HEAVY VEHICLES AND ROAD CONSTRUCTION:

Interaction between bans and technical improvements, 1900–2023

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Promising new technology cannot always be exploited, for society has to regulate and control it. Such was the case when motor vehicles first appeared in Denmark around 1900. Amidst that transition, heavy trucks and buses were especially challenging, for they could quickly destroy the country's roads due to being too heavy.

This article describes the series of bans and restrictions on new vehicle technology in Denmark since the beginning of the 20th century. Only as a result of constant improvements in both vehicles and roads could those rules be relaxed and the possibilities of the technology be better exploited.

Roads for horses

Until only relatively recently, horses had Denmark's roads to themselves. Apart from a brief interlude with a single steam carriage in 1862, horse transport was the only means of transporting goods in the country before 1900. During the 19th century, railways took over long-distance transport together with (steam-powered) vessels, whereas regional transport was performed exclusively by horse-drawn carriages.

Owing to the physics of horses, the use of horse-drawn carriages imposed natural limits on how much could be transported. Usually, one or two horses pulled the vehicle; carriages with four horses were rare but could haul a lot more.

Although the largest horse-drawn carts weighed less than 4 tonnes, even with their contents, their effective weight depended on the condition of the roads. If the roads were poorly laid across hills, as most roads were, then the horses could not carry nearly as much as on optimal roads. On good roads in the 1930s, the heaviest horse-drawn vehicles effectively weighed nearly 5 tonnes, 1.3 tonnes of which was the cart. To that was added the weight of two horses, at 900 kg each.

The roads could generally cope with horse-drawn vehicles, apart from heavy traffic in the wettest months during autumn or during the dreaded thaw, when road strength weakened significantly. The roads were gradually improved, however, especially after the new road construction technology of macadam—that is, using a relatively thin surface of cuttings covered with sand—was introduced in the mid-19th century. Roads near ports and other busy urban areas were paved beginning in the late 19th century, sometimes even with the new and exceptionally smooth cobblestones pavement.

From two to 770 horses. Circa 1900, freight transporters in Faaborg used only two horses per vehicle, for a total weight of a few tonnes per vehicle. By contrast, their counterparts today have the equivalent of up to 768 more horses pulling their vehicles; in theory, the Scania 16-litre V8 770 hp engine can pull a vehicle weighing several hundred tonnes.

Although horse-drawn carriages, on Denmark's roads for hundreds of years, could largely take care of themselves, society has had to manage and regulate motor vehicles since their emergence at the turn of the century. (Faaborg Byhistoriske Arkiv and Scania)

Advertising for early cars showcased the problems that passenger cars caused for Denmark's roads. Their fast rubber tyres sucked up the sand, such that new-and-improved roads literally disappeared in a cloud of dust. The first task of road engineers was thus to secure the surface of the roads.

Motor vehicles: Ruined roads

After 1900, cars became a permanent fixture on Denmark's roads. Although few at first, cars as a phenomenon had to be taken seriously.

A particularly serious problem for road engineers was that cars could not easily be driven on the same kind of roads as horse-drawn vehicles. Their relatively high speed and deafening noise frightened not only horses, already nervous by nature, but drivers as well. Worse still, their speed caused the rubber tyres to suck the sand away from the road's macadam surface. Thus, in rather short order, motor vehicles destroyed Denmark's roads.

Road builders worked to solve the problem and, by the early 1920s, had incorporated methods so that passenger cars could travel on all roads at a reasonable speed. Soon after, many vital roads had their surfaces sprayed with tar, thereby eliminating the problem of dust. This article concentrates on heavier vehicles, which posed entirely different problems that were not so easily solved.

After the rapid development of engines in the early 1900s, vehicles were no longer limited by a tractive effort of 1, 2 or 4 horsepower (hp). In time, engines could be produced with far more than 10 hp and power even vehicles with a gross weight of 20 tonnes or more.

However, it was some years into the new century before it became possible to build reasonably durable heavy vehicles. Thus, the first vehicles on the road were primarily motorcycles and passenger cars.

After World War I, large stable trucks arrived in Denmark. Manufactured in 1918, the U.S.-built Mack truck had a four-cylinder engine with 74 hp, which allowed the truck to carry more than 5 tonnes. Because the truck weighed slightly more than 5 tonnes, its laden weight could exceed 10 tonnes, which far surpassed what most roads at the time could handle. (Photo: Jørgen Burchardt)

After the driving restrictions of World War I were lifted, traffic started to pick up again, and vehicles became larger. Lorries used by the Allied forces in France during the war found their way to Denmark.

