percent for waterway transportation. Both waterway and railway transportation are therefore cheaper and more environmentally friendly than road transport.

AUSTRIA'S FREIGHT TRANSPORT IN COMPARISON WITH THE EUROPEAN UNION'S

The total accumulation of freight transport in the European Union amounted to 2200 billion tons in 2013 [European Union, 2017b]. In 2014 the modal split of freight transport in the European Union was; 75% on the road, 15% on the railway and 7% on inland waterways. In comparison to the EU average,

in Austria, the modal split was; 52% on the roads, 44% on the railways and 4% on the waterways. These figures do not include air freight.





Source: Eurostat, 2017

Fig. 1. Modal Split comparison EU28 – Austria

Whereas the split between the three modes of transport in the European Union has been quite constant in the years 2001 - 2014, in Austria a significant shift from road to the railways can be seen.

Table 1. Modal split comparison EU and Austria

EU 28	**year**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
	Road (%)	74,8	75,5	76	76,1	76,4	76,3	76,3
	Rail (%)	18,8	18,3	18,3	17,9	17,7	18	17,9
	Water (%)	6,4	6,2	5,8	5,9	5,9	5,7	5,8
AT	Road(%)	65,9	65,8	67,4	65,6	64,1	63,2	60,9
	Rail (%)	29,6	29,3	28,7	31,4	32,8	33,8	34,8
	Water(%)	4,5	4,9	3,9	2,9	3	3	4,2
EU 28	**year**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
	Road (%)	76,3	77,5	76,2	75,6	75,3	75,5	75,4
	Rail (%)	17,9	16,6	17,1	18,3	18,1	17,8	18
	Water (%)	5,9	6	6,7	6,2	6,7	6,7	6,6
AT	Road(%)	58,6	59,5	56,3	56	54,6	52,8	51,7
	Rail (%)	37,4	36,4	39	39,9	40,8	42,1	43,6
	Water(%)	4	4,1	4,7	4,2	4,6	5,1	4,6

Source: Eurostat

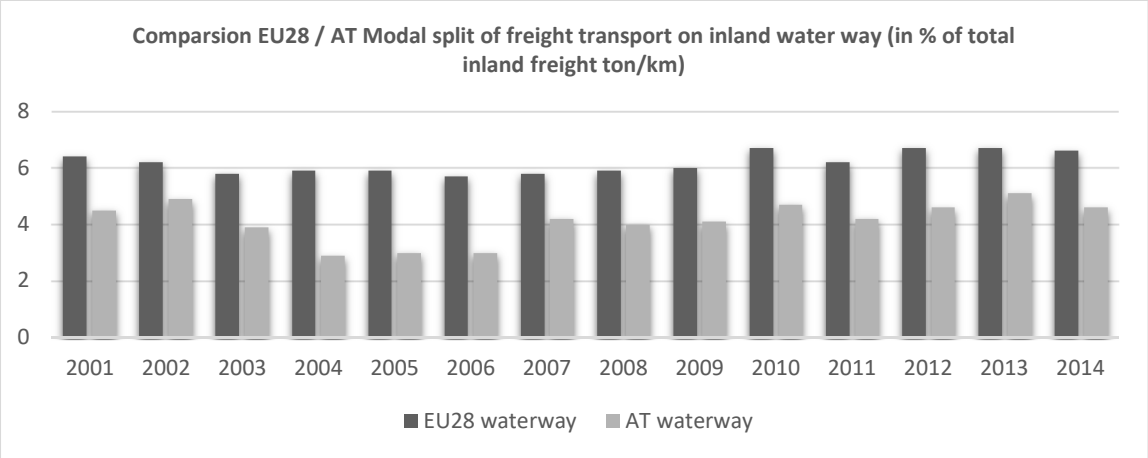
INLAND WATERWAYS

The most important waterway in Austria and the neighboring countries is the River Danube. It is about 2857 km long, from its source in the German Schwarzwald to the marine delta of the Black Sea. It crosses eight countries of the European Union (ten countries in total) and, in connection with the Rhein-Main-Donau Channel, is the most important European inland water transport route. The freight transport volume in 2014 on this route was more than 40 tons [NEWADA duo project consortium, 2016].

