MAN AND THE MACHINE

Articles from Northern European Road History

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Foreword

This joint publication Man and the Machine of the Nordic and Baltic road museums has been in the making for quite some time now. The call for papers was first announced already in spring 2019 but, as we all remember, the global pandemic caused a halt also for the book project. Luckily, the decision of the Estonian Road Museum to host our NordBalt conference in September 2023 after a long pause has worked as a catalyst, forcing this volume finally to be published.

The volume includes eight articles from members of the NordBalt family dealing with different aspects of the mechanization of roads, roadbuilding, and road upkeep. Jørgen Burchardt from Denmark reviews the challenges caused by motor traffic on roads and road structure from the earliest automobiles to modern times. Annika Kupits from Estonia narrates the almost forgotten story of an attempt to introduce a new type of horse cart, easier for roads, at a time when horse traffic was still the mainstay in most rural areas of Estonia. Mikko Pentti from Finland and Andres Seene from Estonia study the history of the motorized grader in the 1920s and 1930s in both their countries respectively. This machine, that had American and Swedish roots was considered ideal for gravel roads. Ernst Sagstuen from Norway has contributed an article on a Norwegian built car, the Giant, whose technological finesse is described in detail. In his second article Andres Seene tells the story of an Estonian machine engineer and inventor Arnold Volberg, who, although a member of the pre-war Estonian road administration, was able to work as an engineer and inventor in Soviet times also. Indra Dziedātāja from Latvia reminds us in her article, that although the Soviet times can today be overlooked, it is still possible to find astonishing engineering feats, like the viaduct over the Lorupe ravine. Finally, Arnulf Ingulstad takes a look into the snowblower industry of the Øveraasen company and describes their importance in keeping Norwegian roads open in winter.

Together the articles offer an interesting view of the machinery used on roads in the Nordic and Baltic countries and on how the road administrations in all these countries have attempted to improve traffic conditions by adapting their machinery to the myriad of emerging problems caused by modernizing traffic.

Mikko Pentti
Editor

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HEAVY VEHICLES AND ROAD CONSTRUCTION:
Interaction between bans and technical improvements, 1900–2023

Jørgen Burchardt
Museum Vestfyn

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.

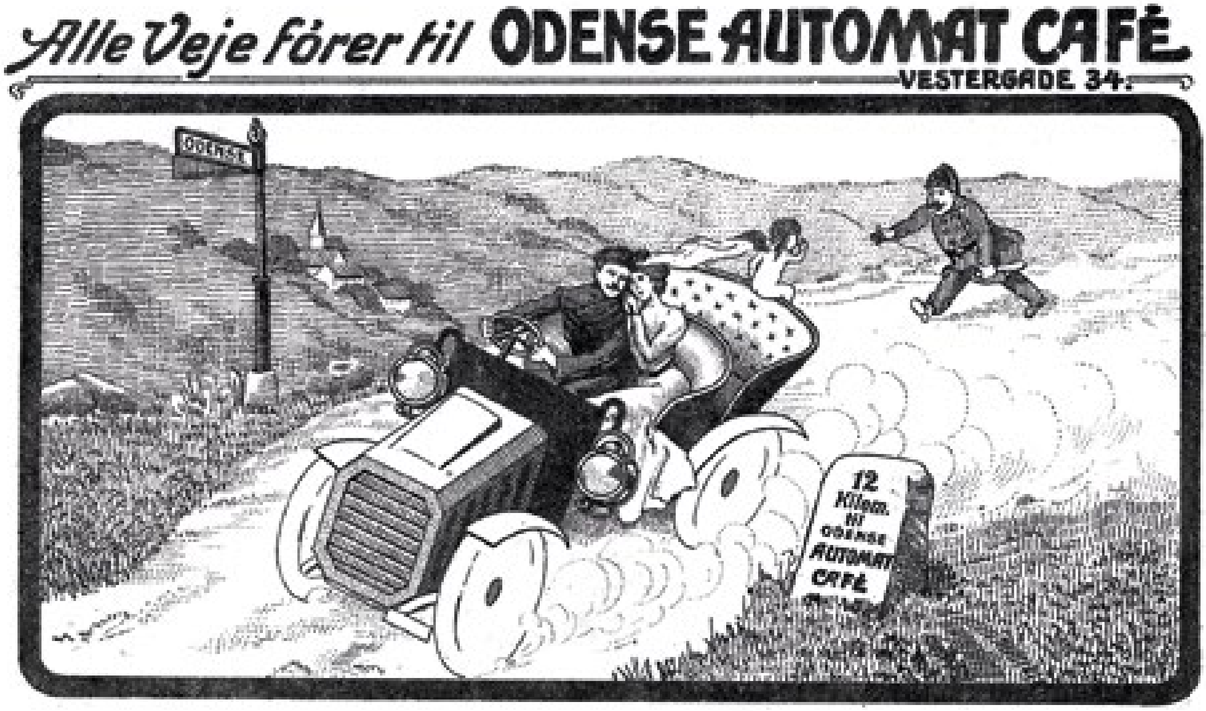
Owing to the physics of horses, the use of horse-drawn carriages imposed natural limits on how much could be transported. Usually, one or two horses pulled the vehicle; carriages with four horses were rare but could haul a lot more.

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

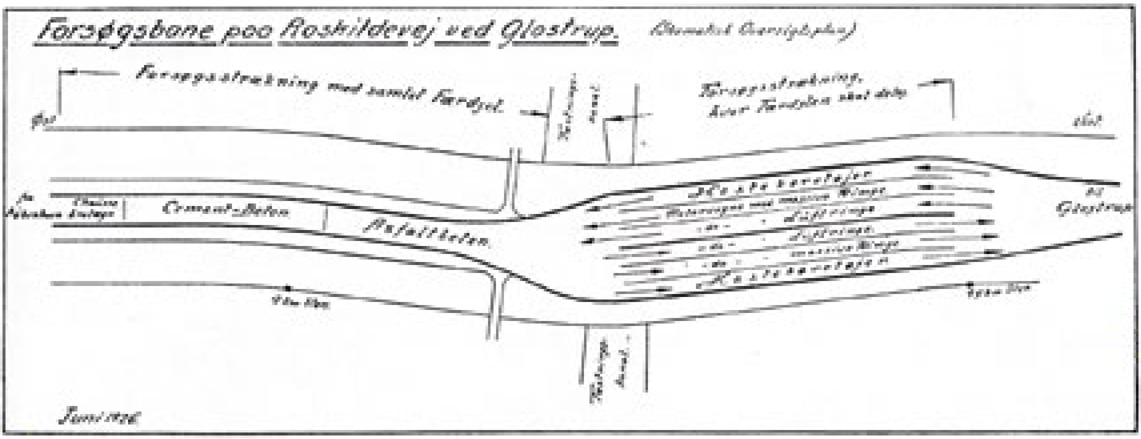
In 1926, an experimental facility was established on Roskildevej, the central road to Copenhagen, which was prepared for three types of transport: horse-drawn carriages, carriages with solid tyres and vehicles with air tyres. The experiment readily revealed how much a road would be worn after the passage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

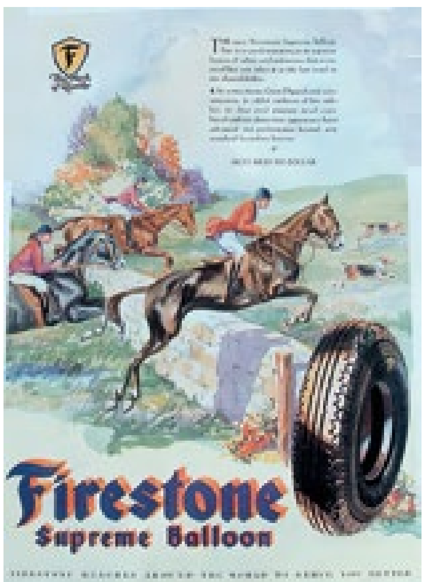
To gain such knowledge, practical tests commenced around the world to determine the wear of traffic on different types of road surfaces. One epoch-making experiment was conducted on a test track on Roskildevej, a road near Copenhagen, in 1926. The large road with heavy traffic to and from the capital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

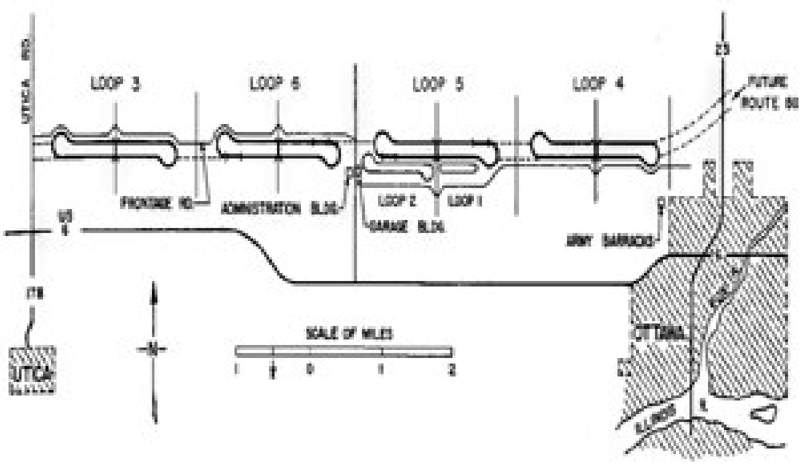
The low-pressure tyres dramatically improved the comfort of riding in cars and, being less vulnerable to puncturing, lasted nearly twice as long. In only five years, half of all tyres were of that type. Such tyres were also produced in Denmark. The company Schiønning & Arvé had been building solid tyres 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.

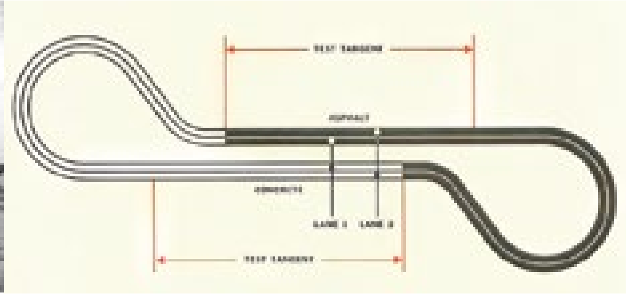
By the 1930s, road engineers had discovered that road wear had a somewhat different composition than assumed and reflected in the relatively rigid established rules. When surface wear was found to be a function of pressure per cm2, and the pressure for all wagons with balloon tyres was no higher than 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)



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)

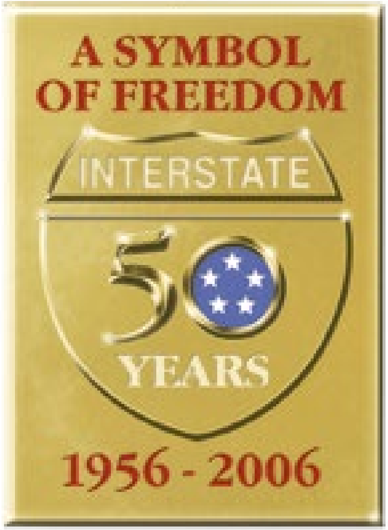
Consequences of the biggest road test in world history, 1958–1960

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!

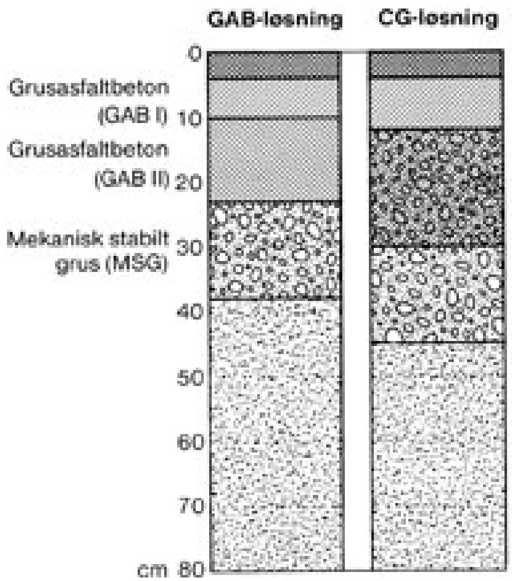
Since the 1960s, such theories about the stress of vehicles on roads have continued to evolve as computers, among other innovations, have provided entirely new ways of calculating the many factors involved. However, the basic understanding of road loading that prompted a significant improvement in road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



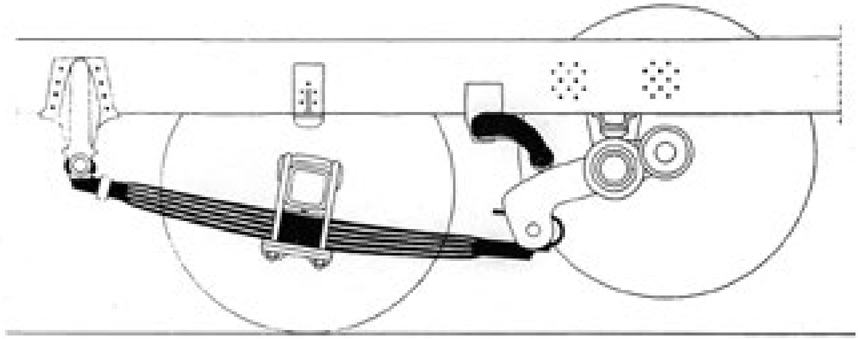
Following remarkable scientific advancements in the 1960s, highly durable roads could be built, and heavier vehicles could be tolerated. The image shows two deep road constructions in Denmark the late 1970s; under the top asphalt layer was an additional asphalt mixture on top of a gravel layer. (from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

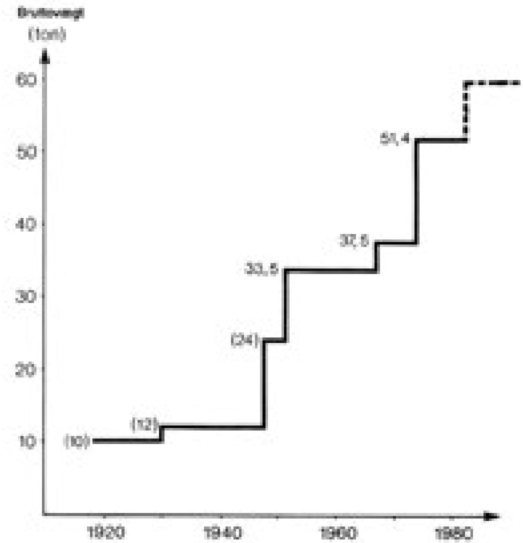


Figure 1. *Over time, the maximum weight for vehicles has continued to rise as roads and vehicles have become better engineered. The curve shows that development in Sweden, which is representative of most other countries in Western Europe.*

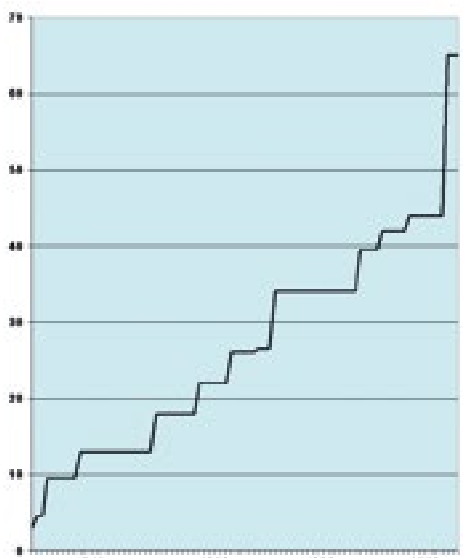


Figure 2. *The figure shows the development of the size of trucks supplied by Volvo. The curve indicates the greatest total weight that a wagon train could have and shows a clear trend: trucks are being built in ever-larger versions.*

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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Road Administration's Attempt to Protect Roads: STORY OF THE MODEL HORSE-CART

Annika Kupits
Researcher-curator of the Estonian Road Museum

Introduction

The collection of the Estonian Road Museum includes a photo series of a mysterious model horse-cart. But no recollection of the cart had been preserved. Research in the periodicals as well as in the National Archives revealed a little but remarkable story, according to which in 1935 the Road Administration started developing a model horse-cart suited to the local conditions and less damaging to the roads. The Road Administration probably intended to find the middle ground between motor vehicle and horse-cart users, but by doing so stepped partly into the field of the Ministry of Agriculture.

The early 1930s was marked by the Great Depression. It slowed down the development of society, including the development of roads. However, the importance of car transport still increased, causing changes in the entire infrastructure. In Europe, Motorways straight as arrows were built, goods were transported in large quantities by trains and lorries and traveling became possible for ever more people. The Republic of Estonia was also about to join the ranks of Western countries where traffic was dominated by cars. Car was no longer a luxury items: private cars, taxies, buses and lorries were a common sight in larger cities. But horse-drawn carts were in no hurry to disappear – their peak lasted until the 1920s, when suburban transport and farm work was mainly performed with carts. In the 1930s, horse-carts still had to be reckoned in transportation of people and goods: a cart could be used in most road conditions whilst car traffic required roads of certain standard. Especially in rural areas, the quality of roads did not catch up with the needs of cars, and cart ruts deteriorated them even further. The state, however, did not have enough money for road management.[1]

It's therefore understandable that the Road Administration started dealing with road maintenance at the grassroot level, especially since most of the roads at the time were unpaved and even horse-carts could not use them during the rainy season.[2] This article tries to describe the results that the harmonisation of Estonian farm horse-carts and the reduction of ruts in the roads was expected to achieve.

Not a stick, but a carrot

The Road Administration probably started developing a new road-friendly type of farm horse-cart in the hope that it would convince farmers of its superiority and cause them voluntarily to start building and using them all across the country. The story of the model cart can be followed from 5 Feb-

1 For further information see Seene 2017
2 Einer 1988, 114

Model farm horse-cart at the Agricultural Exhibition in Tallinn, 1936. (Estonian Road Museum) ruary 1935, when the Päevaleht published the news "Universal cart type for farmers. Newest plan of the Road Administration":

"The Road Administration considers it necessary to develop a new cart type for farmers, which would be suitable for all activities and have a pre-determined tyre width. This is an attempt to find a cart model that would be the most acceptable from the viewpoint of reducing the costs of road maintenance."[3]

The article includes the opinion of the board of the Estonian Farmers Society in Tallinn, who doubted that creating a universal farm horse-cart or changing the tyre width would be possible. These two points remained the main topics in the story of the model horse-cart. In response to the article and to specify the information given in the article, the director of the Road Administration Maksimilian Grasberg,[4] who the press had also called the initiator of the model horse-cart project,[5] sent a letter to the editor-in-chief of the Päevaleht:

"The Road Administration does not intend to prescribe a cart type and it definitely does not intend to cause harm to farmers /.../ but wants to start promoting acceptable cart types after thorough testing, leaving the decision up to our good farmers to make. The article reports that the issue of a universal cart type has not been solved in foreign countries, Germany in particular, but this is not true. They haven't come up with a universal cart type, but the issue of tyre width /.../ was solved in Germany a long time ago. The kind of narrow cart tyre we have is not used there."[6]

The letter was published two days later and included a detailed description of the background of the model horse-cart project. Further concerns were expressed in different sources about the possibility that sanctions were hiding behind the promotion of the new cart type, which would make the lives of farm horse-cart users harder. However, the Road Administration repeatedly reassured people through the press that even though this option did exist, using coercive methods was not a likely course of action. The good will and benefits of all parties were always mentioned in addition to general economic advantages in correspondence with relevant societies and administrations.

3 Päevaleht, 05.02.1935
4 Maximilian Uriko (formerly Grasberg, 1892–1971). Studied engineering in Berlin in 1920's. The director of Road Administration from 1934 to 1939. Emigrated in 1944.
5 Sakala, 30.06.1939 – „Development of Estonian roads, directed by M. Uriko" („Eesti maanteede areng ins. M. Uriko juhtimisel")
6 Päevaleht, 07.02.1935 – „Letters to the editor" („Kirjad toimetusele")

At first, there was a rut

The descriptions of the model horse-cart story have probably survived because of the problems during the process and the need to report on and document how these were processed. In the letter of explanation[7] written by machine engineer at the Road Administration Arnold Volberg[8] about the development of the standard farm horse-cart design (and the acquisition of a test cart based on it):

> *"Having been tasked with developing of a new type of farm horse-cart that causes less damage to roads, the first thing I did was study the differences in the construction of the horse-carts used here at present. In order to collect the necessary data about farm horse-carts, the Road Administration sent a letter on 21 January 1935 to the Chamber of Farm Work, agricultural schools and the farmers societies of Tallinn, Tartu and Viljandi, asking them to send information about the structure and main dimensions of the most used cart types. After receiving the material about farm horse-carts that the aforementioned institutions sent to the Road Administration, I started comparing the cart types used in different counties and determining the main dimensions of the new cart on the basis of these.*
>
> *In order to obtain material for designing the new farm horse-cart type, the Road Administration requested information about the most common cart types from Finland, Sweden, Latvia, France, Germany and Denmark with a letter sent via the Ministry of Foreign Affairs on 20 May 1936. Only Sweden sent information about the farm horse-carts used there and it mostly concerned carts drawn by two horses. The failures of foreign countries to send this information was a disappointment, but nevertheless, I started designing the draft of a standard farm horse-cart on 13 August 1935 and completed it on 21 September 1936."*

When the Road Administration inquired about this in 1935, the response received via the Ministry of Foreign Affairs[9] was that the laws of Denmark included no requirements for horse-carts. Special regulations concerning the maximum dimensions of carts had been established in some countries, but they were not harmonised nationwide. The following was noted about means of transport in general:

7 ERA. 2075.1.350, 11.01.1937

8 Arnold Volberg (1900–1967) machinery engineer, started working as a machine inspector at the Road Administration in 1933. The best years in Arnold Volberg's career were the 1940's-1950's in Stalinist Soviet Estonia, where he made his greatest achievements in the creation of road construction and maintenance machines.

9 ERA. 957.3.341; ERA.2075.1.350

"The use of horse-carts on Danish roads has decreased considerably in recent years. The survey carried out in 1929 revealed that the share of horse-carts in transport across the land was only 18%, and these days it's even lower than it was 1929. The use of carts with rubber tyres is increasing and people often use old car tyres and car wheels."

The response from Finland states that *"the society for rationalisation of agricultural work [has] discussed the harmonisation of farm horse-cart types, but nothing has been done about this so far. This why there is no printed material about this."*[10] The documents received from Sweden described the tyre width of a work-cart established by law already in 1907. The translation of the law concerning farm horse-carts from 1935 is as follows:

"We Oscar, King of Sweden, the Goths and the Wends from the grace of God, announce that We with the Riksdag, have decided to determine as follows:

If the situation in a county demands this, the representative of the royal power has the right, after hearing the opinions of the landsting and the road administrators, to determine that the wheel width of work-carts used on the public roads within the borders of the county may not be smaller than certain dimensions. /.../ For the purposes of this act, a work-cart is a means of transport on wheels, which is drawn by draft animals and which is meant only or mainly for transporting loads. /.../ The width of a tyre may not be less than 7 and more than 12 centimetres."[11]

Based on this act, the counties in Sweden decided to establish the tyre width of two-wheel carts as 8.5 cm, 9 cm or 10 cm from 1912 to 1928. Four different variants ranging from 7 to 9 cm were established for four-wheel carts. In any case, this was and is considerably wider than our most common 2 inch variant and the 2.5 inch variant planned for the model cart. The response of the Swedish Agricultural and Technical Association reveals that in addition to tyre width, there were also regulations concerning axles, hubs and axle nuts, and that none of the cart types used was considered superior to be used as the basis for a universal cart.

The Estonian counterpart of the above was § 10 of the Regulation of Road Use and Means of Transport of the Road Act of 1928, which was repeatedly amended and specified later.[12] However, as noted in the article as well, the regulation was not enforced. Considering the quantity and variety of the types of horse-carts, a catch-all inspection and therefore also the establishment of the regulation could be deemed unlikely for purely practical reasons as well.

10 ERA. 957.3.341; ERA.2075.1.350
11 ERA. 2075.1.350
12 https://dea.digar.ee/cgi-bin/dea?a=d&d=AKriigiteataja19290628.2.4

Stepping on farmers' toes

Primary logic suggests that the development of a universal farm horse-cart type should have belonged in the area of administration of the Ministry of Agriculture. The opinions and experience of farmers were included via farmers' societies but not at the level of the ministry. The special interests of the Road Administration could be expected to receive a boost by offering added value to those who used the carts: changing the tyre width, which was bound to generate additional costs for farmers, had to have direct benefits for them. The innovation was obviously welcomed – after the publication of the first news the press sent the Road Administration many requests for information[13] about the design, which showed that craftsmen and cart users were aware of the need to change and ready to make and test the new cart. But there were also sceptical opinions:[14] although the need for new solutions was obvious by the time, the finances struggled to keep up with the necessities of life. Elmar Järvesoo[15] from the Tartu Farmers' Society referred to the initiative of the Road Administration to develop a well-functioning universal cart in his piece "Attempts to Rationalise the Building of Horse-carts"[16] of 1936, adding that:

> *"/…/ irrespective of the dedicated attempts in this field, they have failed to achieve any satisfactory results so far. Some deficiencies have been reduced to some extent, but in some cases, this has increased deficiencies elsewhere. /…/ The development of wheeled means of transport used in agriculture has been rather slow here as well as abroad. It seems as if the ordinary peasant's cart has become outdated and a museum piece on our roads, which are relatively good by now, and next to other technical means of transport. Good roads and bad carts here and abroad show that the development of carts has not been fast enough and building them is still influenced by old ways and habits more than appropriate."*[17]

Järvesoo highlights some alternative development trends for farm carts: the article promotes the use of rubber tyres and certain principles in cart building. Järvesoo refers to the increasing number of cars used in Scandinavia, which is confirmed by the response about a standard cart received by the Road Administration from Denmark. As for increasing the tyre width, universality and light weight, the vision of Järvesoo coincides with the aspirations of the Road Administration. He adds that means of transport must

13 ERA. 2075.1.350
14 Ibid
15 Until 1935 Elmar Gerberson (1909–1994), Estonian polititian and researcher. Worked at the University of Tartu and emigrated in 1944, continuing his career in the USA.
16 Tehnika Põllumajanduses, nr 1, 1936, 11
17 Ibid

Sprung cart with rubber tyres – a luxury out of reach of Estonian farmers. An ordinary cart with (iron?) wooden tyres in the background. (Estonian Road Museum)

be cheap, durable and easy to make and repair also in rural areas, and that 2-inch wheels are too narrow.

Cart maker Johann Köösel of Pärnu County announces in his response to the initial plans of a universal cart in the end of March 1935 that his customers usually want carts with a set of wide tyres that runs lightly at the same time.[18] Köösel says that the spacing between the wheels of a one-horse cart used to be 36 inches in Estonia, but 39 inches in Latvia and Courland, which made the run of the carts lighter. Köösel put the main emphasis on increasing the width of the cart, which was supposed to be the key to the success of the universal cart. Volberg must have come to the same conclusion, as the wheel spacing of the model cart also was 39 inches. It is also worth mentioning that the model cart of the Ministry of Roads proved to be the most successful in tests carried out at the Pärnu Agricultural Exhibition in August 1938. The carts that competed were the one-horse and two-horse carts of Köösel and the model cart; the latter proved to be the easiest to draw and the first one the hardest. Although, as mentioned in the article[19], Köösel himself was not surprised by this – the width of the cart type determines how lightly it runs.

The general background of the issue of the model cart was covered by R. Tiitso of the Tallinn Farmers' Society in his response of 1936 to the initial design of the standard cart:

18 ERA. 2075.1.350

19 Uus Eesti, 31.08.1938 – „The new farm cart is good. The road minister constructed a cart that demands little traction." („Uus taluvanker on hea. Teedeministri poolt konstrueeritud taluvanker nõuab väikest veojõudu.")

"It's difficult to make any innovations in the carts used in villages, as we're dealing with hundreds of thousands of conservative users and thousands of cart makers, who will stick to their present types unless something radically better is created. Therefore, the task of the Road Administration in our conditions is not to copy old deficiencies and sanction old cart types, but to monitor the new development and testing, and support the building of the new types /.../ and then let the thing speak for itself. /.../ the easiest and cheapest way to increase the tyre width by half an inch, would be to make it obligatory, but this idea was thrown out in the battle between political parties. These provisions must be enforced again, but with certain patience and caution, so that compliance with them would not cause any damage to the owners nor create a massive wave of opposition."[20]

Carriage made by carriage maker J. Köösel that won an award at the Pärnu Agricultural Exhibition in 1931. (National Archives of Estonia)

Already in 1935, having heard of the Road Administration's plan to start developing a model cart, Tiitso sent his study "Qualities of our present cart and its impact on roads"[21], which includes the drawings of the universal vehicle he constructed and the necessary explanations.

His study starts with interesting statistics about horse-drawn carts in rural Estonia in 1935: 151,000 one-horse work-carts with iron axles, 45,000 work-carts with wooden axles and 6000 two-horse carts with iron axles. This shows that the estimated total number of work-carts in Estonia at the time exceeded 200,000. There were also 32,000 charabancs and a similar number of sleds and sleighs. The number of horses according to him was slightly over 200,000. Tiitso probably estimated that the number of horse-carts in Estonia including the one used by the military was about half a million and therefore considered the optimising of horse-carts, that so had far received disproportionately little attention, extremely important. Tiitso also refers to the poor conditions, which were bound to curb the effectiveness of any changes:

20 ERA. 2075.1.350, 10.03.1936
21 ERA. 2075.1.350

"The fact that the old cart with the wooden axles still clings on to its position (to the extent of approximately 30%) is a sign that introducing the new cart type is a very difficult task. In any case, this is not a sign of civilisation or a high level of agriculture, but a sign of poverty."[22]

As for the figures offered by Tiitso, the high number of carts is also underlined by the first thorough traffic count carried out in Tallinn in 1935. This indicated that 3000 people on average arrived in Tallinn in a day: 1300 of them by train and 1600 by road (incl. 350 by coach). The vehicles arriving in Tallinn by road included 700 to 800 horse-carts, 40–50 cars and 50 to 60 trucks. This shows that there were considerably more horse-carts than cars. Although the number of cars exceeded this figure two and half times by the end of the period of independence, the share of horse-carts was still considerably bigger.[23] The aforementioned statistical data from Denmark, that 18% of all loads there were carried by horse-carts, characterised the share of trucks in Estonia at the time.

Poor logistics

The criticism on the lacking comfort of carts was fully justified. People had attempted to soften cartwheels for centuries using leather, metal and various solutions based on wood, not to speak about springs. A breakthrough arrived in 1839, when Charles Goodyear developed vulcanised rubber.[24] The pneumatic tyre – to this day the most efficient aspect of driving comfort – was invented in 1845. Yet, a hundred years later, a farm horse-cart with wooden wheels was still the biggest innovation that Estonia as a state could offer its farmers. The Scandinavian practice mentioned in this article, where written-off car parts were successfully used to optimise the work of horse-carts, could also have become an alternative or even a common practice in Estonia, as suggested by the developing picture of the Estonian secondary car market in the 1930s. People drove their cars for as long as the pneumatic tyres lasted. A car that had changed hands several times could end up costing just 150 to 200 kroons, which was the same as the cost of a good bicycle and two farm horse-carts. The cost of a new set of pneumatic tyres, however, was around 300 kroons.[25]

The state would have needed another decade in its mobile development before it could start recycling pneumatic tyres and/or the chassis under carts. Considering the relatively fast increase in the number of cars, it can be presumed that this indicator would have also reached critical heights

22 ERA. 2075.1.350, 13.04.1935
23 Praust 2018, 120–121
24 Lay 1992, 145
25 Klesment & Valge, 2008, 36

in Estonia by the late 1940s had peace lasted, and they would have moved on to farm households as spare parts.