Such huge vehicles soon proved too heavy for Denmark's roads, and the problem was never fully solved due to three challenges. One, bans and regulations had to be put in place to protect the roads. Two, car manufacturers had to create new vehicles that would not wear out the roads so much. Last, new and better methods had to be developed to build durable roads. The following subsection examines developments in each of those three areas and how they interacted.

Bans, injunctions and regulations on heavy vehicles before 1940

In 1903, when Danish authorities apparently became aware of the problem for the country's roads posed by heavy vehicles, they began both requiring the registration of vehicles and regulating specific technical devices. A general rule was that cars could drive only on the country's main roads. By contrast, secondary roads—the majority of the roads in Denmark—could be driven on only with the permission of the Ministry of Justice, which required the approval of an application by local authorities. Even then, only the most lightweight vehicles were permitted.

Although passenger cars had air-filled tyres, trucks in the first decades of the 20th century ran on massive wheels that could easily destroy most of Denmark's roads after even a single drive. (Roskilde Lokalhistoriske Arkiv)

By 1913, however, the proponents of cars had become so numerous and so powerful that those laws were soon relaxed, even if only slightly. Nevertheless, only small cars under a specific weight limit were allowed to drive on the secondary roads. That limitation led, among other things, to the production of exceptionally lightweight cars at Danish car factories. From another direction, local politicians also imposed restrictions on driving by means of the Police Act.

It eventually became clear that realising the full potential of new vehicles would require Denmark's roads to be improved. To fund such improvements, a vehicle tax was introduced in 1910, the revenue of which went exclusively to road construction and maintenance. The principle was sensible: vehicles would pay for the wear and tear that they caused. For the first several years, the state only rarely diverted that ever-growing source of revenue to other purposes.

The tax was calculated according to the engine power of vehicles, meaning that a motorcycle owner—the relative number of motorcycles compared to cars peaked in 1910—did not have to pay nearly as much as the owner of a heavier car that wore more on the roads. However, whereas the tax was usually 5 to 7 DKK per hp per year, for lorries and buses, it was only 2 DKK per hp.

As vehicles continued to expand in size, the authorities eventually had to impose strict requirements on their weight. In 1921, the unladen weight

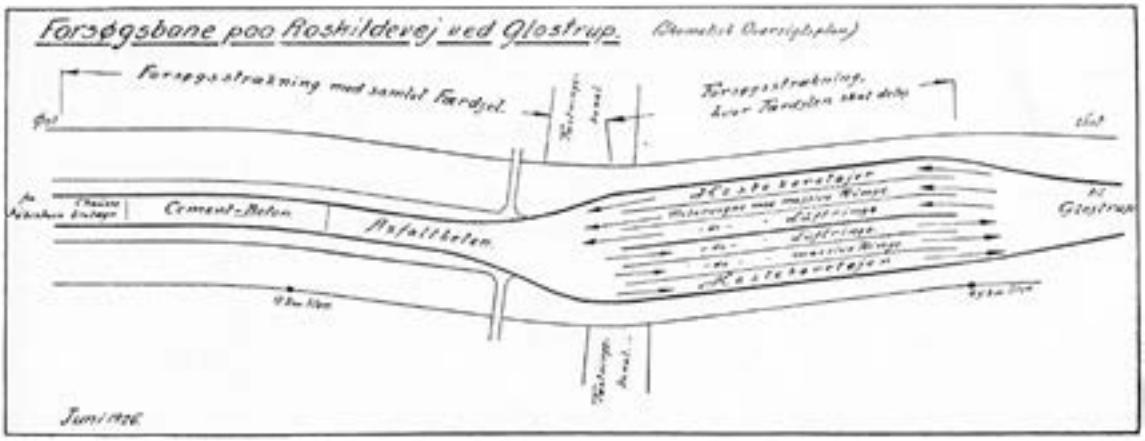
In 1926, an experimental facility was established on Roskildevej, the central road to Copenhagen, which was prepared for three types of transport: horse-drawn carriages, carriages with solid tyres and vehicles with air tyres. The experiment readily revealed how much a road would be worn after the passage of increasingly more vehicles. (Glostrup Lokalhistoriske Arkiv)

of vehicles was limited to 4 tonnes, while the total weight could not exceed 8 tonnes. Moreover, when exceptionally high axle loads were found to be ruining the roads, rules were introduced for the maximum axle load. In 1927, the limit was 6 tonnes. However, local exemptions could be granted, including in urban areas with paving, where heavy vehicles could be driven without causing damage.