Inland water transport is cheap from the point of view of infrastructure maintenance, cost of transportation and protection of the population against negative environmental effects [bmvit, 2017]. Nonetheless, inland water transport has decreased in Austria in recent years. Between 2014 and 2015, water transportation along the river Danube decreased by 15%, to 8.6 million tons. One of the causes of this was periodic flooding. Other problems in water transportation can be low water levels or maintenance work on watergates.

According to the Danube Strategy, published by the European Union [European

Union, 2016], the River Danube has enormous potential. Only 10 percent of its possible potential is being exploited at the moment. Different European projects are working on harmonizing the area's hydrology and hydrography, and improving cooperation between neighboring countries.



Source: Eurostat, 2017

Fig. 2. Comparison EU28/ AZ Modal split waterway

RAILWAY TRANSPORT

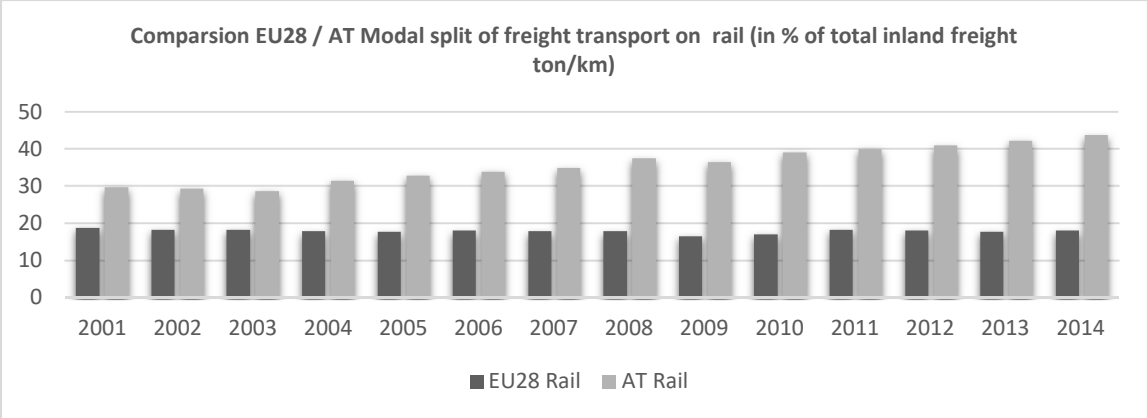
Austria has a rail network of 5568 km, 381km of which has narrow gauges, according to the Ministry of Infrastructure [bmvit, 2012]. According to Eurostat data, this figure was 5522km in year 2015.

The figures for the EU 28 are incomplete, because not every country reports their figures every year. But, assuming that the countries have not reduced their rail infrastructure, in the European Union there were about 214,305 km railways in 2015. What can be seen is that Austria's railway network has been slightly reduced over the last decade. This is due to the shutting down of small regional railways, or their reappropriation for the purpose of tourism. Nonetheless, in the European Union, 18 percent of transportation is carried out on railways. Austria is above average in this area, with the volume of freight transported by rail rising from 29% in 2001 to nearly 44% in 2014. A report by the Economica Institut [Helmenstein, 2013], which analyzed the situation of an Austrian private railway company, mentions general cost-coverage within the railway transport sector, and found that transport with single carriages costs twice as much as block trains. This is the reason, why private railway companies work almost exclusively with block train transportation. The cost advantage compared to truck transportation disappears with a route length of 250km and above. Below 100km there are significant price advantages compared to road transport. 15.2 % of Austrian Rail transport companies are private enterprises.

Table 2. Modal split comparison EU and Austria

	2004	**2005**	**2006**	**2007**	**2008**	**2009**
EU 28	170280,5	210888,3	143829,27	221742,37	218061,1	217565,8
Austria	6256	6256	6256	6256	6256	6256
	2010	**2011**	**2012**	**2013**	**2014**	**2015**
EU 28	223152,67	211356,32	207247	223280,7	220037,6	214305,2
Austria	5828	5500	5566	5531	5531	5522

