THE IMPACT OF VEHICLES LOAD CAPACITY ON ROAD INFRASTRUCTURE

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Quality of transport infrastructure determines the quality of the provision of services for the transportation of goods and passengers. The infrastructure sector is a guarantee of efficiency, mobility and uninterrupted economic activity. However, the high quality of the transport infrastructure implies significant and long-term investments. Moreover, dependence of load capacity and infrastructure cost per mile is exponential, which proves the detrimental effect of large vehicles, especially overloaded ones, on the roadway and infrastructure facilities. Visually, this can be observed in the form of rutting, which leads to a significant decrease in the speed of transportation, and also increases the accident rate of the road and shortens its service life before major repairs.

In our rapidly developing world, transport, especially road one, plays an important role. Freight vehicles provide logistics chains with raw materials, and then deliver finished products to the distribution network and to the final consumer. However, road freight transport is also associated with many different problems. This paper raises the issue of the impact of the load capacity (and weight) of trucks on road infrastructure.

The economies of scale inherent in road transport suggest the possibility of obtaining savings when transporting large consignments. Indeed, the larger the consignment, and, accordingly, the vehicle that transports it, the cheaper the cost of transporting a unit of cargo. However, the weight characteristics of vehicles directly affect the road infrastructure [1]. The heavier the vehicle, the more damage it causes to roads, bridges and other objects. Visually, this can be observed in the form of rutting, which leads to a significant decrease in the speed of transportation, and also increases the accident rate of the road and shortens its service life before major repairs.

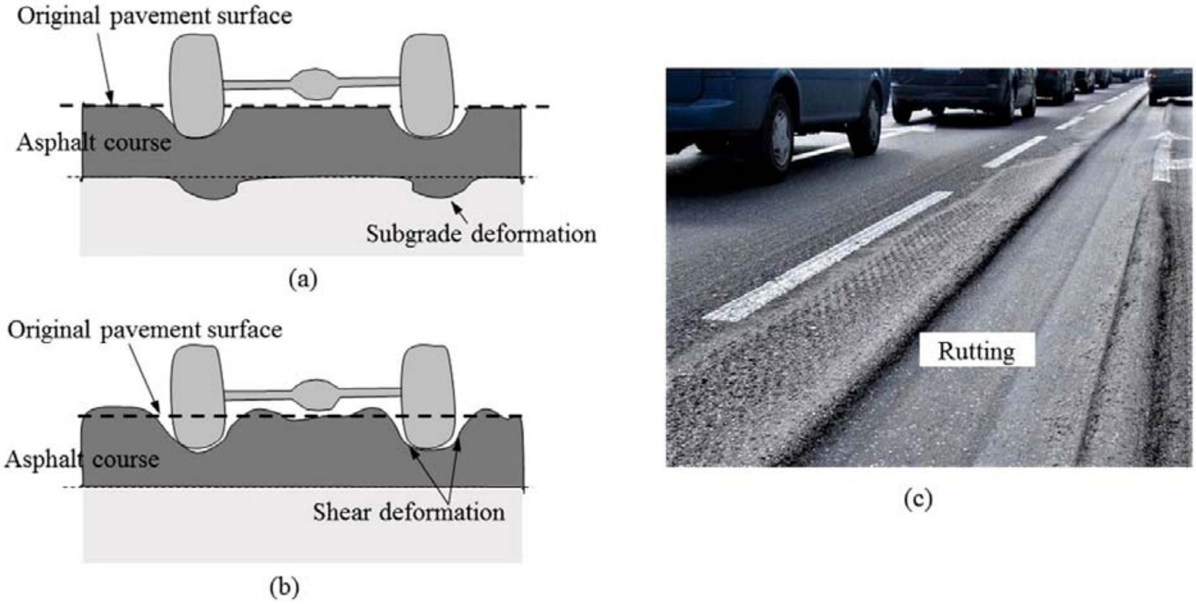

Figure 1. Characteristics of rutting in asphalt pavements. (a) Structural rutting in bottom base and subgrade; (b) fluid rutting; (c) photo of rutting in asphalt pavement [2]

Latvian road operation experience shows several problems associated with heavy goods transport and their impact on road pavements. A large proportion of the paved road network has seen strong rutting, which the reason is cited -the overloaded heavy freight traffic [3].