As mentioned, in addition to complying with weight limits, each vehicle had to be approved by the authorities in order to be registered. Particular motor experts were therefore appointed to inspect vehicles and assess what maximums should be imposed on load and speed, among other things.

In 1927, Denmark's tax system for cars changed. Because calculating engine power had become onerous, the tax was changed to be based simply on the vehicle's weight. Weight was easy to determine, and there was a better correlation between the wear and tear of heavy vehicles and the corresponding tax to be collected. The differences in the taxes thus rose sharply, particularly for most giant lorries. For vehicles up to 1200 kg, each 100 kg of the vehicle's unladen weight cost 13 DKK; weights exceeding 1200 kg demanded 16 DKK per 100 kg, weights exceeding 1500 kg demanded 18 DKK, weights exceeding 2000 kg demanded 20 DKK, and so on.

In the early 1920s, a tax was also introduced on the use of buses, depending on how much they drove and thus how much they burdened the



Different surfaces were experimented with on the test track along Roskildevej. The left side of the map shows marked sections of the road paved with cobblestones, cement and asphalt. (Danish Vejtidsskrift)

roads. Lorries, however, even ones running on routes, were exempt from the tax, which was paid to the local county council according to the number of kilometres driven and the number of seats on board. The tax was abolished in 1927, and, in its place, a new tax was introduced that all motor vehicles had to pay: a tax on petrol.

Knowledge of wear and load capacity

Even as late as the 1920s, neither road engineers nor politicians knew how much vehicles were wearing down Denmark's roads. Although the question was much discussed at meetings for engineers, no clear answer materialised.

Of course, the same question was being asked all over the world, and road engineers from different countries also gathered to share their experiences. In 1908, the International Road Congress was founded in Paris, and, since then, similar congresses have met regularly.

At the time, road design was not an exact science, and meaningful research on the subject was being developed rather slowly. Even so, it was clear that roads wear down over time and eventually break down entirely. Thus, only after a certain period was it possible to gauge how long a particular type of road could withstand a certain amount of traffic.

The experiment on Roskildevej was of unique international importance, and reports were published in English so that foreign road engineers could learn from its results.

To gain such knowledge, practical tests commenced around the world to determine the wear of traffic on different types of road surfaces. One epoch-making experiment was conducted on a test track on Roskildevej, a road near Copenhagen, in 1926. The

large road with heavy traffic to and from the capital had been made 25 m wide so that each type of vehicle would have its own lane. There were three lanes in each direction: one for horse-drawn vehicles, another for fixed-wheel motor vehicles and a third for air-ringed vehicles. The number of vehicles in each row from a point in time was counted automatically, which allowed determining the wear on the road surface caused by the number of passing vehicles. Because each section of road comprised all of the different road structures known, the extent of wear on each type could be ascertained.

The first major report on the results, issued in 1930, showed that horse-drawn vehicles wore down certain surfaces disproportionately. It also directly stated that a few heavy horse-drawn vehicles were probably wearing roads down more than several lightweight ones. Curiously, the same conclusion was not reached for motor vehicles.

The Danish experiment was ultimately a rather ingenious solution for using relatively few resources to obtain results on the loads of different types of vehicles. Data from the experiment were collected until 1939, when the trial was closed—that is, when horse-drawn transport and the use of solid wheels had become outdated.

Balloon tyres and other vehicle improvements

For decades, the carrying capacity of roads did not improve significantly for heavy vehicles. Instead, new technology for trucks as well as buses enabled such heavy vehicles to travel on Denmark's roads. The first new technology in that vein was improved tyres.

In 1924, U.S. company Firestone was the first to produce the revolutionary balloon tyre, whose low pressure allowed vehicles to drive on roads without damaging them. When the pictured advertisement from 1929 was printed, however, tyres for the largest trucks could not yet be manufactured.

To be sure, rubber tyres are necessary for all motor vehicles. Wooden or iron wheels, by contrast, transmit the vibrations of driving into the technical structures of the engine and vehicle. Without some suspension, the technical parts quickly loosen and shake apart. To solve that problem, traditional springs were experimented with in the late 19th century but not to much avail.

Using a trailer was a method of enabling a truck to pull nearly twice as much weight as it can on its own, and once trucks were installed with equipment using compressed air, trailers could be braked. The number of trailers in Denmark first exceeded 1,000 in the early 1930s. (Danish Veteran Car Club)

Although bicycles had used rubber tyres for decades before 1900, no one believed that rubber tyres could also be made to carry the tonnage of cars. The first cars weighed approximately one and a half tonnes, plus the weight of passengers and approximately 200–300 kg more for the many spare parts needed on long journeys.

