Economic effects of new transport technologies

Examples from the introduction of new trucks, goods handling tools, packaging and organizational changes, 1950-1980

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In the years after the World War II, a large transformation of the transport system occurred worldwide, but especially in Europe. Most visibly, the dominant carriage method became lorries, while railroads fell behind, mainly because of the economic advantages to using truck transportation. This study will explain how this economic advantage came about.

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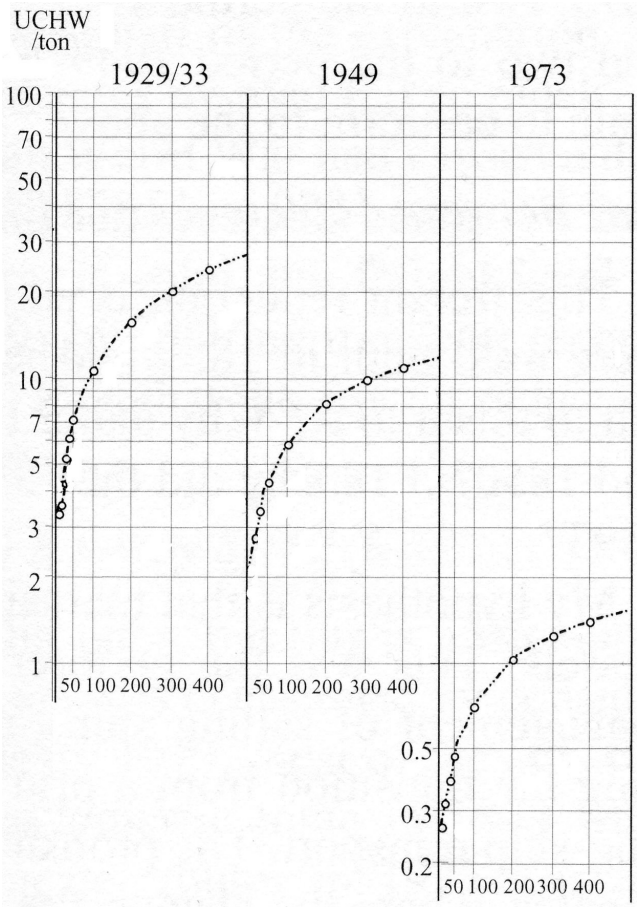
Innovations tend to come in clusters and do not occur evenly over time. It has been said that there have been only two revolutionary logistic changes in road transportation. The first was the shift to new distribution structures caused by the simultaneous introduction of automobiles for transport and telephones for order transfer, and the current revolution is caused by new information technology, more and faster transport and the reduction in barriers between countries.[1]

My impression is that the period after World War II up to 1980 saw such a strong change in the transport system itself and a deep influence in neighboring areas that we can call it a revolution. It is probably a small one but in many ways a radical change in the technology of vehicles, road building, and the whole infrastructure around and not at least the whole organizational change. The word *logistics* became a reality where transport was not only a matter of transportation from A to B but a whole chain of technical and organizational exchange before and after transportation points.

Figure 1
"Average" freight rates per ton of goods in whole vehicle loads over distances up to 500 km[2]



The world experienced a rapid decrease of the freight rates for road transport in this period. While the nearly 50 percent decrease between 1930 and 1950, the decrease continued to a tenth part in the following 30 years. In the period 1810-1973 the total expenses of road transport became stable at approximately 4-6 percent of the gross domestic product (GDP), while the costs of personal travel rose from 1 percent in 1850 to 10 percent in 1973.[3] The years 1950 to 1980 saw enormous progress in the economy with more than a doubling of the GDP and with a stable 4-6 percent portion of the GDP, the transport sector boomed.