Source: Eurostat



Source: Eurostat, 2017

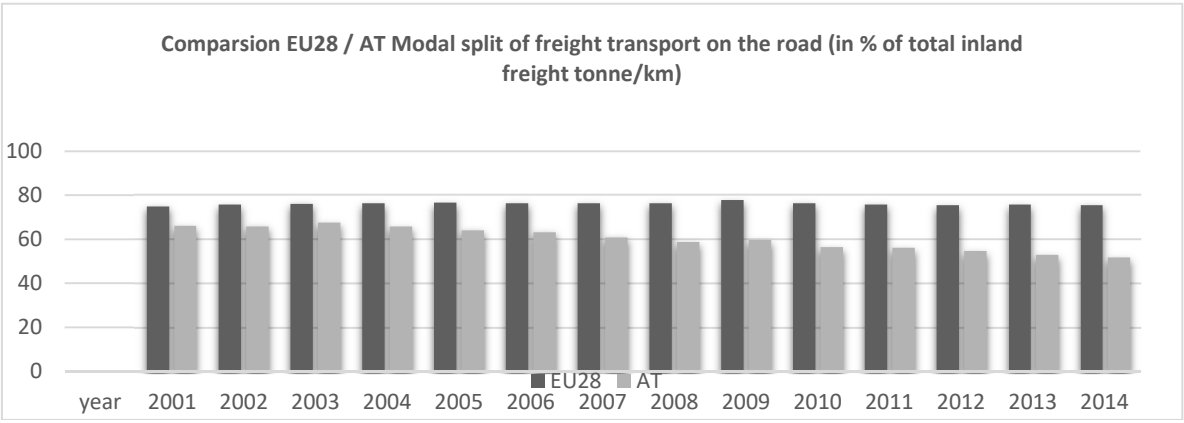
Fig. 3. Comparison EU 28/AT modal split on rail

The ÖBB Rail Cargo Group, the former governmental railroad company, has the largest market share. The cost per railway kilometer is approximately €4.50 in Austria, which is the third-highest in the European Union, where costs range from €13.10 (Estonia) to €0.00 (Norway).

According to the Austrian journal of transport "Verkehr", the railways may be the most sustainable transport system, but different systems cause complications during implementation. The harmonization of these systems will be necessary to speed up the transportation chain [Troger, 2017].

ROAD TRANSPORT

As stated before, 75% of European freight transport is carried out on roads. Austria reduced this from 66% in the 2001 to 52% in 2014, increasing to role of rail transportation. Almost 50% of road transportation within Austria is carried out by foreign transport companies.



Source: Eurostat, 2017

Fig. 4. Comparison EU28/AT modal split road

Austria provides 106,987 kilometers of road network, 2050 kilometers of which are motorways. Austria is a common transit country. The most important transit routes are the Brenner route from Munich to Bozen, the Tauern route from Munich to Udine, the Phyrrn route from Munich to Maribor, the Semmering route from the Czech Republic via Vienna to Maribor and the East-West route (A1), which connects Hungary, Slovakia and

southern Germany and [Zatl, 2010]. The main junctions of these routes also serve as intermodal hubs. According to Schneider (2014), more than 60 percent of freight transport across the Alps is carried out on Austrian roads. Austria's policy is to try to reduce road transit by charging road tolls on transportation by truck, but only on motorways. Some federal states close roads to trucks which try to bypass toll roads and charge them for contraventions. Strict control systems for trucks on the motorways should ensure compliance with environmental and security standards. Road transport is most common for the "last leg" from the final hub to the wholesaler or customer. This situation causes a high volume of traffic on the lower-level street network and traffic jams within cities during rush hours.

TRANS EUROPEAN TRANSPORT NETWORK

The TEN-T (Trans European Transport Network) is the core transport network project of the European Union. In 2014, the European Union declared that a high speed multi-modal transport network should connect the European countries from North to South and West to East, and beyond its borders. The TEN-T network will include 90,000 kilometers of highways and motorways, including security checks and inspection infrastructure. The background of this effort is to remove bottlenecks, find common standards in railway traffic and remove technical barriers in infrastructure to boost the economy and generate new jobs [European Union, 2017a].

FUTURE WAYS OF TRANSPORT FOR AUSTRIA

One new idea for road transport according to Troger [2017] is long vehicle trucks, which are, at least in Austria, currently prohibited. However, it has been suggested that these trucks should not cause additional stress to the road infrastructure and the environment, because of their higher individual transport capacity. Another idea for road transport is also under development. Automated driving and platooning is currently being tested. With this method, many trucks can drive very closely in a row, assisted by an electronic management system. In automatic platooning, vehicles will be automatically steered, controlled and guided along an ideal path [Tuchner, Haddad 2017]. To reach this target, a comprehensive software program is needed to find ideal routes and model the platoon, and steer it within real-time traffic. A study carried out by scientists at the University of Berkley showed that intersections can be crossed by two or even three times as many vehicles when platoons are used [Lioris, Pedarsani, Tascikaraoglu, Varaiya, 2017]. Although it has only been tested in the United States, where street conditions are quite different from those in Europe, it would be interesting if the result could be also replicated in a European study. As well as the technical aspects, the effect of automated driving on the drivers themselves is still unknown, and the psychological impact, especially on stress level, could prove significant. One study found that stress level depends on the perception of being in control of the situation. [Heikoop, de Winter, van Arem, Stanton, 2017]. So, if drivers are allowed to intervene voluntarily, their stress levels will lower than those who are not able to intervene.

