Future developments in the transportation area and their impact on vehicle distribution logistics

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Abstract. The complexity and dynamics of logistics networks have steadily increased throughout the last years. In order to understand the changes and concentrate on the pertinent topics, future trends in the transportation industry have been identified in this paper with a focus on overland transportation. Furthermore, the distribution network of the German premium automotive company, BMW, was analysed. The analysis was based on the year 2019 using the KPIs throughput time, vehicle quality, vehicle stock, distribution costs and sustainability. The focus was on key markets and main routes only without fine distribution, which is why adherence to delivery dates was not measured. Using the scenario technique three possible future outcomes of 2030 were developed and simulated with the simulation tool AnyLogic. This paper shows that automotive companies must invest in the transportation industry in order to meet their own quality, cost and time targets. Especially the progress regarding sustainable drive systems, automatization and digitalisation will have an immense impact on the performance of transportation. In addition, the complexity of the distribution network needs to be limited by minimizing the lengths of the transportation routes in order to counteract the trends of more traffic and, therefore, higher throughput times and costs.

1 Introduction

The volume of vehicle productions and sales is continuously rising, and forecasts confirm this trend for the next several years. Due to the high number of worldwide production plants and dealer locations along with a wide range of diverse products, the complexity and dynamics of logistical networks in the automotive industry have also steadily increased [1].

In addition, the political, social and technological conditions in the area of transportation have changed immensely, which is why the industry faces a variety of challenges and financing problems due to declining profit margins [2]. Moreover, legal requirements have tightened significantly throughout the last ten years. [3].

In 2018, the transport performance in Germany totalled more than 689 billion tkm while the volume of goods exceeded 4,361 billion t, with 3,747 billion t being transported by truck, 417 million t by rail and 198 million t by inland waterway [4]. In view of the forecast that freight transport in Germany will increase by 40 percent to more than 900 billion t by 2030 in comparison to 2010, overall structural measures are necessary [5].

At the same time the pressure to build affordable, sustainable and highly automated cars has increased immensely. To finance necessary innovations established car makers must save costs which can only be achieved through transparent and optimized processes [6] [7].

A performed literature research showed that future studies are underdeveloped in the area of logistics. Therefore, in the following paper the main drivers of future changes in the transportation industry are identified and their effects on distribution logistics are simulated in order to give automotive companies recommendations for the future.

2 Methodology

First, a comprehensive literature research was performed to identify current trends in the transportation industry, which included a variety of sources, such as political initiatives, recently passed laws and published articles concerning technical advancements.

There are various trends that influence each other, which lead to different outcomes. Hence, the future can never be predicted with complete certainty. Therefore, in a next step, assumptions are made, and three scenarios are developed to predict overland transport in 2030.

In order to be able to measure and evaluate the effects of the scenarios on the distribution network, an automotive company was selected, and its network simulated with the simulation tool AnyLogic. Eventually, the resulting changes in selected KPIs are analysed. The KPIs are chosen based on the KPI pyramid shown in figure 1.

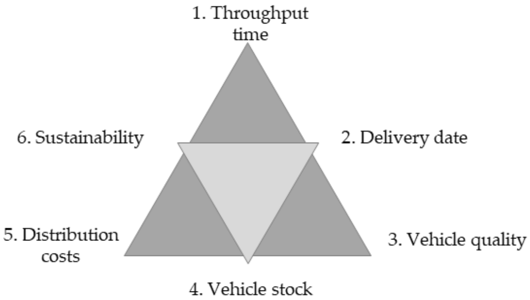

Figure 1. Performance indicators [8].

Based on the findings, measures for all three scenarios are derived.

3 Results of the literature search and simulation

3.1 Current trends in the transportation industry

In the following chapter, the findings of the literature review are presented. In general, multistage and multimodal transport chains are necessary to deliver the vehicles from the plants to the dealer locations worldwide. Means of transport are in general trucks, trains and sea vessels. Planes are only used in extreme cases as they are too expensive, inflexible and capacity limited for shipping vehicles [9]. The literature research focused mainly on overland transportation.

On the one hand, the developments include political efforts to reduce greenhouse gas (GHG) emissions, to expand the rail and road infrastructure as a result of the forecasted increase in traffic, and to improve social working conditions [10] [11]. In addition, the Trans-Eurasia Logistics rail connection of the New Silk Road represents a political development with a potential impact on overland transportation [12]. Moreover, governmental regulations on periods of rest and driving bans on Sundays / holidays are becoming stricter and their compliance more stringently controlled in many European countries [3].

On the other hand, social changes, which influence truck and rail transport, emerged from the research. These include, among others, the increasing customer demand of goods worldwide, which lead to increasing intercontinental ship transports and require a growing number of preliminary trips by truck or train [1] [13]. Furthermore, demographic changes and the increasing shortage of drivers have an impact on the reliability of trucks [13] [15].