Let us examine why this growth was possible. I will make my starting point in a formula for a simple transport system:[4]

$$C = 2\,A/t + 2 \times A/sw$$

where:

A is the cost of the vehicle and its operation per unit of time

t is the speed of loading and discharge of the vehicle in tons per unit of time

s is the speed of the vehicle under way in kilometers per unit of time

w is the loading capacity of the vehicle in tons of the commodity in question

x is the length of the cargo journey in kilometers

C is the cost price per ton of cargo

This is a very simple formula. Later I will introduce a more "truthful" formula but for now I will use this, with some warnings. The formula is developed for a transport system with very few different types of vehicles. It can be used for the rather simple trucks in 1930 that were almost always of only two kinds: the lorry with a capacity of 2 tons and another with a 4-ton load. The reality in 1950 was more complicated, with many more sizes and types of vehicles, and this development continued for the next 30 years.

Another warning. The freight rates mentioned above were the general trend for bulk cargoes. In reality the picture is much more complicated with a lot of differences between the kinds of goods, the time of year, distance, the competition on the route and many more factors.

One of the more important factors is the possibility of a return cargo. The vehicles have to return to their beginning point and the economy is influenced by whether it was possible to have an income on the return trip. Even a lower rate for a return trip would change the economic picture considerably.

Table 1. Road transport (Denmark 1980)[5]

	share	*lenght*	*returns*
Company transport			
Beer, bread, food	10%	S-M	packaging
Oil, coal and chemistry	8%	S-M-L	no
Other	14%	S-M	no
Haulage contractors			
Farming products, fertilizer	13%	M	some
Food	15%	M	some
Chemistry	4%	S-M	no
Cargo, manifactured products	17%	M-L	some
Gravel, sand, cement	18%	S-M	no
	100%		

Some of the factors behind the economy will be described in more detail later in the paper. One of the most important factors behind the differences in the economic structure lies in the kinds of transport. As you can see from Table 1, each kind of transport has its own profile in the length of each trip (small, medium or long), the possibility of income from returns and the way to organize the transport through own vehicles or contractors. The table gives only the main principles; there have been some long-distance transports with beer as an example, but the overall view is that mentioned.

Economic factor: weight

The weight of the trucks increased with many tons through the period. The ordinary truck (a vehicle with a load of more than two tons) had a load of less than 5 tons; only 13 percent of the Danish trucks in 1949 could carry more.[6] On average the typical truck could carry a load of 3.5 tons.[7] In 1980 the picture had changed dramatically; the average load was more than 6.6 tons.[8]

The load on the truck itself was only a part of the picture. The truck could have a trailer, so the total train of carriages could be double or more. While the trailers were of little importance in 1949, there were 3,904 trailers that could carry more than 2 tons. Twenty-four percent were big trailers with more than 5 tons,[9] but still the main part of transportation was made by truck alone.

That was changed in 1980 when driving with trailers were the normal situation and solo driving was a minor part of driving. When you look at tons km but look only at the weight, solo trucks still had the majority of goods, at 106 billion tons against 79 billion tons in trucks with trailers.

The total goods in 1980 totaled 120 billion tons; driving with trailers accounted for nearly 59 billion tons, and solo trucks carried 61 billion tons.[10] While the ratio of trailer to truck in 1949 was approximately 1:7, this changed to 1:2 in 1980.

A closer analysis will tell that the old fashioned trailer type was in the ratio 1: 4 and a nearly similar number of vehicles were of the new hanger type with a four-wheeled drawer. A new kind of truck was a truck with three axles or more, with a number of 7.862—most could carry more than 10 tons—with the traditional two-axled truck still in the majority with its 33.947 in total.[11]

Economic factor: speed

The average speed improved dramatically in the 30 years. Unfortunately we do not have exact statistics for this factor. We do have two strong indicators of this dramatic development—the trucks could drive at an increased speed and the official speed limits were raised.

The speed limits in 1932 at the beginning of the period were 50 km/h for trucks with a weight under three tons, 40 km/h for trucks up to 4 tons and 30 km/h for trucks weighing more than 4 tons. This changed in 1953 when the speed limits increased to 60 km/h for a truck weighing more than 3.5 tons. This was for a solo car since trucks with trailers had lower limits. In 1966 the limit became 70 km/h and in 1974 trucks with trailers also could drive with this speed. For small trucks this was a 40 percent increase in speed and for the largest trucks over four tons the increase was 133 percent. The vehicles could normally drive faster than those limits. For instance a very popular

truck, the Volvo NB 88, could drive at the speed of 85 km/h in 1970, when fitted with a normal motor and similar equipment in the time of a 70 km/h speed limit.