Standard carts in counties

As Volberg mentioned in his writings, the Road Administration contacted county governments in February 1935 to collect information about common local cart types:

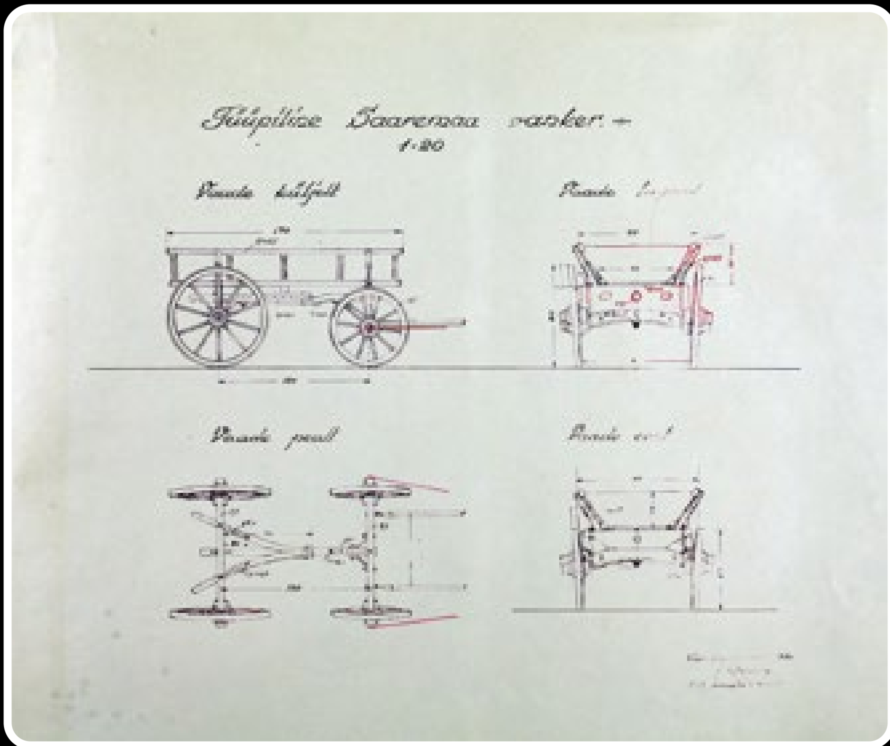
> *"The Road Administration intends to develop a new cart type for farmers, especially where the tyre width of the cart is concerned. The additional requirement has arisen from the fact that finding a cart model, which would be the most acceptable from the viewpoint of reducing the cost of road maintenance (the tyre width) and promoting in after testing it thoroughly and hearing the opinions of everyone concerned, would make it possible to avoid the application of coercive measures in respect of tyre width. Of course, the cart would primarily have to meet the needs and requests of the farmers who use them."*[26]

It's pointed out that resolving the issue quickly is "in the interests of the national economy" and a request is made "not to refuse to provide" detailed information about all parts of the cart, their structure and materials, and descriptions of all kinds of measurements and fastening methods. It was also important that it would be "possible to build the cart from locally available materials, it should be easy to make, light and require as little strength as possible to draw (by a horse)."

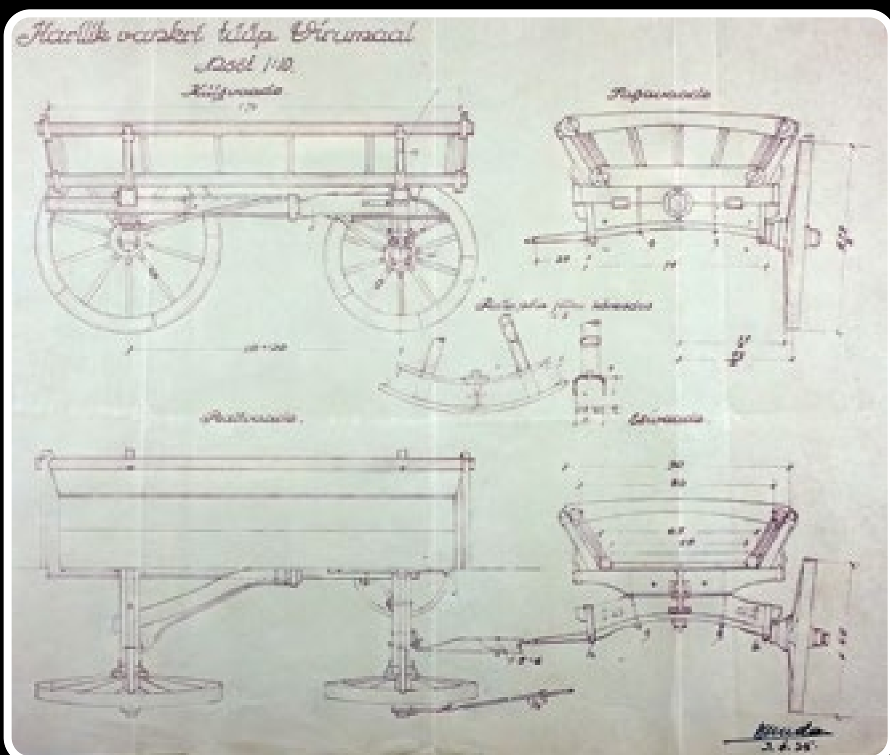
The county governments were contacted for the second time to find additional measures for getting farmers' organisations to act – at first, attempts to secure adequate cooperation with them ended in failure. Agricultural societies and schools lacked the resources for the respective research, so the ones who sent information were the ones who had already recorded observations about horse-carts in the past. However, the Road Administration didn't give up:

> *"The responses sent to this circular indicate that several types of carts are being used depending on the roads, horses, the transported material etc., this question has not been thoroughly dealt with in the past, and the aforementioned organisations obviously cannot give the Road Administration accurate data and, in particular, the necessary drawings concerning this issue.*

26 ERA. 2075.1.350; ERA. 2013.1.1859



Standard Saaremaa county cart. (National Archives)



Standard Virumaa county cart. (National Archives)

Considering the above circumstances and that the issue still needs to be resolved, please do not refuse to inform the Road Administration about the following:

1. *data of one or two types of cart most commonly used in your county according to the questions listed above,*
2. *have the relevant drawings prepared and enclose them with your response,*
3. *your opinion and suggestions concerning this issue."*[27]

To the second circular detailed responses from all counties were received. This made it possible to map the most typical farm horse-carts used in Estonia from Saaremaa to Petseri in 1935.[28]

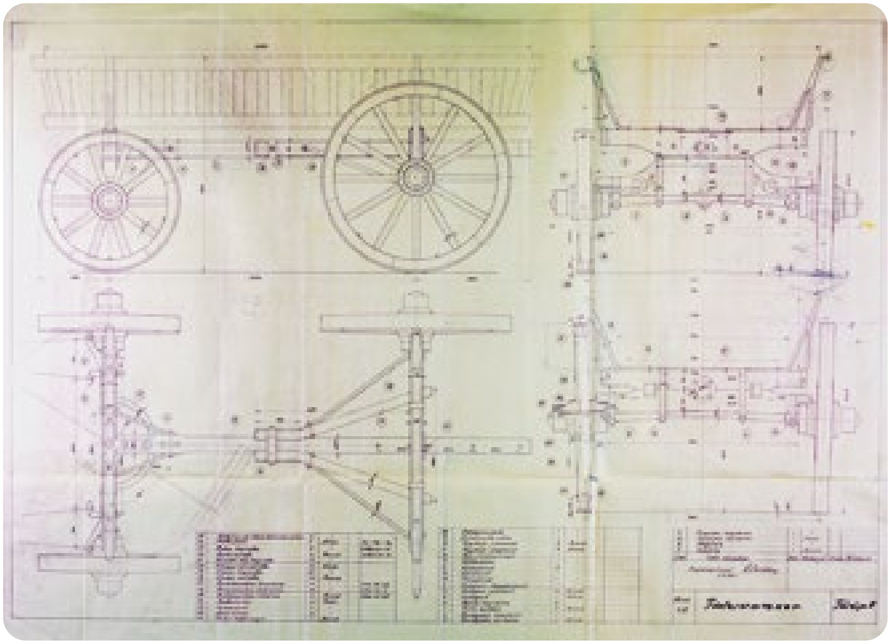
Development of type A

Engineer Arnold Volberg was asked to design the farm horse-cart "type A" based on the drawings and descriptions received, or at least try to take them into account. How much he considered the characteristics of the carts used in different counties or how much he could take over from them deserves a study of its own. Collation and interpretation of the received data took a couple of months: the drawing of a standard cart signed by Arnold Volberg is dated 21 September 1935. The drawing of the model cart was sent to counties and farmers' societies for review in the end of January 1936. The project included information about the differences of the universal farm hose-cart "type A" from the most used farm horse-carts:

1. tyre width 2.5 inches instead of the former 2;
2. bigger wheel spacing;
3. adjustable axle spacing;
4. turning angle increased by almost 100%;
5. wheel hubs encapsulated, which reduced the wear of axles and lubricant consumption by almost a half. Axles lubricated with a pressure sprayer, which makes it easier and faster (the wheels don't have to be removed);
6. advantages: better from the viewpoint of road maintenance; small lubricant consumption plus longer life of axles and hubs; could be used to carry heavier loads on soft surfaces; etc.[29]

27 ERA. 2075.1.350; ERA. 2013.1.1859
28 ERA. 2075.1.350
29 ERA. 2075.1.350; ERA. 2013.1.1859

Model horse-cart "type A". (National Archives)



The design of the new cart received a lot of feedback. Criticism and somewhat more constructive suggestions included contradictions about most things, as Volberg conceded in his writings from early 1937:

"A comparison of the received requests[30] on 17 March 1936 revealed that the suggestions concerning the alteration of the design are contradictory and do not warrant any changes to the design, which is why my proposal is not to change the design of farm horse-cart "type A" and soon build a test cart on the basis of the design, so that testing the cart can start immediately after the snow melts."[31]

A comment made by the Saaremaa cart committee was:

"As the cart is an expensive item for a farmer, it should be kept in mind when a standard cart type is designed that it should be suitable for all kinds of transport." And also, considering the main objective of the cart: "In terms of tyre width, it would be advisable not to determine this by law for one-horse carts."[32]

The people of Saaremaa were not the only ones who wanted to abandon the main constructional change planned by the Road Administration. The most understandable and common obstacle to the project, which has mostly received positive responses, was emphasised in the letter sent by Valga County Government:

30 A. Volberg refers to feedback from county governments and farmers' associations.
31 ERA. 2075.1.350
32 ERA. 2075.1.350; ERA. 2013.1.1859

"We cannot expect great support for this cart type from farmers /.../: namely, it's heavier than the carts currently in use, and the overall price of the cart is also higher than the price of the light carts in use. /.../ instead of increasing the tyre width, which rural people are greatly opposed to and which is complicated, the spacing between the wheels on the back axle of the cart should be made bigger than on the front axle. /.../ Also, the wheel spacing of the cart should not be the same 1.00 m on all carts, but it should be variable and range from 0.95–1.05 m, as such small variation would practically not cause any difficulties.

In the opinion of the representative of the factory [of means of transport in Valga], preventing the emergence of ruts in roads would be a lot easier by following the above principles, as reforming the carts like this would not be particularly difficult: the old carts and wheels would remain the same, only the axles would have to be changed, the material on the market for tyres would remain usable, the weight or price of the cart would not change and, even more importantly, people would still have the carts they're used to. Such a reform would also take a lot less time to implement than the introduction of a new cart type."[33]

R. Tiitso of the Tallinn Farmers Society was critical in his feedback,[34] but it gives us a good overview of the carts used in Estonia at the time:

"In comparison with the carts used in Estonia, the recommended "farm horse-cart type" does not offer anything new other than encapsulated hubs and the rearrangement of the placement of the tubes. This innovation was already used in Estonia in the previous centuries, but it never went further than the testing stage in the case of farm horse-carts. There are obvious reasons for this. Mostly the distance between the thills, which should be 30 cm wider. It would be the optimal width, as a narrow distance of 55 cm is unacceptable.

However, the majority of the deficiencies of the farm horse-cart have been left in the design:

- *increasing the wheel spacing by 8 to 10 cm is the vaguest method if you have to use the cart on rutted village roads, because one side will still run in the rut and if the ground is soft, then all wheels will break into the rut, making it wider, whilst the cart wheels of the old width made the ruts deeper. Such a new cart is therefore hard to draw and doesn't satisfy the user. However, if the wheel spacing was made 40 to 50 cm wider, then a horse would no longer draw the cart into the old ruts, but new, shallower and wider ruts would appear.*

33 ERA. 2075.1.350
34 ERA. 2075.1.350

– *Nothing has been designed to make the cart more elastic and there is no seat, so faster movement in a cart that doesn't have a seat would cause people unnecessary pain and damage the roads. American farm workers refuse to use any means of transport or agricultural implement that doesn't have a seat and we must also make farm work easier and more comfortable.*
– *This one-horse work-cart type with ladders that was used in manors and that is being recommended to us does not meet the requirements of our small farm. In a manor, it had a special purpose among various carts. Here, a man in Virumaa transports grains and hay from the field in a proper painted light cart on which a frame is placed for this purpose. This cart can also be used to transport potatoes, gravel, etc., to go to the mill, the dairy farm and the town. /…/ The cart with ladders and wooden axles is used to transport manure and there are over 40,000 such carts in Estonia. /…/ The multi-purpose charabanc is disappearing here as well and being replaced by the omnibus, car and bike, partly also the telephone.*
– *The short conical 7.5-inch hub, like the one used on the carts of the military, must be considered the weakest part of this construction. After a while, when the cart itself is still fine, the ends of the hubs and axles have become worn and the cart staggers from side to side, which fills the hubs with sand and mud, which now, because their lower ends are encapsulated, doesn't let the muck drip out anymore. /…/ Lengthening the hub by a couple of centimetres would not help. A new structure must be designed here, which would replace one conical hub with two cylindrical ones, the distance of which from each other would be equal to the radius of the wheel.*
– *Also, nothing has been designed for emptying the cart, it must be done by pushing, which is not always successful, or by shovelling or throwing, which wastes a lot of time and which is followed by picking up the stuff thrown off the cart. This deficiency has been more or less successfully eliminated in cars and this equipment is now widely used on carts in America as well as in the West."*[35]

Tiitso's opinion summarises all of the main arguments against the development of a model cart. In general, the opinion shows that Tiitso seriously doubts whether the initiative is reasonable and whether it would be more useful to use the same resources elsewhere. Some approval was received from county governments as well, but they were also concerned about the grease gun and the encapsulation, and as already said, some respondents had doubts about the wider tyre that could presumably only be achieved

35 ERA. 2075.1.350

Testing the cart of Sopi Farm on a tarmac road (Paldiski Road) with a burden of 1000 kg. Testing horse-carts in 1936. (National Archives)

with great difficulty. Another downside that they highlighted was the big weight and price of the model cart and that village smiths would not be able to make the kind of axles required in the "type A" project. The fact that local village smiths must be able to make or at least repair the model cart was pointed out several times.

First tests with first test cart

The first test cart was ordered in May 1936 from cart manufacturer Vaimann via Pärnu County Government. When the presented cart was examined two months later, it appeared that it had not been built according to the design and was not suitable for exhibiting or testing. A. Volberg asked for the cart to be brought to Tallinn for rebuilding and it arrived there in September. However, breaking the cart in started in late October and was followed by the first tests in November.[36]

The programme of testing the farm horse-cart "type A" bearing the signature of A. Volberg on 16 October 1936 consists of eight points: determination of the weight, rotation radius, stability and lubricant consumption of the cart; determination of the carrying capacity depending on the axle spacing and the placement and weight of the burden; carrying capacity

36 ERA. 2075.1.350, 31.12.1936

Testing horse-cart "type A" with a burden of 1000 kg on Kadaka Road. (National Archives)

depending on the road surface.[37] The most widespread farm horse-carts were tested in the same working conditions as model cart "type A" to obtain reference data. Three carts were compared with "type A" during the test series held in November and December 1936 at the National Agricultural Test Station in Kuusiku (and on a section of tarmac road in Tallinn): the Toomani farm horse-cart most widespread in the Kuusalu region, and the Rapla type carts of Sopi and Tuljaku farms. "Type A" differed from the other three carts because of its wheel spacing (alt: 1000 versus ca 900) and tyre width (2.5 inches versus 2 inches).

The results were good for the model cart. Only when used to transport a burden of 500 kilos on a village road did "type A" lose by a small margin to Toomani farm horse-cart. The deficiency was later also revealed in the feedback given by ordinary users:[38] "type A" struggles on a rutted road, but otherwise is more efficient than the others.

37 ERA. 2075.1.350
38 ERA. 2075.1.568

Arnold Volberg explains:

"It can be concluded from the test results that farm horse-cart "type A" is lighter to draw than the currently used farm carts. This phenomenon where cart type A proved to be a little heavier in ruts than carts with narrower tyres will pass, because using a cart with wide tyres on a road with ruts made by carts with narrower tyres will make the bottom of the ruts wider. Also, ruts as deep as the present ones won't even appear again after the implementation of wide tyres."[39]

Testing horse-cart "type A" on a rut road with a burden of 500 kg. (National Archives)

On 10 February 1937, the committee called by the Road Administration signed an act about farm horse-cart "type A". The members of the committee were inspector of machinery and workshops A. Elbrecht, representative of the Ministry of Defence Major F. Kuulberg, Captain A. Pesur from the headquarters of the Defence Forces, special researcher of agricultural implements at the Ministry of Agriculture V. Nurk, assistant director of the National Agricultural Testing Station A. Käspre, agricultural adviser at the advisory centre of the Chamber of Farm Work H. Velbri, machine engineer

39 ERA. 2075.1.350, 31.12.1936.

Testing the model cart in a farm. (Estonian Road Museum)

of the Road Administration A. Volberg. The members of the committee suggested some changes in details. Their overall position was, considering the fact "that only using the cart for its actual purpose and for a long time would clarify the need for changes", was that:

- *"the present test cart does not have any significant deficiencies that would prevent it from being tested on a broader scale.*
- *10-30 test carts should be made and given to people for testing nationwide."*[40]

However, the project of the model cart that had progressed rather fast until then suddenly coming to a halt. Although the committee called by the Road Administration gave its approval, initiating the order for test carts took almost a year.

Production of test carts

In January 1938, a written price request[41] for making 30 sets of axles for model horse-carts was sent to the following companies: AS Fr Krull, AS Ilmarine, Arsenal, National Port Factories, H. Feierbach ja Ko, ETK, AS Aiwaz, C. H. Lellep and G. Peets Machine Factory. Three companies replied. Aiwaz was discarded because of an invalid patent, the price quote of National Port Factories was 66 kroons whilst Peets only quoted 23 kroons. The letter sent to G. Peets Machine Factory in the end of January reads:

40 ERA. 2075.1.350, 10.02.1937
41 ERA. 2075.1.507

"Please be advised that the Road Administration intends to order 30 sets of model horse-cart axles with hubs and capsules according to the enclosed drawings and technical specifications."

Johannes Peets replied instead of Gustav Peets and announced that it was his dairy equipment and metal industry that could take on the procurement. A little later, Johannes Peets sent a specification to the Road Administration:

"As you have set higher requirements to the axles to be made than can be seen in your design, then please delete my previous quote and accept the new quote for making axles for type A, which is 25 kroons per set, fee ex carriage Tartu."[42]

A contract for the axles of "type A", which has now increased to 39 sets, is entered into with Johannes Peets at least. After taking care of a few practicalities, the parts of the model cart were officially accepted in late April. Correspondence with Peets reveals that another 10 sets of wooden parts for the standard cart were produced in Vold. Rükken's timber industry in Kadrina. However, the total number of model carts mentioned in the press in 1939 was 50.[43] The Road Administration's file "Sale contracts of test carts, list of testers and correspondence regarding sale of test carts" includes a note made by Lauringson on 8 February 1941, which reads that: "55 test carts have been made in total, 52 have been sold according to the contract."[44] The sources used in this article did not reveal how and on which conditions the other carts, or their details were made. The owners of the 39 test carts made by summer 1938 were known in advance.

Nationwide tests

Suitable testers were selected via farmers' societies that recommended people who used carts in their work and were also able to make observations and write descriptions. This time, they contacted the societies directly:

"The Road Administration has prepared a new farm cart, which corresponds to all road maintenance requirements and is also suitable for farms. However, the latter still needs to be tested over a longer period of time. For this purpose, the Road Administration asks the Chamber of Farm Work to recommend farmers who could test the new cart."[45]

42 Ibid.

43 Järva Teataja, 04.09.1939 – „Is the farmer satisfied with the new cart" („Kas põllumees on rahul uue taluvankriga")

44 ERA. 2075.1.510

45 ERA. 2075.1.510

The contract[46] with the cart user was made for three years. During this period, the user had to give feedback about the strengths and weaknesses of the cart twice a year. They also had to keep the cart in good order and give unbiased and truthful information to people interested in it. It is separately mentioned that any changes to the construction of the cart could only be made with the consent of the Road Administration. The material for a standard burden necessary for the test, which could be used to compare the model cart with the user's personal cart, was provided by the Road Administration. Although regional farmers' societies made their own suggestions about the testers of the standard carts, not all farmers agreed to buy the standard cart allegedly offered on favourable conditions, i.e. for 80 kroons. For example, P. Kallit wrote to the Tallinn Chamber of Farm Work on 18 April 1938:

> *"Thank you for the honourable proposal to start testing the new horse-cart made by the Road Administration. Unfortunately, I have to turn down your offer, as I don't want a cart purchase almost entirely for my money to have another owner, i.e. the Road Administration. Considering the price of the cart, which is 80 kroons, and the cost of shipping it from Tallinn, then a rather small part of the actual price of the cart, which it would amount to if the cart was made here, will be left as the fee paid by the Road Administration for the testing.*
>
> *As it's not possible for me to attend to the works myself, then it's also impossible for me to make the necessary observations about the cart. For the same reason, the cart could easily be damaged badly enough by the hired workers, so that I would have to pay the full price of the cart to the Road Administration, which I find to be too expensive, especially if the cost of shipping the cart is also included."*[47]

Another refusal, based partly on monetary considerations and partly on the feared rut width:

> *"In response to your letter, I hereby advise you that I do not want to buy the new horse-cart from the Road Administration, because the wheel spacing of the model cart is bigger than that of the carts used a present, which is why transporting the burden on rutted roads would be too difficult for the horse. /.../ If the Road Administration found a way to give the test cart to me free of charge or for a small fee for testing purposes, then I would agree to accept it. Respectfully, K. Jalak."*[48]

46 Ibid.
47 Ibid.
48 Ibid.

E. Salamaa from Elva agreed to test the cart, albeit with some concessions:

> *"In response to your letter about the horse-cart, I can say that I agree to the terms and conditions of the contract in principle. However, it is important to include the exact data – the price, the duration of use, the cost of shipping from Tallinn to Elva, etc. I will say my final 'yes' once the exact contract has been presented."*[49]

The Tallinn Chamber of Farm Work sent a letter to the Road Administration in late 1938, which reveals that the data of the cart, the terms and conditions of purchase and the draft contract were sent to 46 farmers and responses were received from 22 of them. Although enough farmers were interested, they wanted to add to the contract the provisions that would obligate the Road Administration to take back the cart if it proves to be deficient, and the contract should specify the course of action in the case faults caused by the manufacturer appear in the cart. The farmers, whose opinions were archived the Road Administration in the format of correspondence, were interested in the model cart project, but also regarded it with understandable caution, and claimed that the state was not doing them any favours by charging 80 kroons for the cart. However, the necessary number of farmers who agreed to sign the contract and participate in the test was found and the testing period could start.

Test results and feedback from farmers

General questionnaires[50] were sent out a year later, in spring 1939, to those who had entered model cart purchase and sale contracts, incl. private persons, but also military supplies units in Petseri, Võru, Tartu, Narva and Nõmme. 38 addressees in total. They were asked to mention the weaknesses that had appeared in the carts and, if possible, add their suggestions for their elimination, provided that the changes would not increase the price of the cart. The observations ranged from wall to wall. Generally, people were rather satisfied with the new cart, although the new lubrication system caused problems to many of them. Later, it really proved to be an aspect where money could be saved, and a handy change made to the cart. The questionnaires filled in by the cart testers reflect the same observations published earlier by the press.[51]

Inspector of machines and workshops at the Ministry of Roads A. Elbrecht recounts: "A regulation was established five or six years ago, according to

49 ERA. 2075.1.510
50 ERA. 2075.1.568
51 Uus Eesti, 03.11.1938 – „The faults and benefits of the new cart. The opinions of specialists and actual farmers" („Uue taluvankri head ja vead. Ringküsimus eriteadlaste ja tegelike põllumeeste keskel")

which the carts on our roads should have a certain tyre width, which would reduce the damage caused to the road surface." The date of regulation enforcement had to be changed several times and the position taken in the end was that the ministry itself should start creating a new type of cart that would be the most compatible with our conditions. Model horse-cart type "model A" was finally prepared as a result of several tests.[52] Assistant director of the Advisory Service of the Chamber of Farm Work M. Ojamaa:

> *"185 kroons [for a cart] cannot be considered expensive if the cart is painted, equipped with thills, patented axles and a grease gun. Some farmers considered the price too expensive, but not all of them. The price seems particularly unacceptable to the farmers who bought their carts five to six years ago when the prices were low. However, there cart is unlikely to become widely used if the price remains as it is. We should look for ways to reduce the price, which should not be impossible if large quantities were produced."*[53]

One of the main problems in the case of the model cart – the high price – was caused by the large share of manual and special work required. This may have changed if the metal parts of the cart had been put to mass production. However, the specialist of the Ministry of Agriculture counts on the opposite solution, local craftsmen, and presumes that village smiths will be able to make carts with lower costs (in the late 1930s, a horse-cart cost up to 100 kroons). At the same time, A. Elbrecht finds that mass production would guarantee a lower price but only be possible after all the testing and improvement stages gave been passed.[54]

The newspaper article[55] refers to one of the main weakness of the cart – it's almost impossible to push it over, which may become a big obstacle for some farm work. Farmer Karl Indermitte, a tester from Mäo Municipality in Järvamaa, writes:

> *"There is no need to push the burden over. Different carts should be used to transport grains and hay. The model cart is not really suitable for this. I use it more for going out of the farm." The only weakness of the model cart in the opinion of Indermitte is: "parts of the oil gun break very easily. As you cannot find spares, replacing them was difficult and the cart cannot be used for some time."*

52 Uus Eesti, 03.11.1938
53 Ibid
54 Ibid
55 Ibid

Inspector of agricultural implements and machines of the Ministry of Agriculture M. Nurk responds:

"Oiling and lubricating with a gun – this is one of the best things about the new cart. /…/ The mud-proof hub is also good. The wide tyres make the cart easier to use on soft ground, as the wheels don't sink in, and the wider tyre also causes less damage to the road surface. The fact that the wheels of the cart stand straight is an improvement in the structure. This principle has not succeeded in former horse-carts. /…/ The new cart cannot be considered perfect, but no faults really stick out either. The main structure of the new cart type is almost the same as the structure of the old ones, the new one is just wider, roomier, stronger."[56]

A year after the tests with the new carts, representative of the Road Division V. Laurisson published a more detailed overview, in which he admits the same – an aspect seen as a weakness by one person is considered an advantage by another:[57]

"There really are no mention-worthy weaknesses. But people are never fully satisfied with anything. Thus, the main comments made about the cart concern the tubes on the inside of the wheels. Some find that they obstruct turning and their hooks tend to go straight. However, these faults are easy to correct. /…/ The men all say that the cart is light. The cart runs smoothly on a cobbled road because of the wide tyres and it jolts less than ordinary carts. Lubrication is also praised. The lubrication required for the new cart is done with a grease gun or capsule, so that it's not necessary to detach the wheel from the cart for lubrication. Lubricant consumption is 50% less than required for the old carts. It seems that axle grease is the most suitable lubricant. /…/ Everyone is fully satisfied with the wide tyre and wider wheel spacing, which prevents the cart from falling over easily. The general opinion of the two-and-a-half-inch tyre is that it damages the roads less, cuts a rut that's only half as deep as before, and therefore requires less strength when drawn."

Laurisson also emphasises that the use of the cart will not be compulsory, but there will be explanations and advertisements, which help people voluntarily favour the new cart. He also mentions[58] that the testing period of the model cart will last for another two years. The general type of the new farm cart will be developed thereafter considering the pros and cons that have been pointed out. A quote from Volberg's written to report to Elbrecht also confirms this:

56 Uus Eesti, 03.11.1938
57 Järva Teataja, 04.09.1939
58 Ibid

"After proving with tests that horse-cart "type A" has advantages that help keep the roads in order, I intended to develop the finished horse-cart "type B", which would be able to replace all the currently used carts in terms of cart use and road maintenance."[59]

A handwritten comment added later to the same report as a response to the additional question of Elbrecht about the suitability of "type A":

"Horse-cart "type A" is not the final achievement in the design of a horse-cart type, but a finished standard cart must be designed on the basis of the test results of "type A" and the experience obtained in testing."[60]

The project was a success in terms of the objective of the model cart initiative, which was to keep the roads in a better condition, because the result really was a horse-cart that caused less damage to roads. However, it's unlikely that this or the next model "type B" would've found the full support of farmers. On the one hand, the ratio of pros and cons of the new cart type was probably not big enough to warrant a massive change. It's also unlikely that the new carts would have managed to conquer Estonia at the threshold of an era of new mobile options. However, this will always be a speculation, as further developments in mobility and all other areas were caused by other conquerors. The last notice about the model cart project is the handwritten note made by V. Lauringson[61] in 1941, which states that there were 58 test carts.

59 ERA. 2075.1.350, 11.01.1937.
60 Ibid
61 ERA. 2075.1.510

Summary

In the 1930s, Estonia was standing at the threshold of a new era: there were more and more passenger cars, trucks and buses on the roads, however, the past tagged along – horse-carts were still the number one means of transport. For example, the transport of goods in the outskirts of towns and in the countryside was still mainly performed by horse-carts. As the resources were scarce and road conditions poor, paying attention to this hitherto unregulated means of transport may have seemed essential. Therefore, motivated by a failed regulation of the tyre width of carts, the Road Administration started the model horse-cart project in 1935, in cooperation with farmers and the military. With this move, they intended to influence the farmers to voluntarily choose a new type of cart that in addition to saving roads was to be lighter, more reliable and compatible with most farm works.

The model farm horse-cart "type A" was designed by Arnold Volberg, who studied the most typical carts from all counties of Estonia and proceeded from the primary aim of the whole project, which was changing the width of the cart tyre from the widespread 2 inches to 2.5 inches. According to initial feedback, the proposal was not met with massive approval – the higher cost and the relatively small difference from the carts in use made the potential users doubtful of the project's efficiency. However, by 1938 farmers and the military were given 39 model horse-carts for a test period of three years (by 1941, their number had risen to 55). The tests performed by the users and the Road Administration alike proved beneficial for "type A". At the same time, it became apparent that the model horse-cart could not replace all cart types in daily use, as it proved to be most appropriate for highways, since it damaged the road surface considerably less than other horse-carts of its type.

Whether the soil was fertile for the next planned model cart, "type B", is uncertain. Speculations can go both ways, but in the turmoil of war in 1942 the improvement of horse-carts was no longer a priority. However, the story of the model horse-cart surprises with the fact that during the fast-paced golden era of the Republic of Estonia, we were still very much stuck in the horse era. And yet, the model horse-cart with its grease gun and tubes is nothing but long-forgotten past 80 years later.

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EARLY GRADERS ON FINNISH ROADS
The mechanization of road upkeep in the 1920s

Mikko Pentti
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Road grader is a machine designed and built for the construction and maintenance of gravel roads. The graders are equipped with turnable and tiltable blades that cut the road surface to level uneven ground or to produce a surface with a specific degree of incline, or cant. The machines can also be used to remove snow or to level a snow-covered surface. Over the years, graders have become the symbols of road upkeep in the Finnish countryside.

This article covers their early use in Finland in the 1920s, when the Finnish road network gradually came under more direct government supervision. The laws were changed, and the costs of road building and upkeep were transferred to the state. Also, the actual roadwork was mechanized over the decade. This article investigates how the new machines were used, why they were necessary, where they came from and what was their impact.