The pioneer in introducing rubber-inflated rings for wheel rims was French innovator Edouard Michelin, who, in 1894, was the first to put pneumatic tyres on a car. In the first race with the car, the tyres were punctured as many as 25 times, and the car finished last. However, the idea was eventually improved upon, and by 1897 most motor races had vehicles with inflated rings for tyres.

Before that time, engines had to be built quite solidly and were therefore heavy, at approximately 250 kg per hp and thus a full tonne when 4 hp engines became common. With better suspension tyres, however, engines could be more lightweight. Even so, such rubber was designed for very high-pressure hoses, which made it vulnerable to puncturing, and car owners were satisfied if a tyre lasted 1,000 km. With slightly better roads and improved tyre designs, especially with the invention of cord cloth (i.e. stretch canvas) for reinforcement, a tyre could last approximately 10,000 km by 1910.

Nevertheless, large trucks still had to run on solid or semi-solid rubber tyres, if not iron tyres, which resulted in significant deadweight when a truck's weight exceeded its payload. Even the heaviest pneumatic tyres in 1914 could not be used for vehicles weighing more than 2 tonnes. Speed

was also limited, for the best rubber tyres could withstand speeds of no more than 40 km per hour. Further still, trucks could travel only on urban roads, because the surface of secondary roads would be quickly destroyed by the impact of heavy traffic.

Air tyres were therefore a significant technological breakthrough for trucks, because newly developed tyres could cope with heavy loads. In 1919, the first pneumatic tyres for heavy goods vehicles appeared. With up to 1,100 kg of load per tyre and 7 atm overpressure, the tyres could be used for 3-tonne trucks. However, the life of the tyres was only approximately 10,000 km, whereas a tyre on a typical passenger car at the time could last approximately 17,000 km.

Another significant invention arrived in 1922 when U.S. company Firestone launched a new type of tyre. Tests had shown that soft, low-pressure tyres made the canvas in the carcass less likely to crack despite the new tyres had fewer layers of canvas. Instead of being round, the tyres were oval, hence the name "balloon tyres" after the shape of the balloon airplanes of the time. Moreover, whereas the pressure in the old tyres had to be at least 75 psi, low-pressure tyres could make do with 45–50 psi.

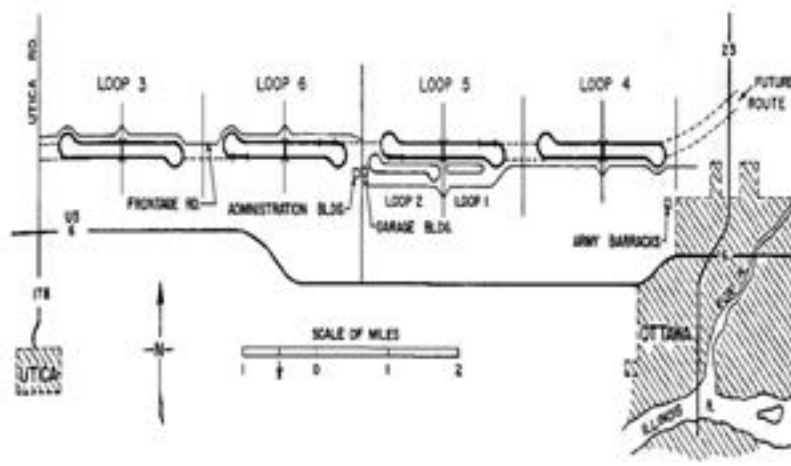
The low-pressure tyres dramatically improved the comfort of riding in cars and, being less vulnerable to puncturing, lasted nearly twice as long. In only five years, half of all tyres were of that type. Such tyres were also produced in Denmark. The company Schiønning & Arvé had been building solid tyres since 1898, including tubes since 1900 and car tyres since 1909. By 1924, they were able to produce balloon tyres from cord canvas. By 1928, it was possible to build tyres with a very low pressure even for heavy wagons, and, by 1934, the air tyres could accommodate wagons with axle loads exceeding 10 tonnes.

The balloon tyres represented an improvement as revolutionary as the transition from fixed tyres. They not only increased the total weight that air rings could carry but also reduced the vibrations of the vehicles, such that more lightweight designs were possible. By the mid-1930s, 25 tonnes of payload could be carried on a vehicle weighing only 13 tonnes. Heavy balloon tyres could now usually withstand more than 100,000 km of driving. That improvement was a major one, for at times tyre costs had previously exceed 30% of the total operating costs for car owners.