Economic factor: loading and discharging time

Again we do not have exact information about one of the most important issues with transport. We can have an insight into the problem when we look at the new dump body. Around 1950, a truck with such a tool could earn 20 percent more on a job according to some local agreements. With this information we can see that the savings with a discharging time around zero is approximately 20 percent of the total price for the job. If the loading was at the same time the payment for loading and discharging would have been approximately 40 percent of the whole job. It is obvious that those jobs were local transport within 10 km or less. For long distance driving the loading time would have been a smaller percentage of the short distance transportation.

We have other scattered knowledge about this time period. The official prices for the Danish haulage companies were rather high for loading and discharging while the driving was nearly nothing. The driving with coal was 3 Dkr. for the first km (and including loading and discharging) but only 0.30 Dkr. per km. for up to 10 km and for the next km it was 0.15 kr, for example. For a distance of 20 km, the price would be pr. tons 3 Dkr. + 4.5 Dkr. for the driving. Again this was approximately 40 percent of the total expenses.[12]

Economic factor: distance

Once again we do not have any exact information. From the statistics based on random sampling we can calculate a total distance with load in 1953 at approximately 461 million km against 1.3 billion km in 1980.[13] The difference between the distances does not look like much but you have to remember that the trucks in 1980 could carry a considerably larger weight than those in 1952. For 1980 we have a statement about the number of trips: there were 36 millions trip and 22 million trips with a load. The trips with a load had an average length of 36 km.

Economic factor: cost of vehicle and its operation

This factor is the most complicated to explain because it constitutes a long row of expenses. Foremost there is the truck itself, fuel, repair, wages to the driver, and the general overhead.

This factor depends on how much the truck has been used through the year. With fewer trips the cost was distributed less than if it had been driving more. The least used vehicles in 1953 were only used 56 percent of the time in the foodstuff business probably caused by the long waiting time for beer delivery in towns) to 100 percent in the construction business. A similar parameter is how large the coefficient of use was when there was a load on the vehicle. Here the lowest percent of load on the vehicle was 32 percent on average atthe lowest at machine factories and 72 percent at the largest in construction where the trucks often are filled 100 percent with gravel and sand. [14]

Table 2
Cartage 5 trucks timber merchant Dkr. 1947/48[15]

	1930/31		1947/48	
driver	12.871	30%	28.030	34%
petrol	6.061	14%	11.300	14%
oil	528	1%	246	0%
rubber	440	1%	4.311	5%
repair	2.177	5%	8.353	10%
tax, assurance	3.656	8%	3.730	5%
garage	400	1%	600	1%
interest due	2.100	5%	4.800	6%
writing off	7.000	16%	16.000	20%
surplus	8.150	19%	4.556	6%
	43.383		81.926	

This numbers shows the same result. The expenses to the driver and other people (included in surplus) are the largest single post. The conclusion is that the most important single factor is the wage to the driver and it is important to lower it. This can be done mainly by reducing the loading and discharging time, have a higher weight, by a higher speed and reducing the non-driving time (no jobs, repair, cleaning).

The example from 1979 (table 3) shows that the expenses for the driver are still the largest single post. Comparing Tables 2 and 3 shows that the relative expenses have decreased. The fuel has decreased 50 percent, probably because of the use of the diesel engine. This is interesting because the speed has increased, therefore reducing the driving economy for both fuel and rubber; rubber was used in the same proportion because of a better quality of rubber.

Table 3
Cartage truck MAN 32.280 VF construction Dkr. 1979[16]

Drivers	95.839	25%
diesel oil	26.400	7%
Oil	3.600	1%
Rubber	24.000	6%
Repair	38.400	10%
tax, assurance	66.700	17%
interest due	48.400	12%
writing off	75.250	19%
Surplus	10.000	3%
	388.589	

The technology

After the overview of the economic factors, we have a clearer view of which areas the technological components have influenced. We know the results; now we will discuss the causes. I will take the single technologies one-by-one. They could be mentioned around each single economic factor, but several of the new technologies have influenced more than one of the economic factors.