Challenges of road upkeep in the 1920s

The old law on roads in Finland named the landowners, mainly the peasant population, responsible for road upkeep and road building. This responsibility included both the costs and the actual labour. The law of 1883 also included the tenant-farmers, factories, sawmills, mills, breweries, distilleries, and crown forests as partakers as these also used the road network. The state could also provide expertise on for example bridgebuilding, but the emphasis of the authorities was clearly in the railway and channel networks. In the late 19th century money entered the Finnish countryside as the growing wood industry began buying timber from the landowners and the ban on rural trade was lifted. New trade needed new roads, although, most of the timber traffic moved in the winter on sleighs and winter roads. The late 19th century also saw the increase of public roads as population and traffic increased. These were maintained by road sects, formed of those responsible of the costs. These could now divide the roads to tracts and auction the labour to the least expensive contractor. As the use and requirements for the roads weren't high, the average contractor was a man or a couple of men with a shovel, and perhaps a horse and cart. Some roads were also directly repaired by the peasants. The overseer of the condition of public roads was the provincial governor.[1]

There had been a steady rise in the number of motor vehicles in Finland already before the first world war. The first motorcycle appeared in 1895

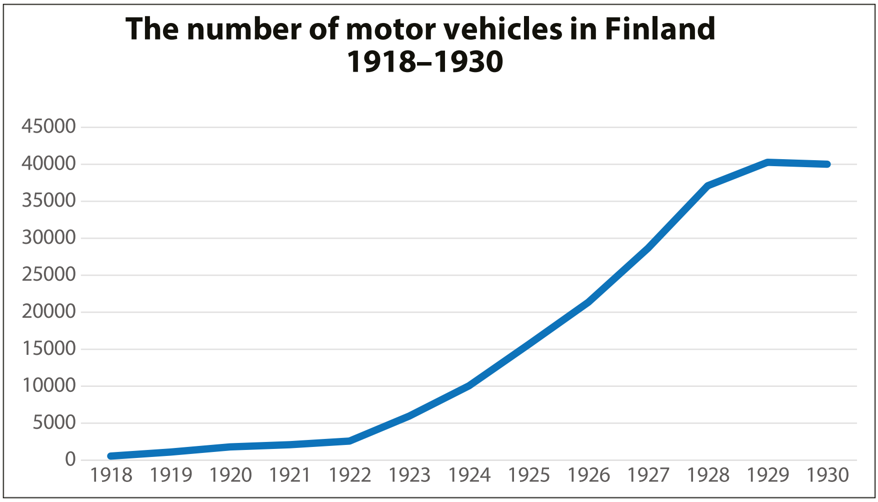
1 Masonen, Antila, Kallio & Mauranen 1999, 96–113.

and the first automobile by 1900. The total number of motor vehicles in the grand duchy rose to about 2000 by 1914. The problems caused by the increased heavy traffic became evident soon after the first automobiles began moving. Complaints over traffic accidents were voiced as horses bolted because of automobiles, but also because the automobiles ruined roads. Some municipalities even tried to ban automobiles on their roads. There were plans to change the legislation concerning both road upkeep and road traffic. These, however, were postponed when the first world war broke out. The war caused gasoline shortage and most motor vehicles entered Russian army service after the catastrophic defeats in the early war. The first attempts to change the road legislation were already made in 1904 and thereafter the motion surfaced annually in the parliament. In the end, it was only in 1917, just before Finland became independent, when the motion eventually leading to the new road law was made.[2]

The new law on constructing and maintaining roads in the countryside was passed on October 11th, 1918. All roads were divided into public roads and local roads. The Government of Road and Water Constructions was to give governors instructions on which roads were to become public roads. The law stated that the costs of building and maintaining a public road were paid by the state. Except for roads directly under government upkeep, maintenance work was the task of the municipalities and their road boards. The law included problematic parts. For example, section 20 stated that the repair of roads should not be ordered during sowing and harvest seasons or while making hay. This was of course important in the 1920s still rural society but also meant that roadwork could not be ordered in seasons, when it was most needed.[3] The maintenance work was auctioned to contractors for a three-year period in tracts ordered by the road board. The approval for building new roads was given by the governor after a proposal by the road board. The new law was to come to force only in 1921, because the authorities needed some time to adjust to its requirements. Before this, the law was supplemented by the road statute in 1920. It included better definitions for the law and stated that it was a government responsibility to define the roads in direct government care. The specific instructions for the different road categories and technical definitions on bridges, roads and parts of road only followed in May 1921, when the law had been in force for half a year.[4]

The total number of motor vehicles on Finnish roads rose from 569 in 1918 at the end of the civil war to 2591 in 1922, the start of the mandatory

2 Pentti & Mäkinen 2017, 25–27. Masonen, Antila, Kallio & Mauranen 1999, 124–125.
3 The law on constructing and maintaining roads in the countryside 147/1918 20§.
4 The law on constructing and maintaining roads in the countryside 147/1918. The road statute 87/1920. Government decision containing more specific technical instructions for constructing and maintaining roads in the countryside 170/1921.



provincial registration, and to 40 015 by 1930. The amount doubled annually from 1921 to 1924 and thereafter increased by a third annually until 1928. 1929 and 1930 saw the effects of the great depression, bringing the motorization to a halt for several years. The new traffic was faster, heavier, and covered longer distances. In addition to the ever-increasing number of personal cars, most of them naturally Ford Model T's, also omnibuses and trucks began to move people and goods all over the country. The number of omnibuses doubled between 1924, when the statistics begin, and 1930 from 523 to 1169. The number of trucks rose from 623 in 1922 to 10724 in 1930. This change in road use, especially the challenge of heavy vehicles, brought altogether different demands for their upkeep and construction.[5]

Dreams of machinery

"When public roads are badly planned from the start, which greatly complicates their upkeep, and when in addition each man responsible for this upkeep has his own thoughts on the matter and habits of upkeep, we have arrived at a state of affairs, where we are close to the truth, saying Finland has the worst roads among civilized countries."[6]

During the era of the small-scale contractors, when the upkeep of road tracts was auctioned to the lowest bidder, usually a local peasant with a shovel, crowbar, pickaxe and perhaps a horse and a cart, buying any kind of purpose-built road machinery was beyond the contractors' reach. This,

5 The number of vehicles before provincial registrations began in 1922 can only be speculated, however there was a country-wide calculation of cars after the civil war in 1918, and it gave a result of 569 vehicles. It must be noted that not all owners reported their vehicles. Leppänen 1973, 22-23. Pentti & Mäkinen 2017, 25-27. Masonen, Antila, Kallio & Mauranen 1999, 198-203.The number of motor vehicles 1922-1930. The number of autobuses 1924-1930. The number of trucks 1922-1930. Official Statistics of Finland.

6 Eerikäinen 1917, 5.

however, did not mean that the machines were unheard of in Finland. The engineers of the National Board of Road and Water Works, for example, seem to have read Swedish and German literature on road construction and road upkeep widely from the beginning of the 20th century. The engineers though, were not directly involved in road upkeep in any meaningful way before the 1920s, except for a couple of new road constructions and several larger bridges, that were directly under the National Board's supervision.

The first official instructions for research, construction and upkeep of public roads were given by the director of the National Board of Road and Water Works Karl Snellman in 1917. The same year engineer Martti Eerikäinen, also of the National Board, wrote a book on the same subject, aimed at the people directly responsible for roads on local level, with the title *Elementary construction and upkeep of public roads*. Whereas Snellman's instructions were general requirements on what a public road should be like, Eerikäinen wrote also about techniques and machinery available for reaching these requirements. This was the first time such machinery was presented to the public in Finland. Eerikäinen used the latest international literature as sources for his book. These included the latest *Atlas of Finland* with its commentary, the German *Lehrbuch des Tiefbaues* of 1908, the *Hütte des Bauingenieurs* of 1911 and the Taschenbuch für Bauingenieure from 1914 and the Swedish *Handlendning I byggnad och underhåll av enklare vägar* from 1915. He also used the latest journals on the subject, like the *Teknisk Tidskrift* from Sweden and the Finnish *Tekniska Föreningens i Finland Förhandlingar* and *Teknillinen aikakausilehti*.[7]

Eerikäinen's book included the first descriptions of modern road machinery in Finnish, both as pictures of the machines and what they were used for. One of the biggest problems in upkeep, according to Eerikäinen, was that when new gravel surface was applied in spring and autumn, all the rubbish, manure and dirt were left under it in traditional method. All these simply resurfaced when heavy loads were transported on the road. In addition, during winter the wet dirt inside the road froze and turned gravel to dust, which in turn meant dust clouds in summertime.[8] The solution was to use a horse-drawn road-scratcher[9] and collect the dirt with a similarly horse-drawn scraper or shovel[10]. After this the road was to be cut to correct form using a road-plough.[11] This was probably the first time the use of a grader was mentioned in Finnish literature. There was also a picture of an American road

7 Yleiset tiet. Tutkimus, rakentaminen ja kunnossapito 1917. Eerikäinen 1917, 4-7. Also, agronomist Bertil Bockström, who seems to have had a good knowledge of American road-maintenance machinery, wrote about the subject in 1917. He used the same pictures and sources as Eerikäinen. Maatalous 15/1917, 258-262. Rakennustaito 22/1917, 201-204.

8 Eerikäinen 1917, 62-63.

9 Tiekarhi in Finnish, vägskrapa in Swedish.

10 Pyöräkauha in Finnish, hjulskrapa in Swedish.

11 Tieaura i Finnish, vägplog in Swedish.

Rural police chief inspecting a roadworks site in the early 20th century. The workers are using a horse-drawn levelling drag. This type of maintenance was adequate for horse-traffic, but not for automobiles. (Mobilia, Väyläviraston kokoelma)

plough, with a thorough description of the machine. This type of machine had been in use in Sweden for about a decade by this point. The pictures and description of the machines and the processes came from the Swedish journal Teknisk Tidskrift. It is interesting to note, that while all the machinery mentioned in the book were horse-drawn, with a notable exception of steam- and motor-rollers, it was also mentioned, that they could be drawn by a tractor or a roller.[12]

Government in charge

When the new law on constructing and maintaining roads in the countryside came to force on January 1st, 1921, the National Board of Road and Water Works had already had three years to prepare. The state took over 23 800 km of public roads, which was about 75% of the total. Of these, only 1300 km were in direct government care, the rest belonged to the provincial governors. The rebuilding of roads and the construction of new roads and bridges were the responsibility of the National Board of Road and Water Works. The idea was to make sure the methods of construction of new roads were systematic, appropriate and of necessary technical level. In an early

12 Eerikäinen 1917, 64–68. Teknisk Tidskrift, veckoupplagan 26.6.1915.

survey of roads, the condition of bridges was noted to be even worse than the condition of roads. Most bridges were built for horses and could only support a weight of 1–3 tons, which was far from the requirements of automobile traffic. These became the early priority of government expenditure.[13]

Upkeep of public roads in provincial care was in the hands of the municipalities the roads were in. Each municipality, or a group of municipalities in areas with few public roads, chose a three-member road board, overseen by the governor and with state money, at a three-year interval to take care of the roads. The road boards then divided the public roads to smaller sections and auctioned their upkeep to contractors. The sections could be just a few hundred meters long in densely populated areas to make sure everyone could take part in the auctions, that the contracts would go to local hands and that the contracts would be as cheap as possible. Before each auction, the road board had to give an estimate of the overall costs of upkeep. After this there was a descending price auction. In the case the winner was thought unable to provide the service required or if the offers were too high, the governor could hold a new auction or give the section over to the National Board of Road and Water Works. In addition to the normal upkeep of roads, also winter upkeep, the upkeep of winter roads (mostly roads over ice) and the maintenance and operation of ferries as parts of the road network, were auctioned in a similar way. In this system there was very little room for professional contractors with modern tools.[14]

The inspection of roads was a task directly involving the members of the road board, the rural police chiefs[15] and the district engineer employed by the provincial government. Main responsibility belonged to the police chief. In 1921 there was only one district engineer in each of the eight Finnish provinces, with responsibility to advice on every road-upkeep and -construction site in his province. In the beginning these officials even didn't have cars at their disposal. The district engineer of Oulu province for example had almost half of Finland to oversee, although it must be said that he had a car already from 1914 on. The ability of the district engineers to improve the quality of roads in areas under their jurisdiction was in these conditions very limited.[16]

The roads in direct government upkeep can perhaps be divided into three main categories: first, the entrance routes to the most important Finn-

13 Suomen teiden historia II, 29–33, 210–211.

14 Id. 33-36. One notable exception was Ab Granit, originally a quarry and stone trading company, that won an auction for over 500 kilometres of road near the town of Pori in 1921. In the next auction in 1924, the company was already responsible for about 1100 km of road. Disagreements with the National Board of Road and Water Works and the provincial government on what counted as upkeep and what was rebuilding caused the company to withdraw from the business altogether the next auction season. Granit AB was one of the few contractors to have trucks and other machinery in the early 1920s. Masonen, Antila, Kallio & Mauranen 1999, 309-310.

15 Nimismies in Finnish, länsman in Swedish.

16 Suomen teiden historia II, 33–36.

A Talkoo-grader pulled by a tractor. Even, when weighed down by a giant water barrel, the combination was still too slow and cumbersome. (Mobilia, Väyläviraston kokoelma)

ish towns, that had intense traffic and were intended for reconstruction for automobile traffic soon; second, the public roads that had been improved or built with government money recently; and third, the roads that were seen to be important for military operations. In all of these, the rebuilding and the traffic needs seem to have been the moving factors. The National Board of Road and Water Works took the upkeep and rebuilding of roads seriously and intended to use modern techniques from the beginning. This can be seen for example in the number of machines bought in 1921: 1 stone crusher with engine, 4 stone crushers without engines, 1 steamroller, 1 motor roller, 4 gravel elevators, 18 levelling drags, 20 horse-drawn graders, 5 scrapers, 4 Loeb-Dinos tractors, 7 transport wagons, 10 MAN or Fiat trucks, 2 vans, 3 Fiat cars, 2 Benz cars and 2 motorcycles.[17]

New machines, old power source

"One autumn day, I had the possibility to see this grading. It had been raining all day. Because of heavy traffic the road was already covered with 10–15 cm of mud in the morning. But then the grader appeared. Drawn by several horses, it went back and forth in the mud. And soon all the dirt was on the edges of the road, replaced by an even surface, like it was made of cement. And that's the secret, missed by us peasants. But we haven't been able to travel abroad to learn.

17 Id. 31–33. Masonen, Antila, Kallio & Mauranen 1999, 306–309. Tie- ja vesirakennukset vuonna 1921, 31–33, 47.

But then what? The even surface was driven over by horses, and heavy loads were drawn on it. Within an hour, there was again 10–15 cm of mud there. A new grading, a new surface, and again, within an hour, the mud reappears, because the centuries of sand have little by little been graded of, and only the soft clay remains. But, for new gravel to be applied, a road needs to be graded to the hard surface. So far, this surface has not been found."[18]

In the following four years the National Board of Road and Water Works bought altogether 6 more horse-drawn graders among its other purchases. This brought the total to 26 by 1925, to which can be added also the ones owned by the provincial governments, local road boards and private companies or entrepreneurs. Unfortunately, there is no clear indication, how many graders these had. There were several manufacturers of these machines in Finland, the biggest seems to have been Ahjo machinery workshop in Helsinki. About half of the National Board graders were made by Ahjo under the tradename Talkoo. In addition to the Ahjo workshop, there were also other manufacturers, for example Maskin- och Brobyggnads AB in Helsinki.[19]

The all-iron Talkoo-grader was meant to be pulled by one or several horses and needed a two-man team to operate: a driver for the horses and an operator for the blade. The front wheels turned with the shaft. The blade was attached to a turntable hung from the hull-beams at the middle of the machine. It had a simple bolt mechanism to turn and to keep it at a certain angle, but no other adjustments. The blade itself could not be tilted. The sideways tilt of the machine was operated by hoisting or lowering the back wheels, both of which had a screw that could be turned by a wheel from the operator's seat. The idea was that on a normal soft road, the iron wheels would cut to the hard surface, keeping the machine from moving sideways and enabling the blade to cut enough of the surface layer off.

It seems that while most of the graders were drawn by horses, also trying out tractors was begun very early although the Board of Road and Water Works only had a couple of tractors available in the whole country. Already in the spring of 1922 Turku Road district used a tractor to pull two graders at the same time. The first grader was pulled along the middle of the road, and the second grader pushed the excess dirt immediately aside. This method needed only one pull per side. The method was dropped a year later, after it was discovered, that it wore the tractor out quickly. As a side note, it is curious that all the surviving pictures of these early graders in use are of graders pulled by tractors. This is probably because pictures were used as learning

18 Ilkka 24.9.1921.
19 Tie- ja vesirakennukset vuonna 1922, 61; 1923, 75; 1924, 87; 1925, 106.

and documentary material. This meant taking pictures of major building sites, new machinery, and novel ways of using existing machinery.[20]

The graders were expected but rarely seen visitors in the countryside. Their performance when spotted, however, was far from perfect. In June 1922, the members of road boards were invited to attend two-day Road days in Tampere by the National Board of Road and Water Works. Some 90 people attended. There they could see modern machinery in action. Although the levellers, trucks and elevators seem to have impressed the attendees, the grader was not to their liking, although the journalists blamed this on the untested horses and drivers. Some writers even deemed the machine unfit, after having watched it in action for the first year. By 1923 the horse-drawn grader seems to have become common enough to no longer interest the press in any fashion, except for some local newspapers that wrote of local purchases.[21]

It seems this type of grader was simply too light for the job and, when more modern motorized options became available in the mid-1920s, the horse-drawn graders quickly became obsolete, at least on roads with direct government upkeep. This didn't end their use, however, as most graders seem to have been sold to local road boards and contractors. This change can also be attributed to the tendency of the National Board of Road and Water Works to save on manpower costs and mechanize work as far as possible. This was partly a show-off strategy towards the other roadbuilders to demonstrate how the work should be done. The mechanization did not necessarily mean lower costs. In fact, the old way of man, shovel and crowbar was usually cheaper. It must also, however, be noted that the roads under direct government upkeep either had the heaviest traffic, or were in thinly populated areas, where it was difficult to find the necessary manpower.

Bitvargen[22]

The Bitvargen, built by Swedish AB Vägmaskiner, was the first motorized grader in Finland. Two of these machines were bought to Turku, one for the Turku road- and waterworks district in 1924 and the other for the city of Turku in 1925. Both machines were of the second production series of 1924, which comprised of 30 sold machines. So far, there is no certain date to the arrival of the Turku district machine to Finland, but late 1924 seems to be the best estimate. We know from letters, that the National Board of Road and Water Works asked each of the district of requests for machine acquisitions for the year 1925 in November 1924 and in the responses, the

20 Uusi Aura 28.4.1922, 10.4.1923.
21 Vaasa 15.9.1921. Tyrvään Sanomat 17.8.1922. Liitto 25.8.1922. Tie- ja vesirakennukset vuonna 1923, 79–80.
22 Roughly translated, Bitvargen means biting or ripping wolf in English.

The first Bitvargen-grader of the Turku Road and Water District on the Turku-Rauma Road. Note the anti-skid chains and the district engineer's car in the backround. (Mobilia, Väyläviraston kokoelma)

Bitvargen was mentioned in almost every district. On January 17th, 1925, Turku district already responded to a National Board question about the import costs of its Bitvargen. Only the grader part of this machine came from Sweden; the tractor-section instead was bought from Turku. This would probably have been to avoid paying extra customs. According to the letter from January 17th, 1925, the total cost of the Bitvargen bought by the Turku district was 88 495,60 Finnish marks. Of this, 23 702,50 mk was the Fordson tractor with its equipment, 61 257,50 mk the grader with its equipment and the remaining 3 535,60 mk different customs and registering costs.

It has often been thought that the Bitvargen was a copy of an American Wehr-grader,[23] an exact copy, even up to the form of the company plate in front. However, it is more likely to have been a case of licensed production since AB Vägmaskiner was in fact the chief importer of heavier Ford products to Sweden. The director of AB Vägmaskiner, Nils Barrén had with his brother Ernst Nilsson acquired the Stockholm dealership of Ford Motor Company in 1923 and imported the first Wehr-grader, based on the Fordson tractor at the end of the same year. In 1924 Barrén and Nilsson divided the company: Nilsson kept the sale of personal cars under the old name Ernst Nilsson & Co AB, and Barrén founded a new company AB Vägmaskiner for heavy and professional vehicles. The company even sold 12 American-made Wehr-graders, marked "original" in the brochure,

23 The Wehr Steel Company was based in Milwaukee, Wisconsin. In addition to the graders, it produced other equipment that could be fitted to Fordson tractors, like roller-fronts and levelling drags. It seems the Wehr one-man grader was patented in December 1922, so the Swedish company started importing them quite early. Ford Dealers Equipment Directory 1923, 118.

in 1924 before the production in Sweden begun. Half of these went to the Stockholm Street cleaning services, the rest to different road districts around Stockholm. The 1st and 2nd production series of the Swedish-built Bitvargen came out in 1924. These were altogether 55 machines, of which two were exported to Finland. By the publication of the 1925 brochure, further 29 machines of the 3rd and 4th series had been built. This makes a total of 96 sold machines, counting American ones, in less than two years. It seems, the Vägmaskiner company had hit just the right spot in the market.[24]

Nils Barrén in Helsinki

On January 7th, 1925, Nils Barrén gave a lecture in Helsinki on the use of machines for road upkeep. The venue was a gathering of the Finnish Automobile Club in the malachite-hall of the Helsinki stock-market building. In the audience sat, in addition to the members of the club, also several notables of the National Board of Road and Water Works. The introductory lecture by engineer Olli Martikainen of the National Board covered the Finnish road conditions in the past and present. He commented the problems of the road legislation, namely how it focused on the costs instead of the proper condition of roads. Martikainen introduced engineer Barrén by talking about how the professionals of road upkeep in the Nordic countries had turned their gaze towards America to see how modern machinery could be used to keep gravel roads drivable by automobile traffic. Although the American methods were not necessarily directly applicable in Finland, Swedish road conditions were almost similar.[25]

Nils Barrén began on how the automobile had changed traffic on old road networks, while the road administration and the road upkeep had been unable to follow the rapid change. He called for the advancement of new practices among local councilmen and among MP's. However, in present conditions, the construction of new roads and the reconstruction of old ones was too expensive for the available resources. Barrén's solution was to rethink the upkeep of already existing roads by using purpose-built modern machinery. The different levelling drags, self-made devices and horse-drawn American graders were already familiar, but all these were far too light for the job. So, Barrén offered a new solution, the motorized grader, originally an American design, improved in Sweden. In tests organized by the road committee of the Swedish Technological Society, when widening a gravel road, the cost of removing old gravel per cubic meter was 1,30 mk with the motorized grader opposed to 30 mk with traditional methods. The complete rebuild of the road surface: cutting away the soil and grass,

24 Bitvargen 1924, 2-3. A/B Vägmaskiner, Stockholm 1925, 3, 47-49. Svenskt Biografiskt Lexikon, Band 26, 653.
25 Uusi Suomi 9.1.1925.

levelling the bumps and holes and straightening the extra corners cost 20 mk per meter if done by contractors. The motorized grader did this for 0,40 mk per meter.[26]

The first and foremost purpose of the machine was the continuous light grading of roads. According to Barrén, American examples had shown that continuous grading made the gravel or macadam roads last ten times longer, because it prevented holes or tracks from forming and water from accumulating into them. Ditches were not enough to keep the water out of the road: the road itself had to be formed so that water could flow off. The new Bitvargen could cut the grassy edges of the road, level the surface, reform the road, widen it, remove the excess dirt, form a thin layer of moving gravel on road surface, do snow ploughing, remove hardened dirt, holes, and ice etc. With this machine, road upkeep would not only become better, but also a lot cheaper. In the end of his presentation Nils Barrén casually mentioned that the construction of these new machines would take place in Finland. He had already started a Finnish company, Oy Tiekone Ab for the purpose and the patent applications for the most important machine parts were already on the desks of Finnish officials. Because the Bitvargen was to be produced in Finland, it needed to be renamed Tiekarhu[27] in Finnish. After his presentation, Barrén showed his excited audience films of the Bitvargen in action.[28]

A Finnish affiliate

The office of the new Tiekone company was in Helsinki, but the manufacture took place elsewhere. The forged parts were made in Vaasa by Onkilahti machine workshop, and the casts came from Taalintehdas near Turku. There was no knowhow in Finland for the blades at the time, so they were imported from Sweden while the Fordson tractor and rubber wheels were of British manufacture. The final assembly took place in the Onkilahti machine workshop. The Tiekarhu had some differences to its Swedish pair: the main beams were slightly stronger; the ripping spikes were placed slightly further away from the blade, so that these could be used at the same time; the front wheels could be tilted so that they could better resist the sideways twist produced by the blade; the joints bearing up the blade support were equipped with ball-and-socket joints; the moving of the blade sideways was eased by a particular device; the cockpit was equipped with a seat for the driver and locks in the hanging springs, so that the floor wouldn't fall when hitting a bump and the start crank would be placed on the right side of the

26 Ibid. Helsingin Sanomat 9.1.1925.
27 Road bear.
28 Ibid.

machine. It seems all these improvements in fact were standard also on all later Swedish built machines.[29]

The Tiekone company published advertisements to its potential customers in newspapers in 1925.[30] Tiekarhu was an immediate success. In the wish lists of the road districts to the National board for the following year in November 1924, some districts requested a Bitvargen, while some wanted something called Bob-grader, also produced by Vägmaskiner AB.[31] In the end, all Finnish water and road construction districts ordered a Tiekarhu through the National Board of Road and Water Works in March 1925. This meant 9 machines. It seems some districts only acquired their grader in spring 1926, and some districts already had several working machines by this time. Also, the Finnish army ordered one grader. There is little information on the provincial governors or local road boards, but it is possible to say from news and photographs that they had several machines also.[32]

After operating the graders for the summer and fall of 1925, the National Board of Road and Water Works called for offers for a second series of graders for all its districts from the main builders and importers of road machinery. They had three answers, that clearly demonstrate why the Tiekarhu was the preferred machine. The first participant, E. Grönblom machine company offered the Swedish Munktell grader that was based on Munktell's petroleum-powered tractor. It took longer to start and was slightly slower, although cheaper to use than Fordson powered machines; the second, Zitting & Co Engineers put forward the Svedala grader, that also had the Fordson tractor as its power source, the third alternative was Tiekone Oy with the Tiekarhu. Excluding the tractor, all machines were quite similar in their size, equipment, and performance. The real instrument of competition was, as so often, the price. The Munktell grader cost 97 500 mk and the Svedala machine 87 000 mk. The price for the Tiekarhu was only 70 750 mk, so it was 27% cheaper than the Munktell grader and 19% cheaper than the Svedala grader. With this kind of price difference, it was clear, that also the second series of graders were ordered from Tiekone Oy.[33]

The Tiekone company seems to have sold its products with Swedish Bitvargen brochures for the first couple of years or so. The brochures that have survived as part of the Procurement archive of the Road administration

29 Teknikern 6.5.1925.

30 Eg. Finsk kommunaltidskrift 8–9/1925, 10/1925; Suomen kunnallislehti 8–9/1925, 10/1925; Tidskrift för Finlands svenska lantmän 5/1925.

31 This machine was considerably cheaper than Bitvargen. It was basically an American horse-drawn grader, minus the front wheels, attached to the back of a tractor and operated from the back of the machine by several meter-long levers attached to the controls of the tractor. The Bob-grader had the same shortcomings as the Finnish horse-drawn grader attached to a tractor, namely that it was far too light, although only needing one man to operate, opposed to the two needed by the Talkoo-type grader. At least one Bob-grader was used in Finland by the Kuopio district of road and waterworks. The machine was cleared in the harbour of Turku in February 1925 and came to Kuopio in an incomplete state soon after. Tie- ja vesirakennushallituksen arkisto Fa A1.1:2 Tarveaineiden ja kaluston hankinta.

32 Vasabladet 14.8.1925. Tha 215. Tiekoneet. Mobilia Archives.

33 Teknikern 6.5.1925. Tha 215. Tiekoneet. Mobilia Archives.

archive in Mobilia show the differences of the old model Bitvargen compared to the late 1925 Tiekarhu. The oldest brochure from 1924 has the statistics of the first series Bitvargen from 1924, but these are partly struck through and replaced with later ones apparently in Finland in 1925. These measurements can be compared to the ones in the Swedish 1925 brochure.

	Bitvargen 1924	Bitvargen 1925	Tiekarhu 1925
Total length	4850 mm	5450 mm	5350 mm
Total width	1840 mm	2440 mm	2440 mm
Total height	1900 mm	1950 mm	1950 mm
Wheelbase	4050 mm	4550 mm	4550 mm
Total weight with single back wheels including tractor	2550 kg	-	2750 kg
Total weight with double back wheels including tractor	3350 kg	3750 kg	3550 kg
Back axle load with double wheels	2500 kg	2760 kg	2600 kg
Front axle load	850 kg	990 kg	950 kg

Although the differences are slight, the added weight counted while working. Another novelty with the second Tiekarhu series, ordered in late 1925, was the addition of a well-built holder for the standard 42-US-gallon (159 liter) barrel petrol tank in the back of the machine. All the second series machines were also equipped with ripper spikes, the modifications increasing the weight and improving the performance of the machines.[34]

Tiekarhu in action 1925–1926

> *"Tiekarhu has now arrived in Kauhajoki, and rumbles industriously on the road between the church and the station. It seems to be able to even the hardest road. Slowly it goes but makes a good imprint. It's only, that the horses seem to be afraid of this monster."*[35]

There is little information on the actual use of the 1920s graders in the archives. Fortunately, the Finnish press followed these machines across the country. Because of the number of available sources, this chapter only covers the first two years, 1925–1926. According to the press, three graders had been in test-use in southern Finland already from fall 1924 on, but this could be just company boasting to the press. To the journalists, the graders, in any case, looked like modern automobiles or even railroad bridges. The first series of Tiekarhu seems to have been operational only in late summer 1925. Until this, only the Bitvargen in Turku was operated. For example, the participants to the assembly of the Agricultural producer's district union of

34 Bitvargen 1924, 3–4.
35 Kauhajoen kunnallislehti 20.5.1926.

An early Tiekarhu in Ostrobothnia. Tiekarhu no:3, still equipped with tilting front-wheels, was given over to the Vaasa Road and Water District. The machine was manned by Tapio and Veikko Koski. Tapio Koski later became senior road master of the Central Finland Road District. (Mobilia, Väylä-viraston kokoelma)

south-western Finland were taken to see the Bitvargen in Aura on a road to Turku. Their opinions were thoroughly positive. In September the Bitvargen was improving roads from Turku, through Paimio and Salo and all the way to Uusimaa province border. The provincial governor also promised to later transfer the machine to the northern part of the province to repair as many kilometres of road as possible and to keep the post roads there open for traffic throughout the winter.[36]

The Tiekarhu appears in press as a working machine in August and September 1925. The press in Eastern Finland mentions the machine shortly, but only as a machine that their area doesn't have. In western Finland a Tiekarhu was already operated by the private company AB Granit between Eurajoki and Luvia in Satakunta province. Winter brought its own problems to road upkeep. Up until 1925 there had been almost no car traffic in Finland during winter. Most cars had open bodies, and snow ploughing was mostly slowly done by contractors with horses or by hand. Around 1925 however, especially busses with closed bodies became a common sight, and their owners, together with the postal services, began to voice their

36 Turun Sanomat 13.6.1925, Vasabladet 14.8.1925, Satakunnan Kansa 16.9.1925.

needs for winter roads. Unfortunately, there were almost no ploughs that could be mounted to tractors or trucks. The road districts had only received enough allowance to buy one plough per district for 1925. The light ploughing equipment meant that the graders were an important part of keeping the roads drivable since only they had the weight necessary to level the icy and snowy road surface. The graders were in use throughout the winter of 1925-1926 on the most important local roads, for example the postal routes. It must, however, be kept in mind, that only very few roads were kept open for automobile traffic at this time.[37]

One of these roads was between Tampere and Kangasala in Häme district. The total cost of this operation, using a Dinos tank-tractor with snow plough drag, a Fordson tractor and a Tiekarhu was 34 000 mk between December 19th, 1925, and March 31st, 1926. In addition to the drivers, there were also several men doing manual labour. Different methods were tested and ploughing the road before grading was found to be the best. In very hard snow also the Fordson tractor was needed for pulling the plough. There were problems also with curves and the machines' tendency to move the drivable area towards the inner curve, outside the road surface. The Turku district was even more modern, equipping its Mannesmann-Mulag truck with an American Champion front plough and operating three motor graders for the whole winter. It was quickly discovered that the plough could not break icy surface, so in some cases it was necessary to send the grader in first. Also, the plough was too low. It threw the loose snow directly under the truck instead of removing it to the side. The high officials of the National Board of Road and Water Works together with members of the army engineering inspected these sites in late January 1926. Their conclusion was that the Tiekarhu was a good machine for the job, especially when combined with a plough attached to a fast-moving powerful truck. The officials' hope was that the state would provide funding in the future too if they only could understand its importance. However, it seems keeping less than 100 kilometres open for winter traffic took all the machines the National board had available, and graders and tractors were moved to these sites also from other districts.[38]

One of the few user voices in the sources can be found in an interview of a Tiekarhu crew in Rauma in late January 1926. It seems the machine was operated by two men, who had just driven the machine from Laitila to Rauma and were doing maintenance before departing back for Laitila. The road was some 35 km long and took the whole day one way. From Laitila the grader would move towards Uusikaupunki and there to Mynämäki and

37 Uusi Suomi 23.9.1925, Itä-Savo 26.9.1925, Länsi-Suomi 1.10.1925, Turun Sanomat 5.12.1925, Länsi-Suomi 8.12.1925.
38 Tie- ja vesirakennukset vuonna 1926, 82. Aamulehti 1.1.1926, 26.1.1926. Turun Sanomat 16.1.1926, 19.1.1926, 23.1.1926. Vaasa 20.5.1926.