If vehicles are overloaded, the damage to the pavement is severe and exponential. As shown below, if all vehicles were 20% overweight, pavement life is cut in half.

The authors [4] obtained the dependence of the cost per mile on the weight of a truck. As seen from Fig. 1, this dependence is exponential, which proves the detrimental effect of large vehicles, especially overloaded ones, on the roadway and infrastructure facilities.

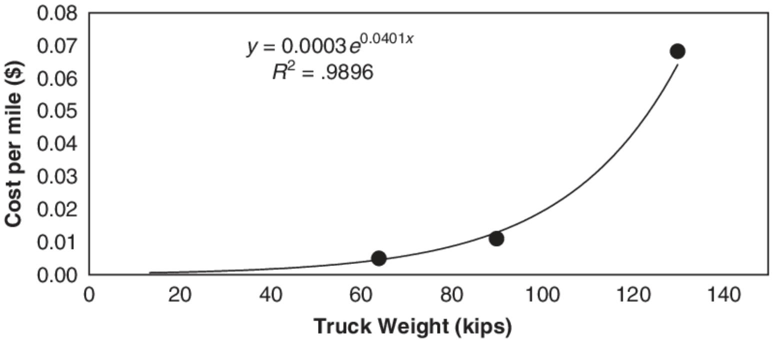

Figure 1. The dependence of the cost per mile on the weight of a truck (in average axle weight (kips)) [4]

This dependence was obtained after studying the data on the cost of damage (including from overload) for various types of freight vehicles (Table 1).

Table 1. Combined Bridge and Pavement Damage Cost (Axle-Based Damage Cost), by Truck Type and GVW (2012 US$) [4]

Truck Type	Trip Length (mi)	Per Mile Damage Cost for Truck Loaded at Legal Weight Limit ($)	Per Mile Damage Cost for Overweight Truck Loaded Up to Maximum Overweight Limit ($)	Per Trip Damage Cost for Truck Loaded at Legal Weight Limit ($)	Per Trip Damage Cost for Overweight Truck Loaded Up to Maximum Overweight Limit ($)	Additional per Trip Damage Cost Above Legal Limit for Overweight Truck Loaded Up to Maximum Overweight Limit ($)
2-axle, 35–40 kips	75	0.3523	0.6748	26.42	50.61	24.19
3-axle, single unit, 46–50 kips	100	0.2474	0.3933	24.74	39.33	14.58
3-axle, combination, 50–55 kips	270	0.4442	0.7444	55.53	93.05	37.53
4-axle, single unit, 63.5–65 kips	125	0.3585	0.4600	96.78	124.21	27.42
4-axle, combination, 65–70 kips	270	0.4884	0.8247	131.87	222.68	90.80
5-axle, 80–90 kips	160	0.4583	0.8420	73.33	134.73	61.40
6-axle, 80–90 kips	160	0.2585	0.4407	41.36	70.52	29.16
6-axle, 90–100 kips	160	0.2585	0.6834	41.36	109.35	67.99
6-axle, 100–110 kips	160	0.2585	1.0123	41.36	161.97	120.61
7-axle, 80–90 kips	160	0.1428	0.2556	22.84	40.89	18.05
7-axle, 90–100 kips	160	0.1428	0.3956	22.84	63.29	40.45
7-axle, 100–110 kips	160	0.1428	0.5880	22.84	94.08	71.23
7-axle, 110–120 kips	160	0.1428	0.8440	22.84	135.04	112.20
7-axle, 120–130 kips	160	0.1428	1.1730	22.84	187.67	164.83
8-axle, 80–90 kips	160	0.1140	0.2005	18.23	32.08	13.84
8-axle, 90–100 kips	160	0.1140	0.3059	18.23	48.94	30.70
8-axle, 100–110 kips	160	0.1140	0.4668	18.23	74.69	56.46
8-axle, 110–120 kips	160	0.1140	0.6497	18.23	103.96	85.72
8-axle, 120–130 kips	160	0.1140	0.9030	18.23	144.47	126.24