In addition to the political and social trends, the most significant technological developments will also lead to a paradigm shift in overland transportation. Increasing digitalisation and automation of trucks and trains, e.g. through platooning, can have an impact on the sustainability and performance of the transport modes in the future [15]. Furthermore, the change in the average truck length due to the expected increase in longer and heavier trucks for vehicle transportation is also one of the trends that could affect overland transportation in the future [13] [16] [17].

The mentioned trends represent the most significant drivers for change expected to massively effect the transportation industry. Based on the predictions and the corresponding numbers found in literature, three future scenarios for 2030 are developed. The scenarios were developed following different steps of formal scenario planning. The results in form of a morphological box are presented in table 1.

Table 1. Morphological box for scenario creation.

Scenario I	Scenario II	Sceanrio III
Shift from road to rail		
No shift	15 % of road transports >300km shift to train.	30 % of road transports >300km shift to train.
Usage of Trans-Eurasia Logistics		
No exploitation	50 % of the volume to China shift from sea to train.	All of the volume to China shift from sea to train.
More sustainable trains through electrification and automatisation		
No further electrification or automation.	50% electrified and automated trains (decrease of GHG by 5%).	All electric and automated trains (decrease of GHG by 10%).
Enhancement of railway infrastructure		
No further enhancement.	Partly enhanced infrastructure (decrease of transport times by 4.5-16.5%).	Completely enhanced infrastructure (decrease of transport times by 9-33%)

More sustainable trucks through alternative drives and automatisation		
No alternative drives or further automation.	16.5% of kms per truck are electric and 12% with natural gas, 1.6% of trucks are long trucks and 10% of trucks are automated (decrease of GHG by 5%).	33% of kms per truck are electric and 24 % with natural gas, 3.2% of trucks are long trucks and 20% of trucks are automated (decrease of GHG by 10%).
Enhancement of road infrastructure		
Much traffic (increase of 54%) and lots of truck journey failures (20%).	Moderate traffic (increase by 27%) and few truck journey failures (10%).	Little traffic and (almost) no truck journey failure.
Change in truck capacity through long trucks and heavier vehicles		
No long trucks.	1.6% of trucks are long trucks (increasing loading factor of 10 vehicles instead of seven vehicles in 1.6% of the journeys).	3.2% of trucks are long trucks (increasing loading factor of 10 vehicles instead of seven vehicles in 3.2% of the journeys).

The first scenario assumes a negative development for European automotive companies, in which truck transport times will increase as predicted because of increasing road traffic and the number of truck breakdowns, e.g. due to the shortage of skilled workers. No efforts of any type are taken to solve the intensifying traffic and truck breakdowns.

In comparison, the second future scenario depicts the respective characteristics of the third scenario but in a weaker form. In scenario three, all political efforts to reduce GHG emissions and to cope with the increased volume of traffic are achieved and a full use of trans-Eurasia Logistics to China is possible. Technological developments in terms of automation and digitalisation of trains, trucks and infrastructure are fully exploited and a shift from trucks to trains has taken place.

3.2 Set up and results of simulation

In order to be able to measure and evaluate the effects of the scenarios, the automotive company BMW Group was selected for the use case. BMW serves well as an example of an automotive company with a complex network as it is a multinational company with CBU (completely built-up) production plants on four different continents. To reduce the complexity, the model is simplified, whereby only the transports to the nine key markets with the highest sales are considered. These markets make up almost 60% of the total volume. In addition, only main routes are analysed excluding the fine distribution. Therefore, the adherence to the delivery date cannot be measured. The simulation focused on the year 2019 and included 10 production plants, 30 different ports, seven compounds and 955,470 vehicles. For the set-up of the simulation the approach of Rabe et al. was chosen [18]. An agent-based model was created with the following populations: plants, compound, destinations, cars, trucks, ship and trains, routes and sections. Figure 2 shows the created flow chart.

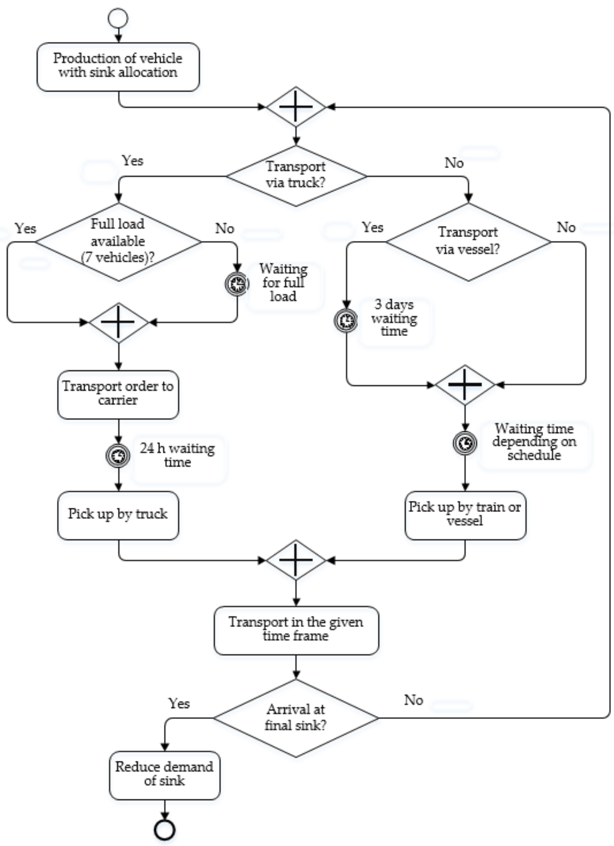

Figure 2. Flow chart.