Tiekarhu in Suojärvi in Karelia. This machine, manned by Kalle and Martti Salo has been fitted with extra weight to give the blades more impact. (Mobilia, Väyläviraston kokoelma)

Turku. The crew was pleased with the machine and its performance. They also used the opportunity to criticize the American snow plough mentioned before. There was also critique towards the mechanized snow ploughing in general. It needs to be remembered, that the removal of all snow, as the graders usually did, meant that the road could no longer be used by sleighs, still the most common transport of the population. Also, the high snow walls next to roads alerted some.[39]

The rasputitsa period in the spring 1926 brought another wave of articles about graders in newspapers. By May, the Turku district graders were at work improving roads that were left out of the previous year's program. There were two district-owned graders. One of these was lent to Granit AB working on roads leading to Tampere from Tyrvää.[40] The other one was near Turku, improving roads near Mynämäki. One province-owned grader worked on the new construction site between Loimaa and Äetsä, and another improved the road between Salo and Perniö and later the road from Loimaa towards Hämeenlinna. All together, these sites were several hundred kilometres long. What the improving meant, was cutting the road to form, and removing excess dirt from the surface. The cutting also at the same time meant widening the road slightly easing automobile traffic. The grading was followed by bringing in new gravel surface, which seems to

39 Rauman lehti 26.1.1926. Laitilan Sanomat 19.2.1926.

40 At least in Uusimaa district the local road boards and contractors could borrow the machine at the price of fuel. Hufvudstadsbladet 13.6.1926.

have mainly been done by manual labour. The graders seem to have been loaned frequently to the local road boards to do labour, like the cutting of the road surface, that was impossible to do by local means. This was evident also in Häme district, where there were three graders available in summer 1926. These were used improving the roads in direct government care but also all the main public roads under local boards. The order of these improvement projects was set by the district engineer. In the Oulu district in northern Finland most roads had been taken over by the state already in 1921. this was because of small population especially in Lapland. Vast distances meant that the graders became important to save manpower. In the summer 1926 there were five Tiekarhu-graders operating there, about fourth or even third of all motor graders in Finland. These worked on roads Tornio-Kolari, Rovaniemi-Posio, Rovaniemi-Kemijärvi, Vikajärvi-Ivalo and Rovaniemi-Kittilä, altogether 730 km.[41]

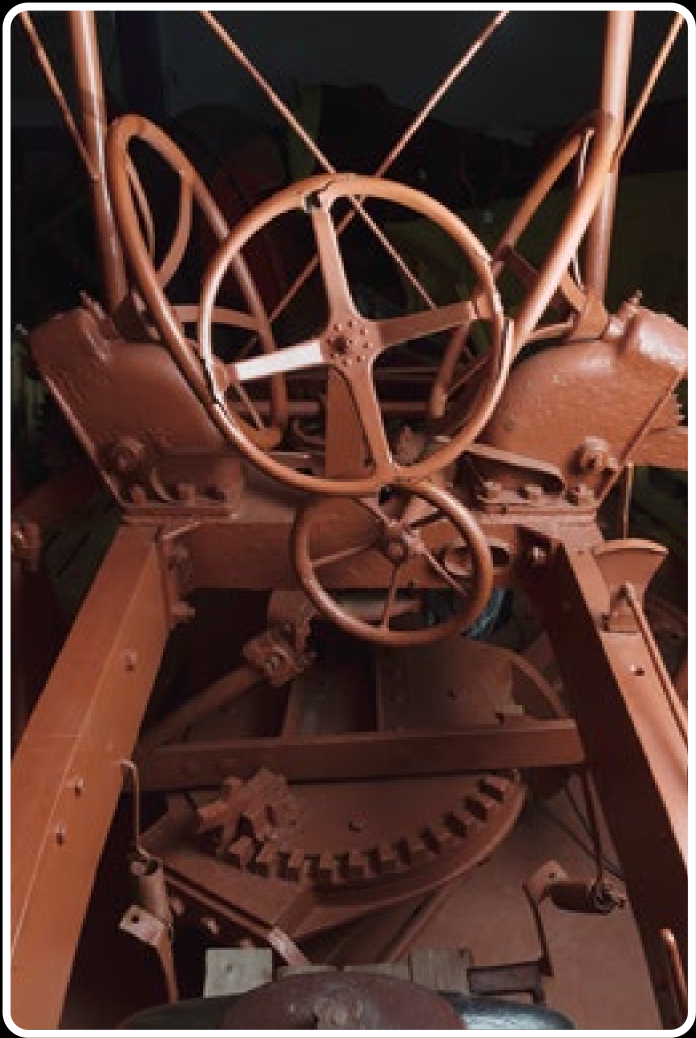
The graders were also used in the construction of new roads. On the road between Lapua and Alajärvi in Ostrobothnia a section of a public road built in 1910 on a swamp was completely rebuilt from 1925 on. The site saw the use of practically all new machinery at the authorities' disposal. The digging seems to have been done by hand but most of the transport of peat away from the site and gravel to the site was done by trucks. A motor roller was used to compress the road and motor grader to level the hardest parts. There was also at least one horse drawn grader on site working on the softer areas. In the article about the site, there is also a picture of the Tiekarhu working at the site. The grader is used to level the foundations of the road and dragging a leveller, on which several men are working to apply surface gravel to spots that don't have enough and to move the gravel left by the grader on the middle of the road to the still unfinished side of the road. It is interesting also, that the grader was fixed with a heavy wooden box in front, probably both for added weight and for gravel or sand that can be applied where necessary. Another Tiekarhu was used on a road improvement site north of Jyväskylä. Here, there were problems because of the dry summer. The same problem was apparent in Kalajoki in Ostrobothnia, where a Tiekarhu couldn't break the grassy central ridge of a road. There were also problems caused by the widening of roads, because when the grader moved gravel and dirt to the side of the road, this was usually not condensed in any way. For example, a taxi drove of the road near Viipuri while passing a bus, because its wheels got stuck in the soft roadside.[42]

Senior engineer Olli Martikainen, who almost 10 years before had been the first to introduce road machinery in Finnish, inspecting the roads of

41 Turun Sanomat 15.5.1926. Vaasa 20.5.1926. Aamulehti 1.6.1926. Uusi Aura 3.6.1926. Pohjolan Sanomat 17.6.1926.

42 Vaasa 31.7.1926. Keskisuomalainen 8.8.1926. Liitto 7.9.1926. Karjala 9.9.1926.

The cockpit of a Tiekarhu. The driver controlled the clutch with his right foot and shifted gears with a lever to his left. The throttle was on a lever to his right. The wheel closest to the driver controlled the front wheels, which could also be tilted with a winch. The blade could be moved sideways slightly with a smaller wheel under the steering wheel. The larger wheels on both sides were used to lower, lift, and tilt the blade. The position of the blade sideways was adjusted by changing its position by removing and refastening it. (Mobilia, Martti Korhonen)



southern Finland, strongly advocated the use of graders on public roads kept by the local road boards, but also complained that the contracts were too short and often too local for the use of heavy machinery. He saw a significant improvement in the roads of Turku and Häme districts, the areas, where the graders were used most widely. Biggest problems he saw in washboarding of the road surface and the old curvy roads, predominant in Viipuri district especially, but also the tendency of the graders to work too deep and remove all solid material from the road. The graders also could only be used on roads, that were wide enough and where all the telephone posts or fences were far enough from the road. The district engineer of Uusimaa asked the National Board, whether the government-owned graders could be used on contractor roads. The board decreed that all graders were available for contractor-kept roads as soon as the work on roads directly in government care was done, if the road boards responsible took care of all the costs.[43]

The private contractors who requested the use of motor-graders on their roads, don't always seem to have understood what grading meant for their own work. So, in Rantasalmi in Savo province, the local road board had to publish a newspaper advert to make them remove the dirt from ditches after a visit from a Tiekarhu. The board emphasized that the excess material should be removed to a place, where it couldn't endanger the passing traffic, which seems to indicate that the contractors usually piled the dirt on the road. Almost a month later, the road board renewed the advert, this time threatening the contractors with an oncoming inspection and that all improvements would be done by the board at the contractors' expense. The same problem arose in September also in Kankaanpää and Honkajoki in Turku district, but here the governor paid most of the expenses to the local road boards. In Somero, same kind of advert was published a couple of weeks later and in Noormarkku soon after. These were all because the contract season was coming to an end and the state was planning to take over several roads. For this to happen, however, the road needed to be in good condition, and the autumn surveys were imminent by early October. It must also be remembered that the road boards only received government allowances for roads that were found decent in these inspections.[44]

In November plans were made for the coming winter. This time the length of roads that were to be kept open for automobiles, was many times that of the previous winter. Proper ploughs that could be mounted on trucks had been ordered beforehand both by the National Board of Road and Water Works, by governors, by cities and by the Postal services. These were

43 Aamulehti 10.6.1926, 14.9.1926. Iltalehti 14.6.1926. Hämeen Sanomat 14.9.1926. Kansan Lehti 14.9.1926. Kouvolan Sanomat 18.9.1926. Maakansa 18.9.1926.

44 Vapaus 20.8.1926, 13.9.1926. Satakunnan Kansa 21.9.1926. Somero 1.10.1926. Satakunnan kansa 2.10.1926.

also constructed in several factories in Finland, for example by Tiekone company in Vaasa. The operations were focused in areas, where traffic relied on roads, e.g., the Turku province. Graders were used as before to level the hard-iced roads. This time, however, they were not intended for normal ploughing. At least some of the graders used in winter had tracks installed. The end of the year also brought problems, as the only professional contractor company, AB Granit decided to leave the field altogether and auctioned of its heavy machines at the end of the year.[45]

The first year's motor graders were used already show their normal annual cycle. During winter they were used to assist snow ploughs in their task, removing the hard ice from roads that was impossible with lighter machines. When spring melted the ground frost softening the roads, the graders were used for reforming and improving roads until summer, as gravel usually became too hard. The new surface was applied normally by local contractors but increasingly with the help of trucks and labour of the road districts. The autumn again saw some road improvements before the ground froze and the acquisition of new machines and preparations for winter.

Competitors to Tiekarhu

Tiekarhu was not the only motor grader available in Finland in the 1920s. As mentioned before, the first competitors were Swedish-built Munktell and Svedala graders, and the much lighter but also cheaper Bob-grader built by Vägmaskiner AB. There were attempts to introduce also other Fordson-powered graders to Finland, demonstrated by the Fordson Tractor Caravan, supported by the Ford Motor Company and several importers of Ford automobiles and agricultural machinery, moving from Kokkola along the western coast of Finland via Turku and Tampere to Helsinki in summer 1925. The caravan exhibited a Swedish Stark grader manufactured by AB Andrew Hollingworth &Co, although rebranded Woima by the Finnish Agros company, and a tracked Svedala grader.[46] When buying new machinery, the Finnish public authorities always asked for bids from several manufacturers and importers. Because of its cheaper price, the Finnish made Tiekarhu seems to have dominated the market for most of the 1920s. The two known Bitvargen's and the single Bob grader were acquired before the production in Finland began. The only serious attempt to compete with Tiekarhu in the late 1920s seems to have come from Ahjo machinery workshop, the biggest

45 Satakunnan kansa 17.12.1926. Helsingin Sanomat 24.12.1926. Uusi Suomi 24.12.1926.

46 The tractor Caravans seem to have been a typical way the Ford Company advertised its products in 1910s and early 1920s also in the United States. The Finnish caravan showcased the durability of Ford products in the distance covered but also several demonstrations on the way mainly to local farmers. Fordson Tractor Caravan in Finland 1925.

A Talkoo-motor grader built by the Ahjo company in 1933. The eventual machine was almost identical to the ones built by Tiekone company. (Mobilia, Väyläviraston kokoelma, Nyblin)

producer of horse-drawn graders in early 1920s. Ahjo offered to build their own version of the motorized grader for the National Board of Road and Water Works on December 31st, 1926. The idea was to utilize as many of the same components already in use in the Tiekarhu as possible, including the Fordson power source; but improve the overall construction and fix all noted shortcomings. What happened during the design and construction process illustrates well, why it was difficult to enter the market.[47]

The original offer was to manufacture two improved motor graders designed by Ahjo machinery workshop for 69 500 mk each. It should be noted that the offer was not a response to a call for bids, but an attempt to let the main customer know, that Ahjo was building up its own production of motor graders. The position of Tiekarhu in the local market can be seen in how the new graders would be built according to the same measures and how the flaws in Tiekarhu's design would be corrected. Ahjo also promised to give the National Board of Road and Water Works opportunity to supervise and inspect the ongoing design and construction process. The new machines would be ready in about four months.[48]

The original design of the Talkoo grader utilized a frame with a steeply curved front. This would have enabled better visibility to the front wheels and blade from the driver's seat, than what the Tiekarhu offered. A more or less similar frame was used in the motor graders built in the United States by Russel and later Caterpillar companies. The basic design, however, was changed, probably because of requests made by the National Board of Road and Water Works, and the final drawings eventually showed a machine

47 Tie- ja Vesirakennushallitus Fa 121:1C Konevaraston hankinta Ta 281/9 1927.
48 Ibid.

almost completely like the Tiekarhu. This meant that many parts would be interchangeable, and the users would be immediately familiar with the machine. The offer to build two Talkoo graders for 95 000 mk each was eventually approved in February 1928 and Ahjo machinery workshop agreed to deliver them by the end of June. The graders were inspected July 7th. It isn't clear how many Talkoo motor graders were eventually sold, but Ahjo workshop used their approval by the authorities in their adverts throughout the late 1920s.[49]

Purchase of road machinery in the 1920s

	Graders	Motor-graders	Tractors	Rollers[50]	Levelling drags	Stone-crushers	Trucks[51]	Cars	Motorcycles	Snow-ploughs
1920								4		
1921	20		4	2	18	5	12	5	2	
1922	3			2	15	2	4	3		
1923	2		2		7		1	2	6	
1924			4		17	2	5	3	7	8
1925	1	7	1		11	3	10	1	8	
1926		13	2	2		3	9	1		6
1927		10					10	5	10	1
1928		3		3	7		10	6	1	3
1929		17	1	3	4	4	23	21	1	11
1921–1923	25	-	6	4	40	7	17	10	8	-
1924–1926	1	20	7	2	28	8	24	5	15	14
1927–1929	-	30	1	6	11	4	43	32	12	15
Total	**26**	**50**	**14**	**12**	**79**	**19**	**84**	**51**	**35**	**29**

Table 1: *The annual purchase of road machinery by the National Board of Road and Water Works 1921–1929.*[52]

The 1920s saw a huge progress in the mechanization of the Finnish road upkeep. The statistics above show only the machinery acquired by the National Board of Road and Water Works, but it gives a good indication

49 Ibid.
50 Includes steamrollers, motor rollers and roller drags.
51 Includes both trucks and vans.
52 Statistics based on Tie- ja vesirakennukset 1921–1929. The table includes only the purchases of the National Board of Road and Water Works. In addition, also the provincial governors, contractors, cities, and road boards bought machinery, although presumably in much smaller numbers. For example, a Finnish Ford Motor Company commercial from 1929 lists all together 119 Tiekarhu graders sold in Finland by August 1929. Of these 49 belonged to the road districts, 43 to provincial governors, 14 to private contractors and 13 to cities. Maanteiden kunnostajana uusi Fordson-traktori on voittamaton 1929, 5.

of the scale of this change of which the motor graders were only a small part. In 1920 the Board had 2 trucks and 5 automobiles at its disposal for the whole country. The cars were reserved for official inspections or used in Helsinki, the trucks were available also for roadbuilding sites and for moving equipment. When the state took over the costs of road upkeep in 1921, the idea had been to rely on small scale private contractors and use horse-drawn machines and manual labour on roads in direct government upkeep. All this was suddenly outdated when the number of cars started to rise far more steeply than had been prognosed. The system of three-year-contracts is evident in the statistics. During the first contract term 1921–1923 most of the new machines were still horse-drawn. They were intended to be used only on road construction sites or roads that were in government upkeep. The new thoughts on using motors instead of manual labour, however, are evident in the increasing number of trucks, automobiles, and motorcycles especially. Heavy machinery, like motorized graders, were not available at this time in Europe. It must also be remembered that the technologically most advanced countries where the Finnish authorities took an example, like

Tiekarhu of the Kuopio Road and Water district. The machine is equipped with a canopy to protect the crew from the elements. The men used the bicycles to move from the machine to their pre-arranged quarters in nearby farm-houses. (Mobilia, Väylä-viraston kokoelma)

Germany and France, built mainly stone paved roads, which were expensive and difficult to maintain in the Finnish climate.

When the Tiekarhu became available in 1925, the motor graders quickly replaced not only horse-drawn graders, but also tractors and levelling drags. At the same time, also the purchase of trucks and snow ploughs that could be fitted on trucks increased. Both can be seen as symptoms of a need to acquire stronger and more efficient machines that could do their jobs faster. The ability to improve or plough long tracts of roads quickly was what the automobile age needed. Also, the inability of private companies to purchase expensive machinery is visible. Considering the system of road upkeep in Finland, the cost of machinery and the contract prices, only the public side had the resources necessary to acquire modern equipment. The eventual legal change was facilitated by the problem of former public roads which were left without any official upkeep. The Finnish government tried to mend the problem by forcing them legally on municipalities, but the parliament, keeping in mind the problems with the contractor system and the spirit of the road law, i.e., giving the road upkeep broader, national shoulders, decided to vote for a bigger change. The three new laws: law on roads, law on taking the former public roads in government upkeep and the law on property roads were passed in 1927, and their coming to force on January 1, 1928, changed how the system worked fundamentally. Now responsibility for all public roads was given over to the rural police chiefs, representing the government, assisted by roadmasters, or professional maintenance supervisors working under the road districts. This meant the roads could be improved without consulting all the local landowners at every turn.[53]

The big picture: the significance of roads in the broader traffic network

The same development is evident also in the construction of bridges in Finland. Bridges designed for horse-traffic became the biggest bottlenecks for motor traffic already in the early years of the 20th century. Almost all larger bridges in Finland were timber truss structures on stone abutments. Their load-bearing capacity was not enough for larger trucks, especially the heavier ones on solid rubber tires. In addition, many bridges, even on public roads, were wooden beam bridges that couldn't support anything bigger than carts. Like roads, also bridges were built and maintained by landowners, who were not ready to pay for their improvement. So, with the introduction of the new law on constructing and maintaining roads in the countryside, also bridges, as parts of public road, became a public respon-

53 Suomen teiden historia II, 36–46.

sibility. In the first half of the 1920s, most work on bridges can be seen as light improvement or maintenance to improve their load-bearing capacity. Things began to change at the end of the first contract term when it became clear that the local authorities were not able to build bridges on the scale needed by the increasing automobile traffic.[54]

In 1924 the National Board of Road and Water Works opened a separate bridge building department that provided plans for individual bridges and began work on a set of normative bridge designs that could be either directly utilized or altered for specific places. This meant that the use of more durable materials, especially steel and concrete could be promoted. In the early 1920s foreign companies had to be relied on for all more sophisticated bridge engineering, but by the early 1930s the public authorities could plan and execute any task by themselves or order the work from domestic companies. All in all, the Board of Road and Water Works built more than 700 new bridges in 1924–1930, of which 49% were made of concrete although often unreinforced, 31% of steel, 6% of stone and 14% of wood. The stone and wood bridges were mostly built in the more remote parts of the country where new skills and materials were difficult to find. Unfortunately, most bridges of this period were built far too narrow and structurally difficult to expand for later traffic and surviving examples are few today. The new steel and concrete bridges meant a similar process of mechanization of labour with steel mills, workshops, cranes, rock crushers and cement mixers. Unlike roadbuilding and road upkeep in Finland, bridgebuilding was specialized enough to support a handful of private companies. Their role, however changed during the 1920s from building almost all concrete and steel bridges to executing only the most challenging projects.[55]

	1921	**1926**	**1931**
The portion of the Ministry of Transport in the government budget	26,8	31,4	29,1
The portion of roadworks in the budget of the Ministry of Transport	2	4,4	11,7
The portion of State Railroads in the budget of the Ministry of Transport	79,3	75,4	63,7
The portion of roadworks in the government budget	0,5	1,4	3,4
The portions of State Railroads in the government budget	21,3	23,7	18,5

Table 2: *Roadworks in the state budget (percent).*[56]

54 Siltojemme historia 2004, 53–59.
55 Ibid. Tie- ja vesirakennukset 1920–1929 passim.
56 Masonen, Antila, Kallio & Mauranen 1999, 228.

Reality on Finnish roads. Two cars passing each other in 1927 in Uusimaa province close to Helsinki. (Mobilia, Väyläviraston kokoelma)

	Water-ways	Rail-roads	Roads	Motor vehicles	Other	Total (million marks)
1922–1924	98	287	93	43	9	530
1925–1929	110	346	167	301	21	945
1930–1934	71	277	272	133	18	771
						Total (percent)
1922–1924	18,6	54,2	17,5	8	1,7	100
1925–1929	11,7	36,6	17,7	31,8	2,2	100
1930–1934	9,2	35,9	35,4	17,3	2,2	100

Table 3: *gross investment of the department of transport 1922–1934 in millions of marks above and percent below.*[57]

As shown in the two tables above, in the big picture roads were not the most important task of the Ministry of Transport in the 1920s. In fact, the State Railways took a lion's share both in construction and overall costs. This reflects the general traffic policies of the era, where first the waterways and then from about 1900 onwards railways enjoyed primacy inside the traffic administration. However, if we turn our gaze from just road construction to the combined costs of road construction and motor vehicles, most of

57 Kiiskinen 1954, 138.

which were intended for road upkeep, we have a different picture indeed. Also, the period 1925–1929 clearly stands out in this sense. In fact, in this period, the combined cost took almost 50% of the total gross investment of the department of transport. This, as shown before, was also the time the National Board of Road and Water Works began to take over regular road upkeep. Apart from the period 1930–1934, the amount spent on purchase of motor vehicles remained more or less the same in the 1930s and 1940s.[58]

The period 1930–1934 can be seen as an anomaly, since during the Great depression the Finnish governments response was to cut all spending apart from emergency public works for the unemployed. This meant largely roadworks, where unskilled labour could be easily utilized. In contrast to the official policy, this time roads could also be built in the southern part of the country, where the number of people and thus unemployed was also largest. By the middle of the 1930s the small-scale man and shovel type roadworks began to evolve into the preplanned improvement of long-distance routes between main cities.[59]

It has been estimated that the amount of traffic in Finland in total grew by 5,4% annually between 1920 and 1930. There were significant changes in the parts played by different modes of transport, mainly that the importance of automobile traffic increased to the detriment of rail- and water transport. The statistics usually don't include short-distance horse- or bicycle traffic at all, but if these are included the increase in the significance of roads for the traffic infrastructure would have increased even more. In the total traffic performance (passenger-kilometre / ton-kilometre) the significance of improving roads can be seen especially in the increase of autobus traffic all over the country. However, during the 1920s in the traffic performance of freight traffic, railways retained their importance. This was mostly because of the small size of available trucks and difficult roads, if we keep in mind that the most important commodities were probably timber, milk, cream, and butter, all of which, on short distances at least, were transported by horse at this time.[60]

Summary: local response to the automobile age

The 1920s was a period when the Finnish traffic authorities adapted to the automobile. New legislation was enacted to transfer the costs over roads and bridges from landowners to broader shoulders. The early half of the decade saw an attempt to utilize private contractors using a system of local auctions. However, this system was not enough for the needs of

58 Masonen, Antila, Kallio & Mauranen 1999, 227–229.
59 Id. 229–243.
60 Leppänen 1973, 17–21, 68–69. Masonen, Antila, Kallio & Mauranen 1999, 184–209. Mäkinen 2022, 26–27.

the ever-increasing traffic, as the cheapest bidders usually were small-scale operators, unable to acquire machinery, and blissfully unaware of what a modern road was supposed to be like. The old ways: man and shovel, or light horse-drawn machinery were not enough on roads frequently used by heavy trucks or buses. So, public authorities, the National Board of Road and Water Works, had to take a bigger role, as advisors, inspectors and, in the end, in the hard work itself. By the time Finland became independent, the road-network in the southern part of the country was already in place. Almost all newbuilt roads in the 1910s and 1920s were in the northern or eastern parts of the country. In the 1920s the road authorities needed a separate permit from the parliament to build new roads elsewhere. Mainly because of costs, instead of building new roads, the normal response was to locally improve the existing road network, improve or rebuild bridges and mechanize road upkeep.

Before the second world war, the Finnish road-network consisted almost entirely of gravel roads. The only exceptions were the cobbled streets in cities and some isolated sites, where some hundred meters of asphalt or different adhesives were tested. Because there usually wasn't enough funding available for completely rebuilding roads or even short stretches of roads, the chosen method was to improve their maintenance by improving ditches, regularly applying new gravel, using moraine or in its absence clay as adhesive, compressing and flattening the road surface using different types of rollers and grading the road surface to the desired cant. This could mostly be done using the old agricultural tools but automobile traffic, and especially the increasing number of heavy vehicles necessitated also heavier maintenance. In Finland the first response was to develop more familiar and affordable horse-drawn machinery following international, mostly American models. This, however, was soon found to be inadequate.

Keeping these developments in mind, the motorized grader arrived in Finland at the best moment possible. The first Swedish Bitvargen-graders were bought and the production of the Tiekarhu began at a time, when the weaknesses of the contractor system were becoming apparent, and the National Board of Road and Water Works was building up its role as a model in the use of new technology to the contractors and taking more roads over from the local authorities. The necessity of the machine can be seen in the speed it spread across the Nordic, and also Baltic countries: The first American Wehr-graders were imported to Sweden in 1923, the next year production of the licence-built Bitvargen began by Vägmaskiner AB in Stockholm, in 1925 in Finland and in 1927 also in Estonia[61]. The graders were built under licence by local machine workshops, Onkilahti in Vaasa, Finland, and Ilma-

61 See Seene: First graders at the service of Estonian roadmen in this volume.

rine in Tallin, Estonia, but sold and controlled by local affiliates established by the Vägmaskiner AB. Because of local affiliates and local production, the machines could be sold for a significantly low price. All graders were built on Fordson tractors, and it seems the Ford Motor Company had a big part in the whole operation. By the end of the decade there were already several hundred of these machines working on the northern gravel roads.

The motor-graders can be seen as an emergency solution in a situation when the entire construction budget of the National Board of Road and Water Works was reserved to building roads in the northern and eastern provinces of Finland and repairing and rebuilding bridges. The graders could be utilized to compact roads, tilt them to remove water, remove washboarding, and in the winter ploughing snow and removing ice from roads. All of these could be done also with older tools, but the graders brought new efficiency, and their weight counted when improving roads for automobile traffic. The motor-grader remained the most important tool in the maintenance of gravel roads in Finland until the 1980s and 1990s when most of the roads were finally paved. They, however, are still missed, especially during winter.

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Yleiset tiet. Tutkimus, rakentaminen ja kunnossapito. Ohjeet teitten tutkimisessa, rakentamisessa, korjaamisessa ja kunnossapitämisessä ynnä Tie- ja vesirakennusten ylihallituksen antamat yleiset määräykset maaliskuun 13 päivänä 1917. Suomen senaatin kirjapaino. Helsinki.

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FIRST GRADERS AT THE SERVICE OF ESTONIAN ROADMEN

Introduction and production of motor graders in Estonia in the 1920s and 1930s

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Introduction

The cheap and easy solution used for road maintenance in Estonia until the first quarter of the 20th century was to delegate road works as an obligation to landowners and farmers. The tools used by the farm workers were simple and working with them was time-consuming and inefficient. The first Bitvargen graders acquired by the Ministry of Roads from Sweden for testing in 1926 have been considered the harbinger of a new era in local road construction.[1] The Roads Act adopted in 1928 created the conditions required for the establishment of the fleet of road construction machines of the Road Administration and the development of the respective procurement policy. The mechanisation of road works in Estonia before World War II forms a period of almost 15 years, when modernisation processes took place in the organisation of the area of roads and the techniques used. The qualitative changes that occurred were not immediately visible and unfortunately did not cover the entire road network.

The objective of the article is to prepare a detailed and generalised overview of the establishment of the road machine fleet in Estonia between the two world wars and focus on the implementation, production and further development of the most important machine type – the road grader – in Estonia. The author also attempts to explain the objectives and policies of the Estonian Ministry of Roads in the mechanisation of the works and to assess their potential impact on the change in the qualitative status of the roads from 1926–1940.

General characterisation of road works in early 20th century

Major changes in road construction occurred after the invention of the car. Whilst almost all road conditions were suitable for horse carts, car traffic required roads of considerably higher quality. At the turn of the 19th and 20th centuries, the Americans started using cement concrete as a road surface material on roads and asphalt concrete became the preferred material during World War I. As traffic volumes kept increasing, it became obvious that daily road maintenance had to be given more attention than before. Thus, the production and development of innovative road construction machines started with the spread of cars.

The implementation of the road grader marks the start of a new era in road maintenance. The Americans invented the predecessor of the modern grader in 1875. The early graders had no engine and they were initially

1 Nerman 2009, 2.

Use of a steam roller in road works in the 1930's. (Estonian Road Museum)

drawn by horses and later by tractors. The road grader soon became the symbol of mechanised road construction and maintenance. In 1920, the Wehr Company, based in Milwaukee in the United States, started producing self-propelled graders, which were powered by Fordson tractor engines. The Swedish factory AB Vägmaskiner also started manufacturing the Wehr model under the name Bitvargen[2] in 1924. 250 self-propelled road graders worked on the roads of Sweden in 1926. There were 35 of them in Finland, 15 in Norway and four in Latvia.[3]

Like other provinces of imperial Russia, there was no need for new roads and technologies in Estonia at first. The number of cars in the first two decades of the 20th century was very modest and keeping the roads in order was an obligation of the peasants; the organisation of work had been the same for centuries. Some horse drawn road machines were used however: carts for transporting gravel, road rollers and old cartwheels for grading. The first machines with engines were introduced in Estonian road construction and maintenance in the early 20th century. They were probably rollers

2 Due to the strength and power of the graders, their models were often named after strong and resilient animals (e.g. Road Wolf). The Finnish model of the machine was called Tiekarhu (Road Bear). Bitvargen can be translated from Sweden as a wolf that tears out bits with its teeth.

3 ENA 2075-2-57, 57.

powered by steam engines. Some stone crushing machines, and crushed stone screens powered by kerosene were also introduced before Estonia became independent or at the latest, during World War I. Before the purchase of motor graders in 1926, the fleet of road construction machines of Estonian counties consisted of six steam rollers, four motor rollers, ca 10 various horse drawn rollers, eight stone crushers, seven crushed stone sorters, three horse drawn ploughs, three lorries, one tractor and some other machines, many of which were not in working order or needed repairs. The equipment list of Viru County even included a horse drawn grader or planing machine, but it also needed repairs. This was the documented status of the mechanisation of road works before the major machine procurements organised by the Ministry of Roads in early 1927.[4]

Organisation of road works in the Republic of Estonia from 1918–1940

When Estonia became independent, the engineers of the newly established Road and Inland Waterways Administration faced rutted and muddy gravel roads, which became almost impassable in spring and autumn. The Road and Inland Waterways Administration was liquidated in 1923 and the tasks related to the immediate maintenance of roads and bridges were assigned to county governments. The duty of the Ministry of Roads was to grant credit and exercise supervision, and the Equipment and Construction Machinery Department of the Ministry of Roads dealt with the issues directly.

