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The Impact of Partially Automated Trucking on the Demand for Human Drivers

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Abstract

The German road haulage industry is currently facing a shortage of drivers, which is expected to increase in the future as freight volumes grow. In the long term, automated vehicles are expected to become part of road transport operations, reducing the demand for drivers and alleviating the driver shortage. During the transition period to full automation, partially automated trucks, which operate without a driver in certain areas and require a driver in others, will become the dominant mode of transportation. This paper examines how much driver demand could be reduced through partial automation. In terms of pure driving time, automated freeway driving reduces the demand for human drivers by about 60%. When loading/unloading time is added, the potential savings range from 25% to 41%. The greatest savings are on long-distance trips, where a greater proportion of the trip is spent driving on freeways. The reduction in driver demand is sufficient to offset current driver shortage estimates.

Keywords: Road freight transport, Driver demand, Driver shortage, Automated driving, Level 4 automation

1. Introduction

According to the International Road Transport Union's *European Driver Shortage Report 2022* [1], the German road freight sector faces a shortage of between 57.000 and 80.000 drivers, representing a 9% deficit. This shortage is expected to grow as freight volumes are expected to increase by 46% between 2019 and 2051, according to a recent German government forecast [2]. According to the International Road Transport Union's *Driver Shortage Report 2023 Freight – Global*, the driver shortage in Europe could increase from 7% in 2023 to 17% in 2028 due to rising freight volumes and the fact that more drivers are retiring than are being trained [3].

However, automated vehicles are expected to become part of the road transportation system by 2050. The introduction of fully automated trucks will significantly reduce the demand for drivers in the long term. During the transition period to full automation, partially automated trucks will become the dominant mode of transportation, operating without a driver in certain areas and requiring a driver in others. The purpose of this paper is to determine

the extent to which driver demand could be reduced by such partial automation.

Automated driving is defined in six levels by the *Society of Automotive Engineers International* [4]. The levels range from Level 0, where all driving tasks are performed by the human driver, to Level 5, where all driving tasks are performed by the vehicle. As the level increases, the driving tasks are shifted from the human driver to the vehicle. The levels of driving automation are shown in **Fig. 1**.

The feasibility of automated driving depends on the traffic environment. Freeway driving is a simpler traffic environment than city driving and could therefore be automated first [6, 7]. Interactions with other road users are limited in freeway driving because there are no intersections, pedestrians, or cyclists and all vehicles travel in the same direction.

For the analysis in this paper, it is assumed that Level 4 partially automated trucks will operate on freeways without a human driver and will require a human driver for off-freeway driving.

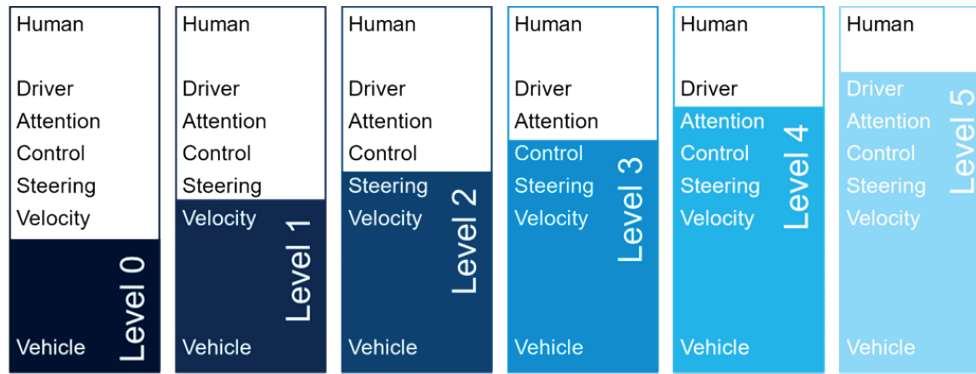


Fig. 1. Six levels of driving automation defined by the *Society of Automotive Engineers International*. Taken from [5].

Several studies have been conducted to estimate the impact of automated trucks on operating costs and driver demand.

An initial study by the International Transport Forum suggests that the demand for truck drivers in the U.S. and Europe could be reduced by 53–69% by 2030 in a scenario of rapid deployment of automated trucks [8]. The study assumes the availability of Level 5 automated trucks and that no drivers are needed at all to operate the automated trucks. The savings in driver demand are therefore equal to the share of automated trucks. The study ignores two important aspects. First, human drivers perform tasks other than driving the vehicle, such as loading and unloading. Second, the operational domain of automated trucks may initially be limited to freeways, as automated trucks may be available first as Level 4 trucks and later as Level 5 trucks. Therefore, there will still be a need for a human driver during automated operation.