In transport, it is not only transit traffic or long-distance transport that causes problems, but also the so called "last mile". The majority of last-mile transport is carried out by truck. Alternative means of transport in urban areas, such as e-cars or tricycles, could reduce transportation-related pollution by more than 50 percent, as a study in Portland, Oregon [Saenz, Figliozzi, Faulin, 2016], has shown.

CONCLUSIONS

In landlocked countries such as Austria, most transportation is carried out by truck, on the roads. Short-distance transport is also faster and more flexible by truck. However, shifting a substantial amount of long-distance road transports onto alternative means of transport such as railways or water routes could be a huge relief to local populations, as well as the environmental and for infrastructure of a country. Toll roads, which are used in some

European countries, are one way to achieve this. Austria, as a seriously affected transit country, supports this idea. But not all external costs are covered by this. It has been established that transportation on railways and waterways is cheaper and more environmentally friendly than on the roads. The disadvantage of these modes of transport is the fact that direct transport from origin to end recipient is normally not possible. With multimodal transport, transportation routes can be split into different means of transport, to achieve the benefits of both. One barrier to multimodal transport is the need to load containers from trucks to trains or ships. Carriers must use containers and interchangeable bodies for transport and efficient exchanges between means of transport. This means that they require either a harbor or a goods station with an efficient crane infrastructure, or they have to invest in trucks with cranes for fast transshipment. Austria's figures over the last decade show that the country has been already successful in shifting some of the transportation burden from road to train. Austria (44%) has a significantly higher utilization of its railway infrastructure than the EU28 average (18%). The European Union has to work on the harmonization of railway infrastructure to remove existing barriers to rail transportation. Although the River Danube is one of the most important waterways in Europe, as well as cheap and environmentally friendly, its utilization as a means of transport has not increased. The capacity utilization of the River Danube is only ten percent. In a modal split, Austria is below the EU28 average, and has even decreased recent years. An investment in effective infrastructure, such as flood protection, continuous maintenance without interruption the operation of flood gates and locks and the expansion of harbors would be sustainable, and seems promising. It would also relieve the Austrian transit situation in the west – east direction. A digitalization system seems to support new and useful ways to manage the increasing traffic load on the roads, such as platooning and autonomous driving. For the "last mile" in consumer commerce, modern concepts of e-mobil fleets supported by information and communication technology for intelligent routing, fast and environment friendly delivery must be developed.

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ANALIZA AUSTRIACKIEGO SYSTEMU TRANSPORTU LADOWEGO I MULTIMODALNEGO

STRESZCZENIE. **Wstęp:** W ostatnich latach obserwuje się znaczący wzrost przewozu dóbr, głównie konsumpcyjnych. Jak rozwiązanie tego zagadnienia w wielu publikacjach wskazuje się transport multimodalny. Austria, będąca krajem śródlądowym, szczególnie dotkliwie odczuwa negatywne skutki transportu lądowego w porównaniu do pozostałych krajów europejskich. Praca obejmuje analizę aktualnej sytuacji austriackiego transportu dóbr materialnych w porównaniu do 28 krajów UE. Poddano również analizie nowe rozwiązania transportowe, służące lepszej kontroli sytuacji transportowej. Na bazie tej analizy wysunięto rekomendacje dla rozwoju strategicznego transportu w tym kraju.
Metody: Podstawą analizy był przegląd porównawczy literatury fachowej dotyczącej sektora logistycznego w Austrii. Materiały statystyczne autorstwa austriackiego i europejskiego posłużyły dla analizy porównawczej sytuacji transportowej w Austrii i Unii Europejskiego.
Wyniki: Użytkowanie dróg kolejowych w Austrii jest wyższe od średniej UE28. Z drugiej strony użytkowanie dróg wodnych jest poniżej tej średniej. Odpowiednie użytkowanie do celów transportowych rzeki Dunaj mogłoby istotnie odciążyć transport lądowy jako tańszy oraz bardziej zrównoważony. Nowe rozwiązania transportowe umożliwiając poprawę bezpieczeństwa na drogach, aczkolwiek realizacja proponowanego rozwiązania zależy od kosztów, jakie będą one generować.