The Roads Act adopted by the Riigikogu[5] in 1928 (in force in 1929) assigned all the direct obligations in the area of road and bridge construction and maintenance to county governments.[6] The state increased the credits and reorganised the revenues to be earned from taxes imposed on motor vehicles and petrol. Roads were divided into three classes based on the Roads Act: Class I – intercity roads with high traffic volumes; Class II – roads of lower traffic volume and less importance; and Class III – village roads. In terms of construction and maintenance, roads were classified as roads maintained by way of road capital and as the statute labour or corvée system.[7] Road endowments were established by the Ministry of Roads and by country governments. Class I roads and some Class II roads were maintained with the funds collected from road capital, i.e. money allocated from

4 ENA 2075-2-57, 141.
5 The parliament of the Republic of Estonia.
6 See Kaldre 2008.
7 In the corvée or statute labor system for road maintenance each person subjected to it was obliged to provide the state with a certain number of days of physical work every year. Corvée in French now means “a chore” or “military fatigue duty” (See Lay 1992, 100-102). In the case of Estonia, this work obligation in road maintenance can be followed in the written documents and decrees issued by Swedish authorities in the 17th century. The principle was completely abandoned in 1959.

various taxes and the state budget whilst most of the Class II and Class III roads were maintained by way of statute labour. Up to 22,000 km of roads belonged to the Estonian road network before World War II, a little over 6000 km of which, i.e. less than one-third of which (Class I and some Class II roads), were maintained with public funds, but two-thirds, i.e. over 15,000 km, still had to be maintained by way of the statute labour system, i.e. with the help of local residents and landowners.[8]

Transferring gravel roads gradually under financing by road capital by the principle of the Roads Act could be completed as a result of consistent activities over a longer period. Pursuant to the Roads Act, the road departments of county governments had to organise the maintenance and supervision of roads, bridges and rafts. The county engineer, elected by the county government but appointed to office by the Minister of Roads, was the technical manager directly responsible for all matters concerning roads. The issues concerning roads were resolved by the county government after hearing the opinion of the county engineer. The technical staff of the Road Department was supervised by the county engineer. Roadmaster regions were formed in counties for the construction, maintenance and supervision of roads. There were 70 roadmaster regions in Estonia in the late 1930s. The roadmaster reported to the head of the Road Department of the county government and in engineering issues directly to the county engineer.[9]

Most of the roads at the time were gravel roads and the state didn't have enough resources to reconstruct them extensively. There were only 700 km of stone-paved roads. Putting the main emphasis on improving the quality of the existing roads was a practical solution, as it made them satisfactory for traffic from spring until autumn. Only then was it possible to gradually start increasing the share of roads with an artificial surface. However, building them required modern equipment in addition to human and horse resources. The road works carried out by way of statute labour were not very efficient and in the best case, roads could only be maintained twice a year, i.e. in spring and autumn. However, roads needed considerably more maintenance. The shortage of machinery made it impossible to abolish the corvée system immediately and it was decided to do so gradually as new road machines were acquired. Considering the conditions of the time, the most critical road machines needed were graders, as they could be used to eliminate ruts and even the road surface.

8 The total length of Estonian roads in 1918 was ca 14,000 km. There were ca 21,000 km of gravel roads in Estonia by autumn 1927, including ca 12,000 km of Class I and II roads and ca 9000 km of Class III roads. There were ca 2530 km of Class I roads in Estonia by 1939 and the maintenance of all of them was financed from the state budget. There were 8167 km of Class II roads, the maintenance of 3509 km of which was financed from the state's funds. However, the maintenance of 4658 km of Class II roads and ca 11,000 km of Class III roads was still organised as an obligation of local residents.

9 Seene, 2015, 121-122.

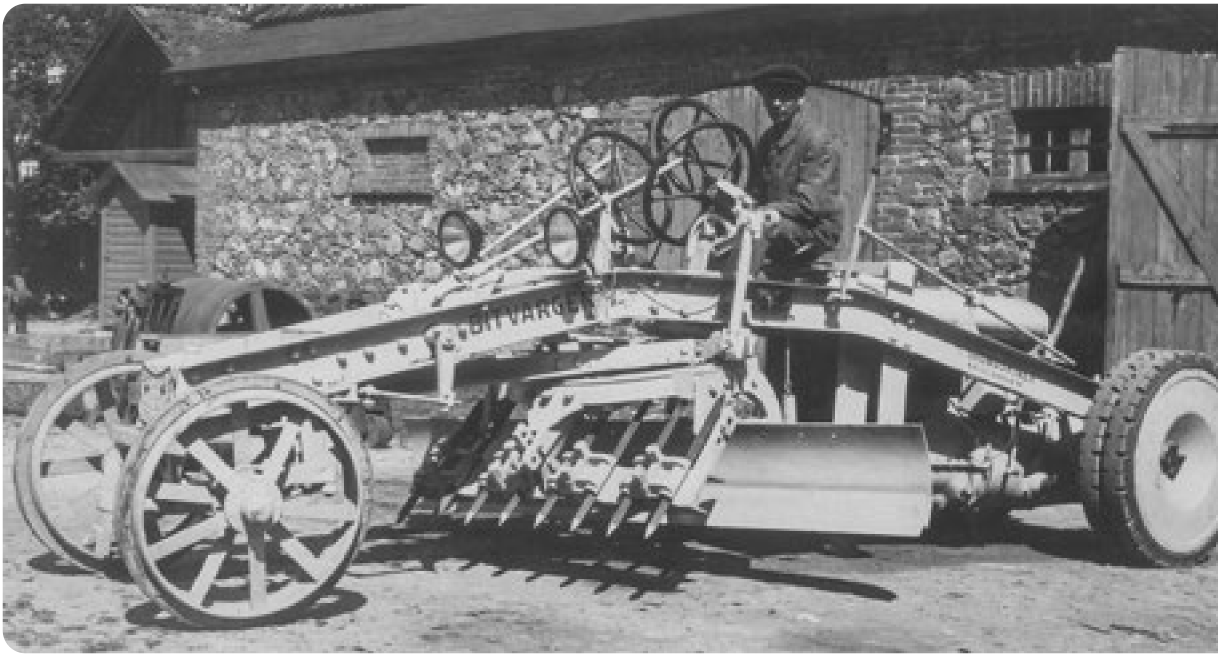
Engineer Herman Perna (1883–1969), the director of the Department of Construction Equipment of the Ministry of Roads and one of the key persons who managed the procurement of new road machines and the development of the respective policies and practices from 1924–1934, went on training trips to Germany, Switzerland and the Scandinavian countries from 1925–1926 to view the road machines used there and the products of local companies. The Department of Construction Equipment prepared the procurements of machines according to the applications received from the road departments of county governments and the state's financial resources. The procured machines remained in the ownership of the state and were given to county governments for use. The machines that were the most suitable for the location conditions were selected based on locally performed tests and the relevant reports received from county governments.

15% of the amount allocated from the state budget for the construction and renovation of roads and bridges in 1929 was spent on the acquisition of machines. In comparison, 6–10% was spent on the wages of the technical staff or the road departments of county governments.[10] In the next year or two, the amounts decreased considerably because of the global recession, which also had a direct impact on the procurement of machines. The high unemployment raised the question of whether using people instead of road machines, as was the case decades ago, would be more reasonable. The machine fleet remained almost the same from 1931–1932, which raised the question of rational use of road machines. As road works were seasonal, machine drivers were also hired only for a season. This meant that the skills of the drivers also left with them at the end of the season. In 1935, it was decided that the drivers needed more training so that the machines could be used more sustainably and rationally.[11]

First procurements for road machines from 1926 to 1927

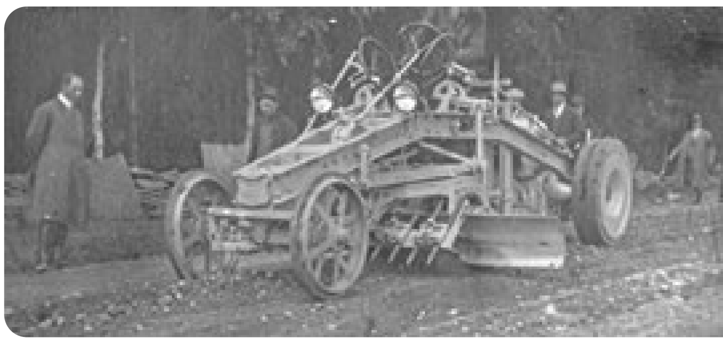
Although quotes for the acquisition of road graders were received from the US as well as other Swedish manufacturers, the one selected by the Estonian Ministry of Roads was the Bitvargen made by AB Vägmaskiner in Stockholm.[12] The Ministry of Roads contacted AB Vägmaskiner for a quote in autumn 1925. The price of a grader was 800,000 marks (8000 kroons in the currency of 1928). On 1 April 1926, Estonian Minister of Roads Oskar

10 ENA 2075-2-106.
11 ENA 2075-2-358.
12 Technical specification and data of the Bitvargen-Ilmarine road grader: the grader was operated by one person and it was powered by a Fordson tractor engine. Total length of grader 5.45 m; width 2.44 m; total weight 3750 kg; blade length 2.44 m; capacity 22 horsepower; speed when empty 15 km/h; speed when in operation (average) 7 km/h.



Bitvargen motor grader. (Estonian National Archives)

Amberg made a proposal to the government to order two Bitvargen road graders from AB Vägmaskiner for the credit allocated to the maintenance of roads and bridges. Two weeks later, the president and the state secretary approved the application for buying the machines. The graders arrived in Tallinn on 23 June 1926. After tests, one of the machines was given to the Road Department of Harju County Court and the other to Tartu County roads.[13]



Testing a Bitvargen motor grader in Estonia in 1926. (Estonian National Archives)

Roadmen confirmed that the new machines worked well on roads repaired with natural gravel and their productivity was high. A big advantage of the road grader was that it could be used to cheaply and quickly widen narrow roads and add the required concave profile to the roads, that became more durable after they were covered in gravel and remained dry. The machine could not be used for grading crushed stone roads, as its structure was not strong enough. As a result of testing, it was found that the performance of road profiling, i.e. planing, with a grader was 5–10 times cheaper than the previous spade work (the estimated cost of planing 1 km of gravel road with a road planer was 5000–6000 marks in the currency of those times, whilst the cost of manual work at the prices of the same era was 52,500 marks). As a result of this, it was decided at the Ministry of Roads that the state had

13 ENA 2075-2-57, 84-93.

to acquire more road graders, so that they could be used on the roads of every county.[14]

The decision to acquire 10 more road graders was made on the proposal of the Minister of Roads on 16 April 1927. These graders were made in the Ilmarine machine factory in Tallinn based on a licence. The quality and condition of roads in Estonia was considerably worse than in Sweden, which is why the graders had to be adjusted to local conditions. Training of grader builders started at Ilmarine according to the plans of the Ministry of Roads. The testing of road graders on Estonian roads and their gradual improvement and adaptation to the local road conditions started with the purchase of the first road graders. As a result, a road grader was developed at Ilmarine, which was a better fit for Estonian conditions.

A larger quantity of various road construction machines was bought from abroad at the same time. Most of them were completely new in Estonian conditions in terms of their type and meant for building roads with an artificial (crushed stone) surface. There were only 270 km of crushed stone roads in Estonia at the time. The new machines were meant for testing in Estonian conditions. Some machines were ordered from two different manufacturers in order to test them in Estonia and select the most suitable ones. The head of the Department of Construction Equipment found in his proposals that the development of cars required appropriate roads, i.e. roads with an artificial surface by the crushed stone principle, and different binders had to be selected in the future depending on the traffic volumes and loads. The need to build artificial road surfaces in the future was also justified by the commonness of bitumen obtained from oil shale in Estonia creating the preconditions for the gradual transfer to the construction of roads with an artificial surface, but which required special machinery.[15] The cost of these machines was about the same as the amount spent on buying 10 road graders. Several machines and pieces of equipment were also acquired outside this plan (snow plough, nine-ton Fordson roller). Thus, 1927 proved to be rather exceptional in the area of road machinery when compared with past and future years, both in terms of the quantity and types of machines acquired.

The guidelines for the gradual construction of roads prepared in the Department of Construction Equipment of the Ministry of Roads in 1928 described properly repaired gravel roads, and the main machine used for their maintenance was a road grader that cut off the ruts and flattened the road. This document was the basis for the majority of the procurements for road machinery that followed.[16] The new strategy of road management pro-

14 ENA 2075-2-76, 23.
15 ENA 2075-2-76, 134.
16 Unt, 2010, 121.

ceeded from actual nationwide needs, according to which the first priority was to get gravel roads in satisfactory order, after which the gradual increase of the share of roads with artificial surfaces could start. The last moment was moved to the second plan and the number of machines required for this was assessed as adequate at first. Road graders and lorries proved to be the most needed machines in the gradual development of roads, i.e. the machines used to profile and maintain gravel roads and cover them with gravel. The large road machinery procurements from 1927–1929 were related to the adoption of the Roads Act, which attempted to abolish the statute labour system, which in turn was made possible by the mechanisation of road works.

Local grader industry and its products

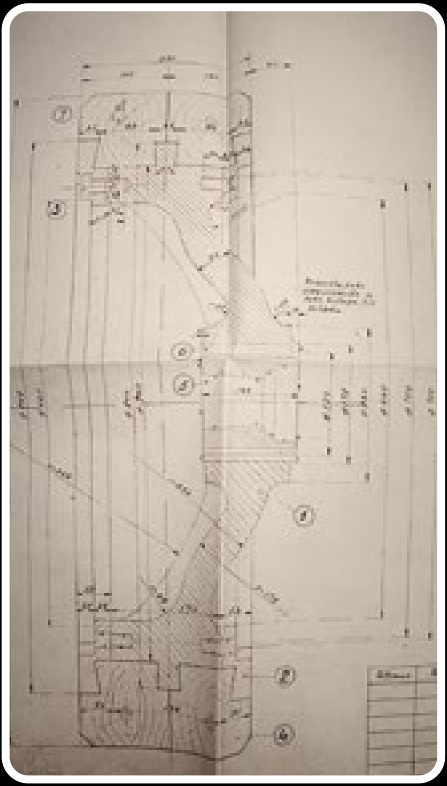
The number of Fordson-Ilmarine, i.e. Bitvargen-Ilmarine, road graders had increased to 35 in 1928. Two local machine factories made tenders to the state – public limited companies Ilmarine and Franz Krull (plus the companies that represented the products of foreign companies in Estonia). Among the tenders received in 1928, the one of Franz Krull factory was a little cheaper, but the Ministry of Roads chose Ilmarine, as the company had experience in manufacturing road graders, skilled staff and the necessary equipment. The fact that Ilmarine factory had specialised in the manufacture of road graders was also considered an advantage.[17] The proposal made by the Minister of Roads in late 1929 was that Ilmarine could continue building and improving road graders and Franz Krull specialise in making stone crushers, crushed stone sorters and rollers. This was supposed to prevent the fragmentation of the limited technical and economic resources and the duplication of work and make it possible to achieve the established goals.[18]

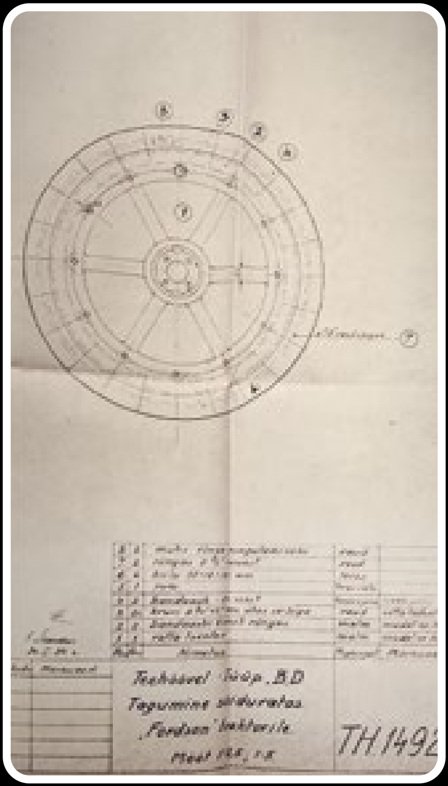
Improvement and modification of the machines to make them more suitable for Estonian conditions began based on the reports received from county governments. The graders of the first series manufactured at the Ilmarine plant in 1927 were equipped with a roof above the driver's head and electric lighting, and the gravel road ripper used on the initial models was left out as unnecessary. The construction of the road graders, e.g. the fastening of the blades etc., was also improved. The solid rubber tyres of the rear wheels proved to be one of the most expensive parts to change. The estimated cost of a pair of tyres during the recession was 1000 kroons, which comprised ca one-eighth of the price of the machine. The estimated duration of a pair of tyres was up to 3 years. Testing oak or ash tyres instead of rubber tyres was planned from 1933–1934. Based on the price quote

17 ENA 2075-2-105.
18 ENA 2075-2-144, 54.

The solid rubber tyres of the rear wheels of motor graders were the most expensive parts that had to be regularly replaced. (Estonian Road Museum)

Drawings of the grader wheels with wooden tyres made at Ilmarine factory in 1934. (Estonian National Archives)





Bitvargen road graders made in Estonia, i.e. Fordson-Ilmarine motor graders at the promotional display of the Ilmarine factory in the late 1920's. (Estonian National Archives)

People and a machine: the road grader made at the Estonian machine factory Ilmarine following the example of Bitvargen and the employees of the Harju County Government in 1932. (Estonian Road Museum)

requested from Ilmarine factory, a wheel with such a wooden tyre cost 450 kroons. We don't know whether this price was also deemed too high, but that the low price of wood would have allowed for bigger savings in the case of more frequent tyre replacement was taken into account.[19] We also don't know whether any tests were actually carried out, but wooden tyres were never taken into use.

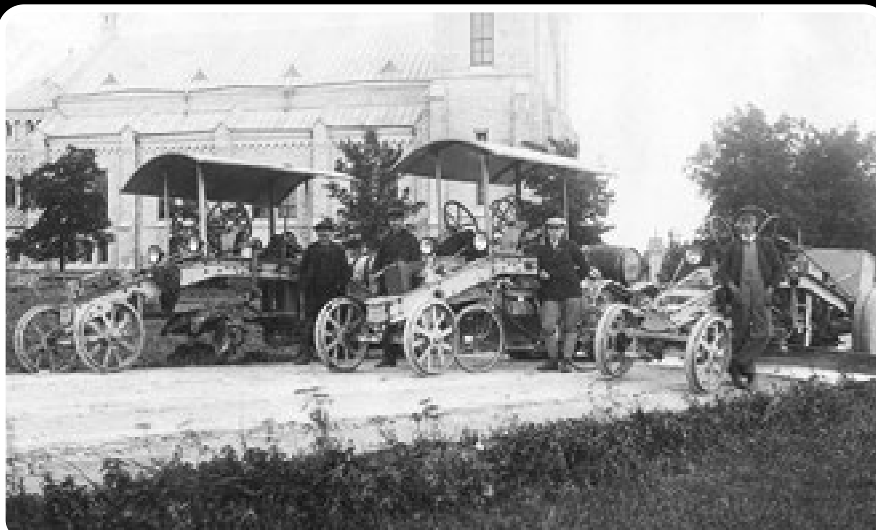
In 1929, tendering proceedings were no longer used to order graders and the orders were sent straight to Ilmarine instead. Another 36 road

19 ENA 2075-2-358.

Roller grader based on the patent of Bernt Lorens Åkesson in the Ilmarine factory in Tallinn. (Estonian Road Museum)

Svedala-type "tank grader" with crawlers. (Estonian Road Museum)

Bitvargen-Ilmarine graders. (Estonian Road Museum).



graders were ordered from AS Ilmarine in 1928, which were divided proportionally between county governments considering the length of the roads located in the counties (the number of road graders in Estonia and the orders for them by years are described in Table 1). Four graders of different types were ordered from Sweden at the same time as well. Two of them were crawler graders and it was decided to test them, as the feedback received from county governments often stated that the grader's rear wheels with solid rubber tyres tended to get jammed in the surface. Two of the machines were roller graders (with Fordson tractor engines), which had caught attention in Sweden, as they combined the qualities of a roller and a grader. The eight-ton machines had two separately moving roller wheels that moved on the same axle, and the grading devices were located between them. The advantage of this roller was that it could turn itself around on a road 6–7 metres wide and didn't need the expensive rubber-covered wheels. Ilmarine started manufacturing these machines on licence in the subsequent years as well. In the early 1930s, the orders for roller graders were justified with the fact that they were suitable for the maintenance of the increasing number of roads with surfaces of artificial or screened gravel, as ordinary graders were not considered suitable for this work.[20]

In 1929 it was decided to start using the new Fordson engines on road graders manufactured in Estonia. They had certain significant advantages, such as the high capacity, which didn't let the engine die out on difficult sections of the road. The decision to order 30 additional graders was made the same year and the decision to start using Deering-type tractor engines instead of the Fordson tractor engines in 1932. A contract for manufacturing five roller graders was made between the Department of Construction Equipment of the Ministry of Roads and Ilmarine factory in 1931. The grader operated by the principle of a roll. The objective of the roller graders was to cut costs and create a 'universal' tool. No new graders were ordered during the global recession, and some became outdated and needed replacement. The Ilmarine factory had manufactured or imported 130 licenced road graders based by 1934–1935. It also built at least five road graders for the state of Latvia.[21]

20 ENA 2075-2-281, 7.
21 Nerman, 2009, 26.

Table 1: *Road graders in Estonia, 1926–1935*

Year ordered	Type and manufacturer of grader	Quantity (units)	Comments
1926	Bitvargen (Vägmaskiner, Sweden)	2	No. 129, 130
1927	Bitvargen-Ilmarine (Ilmarine, Estonia)	10	B-type, no. 1-10
1927	Bitvargen (Vägmaskiner, Sweden)	1	With gas generator
1928	Bitvargen-Ilmarine (Ilmarine, Estonia)	12	B-type, no. 11-22
1928	Bitvargen-Ilmarine (Ilmarine, Estonia)	11	Series II, no. 23-33
1928	Bitvargen-Ilmarine (Ilmarine, Estonia)	36	Series III, no. 34-69
1928	Bitvargen (Vägmaskiner, Sweden)	2	Grader with crawlers, Svedala-type
1928	Åkerman-type roller graders (Sweden)	2	Roller graders
1929	Bitvargen-Ilmarine (AS Ilmarine, Estonia)	30	Series IV, D-type, no 70-99; 1929 Fordson engine; without a ripper
1929	Motor grader International (USA)	1	
1931	Motor roller graders (Ilmarine, Estonia)	5	
1931	Bitvargen-Ilmarine (Ilmarine, Estonia)	6	D-type; Deering engine
1931	Motor roller graders (Ilmarine, Estonia)	6	F-type; Deering engine
1931	Motor roller graders (Ilmarine, Estonia)	2	F-type, Fordson tractor engine
1932	Road grader Caterpillar with crawlers, model 15 (USA)	1	Grader with crawlers
1934	Motor roller graders (Ilmarine, Estonia)	2	Deering engine
1935	Motor grader Caterpillar Road Patrol No 10 (USA)	1	
	Total 1926–1935:	130	

Source: ENA fund 2075 materials; Nerman, 2009.

Work process of grader

In Estonia, road graders were used for profiling gravel roads, i.e. to give a concave profile to the road, and for maintenance. The plan was to acquire enough graders to gradually keep Class I roads in order with money from road capital. It was estimated that a machine had to go back and forth 15 times on average when profiling one kilometre of road. In terms of maintenance, it was estimated that a grader would have to go back and forth three times twice a month. The estimated length of a construction season was 100 days or four months for profiling and six months for maintenance. It was also estimated that 10% of the graders would be undergoing repairs at any time. The number of graders increased to 75 by 1929 and the following year, there were more than 100 of them (see Table 1). The average estimated productivity of a new Ilmarine road grader was estimated at slightly over 50 km upon road planning and approximately 70 km upon road maintenance. Works were performed by work groups (two to five graders in a group). The graders were divided between 11 counties according to the length of roads

View of the grader garage of the road department of a country government in the 1930's. (Estonian Road Museum)

in their territories. In 1929, it was deemed possible to profile 1675 km of roads and maintain 2400 km of Class I and II roads with 75 road graders.[22]

The snow plough Ambra that could be fastened to a lorry, manufactured in the Vägmaskiner factory in Sweden, was ordered in 1927 and arrived in Estonia in late December the same year.[23] The idea was to test the plough in Estonian conditions and for this purpose it was handed over to Harju County Government, advised to use it to keep the Tallinn-Nõmme and Tallinn-Loksa roads clean.[24] Snow clearing had to become more efficient than before, as it was necessary to keep up the regular coach services established at the same time, mainly on the roads connecting towns. The plough performed well during the winter of 1928. In late 1927, Lääne County Government informed the Ministry of Roads that the Risti-Virtsu road could be kept open for coach traffic with a road grader.[25] As the road graders were useless in winter, the Ministry of Roads decided in early 1928 to use the Swedish plough as an example to design a technical device that could be attached to a road grader. As the plough ordered from Sweden was deemed too expensive and the number of lorries was small, four ploughs that could be fastened to road graders were ordered from Ilmarine in 1928 (2 x 2 special-type ploughs). The mouldboards of two ploughs were tilted and the other two had angular ones.[26] Two of these ploughs were handed over to Tartu County Government in January 1929 and the other two given to Harju County Government at the same time. Ilmarine also manufactured two snow ploughs that could be fastened to heavy goods vehicles for the same counties. As a result of the tests, Tartu County Govern-

22 ENA 2075-2-107, 51-64.
23 ENA 2075-2-75.
24 ENA 2075-2-76.
25 ENA 2075-2-76.
26 ENA 2075-2-142, 57.

Road levelling device towed by a tractor in 1931. (Estonian Road Museum)

ment found that the grader ploughs were completely unsuitable for snow clearing. Fresh snow carried the plough, which was equipped with a sleigh, but the front wheels of the grader sank into the snow and moving forward became difficult. Only the blade of the grader cleared the road in this case whilst the snow plough simply slid across the snow.[27] Attempts to use road graders in snow clearing nevertheless continued from 1928.

Since there were not enough graders for Class II, i.e. local, roads, the Ministry of Roads advised using simpler gravel road maintenance devices – levellers – on them. They were devices that consisted of two parallel iron rods (2.4-metre blades with adjustable angles) and drawn by a tractor or a horse. In 1929 the Ministry of Roads ordered 90 sets of levellers from Ilmarine to distribute them via roadmasters to country governments and people bound by statute labour. The levellers were ordered for the broader introduction of a cheap, but efficient method of gravel road maintenance and easy to make on site.[28] The levellers were sometimes also used to maintain Class I and II roads. For example, it was found that maintaining roads with tractor drawn levellers on the sandy surfaces of Pärnu County was sometimes cheaper than using a grader. Using tractors to draw the levellers was also deemed cheaper than using horses. The Road Department of Pärnu County Government calculated in 1931 that a tractor with two levellers could level 10 km of roads per day and the cost per kilometre was 1.2 kroons (the driver's daily wage was 12 kroons). Three horses could level 2 km of roads per day with levellers and the cost of a kilometre was 7.5 kroons. The problem was that the county governments had very few tractors and they were also needed to power stone crushers.[29]

27 ENA 2075-2-142, 71-72.
28 ENA 2075-2-107, 51-64.
29 ENA 2075-2-214, 74.

Caterpillar crawler tractor.

The option of using horse/tractor drawn graders for road works was also studied in Estonia in 1935 and 1936. Järva County Government made the relevant proposal in spring 1935. The problem was the large amounts of works that had to be performed in early spring during the short period after the snow melted, after which the roads dried quickly and became hard, so they were no longer easy to grade. The existing number of graders was enough for maintenance works in the summer and autumn periods of road works, but additional workforce was required during the early spring. As buying more motor graders was deemed impractical, the idea to make graders without engines drawn by tractors was considered instead.[30] The Road Administration bought a Caterpillar crawler tractor (model 30) with a grader (model 33) and ditch cleaning device in autumn 1936.[31] The tractor and the grader were given to Pärnu County Government. However, Estonian factories did not start making tractor-drawn graders and instead opted for the manufacture of Caterpillar motor graders in local conditions.

New generation graders and their production

The grader-type Auto-Patrol developed at the US tractor factory Caterpillar was the new and universal grader that spread rapidly between the two world wars. The new model was introduced in 1931 and it was very well received. The success of the grader was guaranteed by its good technical solutions and the durability of the machine. In 1931, the machine factory of Franz Krull brought a Caterpillar road grader with crawlers (model 15) to Estonia. At the same time, the factory made preparations for licenced manufacturing of these graders for the state of Lithuania. Harju County

30 ENA 2075-2-358.
31 ENA 2075-2-361.

Caterpillar Fifteen motor grader purchased in 1932.

Court tested the machine on the Tallinn-Haapsalu road where the road was covered with crushed granite, which was unsuitable for the graders already in use. The machine was approved, and Harju County Court made the Ministry of Roads the proposal to buy the grader from Franz Krull, which was done in 1932.[32]

After recovering from the recession, the relevant authorities started thinking about acquiring additional modern and durable American graders. In 1935, the Road Administration started looking for options to bring a new Caterpillar motor grader to Estonia in order to test it free of charge. Trade company Traktor, representing Caterpillar products in Estonia, brought a Caterpillar Road Patrol motor grader from America to Tallinn in April the same year. Harju County Government tested the machine for a month with good results. The productivity of the grader exceeded the machines manufactured in Ilmarine by more than a half. More or less similar results were also obtained when the use costs of the machines were calculated and compared. In addition to lower costs, the new machine could also be used on roads with harder surfaces, which was not possible with the Ilmarine graders. The machine was faster, meaning fewer graders were needed for the same volumes of work. The strong structure of the grader meant lower maintenance costs, the light system allowed for the machine to be used in the dark and it could also be successfully used for snow clearing. The machine was bought after the successful tests and given to Harju County Government for use. According to the query of the Road Administration, Ilmarine made the initial offer for manufacturing the new grader based on a licence at the end of the same year.[33] The results of testing the grader brought from America in 1935

32 ENA 2075-2-249.
33 ENA 2075-2-358.

Testing of Caterpillar Road Patrol No. 10 grader in 1935. (Estonian Road Museum)

motivated the Road Administration to acquire at least one modern Caterpillar grader for each county. Ilmarine started manufacturing Caterpillar road graders in 1938. In 1939, the Ministry of Roads entered a contract with Ilmarine factory, where the contractor manufactured six sets of road graders of type Caterpillar Diesel No. 10 Auto Patrol. These machines were equipped with 44-horsepower Caterpillar diesel engines and a secondary petrol starting engine of at least 10-horsepower.[34]

Caterpillar motor grader assembled at Ilmarine machine factory in the late 1930's. (Estonian National Archives)

There are very few archive materials about the manufacture or assembly of Caterpillar graders by Ilmarine on the order of the Ministry of Road. We don't even know the exact number of these graders made in Estonia before World War II or how many and which parts and devices were manufactured on site. Indirect sources allow us to conclude that the state of Estonia had managed to equip all 10 of its counties with at least one or even two of such 'fast graders' by 1940. Photo materials confirm that Caterpillar graders were also successfully used for snow clearing in Estonia. Caterpillar graders were also the only motor graders operating on Estonian roads immediately after World War II. Some of them were used in the Estonian road system for up to forty years after the end of the war. One machine with such a story is also shown in the road machinery collection of the Estonian Road Museum.

34 ENA 1354-1-2235.

Use of Caterpillar Road Patrol No. 10 road grader for snow clearing in Estonia in 1938. (Estonian Road Museum)

Summary

The main road type in Estonia at the time was the gravel roads built in the decades preceding World War II, and the share of roads covered with crushed stone and other surfaces was only a few hundred kilometres. The condition of roads was poor when Estonia became independent and it had an impact on the economy of the state. Road construction and maintenance was still based on the principle of statute labour, i.e. landowners (mainly farmers) were forced to perform road works. One of the objectives of the Estonian Roads Act adopted in 1928 was to gradually abolish the statute labour system and make road maintenance a professional job done by people who were paid for this. This required the establishment of a suitable road maintenance organisation. Paid workers began maintaining Class I roads, the most important roads that connected towns. Road capitals funded by taxes and the state budget were founded and used to finance road works. County governments established regional departments of roads and centres of roadmasters as supervision officers. The Ministry of Roads dealt with funding and supervision.

The construction of roads suitable for cart traffic required the implementation of motorised road construction machines. The Ministry of Roads began

Caterpillar road grader mixing blacktop in Estonia in the 1970's. (Estonian Road Museum)

ordering road machines, placed at the disposal of the county governments so the works could be performed. The Ministry of Roads developed a policy according to which the priority was to make the main gravel roads passable all year round, after which it would have been possible to build roads with artificial surfaces. This also determined the nature of machine procurements. The road grader was the most important machine used for the construction and maintenance of gravel roads. The first Bitvargen-type road graders with Fordson tractor engines were ordered in 1926 from Sweden. The results of testing these machines in the Estonian conditions were good and it was immediately decided to order more. The Ilmarine machine factory in Tallinn started licenced manufacturing of such machines from 1927. Up to 120 road graders, including roller graders, were manufactured in Tallinn by the early 1930's. The American Caterpillar-type road graders were introduced in the late 1930's and Ilmarine started manufacturing them as well.