The performed simulation of the distribution network of 2019 showed that trucks are, as of now, the most unfriendly mode of transport in terms of GHG emissions, emitting almost double the GHG emissions of a ship and triple the GHG emissions of a train. Trucks are also the most expensive mode of transportation, yet necessary to overcome short distances. Rail connections with a distance greater than 300 km are in general more efficient than road transports. In addition, train connections are the fastest mode for the transportation of vehicles. In proportion to the large volume they can carry, ships are the cheapest option being almost four times less expensive than trucks and trains. Yet, in addition to their slow speed on average the overall throughput times additionally originated from long waiting times at the ports.

The simulation with AnyLogic shows that the average lead time of a car will increase in the future. This will occur especially in the first scenario, because of the increase in road traffic, the shortage of skilled workers along with the missing improvements in the areas of digitalization and automatization. In addition, the ongoing globalization leads to an increase in costs due to the increased intercontinental ship transports. The analysis also showed that scenario three recorded the highest increase in costs because the Trans-Eurasia Logistics is fully used for transports to China. Yet, scenario three also shows lower throughput times, damage rates and vehicle stocks than the other scenarios. Furthermore, the GHG emissions are even lower than in the baseline year 2019. The simulation results regarding the KPIs are shown in table 2.

Table 2. Simulation results.

As Is: 2019	Scenario 1: 2030	Scenario II: 2030	Scenario III: 2030
Production volume key markets [vehicles]			
1.400.255	1.351.552	1.351.552	1.351.552
Main route volume [vehicles]			
955.470	1.016.117	1.016.117	1.016.117
Throughput time (average throughput time/car [d])			
19,99	21,27	21,15	20,66
Vehicle quality (average number of vehicles broken [%])			
0,0437	0,0353	0,0303	0,0239
Vehicle stock (average stock/day [vehicles])			
53.171	57.614	56.875	55.854
Distribution costs (average transport costs/vehicle [€])			
157	167	173	180
Sustainability (average GHG emissions/vehicle [t CO_{2e}])			
0,2609	0,2589	0,2412	0,2236

4 Discussion

The results of the analysis provided the basis for identifying areas where action is required. Recommendations differ depending on the effects and, thus, depending on the future scenario.

In the event of scenario one, it is recommended to shift truck traffic from a distance of 300 km to rail, if frequent collection can be ensured. This can reduce the high throughput times that occur in the first scenario. This measure has also a positive effect on the sustainability of the transports. This is of crucial importance in this scenario, as the GHG emissions are not reduced enough by technological progress.

The Trans-Eurasia Logistics is an alternative to the shipping route to China, which can only be applied in scenario two and three. It is recommended that the route is partially used for time-critical transports. In contrast to full use, this prevents a rapid increase in costs and still reduces the average lead time of a car. In addition, strong positive effects can be achieved through a partial usage, especially with regards to sustainability.

In the event of scenario three, European automotive groups are advised to only switch truck transports with a distance of >300 km if the transport per vehicle by rail is actually cheaper than by truck. The same applies to the occurrence of the second scenario provided that the lead time must be reduced.

Regardless of which scenario occurs, European automotive companies will be advised to optimize their transport routes and to relocate the production closer to the target market. In order to reduce throughput times, an agreement to increase departure frequencies of sailing must be reached with shipping companies. These measures ensure that automotive companies continue to meet the growing requirements of the future and, thus, remain competitive.

5 Conclusion

The results of the literature research and simulation can be used to gain new insights into future developments in the field of overland transportation of vehicles. It is highlighted which potential changes should be given special attention. Especially the investments in sustainable drives as well as automatization and digitalisation of modes of transport and infrastructure will play a major role. Automotive companies need to improve their network to shorten distribution routes in order to counteract the trends, e.g. of more traffic, and, therefore, higher throughput times and costs. These results do not only offer theoretical added value but can also contribute to the decision-making of an automotive company within its distribution planning.

However, it is imperative that the findings need to be validated in further research. An evaluation and prioritization of the recommendations for action with the help of a cost-benefit analysis would be beneficial. The simulation represents only a snapshot of a distribution network from 2019. As requirements, conditions, processes, etc. are continuously changing, the set-up of a permanent digital twin, in which real-time information is used, could present a benefit to automotive companies. In connection with an interactive real-time steering, an even higher quality of the decision-making process could be established. For the creation of a digital twin, the simulation model created in AnyLogic, including the simulation visualization, can serve as an initial concept.

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