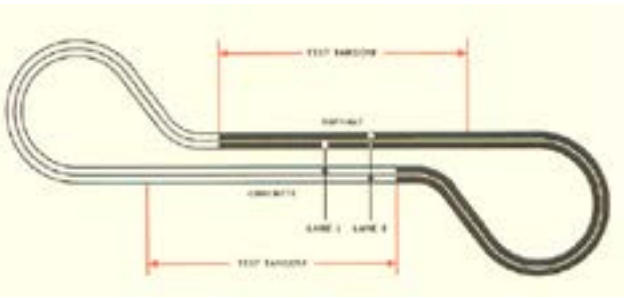
By the 1930s, road engineers had discovered that road wear had a somewhat different composition than assumed and reflected in the relatively rigid established rules. When surface wear was found to be a function of pressure per cm2, and the pressure for all wagons with balloon tyres was no higher than permissible, for the air tyres this meant that the pressure per cm^2 was independent of the load and depended only on the air pressure.

The true destroyers of roads were therefore wagons with massive iron tyres, which, hastened by legislation, were well on their way to obsolescence. In 1927, exceptionally high additional taxes for such massive tyres were introduced: 25% for approved semi-solid tyres and 50% for solid or unapproved semi-solid ones.

It was not until 1950 that real low-pressure tyres became common. Instead of cotton for reinforcement, new materials such as nylon were used, such that passenger car tyres could have pressures as low as 35 psi.



In the United States, outside Ottawa, Illinois, the construction of six test tracks in 1956 started to shed new light on road structures. The tracks were supposed to amount to an extensive network of highways between the states. Today, remaining parts of the lanes form part of Interstate 80. (Washington State Department of Transportation)



Consequences of the biggest road test in world history, 1958–1960

Different types of trucks ran almost non-stop for more than two years to show how the different extents to which different combinations of weight and axle configuration damaged sections of road. Behind the test was the American Association of State Highway Officials, or AASHO. (Washington State Department of Transportation)

In the late 1950s, the most extensive road test in world history was carried out in the United States, namely in Ottawa, Illinois. During World War II, General Dwight D. Eisenhower had realised the usefulness of good roads for German forces in their supply operations, and it was Eisenhower as U.S. president who initiated major interstate road-building projects in the United States. Those projects required knowledge that the road test could provide.

The trials began in 1958, and, until 1960, up to 126 vehicles travelled almost continuously for 18–19 hours a day, 6 days a week, on an 11.3 km stretch of road. At its peak, the test involved 320 military personnel. The road itself consisted of 836 sections, across which 16 parts of bridges were tested. Today, the straight sections of the road are part of Interstate 80 in Illinois.

The goal of the trials was to identify, on the one hand, the relationship between the number of loads with known axle loads and axle configurations and, on the other, different thicknesses of pavement and bearing layers. Six test tracks were constructed, five of which were driven on, while the sixth was used to measure the influence of weather on the pavement. Each track was doubled, for a total of 10 lanes for driving, and each was subjected to different vehicles. In one lane, a lightweight, two-axle truck weighing only 4 tonnes was used, whereas the heaviest vehicle in the trial was a five-axle truck of 108 tonnes.

The test revealed that a slight increase in a vehicle's weight would cause a significant increase in wear. The theory of traffic load, referring to the cumulative number of heavy axle passes, was thus developed. According to the theory, wear occurs every time that a heavy axle passes a stretch of road, which consequently affects the pavement. That dynamic eventually results in a fatigue fracture, similarly to how steel wire breaks after being bent a certain number of times. For that reason, a road has to be dimensioned to be strong enough to withstand the stress that it will experience during its lifetime.

The U.S. Interstate Highway System celebrated its 50th anniversary in 2006. During World War II, General Dwight D. Eisenhower realised the usefulness of good roads for the supply routes of German forces, and it was Eisenhower as U.S. president who initiated the major interstate road construction in the United States- (AASHTO)

According to the theory, the damage to the road changes with the axle load to a power of 4. Comparing a truck with an axle load of 6 tonnes and the rear axle of a passenger car of 0.6 tonnes thus reveals an important fact: the truck has the same degrading effect on the road as approximately 10,000 passenger cars. At the same rate, a truck of 12 tonnes has the effect as 160,000 passenger cars!