Although the number of procured machines could not abolish the statute labour system quickly and completely, a decent machine fleet was created basically from scratch and systematically used to maintain the main roads. Remarkable changes in the condition of the roads could be achieved over a longer period, but the foundation for the modernisation and mechanisation of the roads and roadworks was laid down in these years. In addition to road graders, Estonian machine industries also manufactured stone crushers, motor rollers of the Barford & Perkins system and Munktells-type tractors in the 1930's. The manufacturing of road graders and other road machines at local factories made it possible to perfect them as a result of tests so they would best suit the local conditions. The entire machine fleet used fuel produced from local oil shale. Thus, road machines formed a significant part of the internal market of the shale oil and machine industry products. Machine building gave jobs to the local machine industry, developed the local engineering sector and created the preconditions for the uninterrupted continuation of the tradition of road grader building in Soviet Estonia after the war.

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INNOVATIVE AND ADVANCED TECHNOLOGY IN THE 100-YEAR-OLD "GIANT"

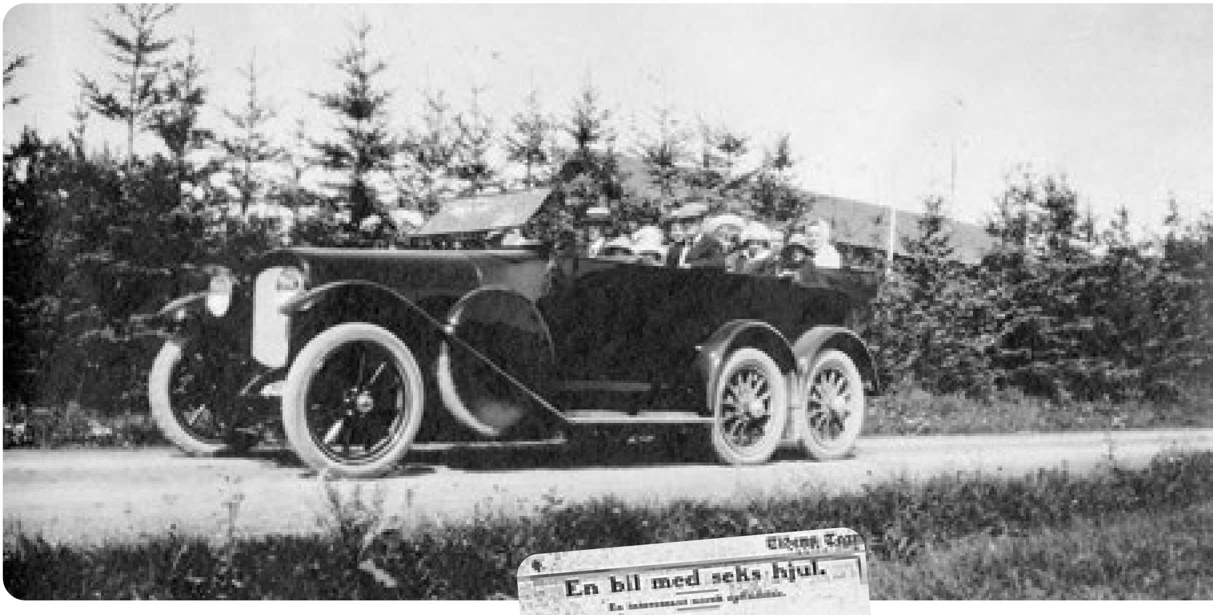
Ernst Sagstuen

In 1917, a unique six-wheeled passenger car was built in Oslo, at that time Christiania. The man behind the car was engineer Clarin Mustad, fourth generation of the Mustad family. After years in France, where he headed the family corporation's metal goods factory, his large family with eight children were moving back home. So they needed a big car with a lot of space. Mr Mustad designed it himself in 1915–16, and the car was in use until 1940. In 1960 it was given to the Technical Museum and stored at Bygdøy, and from 1983 lent out to the Museum of Vehicle Technology at Lillehammer. Now it is one of the main attractions in the Museum of Vehicle History, opened at the Norwegian Road Museum on 9 June 2019. It is the only one of its kind, as only one such car was ever made. But how was it built and from what?

In August 1917, the Norwegian newspaper Tidens Tegn printed an article about an interesting new invention that was attracting attention in the streets of Oslo. This was a six-wheeled passenger car, and the newspaper stated that with the exception of the gearbox, radiator and the electrical system, it had been built in Norway from a design by engineer Clarin Mustad. The car was large and was soon nicknamed "Giganten"– the Giant. The car is 570 cm long and 198 cm wide. The chassis had been built in the workshop of Mustad og Søn, the bodywork by O. Sørensen's Værksteder. There is little information to be found about the car in Norwegian publications, but it was exhibited in Paris in 1922. There it attracted great attention and was presented in technical magazines all over the world.

There is also little documentation to be found about technical solutions and manufacturers of components for this car. The car is very unusual in its size and has many expensive, ingenious and well-functioning technical solutions. It seems that Clarin Mustad possessed excellent technical insight into design engineering, as well as an abundance of financial resources for the development work. In 1916, Mustad took out a patent for the unique turning and propulsion system of this vehicle. It has two rear axles, of which the first one is turnable and follows the turning movement of the front wheels. At the same time, all four rear wheels are powered with differential axles and a centre differential that enables different speeds on all drive wheels.

As mentioned above, only one such car was manufactured, and it was altered a number of times. It underwent a major modification in 1927. The



Tidens Tegn

En bil med seks hjul.

A drive with the family in an open car. (Photo from the Mustad family)

On 19 August 1917, the newspaper Tidens Tegn printed an article about an interesting invention that had attracted attention in the streets of Oslo. This was a 6-wheeled passenger car, built "in this country, based on a drawing by engineer Clarin Mustad."

This photo of the complete chassis before the bodywork was mounted in 1917 shows the patented structure with suspension that allows the rear axles to move independently of each other.

The "Giant Night" event in February 2018 attracted many people, and after the meeting with the designer's three grandchildren, those interested were allowed to take a closer look at the car, among them Anders Kråbøl (in blue jacket). (Photo: Håkon Aurlien)

car was used by Clarin Mustad for transport between his residence outside Sandvika and his workplace in Oslo, and also when travelling to the corporation's factories abroad. Clarin had a large family, and a number of pictures show the car full of children and adults taking a drive.

"Giant Night"

In February 2018, the Norwegian Road Museum organised a "special-interest night" where three of Clarin Mustad's grandchildren introduced the car and its designer through photos and funny anecdotes. When the museum management asked for support from interested parties to carry out investigations to find the origins of the vehicle components and technical solutions used in this car, I signalled my interest.

The findings presented here are the results of a few weeks of searching inside, underneath and around the vehicle. They reveal a number of interesting details, but unfortunately there are still unanswered questions. To examine the vehicle, I was equipped with a car creeper and a lamp. The work took place inside one of the museum's storage facilities, a dry and relatively cool place where the car was stored until it was moved to the new exhibition building. Since the vehicle is owned by the Norwegian Technical Museum, permission was not given for the disassembly of parts in order to access hidden components or manufacturers' marks.

Searches were later made for documentation about the car. A search in the old archives of the Mustad factories at Gjøvik did not reveal any information about the manufacturing or design development of the car. All information from the time of construction must be considered lost. Sources have been contacted which may confirm uncertainties related to the origin of the engine. If readers are in possession of additional information, they are requested to contact the undersigned, or the Norwegian Road Museum.

I would like to express my gratitude to those who have helped me with facilitation and professional support:

Mass Haugen. Facilitating examinations.
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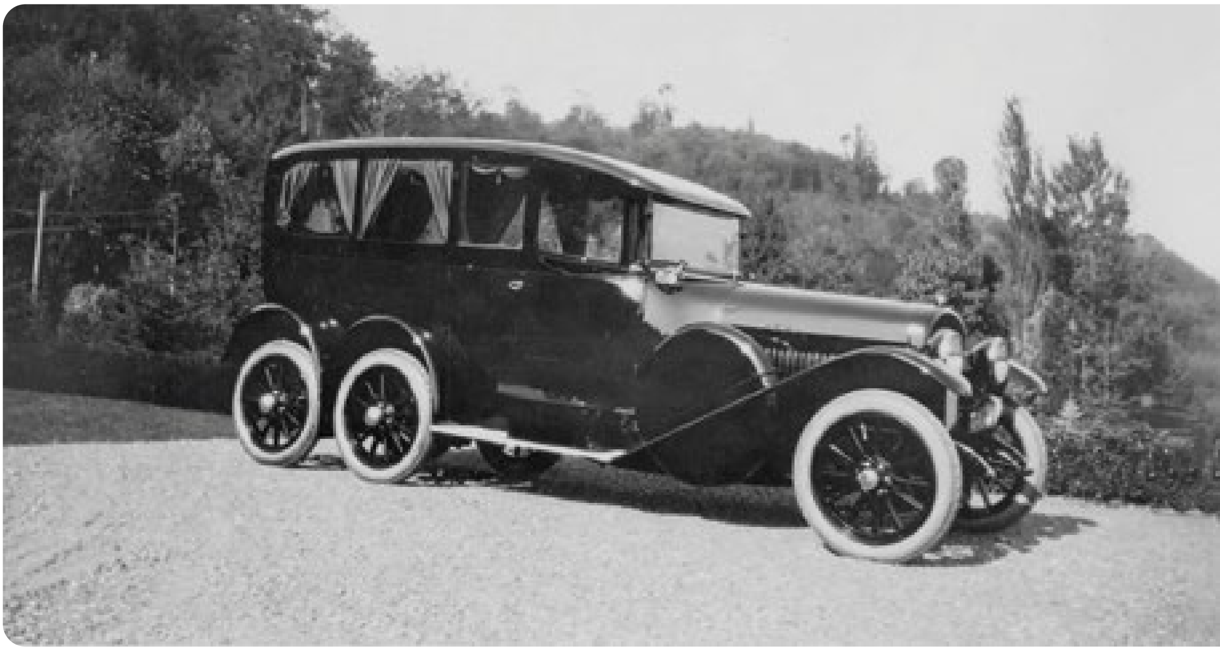
Håkon Aurlien. Source of the request for this study, and sparring partner
Ola-Per Lotten. Technical support.
Odd Jarle Løvold. Technical support.



Clarin Mustad's car when it was brand new in 1917. The car was built as an open car but had a detachable roof for the cold season. (Photo from the Mustad collection)

11 seats

Originally there were seats for 11 people in the car, including the driver. The Giant was equipped with a convertible top, a collapsible hood that could be folded down behind the seats. An attachable hard top had also been manufactured for this vehicle, for use during the cold season. Its unladen weight was specified to be 2,300 kg. Pictures show that the engine was a small liquid-cooled, petrol-driven, four-cylinder in-line engine.

In 1927, the Giant underwent a major modification, where the original small four-cylinder engine was replaced with a much more powerful six-cylinder engine. At the same time, the radiator, gearbox, and tandem axle were replaced, and the wooden-spoked rims were replaced with rims of steel. This was probably necessary to handle the increased engine power.

A picture of Mustad's car under construction in 1917. The chassis was built in the workshop of Mustad og Søn, and then fitted with a body built by O. Sørensens Værksteder. (Photo: H Brinchmann, Kristiania)

Some time later, the bonnet was replaced, along with the upper part of the bodywork. After the modification, the Giant was fitted with a new roof that covered the entire cabin. This could be detached during the warm season. Today the car instead has a fixed roof and fixed tall doors with glass windows.

Without front brakes

The front axle originally did not have brakes. It also did not have an anti-roll bar. When the vehicle was tested, this caused it to tilt sideways when cornering, so badly that it seriously scared Clarin's two aunts who were passengers. They thought the car was about to tip over. Clarin then had an anti-roll bar retrofitted to the front axle. Later, shock absorbers were also retrofitted to all wheels, but these have later been disabled. The mechanical brakes were also improved by means of makeshift return springs that would pull back the brake shoes and thus reduce overheating in the brake drums. The vehicle's unladen weight was increased from 2,300 kg to 3,670 kg after the modification, and the car now seats 12 people. Maximum speed is specified to be 110 km/h.

I have made a detailed overview of all observations and findings and can see that the designer has been creative and ingenious. Here are the findings, some of them in a simplified version:

BODY/CABIN

The car is constructed as a luxury limousine. The bodywork has black finish, and the top has a solid black leather exterior. Inside, the cabin is divided in two, with a partition behind the driver and one passenger who sits in a

This picture is probably of one of the daughters checking that a lifting cylinder is back in place after a puncture. Here the car has the steel rims that were added in the 1927 alteration, but it is still open. The folded hood was attached at the rear, to carry the luggage the family would bring on their trips at home and abroad.

separate compartment. A window can be opened between the compartments if desired. A voice tube has been installed between the compartments to facilitate communication while on the road. The entire cabin has thick leather upholstery from the floor and up to the windows. All seats are also upholstered in black leather. Four seats can be folded down into the floor, as in a modern multi-purpose car. The floor has been fitted with a thick blue carpet covering the entire passenger compartment.

THREE HORNS

There was probably a great need to be able to alert other road users at the time when the Giant was made. Three different horns have been installed in the engine compartment. Two horns are electric, and one horn is pneumatically operated. Behind the engine is an air compressor that is operated by a rubber wheel. The air horn is activated as the rubber wheel is pushed against the flywheel by a pedal placed on the floor in front of the driver.

LIGHTS

The giant is equipped with three large headlights, two indicators and a combined taillight and brake light. The middle lamp at the front follows the turning movement of the front wheels.

Ernst Sagstuen volunteered to write the technical report after the "Giant Night" event at the Norwegian Road Museum on 13 February 2018. Central to this event were (from the left) Mass Haugen and Håkon Aurlien from the museum, Mustad's grand children Axel Mustad, Anne Løvenskiold and Hans Clarin Mustad, and Museum Director Geir-Atle Stormbringer. (Photo: Morten Reiten)

LIFTING DEVICE

Punctures were common at the time when there were many horses and a lot of loose horseshoe nails on the roads. Clarin Mustad solved this problem by mounting two spare wheels on the vehicle, and a hydraulic lifting device for lifting the rear wheels. It is uncertain whether this took place at the same time as the main alteration in 1927.

The lifting device consists of four fixed hydraulic cylinders that are pressed down towards the ground by a hydraulic pump. Thus, the wheels on either the front or rear axle are lifted, and the tyre can be replaced. The hydraulic pump is located in front of the gearbox, which has a power outlet for the pump. To fill air into the tyres, compressed air is taken from a cylinder on the engine.

PRESSURE LUBRICATION

A heavy strain is put on transmission joints for spring mounts, steering rods, and brake rods. Sealing for rubbing surfaces was poor in those days, and dust and dirt would have access. Regular lubrication was therefore required in a number of places. Clarin solved this by installing two hand-operated pumps for lubricating oil. From the pumps there are tubes to most points in need of lubrication. A special hatch that conceals the operation of the pumps was found at the back of the left footboard. I found the place to fill oil when I lifted the carpet in front of the left folding seat. This revealed a hatch in the floor, where you can access the filling tanks. The pumps have been marked "Bowen system".

Ernst Sagstuen and Axel Mustad discussing the perforated pipe he studied for a long time before he realised its purpose and function. This is one of Clarin Mustad's creative devices and is described below. (Photo: Håkon Aurlien)

DRIVETRAIN

A dry plate clutch of the finger type is mounted on the flywheel, at the back of the engine. The cover on the pressure plate is marked with the numbers 118259-2, as well as with a round ring symbol with the letter S in it. This may be a clutch made by Sachs. There is manual transmission from the clutch pedal to operate the dry plate clutch. The clutch pedal is the left pedal in the driver's cabin. There is a short drive shaft between the dry plate clutch and the separately installed gearbox.

The gearbox has 4 gears and reverse, and a power outlet for operation of a hydraulic pump, as well as a rear gearwheel to operate the speedometer. The make of the gearbox is unknown, but an upper cover is marked with the numbers 2826. This number may refer to the cover itself. Then follows a middle axle between the gearbox and the first axle of the tandem-axle group. The middle axle seems to have universal joints at both ends. Finally, there is the tandem-axle group, consisting of two-wheel shafts with separate differentials. The differentials are of the type that has a crown wheel and pinion. The axles are linked together to form one turnable unit, by means of a strong steel pipe. Inside this pipe is a drive shaft that transfers power to the rear axle.

Originally, this car had a centre differential. This was meant to enable different speeds on the two axles. However, there are no visible signs that the centre differential was continued after the modification. It is possible that the centre differential remains "hidden" inside the connecting pipe between the rear axles, or that it is located within a larger unit in front of the front rear axle. There is not much point in a turnable tandem-axle group without a centre differential. Without the centre differential, cornering will place heavy strains on the four rear wheels. The wheels on the first axle of the tandem-axle group are turnable and follow the steering wheel movements synchronously with the front wheels.

BRAKES

All wheels have mechanical drum brakes with cooling ribs. Brake power is enhanced by a brake booster. This is powered by the underpressure in the engine's inlet manifold. It seems that there may have been problems with the return of the brake bands. This causes the brakes to drag and creates overheating in the braking mechanism. This seems to have been solved by retrofitting makeshift return springs to all wheels, attached with wire. At the back of the gearbox there is a brake drum that serves as a parking brake.

WHEELS

The rims are made of steel and the word "Michelin" and manufacturing number have been engraved on them. The tyre dimensions are 7.00 x 20.

ELECTRICAL SYSTEM

The charging system provides 12 volts. The self-starter, the ignition system and possibly the charging system were made by Bosch. Lamps and indicators have been manufactured in various factories in the United States. The engine compartment is illuminated by two and the passenger compartment by three lamps, one in the ceiling and two in the rear corners. A light switch is installed on the right side of the compartment. The brake light switch is installed centrally underneath the vehicle. There are two large headlights at the front, as well as a smaller lamp in front that is turnable and follows the impact of the steering wheel.

FUEL SYSTEM

The fuel tank is installed at the rear, externally, and has a specified capacity of 65 litres.

Carburetor: 1 Stromberg UX-3 carburetor. Labeled "Chicago-USA". There is a flange on the air inlet on the carburetor, but there is no sign that there has ever been an air filter here.

Fuel pumps and petrol filters: There is a total of four units for cleansing the fuel, two of which are electric fuel pumps with clear glass for visual checking and for expulsion of water. These units are installed on the right side of the firewall.

Choke: A mechanical choke has been installed, with a wire connection to the carburetor through a lever marked "Choke" on the dashboard.

STEERING SYSTEM

The steering wheel is on the right side, and the steering gear has a worm drive. The front wheels and the wheels on the first axle of the tandem-axle group can turn. Steering input is transmitted to the front wheels, and via steering arms and a long jointed steering shaft, to the swivel arms and steering shaft on the first axle of the tandem-axle group. The reason why the car has the wheel on the right side is allegedly that the designer believed traffic in the future would be running on the left side of the road.

HEATER AND VENTILATION:

There is a small switch device on the left side of the dashboard. This indicates that a heater has been installed to heat the cabin. There are no signs elsewhere in the car of where the heater was installed. But in a luxury car of this calibre, where no expense has been spared, it is very likely there has been a heater. In the engine cooling system, there are two cut-off tubes, where it is likely that cooling water was taken out to heat the heater register. It is likely that the above-mentioned switch controlled the heating of the passenger compartment with two options for effect or air speed. Ventilation has been taken care of by enabling the side windows on all doors to be rolled down, and by installing two large hatches under the windscreen which can be opened and closed. These are operated by two small wheels on the dashboard.

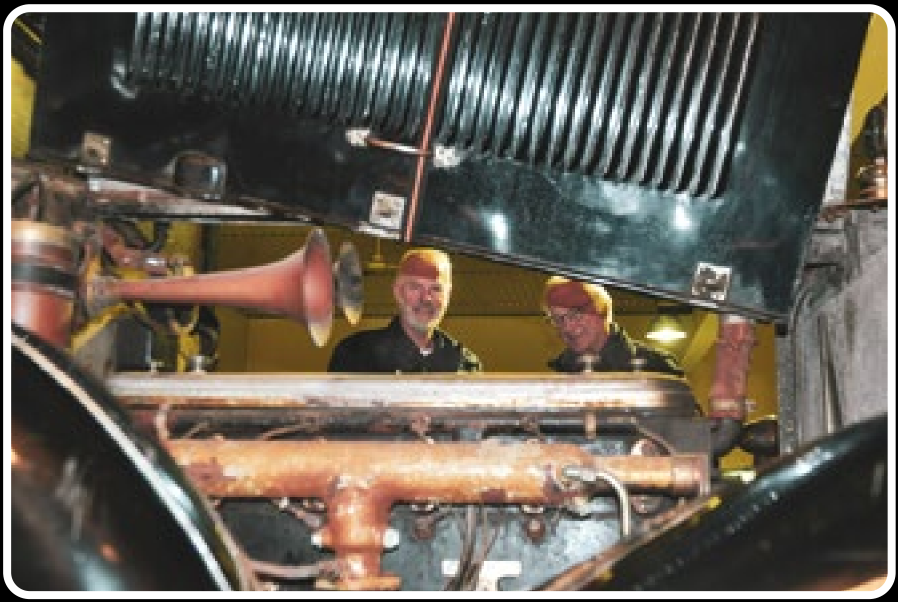
ENGINE

The origin of the engine is not documented. The investigations have revealed no manufacturer's mark on the engine block. The documents that do exist provide different information about the manufacture. One document claims it to be a Mustad product, but elsewhere it is claimed to be a Fiat or a Maybach product.

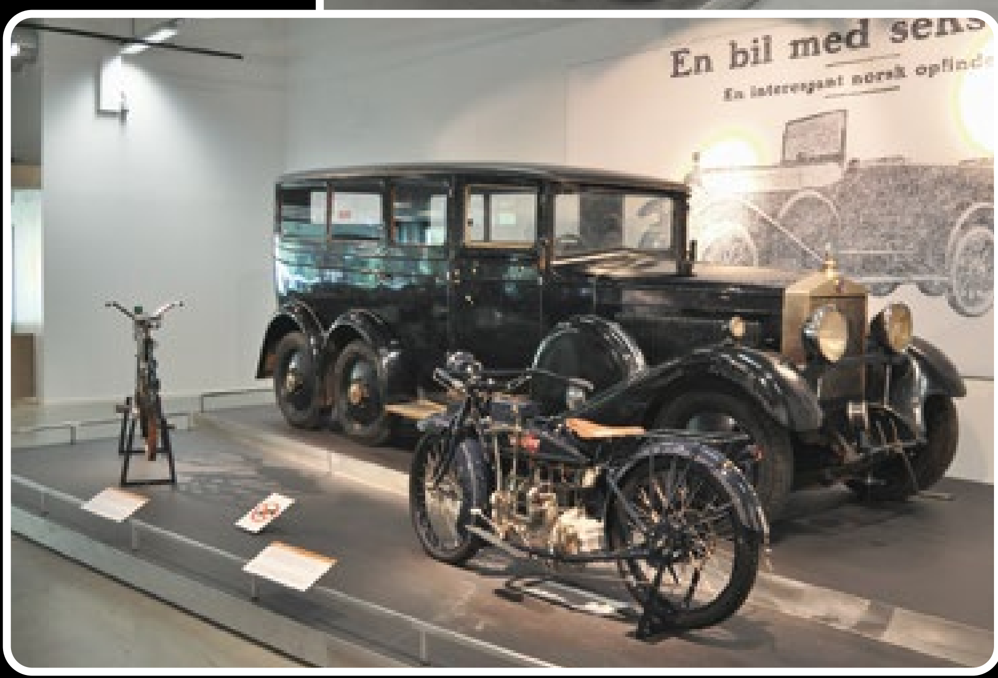
General: 6-cylinder, petrol-driven, liquid-cooled, in-line, overhead valve engine with 2 valves per cylinder and double valve springs, low camshaft, and external push rods for the rocker arms. A wide metal plate mounted between the engine block and the oil sump serves as an engine mount and platform for the engine's electrical components. The platform extends across the frame of the car. The engine is specified to have a 7-litre cylinder volume. Based on the dimensions of the engine block, this seems right.

Power: Engine power output is specified as 40 hp. A plate underneath the left front seat documents this. However, this probably refers to the old "French tax horsepower" of the time, where 1 "regular" hp corresponds to 4.5 "French" hp. Engine power would then be 180 hp. The size, weight

The task of finding out what Axel Mustad's grandfather actually used in terms of parts and constructions to build the more-than-100-year-old Norwegian car is not entirely complete. (Photo: Håkon Aurlien)



The car, clearly affected by the ravages of time, was collected from the Technical Museum's storage facility at Bygdøy and driven to Lillehammer in 1983. There it was given new old tyres, a good cleaning and polishing - and in the years to follow: many an admiring glance. The car was given a second round of polishing before it was taken for a short drive to the new vehicle museum in April 2019. There, Clarin Mustad's car from 1917 has been given a prominent place and once again is getting looks of admiration. (Photos: above unknown, right Håkon Aurlien)


En bil med sens
En interessant norsk opfinde

and load capacity of the car indicate that this would be an appropriately powerful engine.

Fuel gas heating: Exhaust gas is led from the exhaust manifold through a pipe, to the inlet manifold. Here the hot fumes are led through an outer tube, to preheat the fuel gases that pass through an inner pipe in the inlet manifold. Two pipes run from the back and the front of the inlet manifold, down through the engine platform, and under the car where the exhaust fumes are let out.

Carburetor heating: A heating jacket envelops the exhaust pipe just below the exhaust manifold. A pipe runs from the heating jacket to the other side of the engine, to the carburetor. This is for the underpressure in the carburetor to draw in heated air from the heating jacket, and thus provide heated fuel gases for the combustion. This also reduces the risk of carburetor icing on cold days. The mechanism is equipped with a metal grid for a rough filtering of combustion air. However, the original carburetor has more recently been replaced with a carburetor of a more modern type. It has the air inlet turned towards the rear and uses neither preheating nor air filtering. We must assume that replacing the carburetor increased the power of the engine.

Crankcase ventilation: The crankcase has four vent valves, to release excess pressure. These are located one in each corner of the engine.

Oil filling and checking the oil level: The front right vent valve for the crankcase can be used as a pipe for oil filling. The amount of oil affects a float on the right side of the engine, and the oil level is visible through a transparent level gauge on the platform.

Valve cover: The engine valve cover is marked "Mustad E-1". The valve cover seems to have ben made for this cylinder head. This is an indication that the engine is manufactured or modified at a Mustad factory. No other manufacturer's marks are visible to confirm the origins.

Compressed air outlet: The engine cylinder head has been prepared for the installation of two spark plugs for each cylinder, but each cylinder is still only equipped with one spark plug. The spark plugs are located on the right side of the engine. On the left side, slots for the spark plugs have been plugged shut. In the closed spark plug slot of cylinder no. 1, an outlet has been installed for the connection of a compressed air hose. The purpose is to allow filling air in the tyres, as the cylinder in such cases can be used as an air compressor. My theory is that the combustion pressure thus led out into an air tube is so high that any air tube would explode. This has probably been solved in that fuel gases to cylinder no. 1 are removed by adding controlled fake air to the combustion in this cylinder.

At the back of the left side of the engine there is a mounting bracket where a perforated pipe has been installed. This pipe can be easily unscrewed and replaced with a pipe mounted in the front part of the inlet manifold. The purpose of the perforated pipe is that the perforations let in clean air with a lower underpressure than the fuel gases being drawn in from the carburetor. There will then be no combustion of fuel gases in cylinder no. 1, and the pressure it transmits will be much lower. In principle, cylinder no. 1 becomes an air compressor until the perforated pipe is once again replaced with the original, airtight pipe.

The procedure for air filling will then be to stop the engine, switch the two above-mentioned pipes, attach the air tube at the connection point, open the vent valve, start the engine, and let it idle. The engine will now be running on a maximum of 5 cylinders, of which cylinder 1 is producing compressed air without fuel gases. When the air filling is finished, the same actions are performed in reverse order.

Oil circulation: At the back, on the right side of the engine platform, a large pipe has been installed. This pipe leads to the engine oil pump, located on the left side of the engine, under the platform. The oil pump is driven by the camshaft.

Power supply: The engine power/throttle is controlled by a lever in the middle of the steering wheel. A small gas pedal is also located between the clutch and brake pedal. Operation unknown. It seems to have been deactivated.

Exhaust system: The exhaust pipe and silencer are lined with asbestos.

Maximum speed: Maximum speed is specified to be 110 km/h in "Clarin Mustad - fact" by Torleif Lindtveit, a former Director of the Norwegian Technical Museum, who died in the autumn of 2019 after prolonged illness.

ORIGINS OF THE ENGINE

Several alternative manufacturers are mentioned in various articles about the car. For example, the engine is said to be like a Maybach engine, manufactured as a boat engine. This has been well documented by Torleif Lindtveit. This theory is supported by the present writer, based on the following arguments:

The cooling fan and water pump arrangement does not appear to be original for this engine. The device for attaching the cooling fan and the water pump seems completely undersized and "home-made" compared to other components of the engine. On the power transmission to the generator there is a flat belt wheel, which may be intended for the operation of a cooling pump in a boat. The belt wheel has no function in this car.

The engine has a square design, and the platform is so wide and large that it covers the width between the frame rails. This makes it so heavy that the present writer considers it unsuitable for use in aircraft. Aircraft engines also turn out to have a much more rounded design.

My theory is that this is a Maybach engine originally manufactured to be used in a boat, and that the water pump and cooling fan are manufactured and retrofitted at a Mustad factory. The original cylinder head has been replaced with a contemporary cylinder head manufactured by a Mustad factory, as the Maybach engine was originally equipped with an old-fashioned side-valve cylinder head. The Giant's engine has a cylinder head with "modern" vertical valves that will help achieve a power boost. The valve cover is marked with the text "Mustad E-1", which is also marked on the frame.

Originally, the power output of the Maybach engine was specified to be 120 hp. The engine power may have been increased to 180 hp as the cylinder head was replaced with a more effective one and the carburetor was replaced by a newer and probably more effective model. Web searches for Maybach engines indicate that this may be the model referred to as Maybach W5. These engines were manufactured between 1926 and 1928 and were also used in Maybach's own large luxury limousines from this era. It remains to be confirmed whether this is the same engine that is used in the Giant.

The engine oil sump and the gearbox are covered by two large metal sheets to protect them from water and dirt from the roadway. It is possible that a factory mark exists on the engine, hidden behind these sheets.

Afterword

It was an interesting and laborious task to examine the Giant to see how a car was constructed in 1917, not to mention trying to uncover the car's "secrets." It is full of impressive, technically well-functioning solutions, and the designer has shown great creativity and drive.

Unfortunately, no more cars were manufactured in the Mustad factory, as the company management was not convinced that there was a future in car manufacturing.

Searching for documents online, I found that in 1926 Mercedes had developed a vehicle with many similarities to the Giant. It had tandem axles, but it is unknown whether the first of the tandem axles could turn. This car, Mercedes G1 Dinosaur, was further developed into G2, G3 and G4. Images of the latter from the 1940s show striking similarities to the Giant in terms wheel layout, size, and body shape.

Documentation remains to be found of the engine manufacturer, as well as manufacturers of the gearbox, mid-axles and the tandem axles. On these I have found no factory marks, nor any other documentation of their origins.

"Grandpa was very interested in cars, but first of all he was a design engineer and developer. I can very well imagine him constantly rebuilding and altering the car, precisely because he had found new technical solutions he wanted to demonstrate."

This was said by his grandson Axel Mustad in an article in the 2017 yearbook. Clarin Mustad was one of five brothers of the fourth generation, and was sent to France, where he first received his education as a design engineer. He then became the manager of the family's horseshoe nail factory in the town of Duclair.

"He probably built the car to take the whole family for a drive. He had a big family, with eight children. He loved his family very much, some would say he absolutely needed to be near family all the time", Anne Løvenskiold recalled.

"At the same time, he also worked as a designer and developer, and technical solutions were constantly on his mind. The minute he had an idea, he had to follow up on it immediately", her brother Hans Clarin recalled. In his bedroom, their grandfather had a blackboard so he could sketch out ideas that woke him up.