In a cost of ownership analysis, Wadud assumes that 60% of a truck driver's working time is spent driving and 40% on non-driving tasks [9]. The author further notes that fully automated vehicles may require additional resources at origins and destinations to load and unload the vehicle.

Gittleman and Monaco estimate that 18–24% of U.S. truck drivers could be affected by Level 4 partial automation, but they do not specify how much the driver demand could be reduced for that fraction [10]. The authors assume that only long-haul operations will be affected by Level 4 automation. Out of a total of 1,7 million drivers in the US, they estimate that 300,000 to 400,000 drivers work in long-haul operations. The authors note that the need for human drivers will not be completely eliminated because human drivers perform more tasks than just driving. Loading and unloading may shift to trucking support services, while customer service and freight delivery may still be part of first- and last-mile operations. Gittleman and Monaco do not specify what proportion of long-haul drivers would still be needed for Level 4 partial automation.

Mohan and Vaishnav calculate that 94% of long-haul driving hours in the U.S. could be automated by Level 4 automated trucks [11]. The authors use shipment data from the Commodity Flow Survey for the U.S., from which they

include only for-hire and private truck shipments over 150 miles. For all shipments, they calculate the route using Google Maps and estimate freeway and off-freeway travel times. Unlike the other studies presented, the authors assume that the role of the human driver in long-haul operations is limited to driving.

In contrast to the existing literature, the analysis in this paper determines the impact of Level 4 automated trucks on driver demand by explicitly modeling driving times and non-driving work times for loading and unloading.

The next section presents the methods of the analysis. The results of the analysis are then presented. Finally, the paper closes with a discussion of the results and a conclusion.

2. Methods

This section describes the methods used to determine the driver demand for Level 4 automated trucks. Driver demand is determined for the German road haulage sector. The statistics used are for Germany, but the methods can be applied to other countries as well.

The driver demand is based on the total driving time of all trucks. The total kilometrage of European trucks in Germany is recorded in national statistics according to individual trip distances in twelve distance classes [12]. Information is available on the respective number of trips divided into loaded and empty trips, average load, average trip distance, and total transport volume. In this study, the distance classes are based on the national statistics, with the first two distance classes, distances up to 25 km and distances between 25 km and 50 km, combined into one distance class. For each distance class, total driving time is calculated based on the total distance traveled and the average speed for the distance class. The average speed for each distance class is calculated from the urban, rural, and freeway trip shares, assuming speeds of 25 km/h, 40 km/h, and 70 km/h, respectively. The urban, rural, and freeway trip shares are calculated based on the distance traveled. The freeway share p_{freeway} of a trip of length S is determined based on an empirical relationship found for trip distances in Germany [13].

$$p_{\text{freeway}} = 1 - e^{-\frac{s}{127.25 \text{ km}}} \quad (1)$$

The remaining trip shares are distributed to rural and urban traffic with a share of 90% and 10%, respectively.

In addition to pure driving time, loading and unloading times for the vehicles are considered to determine driver demand. Loading and unloading are assumed to occur after each trip. The total loading and unloading times are set in a range of 1–3 hours for each distance class. The maximum loading and unloading times are assumed to be higher for shorter distances. This is intended to resemble the work profile of drivers in local transport and delivery. The chosen loading and unloading times are consistent with assumptions made in other cost studies of automated trucks. Engholm et al. assume 1–2 hours of loading and unloading before and after each trip, depending on the type of cargo (dry, liquid, general cargo) [14]. Ghandriz et al. assume 15–44 minutes of loading and unloading time per 20-foot container, depending on the loading strategy, resulting in up to 3 hours of loading and unloading time for a truck carrying two 40-foot containers [15]. Finally, Huang and Kockelman assume a uniform 4 hours of loading and unloading per trip for all trucks in an analysis of how automated trucks might affect US truck flows [16].

The distance classes used, the total trip distances, the average trip distances, the calculated freeway, rural, and urban trip shares, and the assumed loading and unloading

times are summarized in **Table 1**. For the calculation of average trip distances and trip shares, only the mileage of domestic traffic in Germany was considered. Interchange, cross-trade, and through traffic were not considered because their data showed some inconsistencies, e.g. their respective average trip distances for the distance classes fell outside the respective distance classes.

To calculate the number of drivers required, it is assumed that a driver can drive nine hours a day and drives 220 days a year. To account for the additional time spent loading and unloading the vehicle, a maximum daily working time of twelve hours is assumed. The working time consists of any number of hours for loading and unloading and a maximum driving time of nine hours. Working and driving times for truck drivers are regulated in the EU [17–21]. The daily driving time of a human driver may not exceed nine hours, except for two days per week when the daily driving time may be increased to ten hours. In addition, driving time must not exceed 90 hours in any two consecutive weeks. Finally, an uninterrupted daily rest period of eleven hours must be maintained.