The tires

I will start with a technology that started around 1923, the balloon tire that was introduced by Firestone for personal cars and soon became the standard tire for those cars. It changed the transport sector because it was a low pressure tire that was very stable against punctures. Therefore cars could be used for daily driving.

It had other important consequences—it gave a much better suspension that could give a stronger and heavier body and motor—the new generation of cars around 1927 had this tire as a precondition. The other consequence was its gentle driving with much less wear and tear on roads than the old tires. More about this will be mentioned later.

It was in the middle of the 1930s that this tire could be made for heavy trucks. The construction of the karkas was lighter but the tire itself was larger and broader. Therefore it did not fit most trucks at that time and the new trucks had to be built to this new tire. After the war the tire companies tried to develop new, smaller types of tires and the layers of cotton ply (that made a rigid tire that developed heat that destroyed the tire from inside) were replaced by new synthetic fibers made of rayon, nylon or the like and the use of metal gave the tires a much more solid shape.[17]

The balloon tire had its success. A little of the revolution in the construction of personal cars came into action with trucks in the late 1930s with larger bodies built on this special tire. This époque did not have its breakthrough until long after World War II because the supplies first became available around 1950 or later. Some trucks came to Denmark in the 1940s, but the last restrictions first disappeared in 1952 when it was possible to buy trucks freely and when the factories could deliver.

Some very important new features for tires occurred during our time period. The radial tire was introduced for trucks in the early 1950s. In this construction the karkas was separate from the upper part with the tread and it gave a much better possibility for retreading. A karkas could be reused several times and it improved the economy.

Minor progress came in the 1960s with the tubeless tire. The tire became more stable and the air did not suddenly disappear but went slowly out in case of a puncture. Until 1980 no new technologies were developed, but the tires became specialized with specific construction of tires for each single use. There were tires for the steering axles with their straight patterns for exact steering, tires for the drive shaft with a pattern for driving and tires for the bearing axles. The supply was extended with tires for driving under heavy duty in gravel pits, broad tires and many more. It became a science to know the best tires for a specific type of truck and the governmental rules became more and more detailed.

Here is the place to tell the story about the effort to reduce the use of tires. The use of extra axles could spread the weight on more wheels. With the bad tires in the 1930s, this was necessary, but with the new improved balloon tire it was not necessary. After 1960 it became important once again to spread the weight and people realized the problem with the wear and tear on the tire could be solved by raising an axle when the truck had no load. This system was introduced by the Swedish truck builders Volvo and Scania Vabis and it was called the *Nordic boogie*.[18]

The road construction

The construction of roads was an important factor for the economy of driving. It was such an important factor that it needs its own chapter. The authorities always have tried to prevent too much wear and tear on the roads. Therefore they have made regulations to prevent the destruction of the roads. One important regulation was on the weight.

In the situation in Denmark it can be seen that the weight limits increased dramatically in 1939. The total weight increased from 8 tons and to 18 tons. The use of the balloon tire was an important factor behind this—at the same time there came restrictions against the solid tire. The increase was another reason for the use of hangers as will be described later.

The next increase in 1955 to a 32-ton total weight was one more important step forward for road transportation. Since 1947 there had been a general dispensation to 12 tons total weight and an axle weight of 7 tons but there had not been that many heavy trucks; they came now from the truck factories.[19] Again the use of hangers and more axles was important to protect the roads.

The increase in weight looked impressive but it was difficult to have such a heavy goods vehicle when the rule for a maximum axle load was 7 tons and a normal truck could reach a total weight of 9 tons. The increase in 1977 to 44 tons to 48 tons in 1984 had its explanation mainly in better road construction methods with the use of gravel and sand to build a stable bottom for the asphalt road surface.