As a design engineer, Clarin Mustad was very interested in the development of vehicle technology. He bought his first car in 1902, and in 1906 drove from Kristiansand to Kristiania. He then found that cars needed an easier way to start than using a hand-crank and invented a self-starter. In 1909 he designed a slide valve engine, a construction he sold to Renault.

This engine was produced in large numbers but was not a commercial success. Mustad was constantly coming up with new ideas within automobile engineering. "He suggested building a car factory, but he didn't get his family to go for the idea," says Hans Clarin. But he and a nephew built several cars. The best known one is the one-seater nicknamed "the Egoist" which he built to drive alone to work.

In 1912 he bought the property Sjøholmen in Bærum, and hired the great architect Arnstein Arneberg to rebuild the main building so that the family could eventually move home. So, they did in 1918. The Giant remained there until the property was sold (it is now a municipal centre for cultural activities). The car was donated to the Technical Museum in 1960, and from 1983 it was exhibited at the Museum of Vehicle Technology at Lillehammer. Now it is in the Road Museum.

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ENGINEER ARNOLD VOLBERG AND HIS ROAD MACHINERY

Andres Seene
Research Fellow at the Estonian Road Museum

One of the most outstanding Estonian machine engineers, Arnold Volberg (1900–1967) was born at the start of the 20th century to a peasant family in Northern Estonia. In addition to Arnold, two of the family's eight children grew up to become outstanding representatives of the budding technical elite of Estonia – well-known architects Erika Nõva and August Volberg. Since early childhood, Arnold showed an interest in making things with his hands. He dropped out of upper secondary school because of the Estonian War of Independence (1918–1920). Technical interests took Arnold to the newly established Tallinn Technical School,[1] which initially also admitted students who had not graduated from upper secondary school. In 1932, he graduated from the Department of Mechanics with the qualification of an engineer and mechanic in the specialty of machine building. His studies took so long because he had to finance them himself. He practised at Ilmarine factory and as an assistant engine driver on the state railways and worked as an adviser, instructor and lecturer in the Union of Agricultural Machine Users. At the same time, the future machine engineer published overviews of the developments of new agricultural equipment in magazines.[2]

This article introduces Arnold Volberg as an engineer and the devices and machines he constructed, which had a significant impact on the modernisation of road construction in Estonia after World War II. As Estonia was occupied and annexed to the Soviet Union during the developments described here, many of the machines constructed by Volberg had a noteworthy innovative meaning in the context of the USSR. This applies to the motor graders constructed by Volberg in particular.

First achievements as engineer and inventor

Arnold Volberg started working as a machine inspector at the Road Administration in 1933. This was also the start of the young engineer's contact and work with road machines. By 1940, he had become the acting inspector of machines and workshops at the Road Administration. In 1937, Volberg managed to patent the compact and small wheel load scale (hydraulic wheel load scale) as his first invention in Estonia. The vertical pressure of the vehicle's wheel when driving over the scale was transferred to the centre line of the piston via a joint, which put pressure on the liquid under the piston. The reading was displayed on the manometer attached to the device.[3] This invention attracted attention in foreign countries (Finland and Sweden) as well, but the outbreak of the war and the occupations prevented the young engineer from realising his invention to the full. According to his sister Erika,

1 Tallinn University of Technology since 1938.
2 ERM 374:33 A 279:33, 1–2.
3 ENA 916-1-1176.

Engineer Arnold Volberg (1900–1967). Photo taken in 1941. (Estonian Road Museum)

First meetings with contemporary road grader. Machine inspector of the Road Administration Arnold Volberg and new motor grader Caterpillar in 1938. (Estonian Road Museum)

Arnold Volberg with the portable wheel load scale he invented. (Estonian Road Museum)

Testing of Volberg's wheel load scale. (Estonian Road Museum)

the invention was also neglected after the war because his perfectionist brother believed that there were not enough quality materials for building the scales at the time.[4]

Arnold Volberg continued working in the area of machines in the Estonian road system during the German occupation (1941–1944). There is not much information from this time and considering the developments that followed, there probably wasn't much reason to highlight his activities at the time.

As constructor and rationaliser in Soviet Estonia

The best years in Arnold Volberg's career were 1940s–1950s in Stalinist Soviet Estonia, where he made his greatest achievements in the creation of road construction and maintenance machines. Road administrations were usually very badly equipped with machines in the 1950s. Most of them only had a couple of lorries. Although the construction of blacktops of bitumen and crushed stone began at the same time, most of the road works, especially the earthworks, still had to be done by hand. A man with a shovel and a horse was still the main 'tool' used for road works after the war. 15 different kinds of road machines were manufactured in the USSR in

4 ERM 374:33 A 279:33, 6.

the 1950s. Most of them were drawn by the heavy crawler tractor S-80 when used for road works.

After Estonia was occupied again by Soviets in 1944, a decision was made to build the Mechanical Central Repair Workshop of the People Commissariat of the Internal Affairs of the Estonian SSR in the territory of the former match factory in Paide. The construction works were completed in early 1946 and the workshop initially started repairing engines and road machines from before the war. During its first years of operation, the central repair workshop supplied spare parts of road machines to a few road departments and carried out a few major repairs. It started experimenting with the construction of new road machines in 1948. A self-propelled road grader was built according to the constructions of senior engineer Volberg of the Road Administration, which brought the workshop fame all over the USSR; it was the first self-propelled road grader in the Union's history.[5] The Central Repair Workshop was renamed the Paide Road Machine Factory in 1950. Senior engineer Volberg's work as a machine engineer and constructor found its outlet in the form of the machines manufactured at this factory.

The first motor grader in the USSR

In 1946 Arnold Volberg started constructing a motor grader based on the aggregates of the GAZ-AA lorry, which was given the model name V-1 after the initial of the constructor's surname. The first grader was completed in 1947 and it took part in the 1 May demonstrations in Tallinn in 1948. The committee formed at the Chief Road Administration in Moscow tested the machine on site and decided it was satisfactory. The machine's authors were awarded the Soviet Estonia Prize and the machine itself participated in the Exhibition of the Achievements of People's Economy in Moscow. Later, the permission for serial production of the grading machine was also obtained.

Although the construction of the V-1 was rather primitive, it was still the first self-propelled grader manufactured in the Soviet Union at the time. The USSR did not manufacture motor graders before or immediately after World War II. The industry was primarily based on the manufacture and use of trailer type graders. The Volberg's motor grader was classified as an intermediate type that was meant for profiling dirt and gravel roads as well as crushed stone roads with light surface covering. The machine could be used for the planning and flattening of surfaces, the construction of embankments, loosening gravel and crushed stone surfaces and snow clearing. Volberg's road grader was powered by a 52-horsepower petrol engine of the GAZ-M-1 lorry with a top working speed of 15 km/h

5 Järvalane, 28.05.1949.

Man and machine – Arnold Volberg and road grader V-1. (Estonian National Archives)

Testing of motor grader V-1 in profiling works. (Estonian Road Museum)

Motor grader V-1 with the slogan "Achievement of Soviet Estonian Roadmen". (Estonian Road Museum)

The machine weighed ca 3.5 tons and it was ca 6 m long and 2.4 m wide. The length of the mouldboard of the V-1 was 3 metres and it was moved by the hydraulic principle, i.e. by oil pressure. The lifting cylinders of the mouldboard were fastened to the sides of the driver's cab. The turning angle of the machine's mouldboard was 86 degrees (43 degrees both ways). Its advantage in comparison with the other motor graders left in Estonia from the pre-war era (Caterpillar) was the fact that the mouldboard of V-1 was located closer to the rear axle of the machine, which guaranteed a more even result when the road surface was flattened and helped the front wheel stay on the road better. The machine's frame was straight, which made it easier to manufacture. It was also possible to add snow clearing devices and a ripper to the machine. The technical specification of the machine prepared by Volberg states that the construction of the grader is simple, reliable and easy to make. In terms of blade length, working speed and productivity, Volberg considered his machine equal to the heavy graders of the time. The assemblies of Soviet lorries accessible at the time were used in the construction of the machine. In addition to the engine, which was borrowed from GAZ-M-1, the gearbox, clutch, front and rear axles, brakes, steering mechanism, radiator and front wheels of the GAZ-AA were used on the machine. The rear wheels were borrowed from the lorry ZIS-5.[6] 13 V-1 motor graders had been manufactured by late 1949. 122 V-1 road graders in total were manufactured at the Paide factory in five years. As far as we know, none of them survive today,[7] but in 2023 replica of the V-1 grader was built for Estonian Road Museum's collection.

Perfection of V-series road graders

After the completion of the V-1, Arnold Volberg continued perfecting his grader and constructing new types. Graders V-3, V-4, V-5, V-6 and V-8 were prepared in short succession. The test version of the latter was completed in late 1950. The V-8 weighed 8 tons and it was almost a metre longer than the V-1, so it was classified as a heavy motor grader in those days. The model was powered by a NATI-3 kerosene engine with the capacity of 55 horsepower. The mouldboard of the V-8 was 3.7 metres long and it was moved by hydraulics like those of the other Volberg graders. As far as we know, only six V-8 graders were ever made. The machine was built and tested from 1951–1953. While the V-8 was being developed, work with E-6-3, the first model of a three-axle heavy road grader built on the aggregates of the GAZ-51 lorry, was also ongoing. This machine proved to be more successful than its predecessors, as more than 500 of them were manufactured.[8]

6 ERM 306:5 A 255:5.
7 http://www.kolhoos.pri.ee/?action=text&cat=1&ID=197
8 http://www.kolhoos.pri.ee/?action=text&cat=1&ID=197

Motor grader V-8. (Estonian Road Museum)

Volberg's three-axle motor grader E-6-3. (Estonian Road Museum)

Anold Volberg with a model of motor grader E-6-3. (Estonian National Archives)

Volberg's most successful motor grader V-10

In 1954, engineer Volberg started constructing his most successful road grader – the V-10. During this work, he visited the Chelyabinsk Road Machine Factory, the best known of its kind in the USSR, and studied the new type of motor grader, D-144, that had been developed there. The test model of Volberg's new machine, V-10, was prepared in 1955. Serial production at the Paide factory started a year later. This grader was powered by the diesel engine of crawler tractor DT-54. The new road grader was of the heavier type and the possibility to change its aggregates made it very universal. In addition to road construction, it could also be used for various road maintenance works. In comparison with the other graders manufactured in the USSR at the time, the V-10 was undoubtedly the most modern in terms of technical solutions. Whilst the lifting equipment of the graders manufactured in the USSR at the time was mechanical, the solution used on the V-10 was hydraulic and its mouldboard also had a 360-degree turning radius. The V-10 became the most successful grader of Paide Road Machine Factory of all time. 2040 V-10 road graders in total were produced in Paide from 1956–1962.[9] Paide Road Machine Factory was one of the three factories that made road graders in the Soviet Union (the other two were Chelyabinsk and Bryansk). Estonia itself needed about 250 road graders at the time. The quick implementation of the machines produced in Estonia made it possible to increase the level of mechanisation of road works considerably by the early 1960s, which in its turn made it possible to undertake more extensive road works, such as straightening road tracks with the establishment of new embankments and stronger road surfaces, and building road bases.

Testing of road grader V-10. (Estonian Road Museum)

9 http://www.kolhoos.pri.ee/?action=text&cat=1&ID=197

There was a big shortage of tipper lorries in Estonia in the 1960s. A separate device – a poker – was mounted on road grader V-10 for unloading loads of gravel from lorries. (Estonian Road Museum)

Road grader V-10 in the exposition of the Estonian Road Museum in 2019. (Estonian Road Museum)

Later generations of Estonian road graders

The Paide Road Machine Factory was merged with the Tallinn Excavator Factory in 1962. Arnold Volberg retired at the same time, but the traditions of road grader construction and production continued at first. The construction of a road grader with an improved construction started in 1958 under the supervision of Villem Gross (1932–1999) at the newly established Construction Bureau of Paide Road Machine Factory, which was marked D-512 according to the USSR standard. The first test batch of D-512 graders was completed in late 1962. The D-512 grader was powered by the diesel engine (75 hp) of crawler tractor T-74, and the D-512 was also the first grader manufactured in Paide equipped with hydraulic power steering.

Motor grader D-512. (Estonian Road Museum)

The arrival of Corbex-Vammas CG-18, the first motor grader manufactured in Estonia in 1993 after the restoration of independence, to the collection of the Estonian Road Museum in November 2019. (Estonian Road Museum)

The manufacturing of road graders in Paide ended in 1966 when it was decided in Moscow that the Tallinn Excavator Factory had to increase its production of bucket-chain excavators, their main product. Since production capacities were desperately needed for this, it was decided that the production of road graders in Paide would be terminated. Thus, the D-512 remained the last road grader manufactured in Paide. A little less than 1700 of this grader model were manufactured in total.[10] Although the production of local road graders ended as a result of the decision made in Moscow in the second half of the 1960s, the graders made in Paide remained the most

10 Juksaar, 2012, 36–38, 355–360.

widespread road machines in Estonia for a long time. The graders produced in Estonia were also widely used in the other Soviet republics. Over 4000 road graders in total were manufactured in Paide over a period of ca 20 years, most of them models V-10 and D-512. The traditions of road grader production were revived for a short while in Estonia in the 1990s when the production of road graders was launched under the conditions of market economy in the company Corbex Engineering established in Northern Estonia, which produced machines on the basis of the licence of Finnish company Vammas and also introduced a model created by local constructors.

Other road machines of Volberg

In addition to road graders, many other machines and devices were prepared according to Volberg's drawings as rationalisation proposals in the early 1950s and implemented in the mechanisation of road works after the war. The construction of blacktop roads, started at the time, desperately needed the auto-gudronators constructed by Volberg. They made it possible to pour bitumen on fine crushed stone, so the resulting road surface could then be compacted and flattened with a roller. The gudronators designed by Volberg were built on the Ford-6 lorries that the US had sent to the USSR as aid during the war. It is also known that road surface rippers and blacktop mixers were also made based on Volberg's designs in these years. In the 1950s, Volberg also constructed the VK-1, a mechanical ditch plough or ditch digging device, which made it possible to mechanise and speed up the work. Trailer graders were used in the construction of the device by attaching the ditch digging mechanism or plough to the machine instead of the mouldboard. The device could quickly be turned back into a grader by changing the implement of the machine. The ditch plough could also be used in agriculture.

At the same time, Volberg also completed the test model of the mechanised machine for producing snow fences. The machine tied the boards together with wire. This made it possible to transport and store (after assembly) snow fence in pieces of 5–8 metres in length. Instead of the former running 100 metres of snow fence, 750 metres of snow fence could be packed into a lorry instead. Making a snow fence by hand took more than an hour, but the new machine could make up to 60 metres of fence per hour.[11] In the 1950s, road administrations were badly equipped with snow clearing devices and snow fences were the simplest means for protecting roads from snow during the winter season. Volberg's devices and equipment were also used in other sectors of the people's economy. One of his last works before retirement that went into production was the peat-briquette press.[12]

11 Järvalane, 09.09.1950; Järvalane, 30.11.1950.
12 ERM 374:33 A 279:33, 6.

Gudronator AV-1 constructed by Arnold Volberg based on the Ford-6 lorry in 1950. (Estonian Road Museum)

Model of ditch plough VK-1 mounted on a trailer grader. (Estonian Road Museum)

Machine for making snow fence constructed by Arnold Volberg. (Estonian Road Museum)

Summary: a life dedicated to machines

The most prolific period in the career of Arnold Volberg was in the road system of Soviet Estonia in the 1950s, when the road machines and devices constructed by him were used to shape and develop the post-war road network. One can only imagine how successful Arnold Volberg might have been if he could have worked in a normal society with more freedom. In addition to Estonia, the machines he created were also used all over the Soviet Union from the White to the Black Sea. As historian Mairo Rääsk said, Arnold Volberg was a man who largely remained a mystery as a person and lived more than half of his life in the free world but made his greatest achievements during the most complicated times in the closed Soviet Union.[13]

Arnold Volberg dedicated himself to his work and pushed his personal life to the background – he never had a family. Volberg earned the respect of his colleagues in Estonia and the USSR with his inventions and machines. He was awarded several prizes for his work, but according to his sister Erika, Arnold was always a modest man who shunned the limelight, not someone who tried to attract attention.[14] Every serious roadman would probably be honoured to be characterised like this.

Arnold Volberg's life and work are a good example of the professional continuity of the staff of the Estonian road system. The Soviet authorities obviously didn't trust the people who had worked in the Estonian road system in the 1920s and 1930s enough to make them managers in the 1940s and 1950s, but they were still needed as qualified specialists. These people carried their earlier skills and knowledge to Soviet Estonian road managements. Arnold Volberg, who started working in the Road Administration of the Ministry of Roads in the 1930s, also brought his experience to the new conditions. The road graders constructed by Volberg made a significant contribution to the development of the Estonian road network in the years when road administrations mostly struggled with a shortage of machines and equipment.

13 Rääsk, 2018, 94.
14 ERM 374:33A 279:33, 6.

An older Arnold Volberg converting his ideas into drawings .(Estonian Road Museum)

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VIADUCT OVER THE LORUPE RAVINE

Indra Dziedātāja

The 20th July 2018 was the 50th anniversary of the opening of the Lorupe viaduct. Its idea, design and construction were a significant turning point in bridge construction in the entire Soviet Union. In the comparatively small Republic of Latvia it was a unique project that required a lot of boldness and skills of road workers. Therefore, the construction of this bridge is memorable, especially since several bridges were built using this technology later in the former Soviet Union.

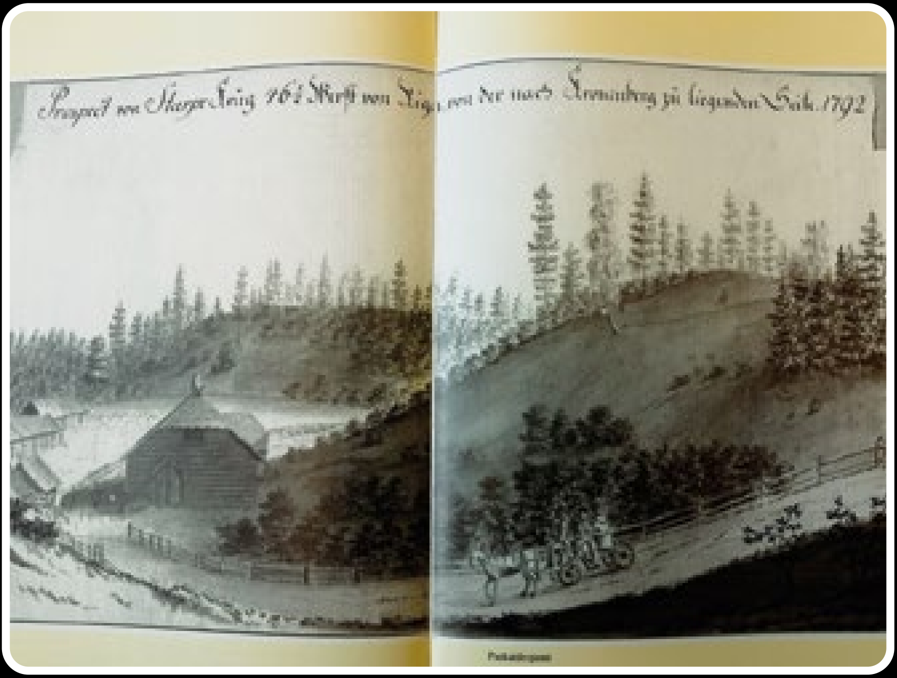
Road history

Sigulda is a town 70 km NE from the capital of Latvia Republic Riga that attracts a lot of tourists. Latvians and travellers from other countries go there to enjoy the beautiful surroundings and views of the Gauja river valley. Not far from Gauja river is Lorupe, a smaller tributary on the left bank of the river. It is 11 km long and begins in the Ummuri lake. Lorupe has a considerable drop – 89 metres, i.e., 8.1 m per km. Because of this, the river has formed a deep ravine with steep banks. Today, the Lorupe viaduct crosses this ravine, but once only a winding road in the bottom of the ravine was there for the travellers. The road that led from Lorupe to Sigulda has a long history. It was used since the 12th century. However, the first images of bridges are only from the end of the 18th century, when Johann Christoph Brotze, a remarkable researcher of local history, painted them in his pictures.[1]

In 1856, the Russian Empire constructed a highway Riga – Pskov in place of the old road. The highway was an important mail path. For crossing Lorupe, a culvert from chiselled granite blocks was built. Nowadays, this culvert and the old road section have been restored and may be seen. The old road that crossed Lorupe was winding. It was built by bypassing the old watermill of Kronnenberga Manor that was located 50 m above it. There is an old legend, that the miller had a beautiful daughter, with whom a man designing the road fell in love with. He wanted to spare the mill, so he deliberately made the road with so many bends. In the 20th century road transport was developing and driving on the winding road, especially in winter, was difficult and there were many accidents.[2]

1 E. Jemeljanovs 2018; Z. Vecvagars, J. Binde "Ceļi" 1998, 5-11.
2 E. Jemeljanovs 2018; Z. Vecvagars, J. Binde "Ceļi" 1998, 5-11; Z. Vecvagars "Ceļi" 1999, 8-67.

Road in the Lorupe ravine. 1978. (Latvian Road Museum, SJSC "Latvian State Roads", The road History Collection



View of Starpas tavern and road from Lorupe to Sigulda. Picture by J. Ch. Brotze. 1792 (J.K. Broce. "Zīmējumi un apraksti 3. sējums. Latvijas mazās pilsētas un lauki" "Zinātne", 2002. 138 – 139.)

Road in the Lorupe ravine. 1960. (Latvian Road Museum, SJSC "Latvian State Roads", The road History Collection)

A traffic accident in the area of Lorupe culvert in the beginning of 1960s. (Z. Vecvagars. "Ceļi" 1999, 8-67)

The project of crossing the Lorupe ravine

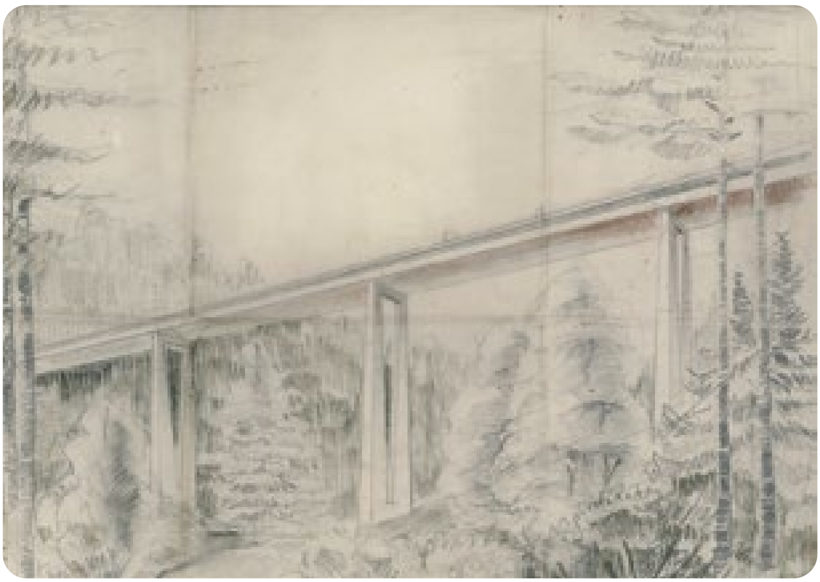
Since the beginning of the 20th century, the crossing of the Lorupe ravine has preoccupied the minds of several generations of Latvian engineers, according to information from Kārlis Gailis, professor of the University of Latvia, and documents of the former Department of Soil Roads and Highways. To improve traffic on this road section, alignment research works was already begun in 1942, during the time of German occupation, with financing from a German construction company. For historical reasons, the work naturally did not continue.[3]

The research works restarted for the second time in 1959, when specialists from Bridge Department of the institute "Ceļuprojekts" (Road Design) undertook the preparation for reconstruction of Lorupe ravine crossing. By

3 Z. Vecvagars, J. Binde "Ceļi" 1998, 5-11; Z. Vecvagars "Ceļi" 1999, 8-67.

examining the new alignment, the specialists concluded that the best solution for straightening was the axis for ravine crossing outlined already in 1942.[4]

In 1960, design works began in several stages. The first and most important question was, how should a road profile in the Lorupe ravine be created? There were two technical options: to build a road over the ravine as a high embankment or to cross the ravine with an artificial structure – a viaduct. In this matter, aesthetical architectural factors and technical economic factors were equally important. Therefore, the architect Velta Reinfelde worked alongside road engineers in all the stages of research and design. He achieved a synthesis of the structural solutions and aesthetical architectural ideas. After a dendrological research of the area, the project provided for the preservation of valuable and significant trees in the landscape, as well as for the reconstruction of the current typical terrain.[5]



Viaduct sketch of the architect Velta Reifelde, 1959. (Latvian Road Museum, SJSC "Latvian State Roads", The road History Collection)

For a 30 m high road embankment, almost 200 000 m^3 of gravel would have had to be brought in the ravine. The width of the embankment at its foot would have reached 150 m. In addition, 140 m long culvert would have needed to be built for the river to pass. Extraction of soil in such proportions from the closest quarries would have damaged the beautiful surroundings, included in the natural preserve foundation of the republic (currently the territory of the Gauja National Park). The huge mass of embankment would have divided the ravine in two parts.[6]

4 Z. Vecvagars, J. Binde "Ceļi" 1998, 5-11.
5 Z. Vecvagars "Ceļi" 1999, 8-67.
6 Z. Vecvagars, J. Binde "Ceļi" 1998, 5-11; Z. Vecvagars "Ceļi" 1999, 8-67.

However, a scaffold bridge of light construction with narrow, light piers would allow the ravine to preserve its unity and beauty. The technical solution of the new structure had to maximally preserve spatial unity of the beautiful ravine, and technology of construction works had to meet the requirements of environmental protection. Considering these issues, the authors selected the artificial structure, a reinforced concrete viaduct, as the key solution. Construction costs were approximately the same for both options.[7]

Inspired by crossings of ravines of mountain rivers in other countries, as seen in West German magazines, Ziedonis Vecvagars, Head of the Bridge Department of the institute "Ceļuprojekts" at the time, considered that filling up the Lorupe ravine was unacceptable from the aesthetical point of view. However, to refer to foreign experience in the advocacy process for the viaduct solution was not appropriate and even dangerous on a personal level. It could mean losing a job or even personal freedom. After long discussions with functionaries of the Soviet Union, however, the scales tipped in the favour of the viaduct.[8]

The next issue was the selection of viaduct structure. The solution was made more complicated by the campaign of "Combatting of excesses" initiated by Nikita Khrushchev. A. Afanasjevs, Deputy Minister of Road Transport and Highways of the Latvian SSR at that time, supported this campaign enthusiastically. He considered Lorupe viaduct to be an example of excess. According to his views, ravine should be crossed with a bridge that complies with the standards of bridge construction of the USSR – several interrupted beams on 2 m thick, firm piers.[9]

To avoid this, Latvian engineers had to select an unconventional structure – a continuous girder – and to build it themselves based on individual design.[10]

The technical magazines of the time contained descriptions of bridge construction in Venezuela. In 1962, a stressed continuous girder was built over the Caroni river. This girder, weighing approximately 10,000 t, was moved onto piers with a unique method in construction of reinforced concrete bridges – longitudinal sliding.[11] If not for this prototype, bridge designers in Latvia or USSR would not have come to the idea of using sliding in the installation of reinforced concrete girder. This example determined the choice of technology for span construction and installation of the viaduct.[12]

7 Ibid.
8 Z. Vecvagars "Ceļi" 1999, 8-67.
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11 VSL INTERNATIONAL LTD. Berne/Switzerland. (1977).
12 Z. Vecvagars "Ceļi" 1999, 8-67.

Long, creative search for the best versions of viaduct had begun. After careful calculations and comparisons, the designers concluded that the most appropriate structure was a continuous, prefabricated, stressed girder that stretched as a concrete band from one ravine bank to another. However, stressed continuous girder was a very rare solution in the practise of bridge construction, even rarer in prefabricated reinforced concrete structures.

Until this, bridge piers had been associated with something massive, mighty and indestructible. The piers of Lorupe viaduct are not washed by a rapid stream, they do not have to take on the impacts of broken ice; therefore, they can be very light and flexible. Already narrow bodies of the piers become even narrower at the bottom to be able to bend freely in the connection point with support. In all the length of the viaduct, there is only one rigid point – the anchor support in the Sigulda bank. Its big mass is hidden in an alcove carved out in sandstone rock. The decision was to create continuous girder with five spans according to the following scheme: 33 + 3 x 43.25 + 33 m on 24 m high piers.[13]

Construction stages of the viaduct

Construction of the Lorupe viaduct took place from April 1965 until July 1968. Considering the originality of the bridge structure and the construction technology, the speed of construction was indeed very fast. From today's perspective, construction costs were small – 400,000 roubles.[14]

The construction works may be divided into the following sets of works:

1. Construction of accesses was done in two stages: in 1965, the alignment preparations, the main earth works and the partial construction of road foundation were done; from April until July 1968, the construction of road foundation was completed, asphalt concrete laid and finishing works carried out.
2. Construction of viaduct piers – the foundations were built in 1965, the bodies of piers and headers in 1966.
3. Span blocks were manufactured from January until June 1967.
4. Assembling of the span structure and sliding it on the piers – from June until November 1967.
5. Rearrangement of stressed cable bundles for operation and canal injection was performed in two stages: September and October 1967, for the first girder, and March and April 1968, for the second one.
6. Pouring of concrete over stressed cable bundles and the joining of both girders was carried out in April and May 1968.

13 Z. Vecvagars, J. Binde "Ceļi" 1998, 5-11.
14 K. Kalniņš 1965. gada 28. oktobris, 1.Z. Vecvagars "Ceļi" 1999, 8-67.

7. Construction of the carriageway and sidewalks was performed in June and July 1968.
8. Scaffolding and subsidiary buildings were demolished and the whole territory tidied out from May until July 1968.[15]

Challenges during the bridge construction

Due to the poverty and underdeveloped technical capacity of the USSR, there were many challenges to address. The 200 m long girder of the prefabricated, continuous span structure weighs more than 1000 t. Installation of such structure could not be solved with the usual methods in these specific circumstances. Therefore, the attention of the designers was attracted to the sliding method. However, this issue was very complicated, almost unsolvable, when this method usually for assembling classical steel bridges was applied to reinforced concrete. During the installation, the sliding girder reaches a condition that according to calculations is opposite to the one it will be later have during the time of operation. For steel girders, such condition change is not dangerous, since they resist both tension and compression equally well. Steel girders may also be reinforced in a constructively simple way during installation. Reinforced concrete resists only compression well, it takes on tensile stresses poorly. It is also very hard to reinforce a reinforced concrete girder during installation, since the cables that take on tension are hidden deep in the concrete mass.[16]

Modification of sliding equipment was also a complicated matter. Steel spans are slid on rollers. Spans are relatively light and rolling friction between rollers and sliding tracks formed in the steel is insignificant. A similar method is not suitable for reinforced concrete spans. They are very heavy, and concrete crumbles on the circular surface of rollers.[17] Notwithstanding, it was decided to install the spans of the Lorupe viaduct by sliding, also without temporary piers. The play of forces in the span, depending on the condition during installation, was regulated with special, movable stressed cable bundles. Therefore, it was possible to create as big compressive stress as necessary artificially in the respective installation moment on any side of the span.[18]

The issue of sliding equipment was also solved. Help came from the latest achievements in chemistry. Girders were not pushed but slid on plates of a special polymer – polytetrafluoroethylene. Friction between fluoroplastic and concrete surfaces was only a few percent. Therefore, the whole thou-

15 Z. Vecvagars, J. Binde "Ceļi" 1998, 5-11.
16 VSL INTERNATIONAL LTD. Berne/Switzerland (1977); Z. Vecvagars, "Ceļi" 1999, 8-67.
17 Z. Vecvagars, J. Binde "Ceļi" 1998, 5-11; Z. Vecvagars "Ceļi" 1999, 8-67.
18 Z. Vecvagars, "Ceļi" 1999, 8-67.

sand-ton girder could be easily slid with the help of several winches with the pulling capacity of few tons. In addition, there was an option to use a special material – concrete cylinders coated with neoprene cord – instead of fluoroplastic plates.[19]

Construction of the viaduct

Since a completely new technology for structures and construction works was used for the construction of Lorupe viaduct, many and different auxiliary devices and special materials were necessary. Most of the auxiliary devices were non-standard. Therefore, companies in the industry manufactured them. Only the special equipment – hydraulic jacks and pumping stations – were brought in from other republics. Height of every bridge pier had to match the ravine terrain. The concrete was poured in a way that there would be no interruptions, so that all the mass from the foundation to the top was poured without any possible gaps in between. It was not easy; cranes for delivering the concrete upwards could not be used. The workers themselves constructed an elevator-like concrete vat that could be lifted between the scaffolding. With its help, the concrete, prepared on site, could be lifted in an uninterrupted flow up to the very top (30 m high).[20] A newspaper of the time "Latvijas Auto un Ceļu Darbinieks" (Latvian Road Worker) published the following:

> *"Several scaffoldings of bridge piers rise as mighty skyscrapers over serrated spruce treetops. When looking from their tops and imagining how it is going to look like when the road is ready, the impression is magnificent."*[21]

Construction of Lorupe viaduct was characterized by a very high work ethic and quality. Organization of works ensured that environmental damage to the Lorupe ravine were minimal. Only few trees and bushes, included in the design, that hampered pier construction works were cut down. The preparation of blocks and the assembly of girders were performed on access roads. The construction site did not impede traffic, so making span blocks on construction site justified itself completely. Their quality was considerably better than that of the mass production of a reinforced concrete shop. This success was achieved by the conscientious and creative attitude of workers.[22]

19 Z. Vecvagars, J. Binde "Ceļi" 1998, 5-11.
20 Id.
21 Lorupes rītdiena top. Laikraksts 1968. gada 9. jūnijs, 2.
22 Z. Vecvagars, J. Binde "Ceļi" 1998, 5-11.