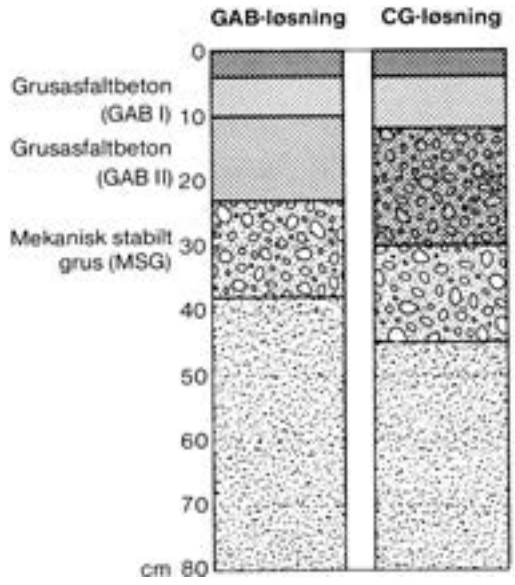
Since the 1960s, such theories about the stress of vehicles on roads have continued to evolve as computers, among other innovations, have provided entirely new ways of calculating the many factors involved. However, the basic understanding of road loading that prompted a significant improvement in road construction was developed in the 1950s and 1960s.

After World War II, strict restrictions against heavy vehicles in Denmark were relaxed somewhat. It turned out that during the thaw, when the roads had been weakest, the politicians had been too optimistic. Even many country roads could not bear the vehicles, as shown in this photograph from 1955. (Det Kongelige Bibliotek)

New road surfaces since the 1950s

Once cars began kicking up dust on the world's roads, the most common road treatment was a simple spray of tar or asphalt, although emulsions with binders dissolved in water were developed soon after. On top of the binders, a thin layer of stone was spread, for a road surface that was suitable for passenger cars but not heavy vehicles.

Cement was a widely used material in the United States and Germany but not in Denmark, where only a fraction of the roads were built with the material. Most Danish roads were instead built with soft binder asphalt mixed with stones and gravel. Beginning in the mid-1950s, however, asphalt became virtually the only material used.

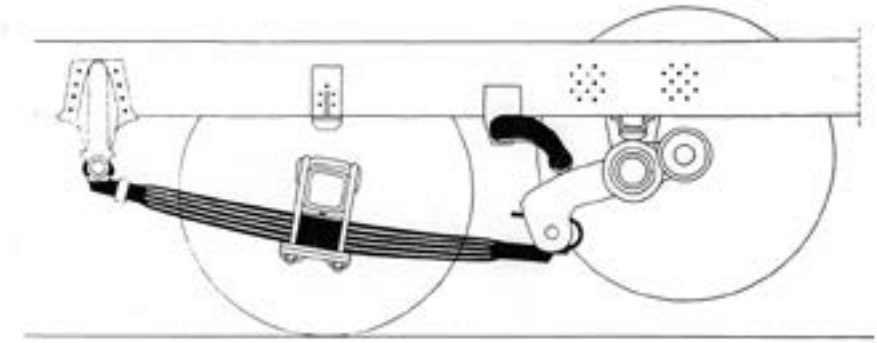


Following remarkable scientific advancements in the 1960s, highly durable roads could be built, and heavier vehicles could be tolerated. The image shows two deep road constructions in Denmark the late 1970s; under the top asphalt layer was an additional asphalt mixture on top of a gravel layer. (from Burchardt & Schönberg)

Other significant advances in road technology emerged as people became aware of the importance of the soil underneath. New methods of geological investigation meant that road surfaces were being taken into account, which resulted in better road designs. Different methods of stabilising the subgrade thus surfaced, including adding cement and hydrated lime.

Road materials have undergone a similar technological evolution. Since the 1960s, construction has been mechanised into nearly industrial production, in parallel to organisational changes that have transferred road construction to large, often international companies. In the final decades of the 20th century, for example, several asphalt mixes were developed, and, in the 1970s, road engineers introduced asphalt laid at depths of 37 cm. Those improvements were not only the result of better materials technology but also better road design.

The enhanced roads allowed higher weight limits for vehicles and thus higher loads. However, those limits have since led to the problematic rutting of pavement. Added to that, when the maximum tyre pressure was raised and super single tyres were used, new problems arose. New technical solutions again had to be developed in order to obtain asphalt soft enough that the surface would correct itself after sustaining the impact of heavy vehicles. On that count, polymer-modified bitumen emulsion emerged in the late 1980s, and, once again, road construction improved.



More axles can distribute the weight to more wheels and, in turn, reduce wear and tear on roads. In Denmark, one method was to place two axles close together, for a so-called bogie. A bogie in which one axle can be lifted when there is no load is called "Nordic", because the Swedish companies Scania and Volvo introduced the type.