As for the physics of the interaction between the truck and the road, the spatial movement of the vehicle is both translational and rotational. At the same time, vertical forces cause deformation of the road surface, as well as tangential forces, the most important of which arise during acceleration and braking of the car in the contact zone of the wheel tire with the road surface, creating a relative shift of the upper layers of the roadway [5]. Particularly problematic is the movement of the car on the approaches to turns in the plan, as well as on the curves themselves, where the car turns around a vertical axis. In such places, both the car and the top layer of the road surface are subject to lateral loads that have a significant impact on the stability of the car. In this regard, the curves and approaches of the plan are largely designed to ensure that the car runs smoothly and prevents it from rolling over and slipping. As a result, there is a system of forces acting on the vehicle on the road, different in direction and amplitude.

Quality of transport infrastructure determines the quality of the provision of services for the transportation of goods and passengers. The infrastructure sector is a guarantee of efficiency, mobility and uninterrupted economic activity. However, the high quality of the transport infrastructure implies significant and long-term investments [6]. If money were not an issue, then building all roads to handle the heaviest legal loads would be the solution to accommodating freight on roads. Truck sizes and weights have increased faster than roads have been improved. When most roads are reconstructed today, they are built to carry 10-ton loads. Asphalt and gravel roads are at their weakest in late winter and spring, when the ground begins to thaw and the materials that support the road’s surface are saturated. In order to account for their weakened state, some asphalt and gravel roads are restricted in the spring, this means that a 9-ton road may become a 7-ton road for a few weeks until the roadbed dries and returns to its normal load-bearing capacity [7].

Today, roadways are designed using engineering factors that establish the quantity, type and thickness of material that needs to be used to balance vehicle loads and roadway use.

Among other factors, current pavement design considers the amount, type and weight of the traffic using the road. This data is used to calculate an ESAL (equivalent single-axle load) factor; this factor is a way of measuring the impact that a vehicle will have on a pavement.

Pavements can be viewed as a “consumable” and are designed to carry an estimated number of ESALs over their design life. As each vehicle passes over a pavement, a portion of its life (the vehicle’s ESAL factor) is consumed. Eventually, a pavement’s life is expended, and it needs to be reconstructed.

To sum up, deliveries may become less frequent as a result of the use of larger trucks: with each vehicle having a greater weight, fewer trips are required to transport a given volume of cargo [8]. However, as a result of less regular deliveries, inventory builds up, resulting in a capital freeze and reduced inventory turnover. In addition, less frequent deliveries can lead to disruptions in supply chains. Having additional safety level of stock can help avoid some of these failures, but it comes at a cost. In addition, for some perishable or highly specialized goods, additional safety stocks are not possible due to the nature of the cargo.

Alternatively, to maintain delivery frequency, transferring to larger vehicles can be combined with enhanced cargo consolidation, forming consignments from different shippers on the same vehicle. Naturally, this implies additional costs for the functioning of the consolidation system - both physical objects and the management structure. To be economically beneficial, the cost of consolidation must be less than the cost savings of liner transportation.

In the end, the increase in the overall weight and flow of trucks has prompted road facility managers to conduct frequent inspections to make sure the infrastructure can still handle the traffic while maintaining an appropriate level of safety and cost. More accurate methodologies are being developed to assess the impact of new truck configurations on pavement, surface layer (rutting) and overall structure. As a result, the challenge is to reconcile the parameters of road freight transport and its associated environmental costs and impacts (by encouraging heavier and larger vehicles) with an optimal road infrastructure management plan.

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