A view of Lorupe viaduct piers,1967. (Latvian Road Museum, SJSC "Latvian State Roads", The road History Collection.)

The newspaper "Latvijas Auto un Ceļu Darbinieks" described the process of sliding the girder sections on piers:

"So the sliding of span girders on the bridge has already begun. Currently the speed is 6 m per hour or 1 m in 10 minutes.

Only when looking closely, it may be seen that the first twenty sections of span girders, weighing more than 3 t are indeed slowly moving in the direction of the ravine. The first ones, right after the pushing mechanism, are lined right next to each other on a support structure on a special rail track without any support.

Farther ones, already stressed and concreted in one section, are moving over the abutment. In front, the long iron launching girder has already passed the "fifth" pier. For a moment, the engine stops. Men transfer the next section on the tracks with a crane, and the peculiar "train" continues its slow movement.

At the top of the closest pier, workers are regulating sliding of the launching girder and span section over the pole with different mechanisms. Chromium-plated metal plate and plastic plate are being placed between them so that the brake friction would not come into effect. The pier itself is carefully linked with iron cables.

The workers are laughing: In the past, bridges were built; now they are crossing over themselves."[23]

23 K. Kaugurs 1967. gada 20. jūlijs, 1.

Sliding of span girder sections. (Latvian Road Museum, SJSC "Latvian State Roads", The road History Collection)

The workers also implemented many small improvements during the sliding of span girders. The biggest and the most modern project of the Latvian road workers at the time was created with intense, interesting and creative work.

Before opening, the viaduct was tested with loading. The test was performed by the workers of the Riga Polytechnic Institute. The total weight in the test reached 109–120% of the normative load – 2 columns of loaded heavy vehicles. The test results showed that the actual span deflection was only a 10th of the permissible standard. The concrete of the viaduct has good elastic properties.[24] On 20th July 1968, the new viaduct over the Lorupe ravine was opened.

Cross section of a span girder and pouring of concrete on stressed cable bundles. (Latvian Road Museum, SJSC "Latvian State Roads", The road History Collection)

24 Z. Vecvagars, "Ceļi" 1999, 8-67.

Static loading of the Lorupe viaduct, 1968 (Latvian Road Museum, SJSC "Latvian State Roads", The road History Collection)

Importance of construction of the Lorupe viaduct in the Soviet Union

The most qualified and objectively minded engineers and representatives of scientific organizations in the USSR were following the process of design and the construction of the Lorupe viaduct with great interest. At the same time, there were specialist circles that did not like that an experimental structure of this magnitude is in the hands of representatives of a small national republic and not their own. The construction site was often visited by representatives of large bridge construction companies and design organizations subjected to the Ministry of Construction of Transport Structures of the USSR. However, when the German technical magazine "Die Strasse" started to publish materials about the viaduct construction, the Ministry of Construction of Transport Structures of the USSR called a special meeting where colleagues in Riga were criticized about "implementing the foreign experience". There were also other attempts to stop the expansion of the method of longitudinal sliding of bridge spans. However, its victory march through the whole territory of the USSR was unstoppable. Construction without any handles or cranes is organically connected with the constructive nature of a continuous girder. Before the collapse of the USSR, 14 reinforced concrete bridges were built according to this technology, one of them in Latvia.[25]

Conclusion

It has been 50 years since the construction of the Lorupe viaduct. Generations have changed, and young bridge builders have little knowledge of the challenges and hardships that the workers of the 1960s had to overcome during its construction. Nowadays, assembling a bridge with longitudinal sliding is a common practise. However, the principle implemented for the first time in the Lorupe ravine has stayed the same. Total length of the bridge is 195,75m, highest pier – 24 m, last reconstruction was made in the year 2000.[26]

The purpose of this paper has been not only to describe the idea and the construction stages of this bridge, but to tell the wider society about the courage, initiative, and the creative and meticulous work of the Latvian road workers that allowed the implementation of a European scale project in difficult, constrained circumstances.

25 Z. Vecvagars, "Ceļi" 1999, 8-67; Z. Vecvagars 1966. gada 6. janvāris,
26 Latvijas Vēstnesis 22.08.2000. Nr. 296/297. Retrieved from: https://www.vestnesis.lv/ta/id/9933

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SNOWBLOWERS IN NORWAY

Arnulf Ingulstad

Norway, a country with deep fiords and many high mountains, has faced major challenges with building and maintaining roads. Winters, which often come with heavy snowfalls, often make it very difficult to keep roads open. Many roads across mountainous areas throughout the country have been partially or completely closed in the winter because machinery and equipment have not been able to remove the snow. There are still several roads in Norway that are closed in winter. However, this article will describe the development of snowblowers through nearly 100 years, and how the Norwegian Public Roads Administration (NPRA) in cooperation with manufacturers has over time succeeded in developing machines that make it possible to keep an increasing number of road sections open in winter.

The first attempts to keep snow-covered roads open were made with shovels and horse-drawn wooden ploughs. In the mid-1920s, snow clearance equipment mounted on cars was tried out for the first time. The first equipment was a small diagonal steel blade that was mounted in front of each wheel on the car. Then these blades were made longer to form a V-shaped plough. In 1936 the company called Øveraasen Motorfabrik at Gjøvik made the first snowblower. It had an 80-hp engine and the snowblower weighed 2 tonnes. During this period, the NPRA and the factory started to develop a cooperation regarding product design. But no production of snowblowers was started before the war.

When the Germans occupied Norway in 1940, we entered a new era with winter maintenance. The Germans were very concerned with keeping the roads open in winter. This applied especially to Hardangervidda, the highland plateau between Oslo and the North Sea coast. To keep the roads here open, 70 large snowblowers of the type known as "Peter blowers" after its Swiss designer Konrad Peter AG, were sent to Norway. These were heavy machines. They were equipped with wheels or tracks and had either a petrol or diesel engine that was connected to an electric motor to be able to work at low speeds during snow blowing. These were very complicated machines to operate and maintain. And the efforts to keep the road across Hardangervidda open through the winter were not successful. When the war ended in 1945, the NPRA took over 50 of these snowblowers.

Opening the road up to Dalsnibba. It takes a lot of horsepowers to bring the snow up to the top of the snowbank; here it became as much as 12 metres high! (Photo: Arnulf Ingulstad)

John Øveraasen and Otto Kubberud gently coaxing the "Trygg" engine to make it start. (Photo: Arnulf Ingulstad)

After the war, Øveraasen started to manufacture smaller snowblowers mounted on tractors. The need for larger wheeled and tracked machines was partly covered by the "Peter blowers" that the Germans left behind. But because these were difficult to maintain, they were eventually phased out. Some were rebuilt by Øveraasen and converted to diesel operation and hydrostatic propulsion.

All-year road over Haukelifjell

In 1966, the NPRA faced a new task within winter maintenance. The very important road over Haukelifjell between Eastern and Western Norway was nearing completion, and the maintenance departments in Hordaland and Telemark were beginning to realise that they would need snowblowers to keep the road open in winter. The machine departments of the two counties and the Directorate of Public Roads Procurement Office were faced with the demand that within one year they had to provide four snowblowers with a capacity that could not be found in snowblowers anywhere in the world at that time.

The old archives of the Directorate of Public Roads contain the first memorandum written about the procurement of snow removal machines for the road over Haukelifjell - Haukeliveien. The memorandum is dated 20 May 1967 and the first page reads like this:

"By the road directors in Telemark and Hordaland, the Procurement Office has now been asked to procure snow clearing equipment for

Haukeliveien where snow clearing is expected to be required from September.

The road director in Telemark proposes that the following be purchased:
2 x Viking Super snowblower with propeller, NOK 694,000
1 x tracked snowblower approx. 8 tonnes, NOK 220,000
1 x Magirus 200 snow ploughing vehicle NOK 235,000
In total NOK 1,149,000

The road director in Hordaland proposes the following:
2 x Viking Super snowblower with propeller, NOK 694,000
1 x Magirus 200 snow ploughing vehicle NOK 235,000
In total NOK 929,000"

From the 30th anniversary of the opening of Haukeliveien. In front of the 30-year-old Viking Super snowblower on the right: Central people in the maintenance of Haukeliveien. From the left: Snow plough driver Olav Veslestaul, Foreman Hjalmar Stenstad, and Roadmaster Torleif Kilen. (Photo: Arnulf Ingulstad)

On the next page of the memorandum, an estimate is given of total annual operating expenses for the machines in the two counties together. It is estimated that each Super blower would have 430 operating hours per year, the tracked snowblower 60 hours and each of the ploughing vehicles 1,000 hours. In addition, expenses are included for 2 graders, 2 smaller ploughing vehicles and 2 vans, as well as any private ploughing vehicles.

The conclusion is that

"The snow clearing costs for Haukeliveien will thus amount to, given a normal winter, around NOK 7-800,000."

The conclusion also includes the following remarks:

"The all-year road over Haukeli will make great demands on the quality

One of Øveraasen's largest attachment snowblowers at work. (Photo: Arnulf Ingulstad)

and capacity of the equipment. The recommended and newly developed Viking Super snowblower is currently the most powerful blower in the market.

If the NPRA is to acquire the blowers in time for the winter season, an order should be placed within the next few weeks with the Øveraasen company, Gjøvik.

The proposed procurement plan from the two counties is based on the premise that it should be possible to keep Haukeliveien open even during tough winters with much snow, and that it should be reopened soon after a storm."

On the front of the memorandum at the top left there is a series of initials. And at the end it says: "The proposal is accepted. C.L."

C L stands for Carl Lomsdal. He was then director of the operations department of the Directorate of Public Roads. And the date 22 May is worth noting. In two days, the case had been processed by three executive offices and been finalised by the top manager. This must be a record-fast case processing for the Directorate of Public Roads!

But then again, it was in fact quite necessary. The road directors in Telemark and Hordaland had asked to get the machines by the end of September. In other words, four of the largest snowblowers ever built had to be completed within 4 months! One of these blowers, however, was already in the prototype phase and had been tested a few places in Telemark during the spring with good results.

John Øveraasen and Alfred Schmidt studying a Schmidt tracked snowblower being tested at Grotli. (Photo: Arnulf Ingulstad)

Specifications

In record time, an excellent cooperation was established between the companies of Øveraasen, Hesselberg, Volvo and the NPRA in Telemark and Hordaland, and the Directorate of Public Roads Procurement Office. But how fast would it be possible to build these snowblowers? John Øveraasen took the challenge and presented a sketched solution, which was accepted. And the snowblowers were built by Øveraasen's factory at Gjøvik within the specified time frame. The blowers were given the name Viking Super. The carrier vehicle was a 4-wheel-drive Michigan AWS 65-wheel loader with a 120-hp propulsion engine. Two Volvo diesel engines, each of 250 hp, were mounted on a rear frame extension. From these, a drive shaft ran on each side of the driver's cab to the two propellers. These had a diameter of 1.4 metres. Capacity was around 2,000 tonnes of snow per hour.

Experience with the snowblowers

In the initial period of operation, there were problems with the engines - the pistons would get stuck. Volvo was consulted and lowering the rotational speed and adding pistons with more clearance at the top solved the problem.

In the winter of 1969, all the snowblowers were equipped with larger dynamos. This was done in response to the experience during a storm when the road suddenly had to be closed. Everything went wrong for the NPRA: there was a rockslide in the tunnel, equipment got stuck, and radio communication in the snowblowers broke down completely because of inadequate electrical systems. And in the middle of all this, among some hundred cold

One of the last tracked snowblowers Øveraasen supplied to the NPRA. (Photo: Arnulf Ingulstad)

and angry motorists who had been waiting 24 hours for the road to open were also 30 of the country's most competent snowblower operators who had been to a snowblowing course at Prestegård, 10 km away. But this was on the other side of the mountain pass, which they were not able to cross because of the very serious snowstorm. And there they were, 12 large snowblowers that had been driven there for the sake of the course but could not be accessed and used. Newspapers and TV obviously did not fail to comment on this situation.

When weather conditions were difficult, the driver's cab, with a high noise level and poor forward visibility, was a serious problem in the Viking Super snowblowers. At the end of the 70s, the cab was rebuilt to include two driver seats. The ones in Hordaland were given forward sloping windscreens with double glazing with special heating wires in it. The snowblowers in Telemark had straight windscreens but they had two rotating screens. These alterations made things a little easier for the drivers.

Following a reorganization of the snow-clearing services in 1983, the responsibility for the entire Haukelivegen road was assigned to Telemark and the machines transferred to Haukeliseter Road Office. These snowblowers were very successful and spent 30 years at Haukeli, each accumulating close to 15,000 hours of service.

It can truthfully be said that the snowblowers were more efficient than anyone had expected. Evidence can be found in the fact that all the snowblowers were in use at Haukeli until 1986. One was then scrapped, and

The first demonstration of Big John in April 1983 at Valdresflya. Director General Eskild Jensen of the NPRA and Senior Principal Engineer Arnulf Ingulstad at the sticks. (Photo: Bjørn Prebensen)

another became a parts donor for the two remaining ones. One of these snowblowers can today be found in the Norwegian Road Museum at Øyer. But the snowblower with identification number 560-02 remained in service on less demanding road sections in Telemark until the season of 94/95. Since, it has been taken good care of and can now be found at the Driver and Vehicle Licensing Office at Haukeliseter.

Tracked snowblowers

During winter, up to 10–15 metres of snow may accumulate on mountain roads that are not kept open. When these roads are to be opened in the spring, it is necessary to use tracked snowblowers that can run on top of the snow and remove it layer by layer. From the 1960s onwards, Øveraasen built tracked snowblowers with diesel engines and hydraulic propulsion. These were all equipped with an auger that cut the snow loose, and an impeller that threw the snow up and to the side. The design of the auger and the blades, for these to glide easily into the compacted snow and be as effective as possible, was the object of many redesigns and tests. The last tracked snowblower was delivered to the NPRA in Buskerud and later transferred to Sogn og Fjordane in 1976. Its product designation was PEX 1400 BH4. Since 1965, Øveraasen had then delivered about 15 such machines to the NPRA. Some of these are still in service opening winter-closed roads, of which Norway still has quite a few.

A new auger/impeller attachment snowblower is demonstrated during the PIARC World Road Congress in Luleå. (Photo: Arnulf Ingulstad)

Attachment snowblowers

In the mid-60s, the NPRA was facing the question of what kind of snowblowers to invest in for the years to come. There were different options to go for, and the Road Office machine departments had very different wishes. Thus in 1968, a snow clearing conference was organised at Nystuen, with representatives from all counties. The NPRA was faced with the following alternatives:

- Further develop tracked snowblowers that could run layer by layer in deep and compacted snow and replace the old Peter blowers.
- Further develop larger wheeled snowblowers built as special purpose machines.
- Further develop smaller wheeled snowblowers mounted on wheel loaders or other standard machines.
- Further develop the so-called "Unit" snowblower, an attachable snowblower where the engine and the snowblower device were built together as one unit that could easily be attached and detached on a wheel loader through a quick-release coupling.

When it came to the first three options, no clear conclusions were drawn. However, Øveraasen won support for their proposal to further develop attachable snowblowers with different engine power, weight, and capacity.

Øveraasen had been developing their "Unit" snowblowers for a few years. These were much more economical machines than the automotive snowblowers because the snowblower units could be detached and the wheel loaders used for other important purposes in summer. The NPRA found it right to support the further development of attachment snowblowers, a sensible choice. The "Unit" snowblowers became popular, and in the year 2000, the NPRA had 140 of them in service.

But the development of these attachment snowblowers was not without problems. There were tough demands placed on these machines in terms of operational reliability, and they were often exposed to heavy strain. The NPRA was often under great pressure from the public to keep mountain passes open. And if they were closed during a storm, there would be demands to reopen them as fast as possible. Snowblowers and snow ploughs were essential in this effort. As the supplier of most of the snowblowers, Øveraasen was criticised on several occasions for their structure being too weak and their engines too small. In 1973, a number of large "Unit" snowblowers were sent to Finnmark, Troms, and Nordland. A number of these experienced a breakdown of bearings due to construction faults. After some time, Øveraasen solved this by rebuilding the snowblowers with a flexible connection between the auger housing and the transmission for the impellers. This is worth mentioning because the development and use of "Unit" snowblowers would probably have ended if the factory had not solved this problem.

Today there are close to 1,000 "Unit" snowblowers in Norway. Of these, around 300 are of the UTV type (in English UAI, letters standing for Unit, Auger, and Impeller), and around 300 of the UPV type (in English UPI, letters standing for (attachment) Unit, Propeller, and Impeller) with the Twin Spin system. The rest are older snowblowers with propellers, of the types PW 1150, PW 1200 and PW 1350. These are owned by the NPRA, the Norwegian State Railways, Avinor and private contractors.

Testing the large snowblowers

We have only had one significant manufacturer of large snowblowers in Norway, but a handful of manufacturers have made snow ploughs and snowblowers for tractors. Good cooperation between manufacturers and NPRA purchasers and machine operators has been important for product improvement and has ensured a high level of quality in machinery and snow

Two of Øveraasen's gigantic runway sweepers at work on Frankfurt Airport. (Photo: Thor Øveraasen)

clearing equipment for winter maintenance. But things have often been far from perfect!

The Procurement Office in the Directorate of Public Roads, known as the Office of Machinery and Materials, oversaw all procurement of major machines for the NPRA. They had the development of all types of construction and maintenance machines as one of the principal tasks. NOK 10 million was allocated annually to the purchase of new and improved machines and the testing of these. Each year, an overview was made of ongoing machine projects, including purpose, cost, and time consumption. Projects to improve equipment for winter maintenance such as more reliable and efficient snowblowers and snow ploughs for snow-clearing vehicles and road graders, were given high priority. The Procurement Office was continuously in contact with NPRA machine instructors in all counties. This provided the Office with very useful and direct information about their experience and need for improvements to all major types of machines. Such input was highly valuable and resulted in requirements being imposed on suppliers and manufacturers when the NPRA was to purchase equipment and sign contracts with suppliers and contractors.

Both the NPRA and the Øveraasen company have for nearly 100 years worked to improve snow plough equipment and snowblowers. There are few machines that are subject to stricter requirements for operational reliability and dependability than snowblowers. The machines often work under extreme weather conditions, with very poor visibility, low temperatures, cold winds, and icing. And the pressure from a tunnel half full of drivers with their families going on Christmas or Easter vacation, is enormous.

Increasing and understandable demands for more operational reliability, greater comfort for operators, larger capacity and throwing distance, and greater efficiency were a constant challenge. Haukeli turned out to be a valuable testing ground for new machines. But this was not just because of the snow and the road conditions. It was not least due to the competence and positive attitude in the management as well as machine operators and workshop personnel at Haukeli, towards machine development. Large foreign snowblowers were put to work at Haukeli, to test and compare them alongside our own Norwegian-made machinery under the same conditions.

In 1976, the Directorate of Public Roads initiated a comprehensive test of the largest snowblowers in Europe, from the Swiss Rolba factory and from the German Schmidt factory, together with a large wheeled snowblower from Øveraasen with the product designation HHV 150. It had 2 large Volvo engines for the snowblower unit and a smaller Volvo engine for propulsion. A total of 1,000 hp. The snowblower was built on an upside-down Viking dumper chassis. It was subsequently rebuilt and sold to Norilsk Nickel in Russia, where it was to replace a snow blower that had been lost in a snowstorm!

The tests took place over 2 years at Haukeli, Valdresflya and Saltfjellet. Testing cost a lot in terms of time and money but provided the NPRA with excellent insight into the positive and negative aspects of the various brands, and a basis for placing more stringent requirements on Norwegian products, especially to operator comfort. The Swiss machine Rolba 3000 was very advanced and impressive. And so was the price, which in 1978 amounted to NOK 2.4 million. But it had some obvious weaknesses and limitations, uncovered during the tests. The German snowblower labelled TS-7, from the Schmidt factory, was also an impressive machine. And after the tests at Haukeli it was transferred to the Norwegian Civil Aviation Administration and Gardermoen Airport. Later it was bought back by the NPRA and put to work to keep the road across the Hardangervidda mountain plateau open. It has not been in use for the past 12 years and can now be found in a local museum in Sirdal.

Another snowblower deserves mention, also built on a Michigan wheel loader. Its snowblower unit was hydraulically operated, with oil supplied from an engine placed on an extended frame at the rear of the wheel loader. The snowblower unit could be lifted high and had an auger that was very

Thor Arve Øveraasen, who has managed the company through 28 years, in front of runway sweeper. (Photo: Stein Erik Pettersen)

efficient in hard snow. This snowblower too was first tested at Haukeli in 1978, then sent to Saltfjellet in Nordland, and then back to Haukeli where it was in service from 1985 to 1990. There it was referred to as the Nordland snowblower. In Nordland, it was called Røderen ("the Redder"). It got this name because it always left behind a strip of red hydraulic oil. Apparently, this was also the case at Haukeli.

Criteria for new snowblowers

In 1968 it was decided that the road over Saltfjellet in Nordland was to be kept open in winter. Again, there were demands to provide large wheeled snowblowers. And once again a cooperation with Øveraasen A/S was initiated. This time, the snowblowers were built from scratch as special-purpose machines, and the carrier machine was also made by Øveraasen. Three such machines were delivered to Nordland, and two machines were later sent to Finnmark. The snowblowers had hydraulic propulsion, but the snowblower units were mechanically operated. There were 2 types, with the labels PW 1400 HH4 and PEX 1400 HH4. The first one had a propeller, the other one an auger. The letters HH stood for "wheeled, hydraulic".

In 1981, the Directorate of Public Roads appointed a so-called snowblower committee with representatives from counties with difficult snow conditions, such as Hordaland, Telemark and Nordland. The committee was to present requirements specifications for a new generation of large maintenance snowblowers. And these were primarily intended for Haukeli and Saltfjellet. The requirements were presented in 1982. This resulted in a new big snowblower being ordered from the Øveraasen company. It was delivered in 1983 and was given the name "Big John" as a tribute to John Øveraasen who died far too early in 1979.

This snowblower was a giant of 22 tonnes, an engine with 750 hp and a capacity of approx. 3,000 tonnes of snow per hour. It was fitted with a new type of blower head which was named Twin Spin. Ordinary blower heads were equipped with two propellers with the same diameters. They rotated at the same speed and were placed next to each other. This meant a large idle surface that made it difficult to cut into the snow when working in hard-packed snow. Big John's new blower head consisted of two significantly larger spinners overlapping each other so that the idle surfaces were eliminated. The front spinner, known as the propeller, had low speed and therefore went easily into hard snow. The rear spinner, known as the impeller, rotated significantly faster and threw the snow to the side. This proved to be a very successful construction and was eventually adopted in all attachment blowers labelled UPV blowers.

After tests at Haukeli, Big John was also sent to Saltfjellet where it was in service until the road was realigned in 1992 and the need for snowblowers was drastically reduced. It was then brought back to Haukeli where it is still in full service and takes the heaviest jobs. In 2008, it was Big John and two UPV 150 attachment blowers as well as 4 snow-ploughing vehicles with diagonal blades and V-blades that kept the road over Haukeli open. Today, only attachment blowers of the types UTV 430 and UPV 410 Twin Spin can do this job.

Snow ploughs

Another essential tool required for winter maintenance is the snow plough. Until the 1970s, V-blades were the dominant snow-ploughing tool. Around that time there was a transition towards diagonal blades, which proved more efficient on new and better roads. Throughout the years, Øveraasen was a major supplier of snow ploughs to the NPRA, and was in close contact with the NPRA's supervisors, who reported from experiences and communicated needs and preferences regarding plough design. This resulted in constantly changing designs and new improvements to the ploughs. In 1970, Øveraasen made as many as 35 variants to cover all the NPRA's wishes about snow ploughs around the country.

To achieve more standardised snow-ploughing equipment, the NPRA in the 1970s introduced quality requirements to apply to snow ploughs. John Øveraasen played a very central role in this and was behind the proposal to introduce the German standard for plough lift and quick-release coupling to snow-clearing vehicles in Norway. This was developed by the German Schmidt factory. This proposal was accepted. Standardisation meant a major improvement in the work to replace blades and plough attachments, while the risk of the being run over by the snow plough was significantly reduced. Throughout the years, there was a cooperation with the NPRA on improving and developing different types of ploughs. Of particular importance was the development of so-called slush ploughs with rubber slats that scraped away snow and slush on salted motorways.

Viking dump trucks

The development of a Norwegian-manufactured dump truck deserves mention. In 1970, John Øveraasen presented a proposal to develop and manufacture a Norwegian road grader. After close consideration of the proposal, the Directorate of Public Roads suggested that he should rather investigate the possibility of manufacturing a dump truck. This led to the development of an articulated dump truck with 6-wheel drive and a 205-hp engine. The dump truck was called Viking, and ten such machines were ordered as a development contract.

The dump truck proved to be very successful and fulfilled expectations. For a number of reasons, Øveraasen discontinued production of this machine, and sold it to the Moxy factory in Møre og Romsdal. Under the name of Moxy, with relatively small changes to the main concept, but with impressive technical improvements, this dump truck has been manufactured up to the present day. No less than 10,000 dump trucks have rolled out from the factory in Molde to construction sites around the world. This is an example of how creativity and cooperation between the NPRA and Norwegian industry has provided the basis for substantial production and industrial activities.

The people behind the machines

When describing the contact between Øveraasen and the NPRA, it is necessary to say something about the people behind the machines. What has characterised the factory is its stable and competent workforce. And it is natural to single out three people from the period up to 1979.

John Øveraasen was 25 years old when he took over as manager of the factory after his father. He managed the factory for more than 30 years.

He knew every nook and cranny of our country, and he knew personally all NPRA supervisors and drivers who were involved in the snow-clearing service. He was always looking for new challenges and technical solutions that could ease the NPRA's job of removing snow and ice. His happiest moments were when he was inspecting the work of a new snowblower, with watchful eyes assessing its capacity and thrower distance, and was able to identify improvements compared to previous constructions. Many of us will remember gathering around the coffee pot, which for 20 years was made up of a tin with a handle, discussing new snowblowers. Slacking off was never an option. Some may remember a machine demonstration at Grotli. There had been some problems with machines at Saltfjellet, and John Øveraasen had been summoned. Having finished his job there, he drove directly to Grotli. He arrived there at 6 in the morning, slept for an hour in his car, and carried out the machine demonstration the next day as planned. John Øveraasen was a personality to whom the NPRA is greatly indebted, and whom we remember with respect.

Hans Petter Hval was a designer and constructor. He worked for Øveraasen from 1969 to 1982. He had a great capacity for work and had the challenging task of transforming more or less well-founded proposals and ideas into finished constructions. Otto Kubberud was a machine operator and mechanic. He always took part in the testing of new machinery and equipment. His views on the different machines would carry a lot of weight.

A new generation

John Øveraasen died unexpectedly in 1979. His sons Thor and Even managed to take on their heritage and lead the factory and the technology into the future. The close cooperation with the NPRA continued. The Big John snowblower is a good example of this, with the NPRA identifying needs and requirements and Øveraasen finding practical solutions. And the new snowblower design with a slow-moving propeller and a fast-moving impeller, which proved to be very effective, was Thor Øverraasen's idea. The development of the "Unit" snowblowers continued, and these became increasingly reliable and effective.

John Øveraasen was in close contact with the major suppliers of winter maintenance equipment in Germany and Switzerland and would often participate in international winter maintenance conferences with snowblowers in exhibitions and competitions. Such participation was also continued in cooperation with the NPRA. It was often snowblowers ordered by the NPRA that were exhibited and demonstrated. Of particular interest is the PIARC World Road Congress in 1990, which Director General Eskild Jensen of the NPRA placed in Tromsø. This congress included extensive machinery demonstrations, and Øveraasen won a fair share of the prizes awarded because of the excellent performance of their new attachment snowblowers.

Up until 1985, the factory was run by the two brothers together. Then Even pulled out, and running the factory was continued by Thor. In 2000 he chose to sell the factory to the German Schmidt company. This company experienced some problems with operations, and in 2003 Thor bought the factory back. He then made some adjustments and outsourced much of the component production to several subcontractors. Øveraasen also became part-owner of a company in Riga, where large parts of their production took place. The factory at Gjøvik was gradually directed towards development and assembly. The range of products was reduced and standardised.

The situation today

Today Øveraasen offers two sizes of sweepers for clearing airport runways and is probably the world's leading supplier of these large machines. The factory offers five sizes of attachment snowblowers, one large self-propelling snowblower, and ten different types of snowploughs. A large snowblower is now about to be delivered to Gardermoen Airport, and has a weight of no less than 35 tonnes and an engine with 2010 hp.

Of their total production, about 75% is delivered abroad. Most of it goes to Europe, but deliveries to the USA, China and Russia are increasing. Their total turnover was around NOK 30 million in 1980; in 2005 it was around 240 million. Today it is 650 million. Of this amount, around 80% goes abroad. Of the 20% that is sold in Norway, around 30% comes from large snowblowers, 60% from runway sweepers for airports, and the remaining 10% from snow ploughs etc.

The close cooperation with the NPRA on development of machinery was discontinued after the reorganisation of the NPRA, but Mesta and the other major contractors that took over winter maintenance of the road network are among Øveraasen's important customers. Machine development is no longer done by the NPRA and machine operators; it has mainly been taken over by machine manufacturers and takes place in response to competitive tendering based on price, efficiency and production capacity.

It is fun and impressive to see how a Norwegian company has managed to maintain its position through three generations, and today is able to deliver first-rate technology for winter maintenance of roads and airports all over the world. NPRA people look back with fondness on their cooperation with the Øveraasen company and its leaders regarding machines and equipment through three generations.

Challenges

Since road maintenance started to use machines and up to around the year 2000, the improvement of working conditions within operation and maintenance has been a central issue. Noise in the driver's cabins, toxic exhaust gases from diesel engines, coldness and poor heaters, vibrations in steering wheels and sticks, poor visibility during snowstorms, lack of rollover protection, and unreliable communication are some of the problems we faced in connection with winter maintenance and snowblowers. In particular, this applied to machines that were used to keep mountain passes open during the winter. Improving such conditions for machine operators was a challenge for manufacturers and for purchasers in terms of requirements and specifications in purchase agreements.

At the beginning of the year 2000, it seemed that most of these problems had been solved. For the last 10–15 years, challenges for manufacturers and purchasers have mainly been related to price, operational reliability, capacity, and delivery times. The task manufacturers are facing today is to reduce the pollution of the exterior environment. How much of the air pollution in the world is caused by construction and maintenance machines is not entirely clear. But in recent years, requirements regarding exhaust gas emissions from diesel engines have become increasingly strict, which has changed the design of these. This has in turn made it necessary to make significant changes to the construction of snowblowers.

But the Øveraasen company now confirms that they are exploring the possibilities for switching to electric engines and engines running on biofuels in their various types of snowblowers and in runway sweepers for airports. They are estimating that this may be feasible within a time frame of 5–10 years.

It will be exciting to see if the speed of development can match their expectations.

AUTHOR

Arnulf Ingulstad (born 1935) led from 1979 the Road Directorate's purchasing office, later called the Machine and Material Office (MMK). He retired in 2005.

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