Improved vehicle technology and the driving economy

With improved roads, heavier and therefore more economical vehicles could be used. Despite government subsidies and heavy restrictions on lorry traffic, the proportion of goods transported by rail fell because lorries were flexible, fast, highly accurate and not bound by timetables. As early as 1952, trucks were carrying more than half of Denmark's freight, and 15 years later, more than 80%.

Increased lobbying to raise permitted weights had an unsurprising outcome. In 1975, Danish hauliers argued that axle weights should be raised to 10 tonnes, an increase that would result in annual savings of DKK 200 million. From the other direction, road officials claimed that it would cost up to DKK 1.5 billion to upgrade roads to accommodate that weight. In 1977, the new weight limit was agreed upon and an increased tax introduced.

As a result, many new forms of technology became essential for the development of trucks. By the late 1920s, compressed air had already been introduced for brakes that allowed extending the traditional four-wheel, one-load vehicle with an extra trailer. As weight distribution also improved, larger vehicles became legal in Denmark. In time, the combination of trailers and wheels also varied widely, with semi-trailers becoming especially popular, because a semi-trailer can be uncoupled, and the driver and tractor do not have to wait for unloading and loading. Suspension has also evolved, not least with air suspension beginning around 1960.

In short, the speed and reduction in unladen weight in relation to net weight have steadily improved over time. As the graph of the total loading capacity of lorries, including trailers, in Figure 2 shows, road trains have also steadily become increasingly large. Despite plateauing in the 1940s and 1980s, the trend towards even larger, more powerful vehicles shows no signs of stopping.

RESTRICTIONS ON VEHICLES

Despite the sporadic relaxations of restrictions on motor vehicles in Denmark over the years, a great many new rules and restrictions—often complex ones—have had to be introduced.

TOTAL WEIGHT

New rules have been introduced in Denmark, particularly in response to new and higher standards for large parts of the road network. Beginning in 1939, bridges on major roads had to be able to carry a 50-tonne block truck. Bridges built beginning in 1965 have had to accommodate a weight of 100 tonnes per vehicle, and, in 2002, the weight was further increased to 150 tonnes.

Meanwhile, in 1977, the maximum weight for a wagon train was raised to 44 tonnes, and, in 2016, to 56 tonnes, namely for vehicles with at least seven axles.

Even weighty vehicles have been allowed to travel on certain roads in the country. On that count, special rules were established as early as the 1950s for export hauliers carrying goods abroad on particularly durable roads.

AXLE PRESSURE

The 6-tonne limit was maintained in Denmark until 1947, when 7 tonnes was first permitted. In 1955, that weight became the limit for all roads. That same year, twin wheels were allowed so that an axle could weigh 8 tonnes. In 1977, that limit was raised to 10 tonnes.

Numerous special rules depending on the number of axles and bogie weight, among other things, have been introduced in Denmark, some of which remain in force. In 1977, a two-axle bogie could carry up to 16 tonnes and three-axle one 22 tonnes, as long as the distance between the axles was at least 1 m. In 2016, a four-axle group could reach 30 tonnes under certain conditions.

Special transports may be needed, for example, to move large technical units. Transformer stations for power stations were among the largest transports in Denmark in the mid-20th century, while windmills became particularly large in the early 2000s.

Initially, police and authorities could jointly authorise special transports in Denmark, but as the number of such transports grew, the rules had to be formalised in 1977 with the "blue road network", within which heavy vehicles are allowed to travel.

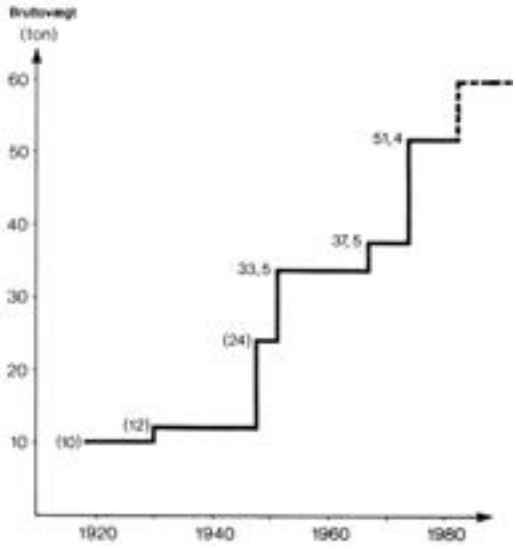


Figure 1. *Over time, the maximum weight for vehicles has continued to rise as roads and vehicles have become better engineered. The curve shows that development in Sweden, which is representative of most other countries in Western Europe.*