To calculate the total driver demand, the first step is to determine the number of drivers needed based solely on total driving time. Then, the amount of loading and unloading time that these drivers can already cover is checked. Finally, the additional driver demand due to work time constraints is calculated for the excess loading and unloading time.

To estimate the driver demand for Level 4 automated trucks, it is assumed that the freeway portion of trips is automated and no driver is needed for that time. Otherwise, the estimation is the same as for the non-automated case.

Table 1. Distance classes used, total trip distances, average trip distances, calculated freeway, rural, and urban trip shares, and assumed loading and unloading times.

Distance class	Total kilometrage (thousand km)	Average trip distance (km)	Trip shares freeway / rural / urban	Loading and unloading times (h)
≤ 50 km	5.505.544	20,4	15% / 76% / 9%	1–3
51–100 km	5.038.894	72,0	43% / 51% / 6%	1–2
101–150 km	4.010.927	122,6	62% / 34% / 4%	1–2
151–200 km	3.040.186	173,2	74% / 23% / 3%	1–2
201–300 km	4.637.340	244,8	85% / 13% / 2%	1–2
301–400 km	3.312.119	344,5	93% / 6% / 1%	1–2
401–500 km	2.661.607	447,8	97% / 3% / 0%	1–2
501–700 km	4.382.347	580,0	99% / 1% / 0%	1
701–900 km	2.575.819	769,4	100% / 0% / 0%	1
901–1000 km	922.604	939,2	100% / 0% / 0%	1
> 1000 km	6.925.825	1.497,8	100% / 0% / 0%	1
Total	43.013.212	97,5	75% / 22% / 3%	-

3. Results

The total driving time for German road freight transport is estimated at 711 million hours in 2019. Trips up to 50 km account for the largest share of driving time at 18% followed by trips over 1000 km and trips between 51 and 100 km at 14% each.

For Level 4 automated trucks, only non-automated driving time is relevant for determining driver demand. It is assumed that Level 4 automated trucks operate on freeways without a human driver and require a human driver for off-freeway driving. Non-automated driving time is therefore equal to off-freeway driving time. The total off-freeway driving time is estimated to be 284 million hours. As in the case of total driving time, driving distances up to 50 km account for the largest proportion of driving time at 43%. However, for off-freeway driving time, the driving time per distance class decreases with distance as the proportion of freeway driving increases.

Looking only at driving time, Level 4 automated trucks could reduce driver demand by 60% compared to the non-automated case. The off-freeway driving time is 60% lower than the total driving time. However, due to the different proportions of freeway driving for each distance class, the off-freeway driving time is to a varying extent lower than the total driving time for each distance class. For short distances, a large proportion of total driving time remains. For trips up to 50 km, the freeway share is 15%, so only 5% of driving time is spent on freeways. For trips between 51 and 100 km, 23% of the driving time is spent on freeways, and for trips over 700 km, it is assumed that 100% of the driving time is spent on freeways. A comparison of total and off-freeway driving time by distance class is shown in *Fig. 2*.

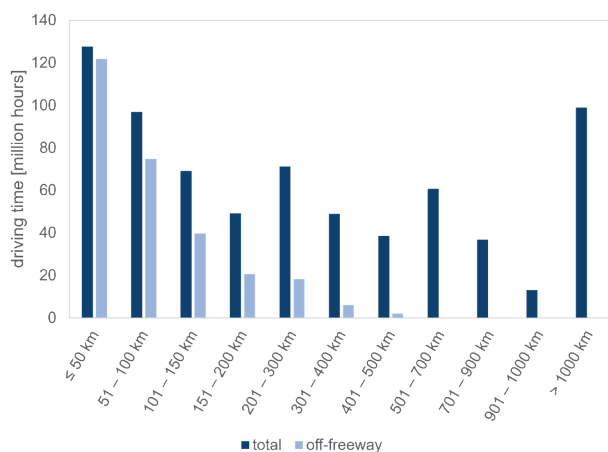


Fig. 2. Estimated total and off-freeway driving time by distance class for the German road freight transport sector in 2019.