Wnioski: Poprzez przesunięcie części transport drogowego na główną drogę wodną Austrii, rzekę Dunaj, zmniejszą się w pewnym zakresie problemy zatłoczenia na drogach i jego wpływu na środowisko. Digitalizacja logistyki, wprowadzenie systemów transportowych opartych na rozwiązaniach komputerowych typu platooning, samochody autonomiczne czy transport multimodalny, mogą się pozytywnie przyczyniać do polepszenia sytuacji na drogach, obniżenia poziomu zatłoczenia oraz emisji spalin, jak również zwiększenie bezpieczeństwa na drogach. Należałoby kontynuować te badania w celu doprecyzowania gotowości na nie rynku oraz efektywności kosztowej proponowanego rozwiązania.

Słowa kluczowe: transport mulitmodalny, Austria, rzeka Dunaj, platooning, kierowanie autonomiczne

ANALYSE DES ÖSTERREICHISCHEN LAND- UND MULTIMODALEN TRANSPORTSYSTEMS

ZUSAMMENFASSUNG. Einleitung: In den letzten Jahren wird ein steigendes Beförderungsvolumen von Gütern, hauptsächlich von Verbrauchsgütern, beobachtet. Als eine mögliche Lösung dieser Frage weist man in vielen Veröffentlichungen auf den multimodalen Transport hin. Österreich als ein Binnenland empfindet im Vergleich zu anderen europäischen Ländern besonders schmerzlich die negativen Nachfolgen des Landverkehrs. Die vorliegende Arbeit stellt eine Analyse des gegenwärtigen Standes der Güterverkehre im Vergleich zu 28 Ländern der Europäischen Union dar. Dabei wurden auch neuere Transportlösungen, die einer besseren Kontrolle der Transportsituation dienen, einer Analyse unterzogen. Auf Grund dieser Analyse arbeitete man Empfehlungen für die Entwicklung der strategischen Transportart in diesem Lande aus.
Methoden: Die betreffende Analyse wurde anhand einer vergleichenden, den Logistiksektor in Österreich anbetreffenden Fachliteraturübersicht vorgenommen. Die statistischen Unterlagen österreichischer und europäischer Provenienz dienten zur vergleichenden Analyse der Transportsituation in Österreich und in der Europäischen Union.
Ergebnisse: Die Inanspruchnahme von Eisenbahnstrecken in Österreich liegt höher als dies durchschnittlich in den 28 Ländern der EU der Fall ist. Auf der anderen Seite liegt die Auslastung von Wasserstrecken dort unter dem besagten Durchschnittswert. Eine entsprechende Beanspruchung des Flusses Donau zwecks Beförderungszwecken, was billiger und mehr ausgewogen zu sein scheint, könnte wesentlich den Landtransport entlasten. Neue Transportlösungen ermöglichen die Verbesserung von Sicherheit im Straßenverkehr, allerdings die Umsetzung der vorgeschlagenen Lösung hängt von den durch sie generierten Kosten ab.
Fazit: Durch die Versetzung eines Teiles von Straßentransporten auf die Donau als die Wasserhauptstrecke Österreichs werden im gewissen Ausmaße Stauprobleme im Straßenverkehr und die durch ihn verursachten Umweltschutzprobleme reduziert werden. Digitalisierung der Logistik, Einführung von auf die Rechnertechnik in Form von Platooning gestützten Transportsystemen, autonomischgeführte Transportfahrzeuge oder der multimodale Transport können positiv zur Verbesserung der Situation im Straßenverkehr, zur Reduzierung von Staus und Emissionen von Abgasen, sowie zur Gewährleistung der Sicherheit im Straßenverkehr beitragen. Diese Art Forschungen sollten zwecks der Prüfung von effektiven Umsetzungsmöglichkeiten dieser Lösungen und deren Kosteneffektivität fortgesetzt werden.

Codewörter: multimodaler Transport, Österreich, Fluss Donau, Platooning, autonomische Fahrzeugführung

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