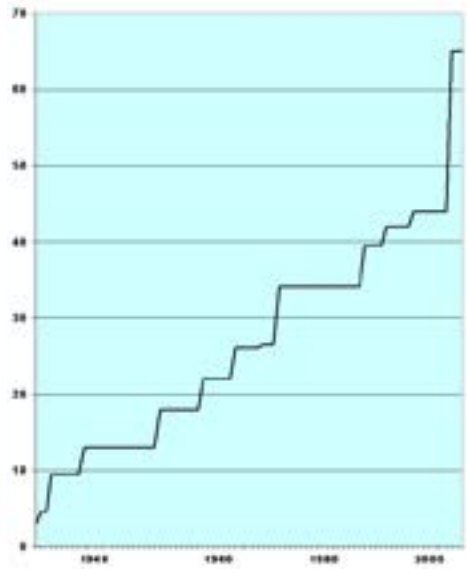


Figure 2. *The figure shows the development of the size of trucks supplied by Volvo. The curve indicates the greatest total weight that a wagon train could have and shows a clear trend: trucks are being built in ever-larger versions.*

International rules and standardisation

One of the most important meetings of the world's road professionals was held at a road congress in Munich in 1934. Although the aim was to establish international rules, major differences between countries proved to challenge any progress.

In several areas, Denmark was especially lagging behind other countries. It maintained the rigid rule of a total weight of 8 tonnes, regardless of how many axles the weight was distributed across. Most countries usually compared with Denmark had instead introduced varying weights according to the number of axles. In Great Britain, for example, a wagon train had to have a total weight of more than 22 tonnes. Likewise, some countries allowed much higher speed limits than Denmark. In several countries, speed limits did not exist for lorries weighing less than 3 tonnes, and, in Italy, for ones weighing up to 6.5 tonnes.

After World War II, it soon became apparent that international road traffic would increase sharply. In response, the United Nations established an international standard for road traffic. In particular, a congress in Geneva in 1949 proposed international standards with rules for width and axle load. The maximum axle load in Denmark, at 6 tonnes, was on the lower end. Only Norway and Sweden had lower limits, albeit with the possibility of derogation, while some countries' roads allowed a standard of up to 16 tonnes. The congress thus recommended working towards a European standard of an 8-tonne axle load.

Other common European standards were also developed. In 1984, a directive

Volvo's LV76 was launched in 1934 as a slightly larger truck than the vehicles supplied by its main competitors, Ford and Chevrolet. (Volvo)

As of 2023, Scania's biggest truck is the model 770 S. With a 16-litre engine of 770 hp, the truck's train can bear 77 tonnes of approved gross trailer weight. (Photo: Dan Boman, Scania)

In Denmark and elsewhere, modern society needs to transport oversized units. Many of Denmark's roads can handle the transport of more than 100 tonnes at low speeds when the weight is distributed over many wheels. The transformer in the figure is on a block wagon with a total weight of 280 tonnes. (Torben Rafn & Co)

from EEC was adopted on the load and dimensions of heavy goods vehicles, rules that were to be in force in EEC member states two years later. The most significant change was a decision that the countries would allow an axle weight of 11.5 tonnes beginning in 1992. However, there were also calls for further increases in weight limits, and work began on allowing vehicles of unique roadworthy construction to have their limits raised. Air-suspended vehicles were known to be relatively gentle on the roads, and the availability of other gentle suspension systems was investigated as well.

Since then, vehicles weighing 19 tonnes have been allowed on a bogie for four-axle trucks, and, in 2003, new rules were introduced for 4-axle trucks with two steering axles and a distance between the front and rear axles of at least 5 m.

Owing to such traffic signs, the general weight restrictions can be set aside if a part of the road or a bridge is too weak for heavy traffic.

Conclusion

Since the early 1900s, vehicle regulations have sought to strike a balance of terror. On the one hand, hauliers have desired to drive larger and therefore more rational vehicles. On the other, road authorities have had to protect roads from the heaviest and therefore most damaging traffic. Caught between them, politicians have had to promote development prudently, such that they have followed the wishes of the industry somewhat but also withstood the pressure to dedicate vast sums to increasing the carrying capacity of roads.

The desire for larger vehicles, likely never to be satisfied, will continue to be met by technical improvements in both the carrying capacity of roads and the suspension of vehicles, together with complex regulations adopted to tame the new technology.

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