In addition to driving time, loading and unloading times are considered for determining driver demand. The total loading and unloading time for German road freight transport is estimated to be between 441 and 1.136 million hours in 2019. The maximum total loading and

unloading time is greater than the total driving time. A comparison of loading and unloading times per distance class is shown in *Fig. 3*. Trips up to 50 km account for by far the largest share of loading and unloading with 61–71%. The contribution of trips up to 50 km is so large because it is assumed that loading and unloading occurs after each trip and the number of trips is highest for trips up to 50 km. The minimum loading and unloading time after each trip is assumed to be 1 hour regardless of the distance class. Therefore, differences in the minimum loading and unloading times for each distance class are based solely on the number of trips per distance class. The number of trips per distance class can be calculated from the total kilometrage and average trip distance for each distance class. In 2019, there were 270 million trips up to 50 km, 70 million trips between 51 and 100 km, and only 5 million trips over 1000 km. The proportion of loading and unloading time for trips over 1000 km is therefore negligible.

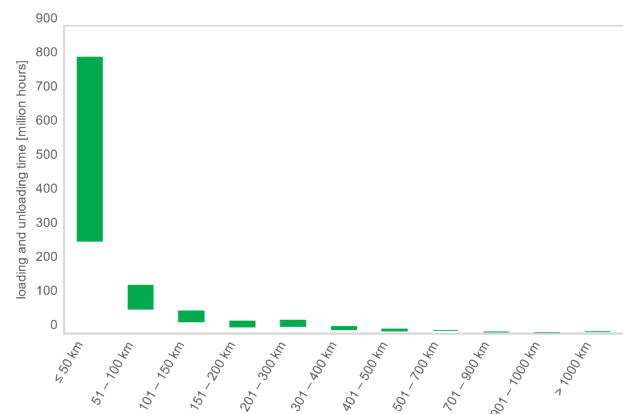


Fig. 3. Estimated loading and unloading time by distance class for the German road freight transport sector in 2019.

Based on driving times and loading and unloading times, we estimate the total driver demand for German road freight transport in 2019 to be between 463.697 and 720.184 drivers. The estimated driver demand is in line with recorded employment statistics. According to a report by the Federal Logistics and Mobility Office, 572.000 drivers were registered in Germany in 2019 [22]. The reported value is within the estimated range of 463.697–720.184 drivers. The estimated driver demand is also in line with the assumptions of the International Transport Forum study presented earlier [8]. The study assumes that each driver drives a certain number of kilometers per year. A driver in Europe is assumed to drive 58.824 km per year, while a driver in the U.S. is assumed to drive 123.457 km per year. Applying the International Transport Forum's approach to the 2019 kilometrage in Germany used in this study results in a driver demand of 348.405–731.221 drivers. The estimated range of 463.697–720.184 drivers is within this range. The comparison of the estimated driver demand with recorded employment statistics and the International Transport Forum's approach is shown in *Fig. 4*. Overall, the comparison shows that the chosen approach provides a plausible estimate of the total driver demand.

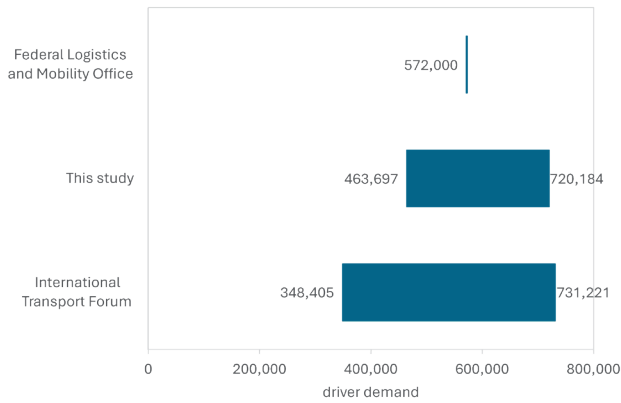


Fig. 4. Comparison of the estimated driver demand for 2019 with recorded employment statistics by the Federal Logistics and Mobility Office [22] and the International Transport Forum's approach [8].

For Level 4 automated trucks, the total driver demand for German road freight transport is estimated at 274.487–537.561 drivers in 2019. The savings in driver demand are therefore 41% and 25%, respectively, compared to the non-automated case. The additional driver demand due to work time constraints for loading and unloading is greater for Level 4 automated trucks than for non-automated trucks. The total number of drivers required for pure driving time is lower for the automated case, while loading and unloading times remain the same. Consequently, in the automated case, a smaller proportion of the loading and unloading time can be covered by the drivers required for pure driving time, and the additional demand for drivers required for loading and unloading increases.

A comparison of the estimated driver demand for the non-automated and Level 4 automated cases is shown in **Fig. 5**. For each case, two lines are shown representing the minimum and maximum driver demand, respectively. For short trips, the estimated driver demand for the Level 4 automated case is nearly identical to the non-automated case for both the minimum and maximum driver demand. However, as the trip distance increases, the non-automated and Level 4 automated cases diverge. Driver demand for the non-automated case increases steadily with trip distance, while driver demand for the Level 4 automated case increases more slowly and remains almost unchanged for trip distances above 300 km.

4. Discussion

Compared to Mohan and Vaishnav's estimate, the driver demand savings in this study are lower. Mohan and Vaishnav calculated that 94% of long-haul trucking hours in the U.S. could be automated by Level 4 automated trucks [11]. The authors assumed that the role of the human driver in long-haul operations would be reduced to driving only. In contrast, this study also considers loading and unloading tasks. For long-haul trucking over 150 miles (all distance classes over 200 km), the reduction in driver demand in this study is 78–84%. This estimate is lower than that of Mohan and Vaishnav, which can be

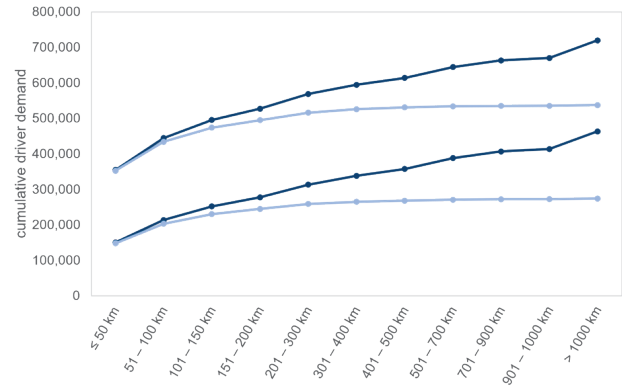


Fig. 5. Comparison of the estimated driver demand for the non-automated and the Level 4 automated cases by trip distance. For each case, two lines are shown representing the minimum and maximum driver demand, respectively.

explained by regional differences. The annual mileage of truck drivers in the U.S. is much higher at 123.457 km than in Europe at 58.824 km [8], which means that in the U.S. loading and unloading can only account for a much smaller proportion of drivers' working time.

The range of estimates in this study illustrates the importance of including loading and unloading times in determining driver demand. The total driver demand for non-automated road freight transport in Germany is estimated to be between 463.697 and 720.184 drivers in 2019. The range of estimates is based solely on assumptions regarding loading and unloading times. In this study, loading and unloading times occur after each trip and therefore vary in frequency for each distance class. Loading and unloading times are much more relevant for short hauls than for long hauls.

In every case considered in this study, the savings in driver demand from Level 4 automated operation are greater than the current driver shortage of 9% reported by the International Road Transport Union for Germany in 2021 [1]. However, the transition to automated vehicles is a gradual process that will take place over many years. During this time, driver shortages are expected to increase due to rising freight volumes and the fact that more drivers are retiring than are being trained [3]. Therefore, the labor market will have time to adjust to changes in driver supply and demand, and potential layoffs caused by reductions in driver demand from Level 4 automated operation beyond the current driver shortage are unlikely and could be minimized.

The estimated savings in driver demand from Level 4 automated operations could be further increased by optimizing loading and unloading processes to reduce driver wait times. For example, in distribution centers, where warehouse workers load and unload vehicles instead of drivers, drivers can switch vehicles and continue to drive another vehicle while the warehouse workers load and unload the initial vehicle. This reduces the need for drivers while increasing the need for warehouse workers, who typically require fewer skills than truck drivers.

In addition, Level 4 automation can address the driver shortage without reducing the driver demand by making the driving profession more attractive. Level 4 automated vehicles could perform long-distance trips without the need for a human driver to be on the road and away from home for several days. In Level 4 automated operation, human drivers could have purely regional assignments only and go home at the end of the day. This makes it easier to balance work with family and personal life. Such an operation would also reduce the number of parking spaces needed along freeways.

5. Conclusion

The analyses in this study have shown that Level 4 operation can already make a significant contribution to reducing driver demand and counteracting the driver shortage in Germany. Level 4 automated operation can reduce total driver demand by at least a quarter compared to the non-automated case. The reduction in driver demand due to Level 4 automated operation is greater than current estimates of the driver shortage in Germany. However, the transition to automated vehicles will take place over many years, and the driver shortage is expected to increase over the same period. Therefore, potential layoffs due to reduced driver demand from Level 4 automated operation are unlikely and could be kept to a minimum. The modeling of loading and unloading times in addition to pure driving time in this study is necessary to properly estimate total driver demand. In addition, including loading/unloading times reduces the estimated driver demand savings from Level 4 automated trucks from about 60% for pure driving time to 25–41% when loading/unloading time is included.

6. Nomenclature

P_{freeway}	freeway share
S	trip length

7. References

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