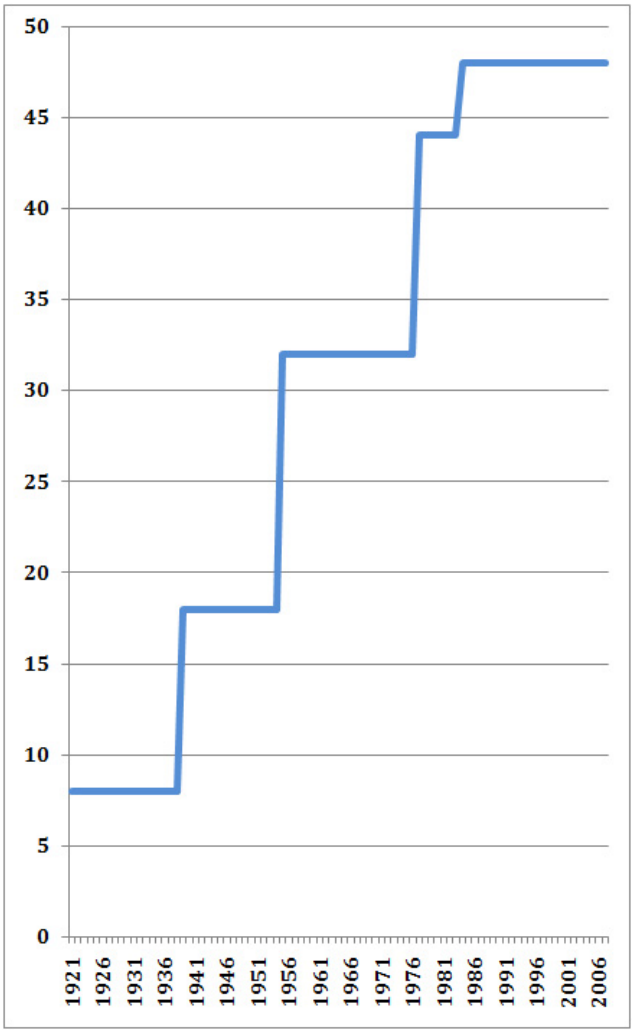
The illustration gives an impression of the general trend. There were a lot more regulations and rules. There could be dispensation so heavier trucks could drive on main roads. For instance the trucks for export driving were allowed to drive with heavier loads.

On the other side there were a lot of other regulations to lower the weight. With the spring thaw there could be a lot of prohibitions against driving by heavy trucks even on the best roads until the soil was not frozen, and a lot of bridges and small roads had road signs signaling the prohibition of heavy trucks.

The theoretical insight into the forces behind the wear and tear on the road made it possible to protect the roads more precisely. There were a lot of rules for the total weight for a vehicle according the distances between the axles, the percent of the weight on the steering wheels, the use of double tires, the use of new airborne suspension systems, etc.

In this time period the road builders got the insight that a heavy truck had the same wear and tear than 50,000 small personal cars. Therefore the taxes were calculated in such a manner that the tax increased proportionally with the weight of the truck. A higher allowed load meant a higher tax. The figure shows the overall limits. In large period of time the trucks could not make use of all the allowed weight.[20]

Fig. 2 The maximum load for a heavy goods vehicle in tons, Denmark



Another way to protect the roads was official rules for speed limits. At least for the first period the regulation had to protect the roads against the fast wheels that destroyed the roads by sucking the gravel up from the road and creating dust clouds. After the road administration gave the roads a surface treatment together with the new balloon tire (for personal cars), speed limits could be raised.

Another important factor was security. The number of traffic accidents rose dramatically after each increase in the speed limit. Only tedious work with the straightening of curved roads, broadening the roads, erecting of traffic signs, education and much more could lower the risks. The dramatic rise in the speed limits in 1953 was possible after many years work with the security problem. There was another more simple technological reason in the construction of the new generation of cars, including improvement in the brake system. Again the illustration only shows the general rule. In

reality there were a lot of restrictions on local roads, in towns and driving with special combinations of trucks and trailers.

Pneumatics and hydraulics

One of the more important technologies was the use of compressed air and later of compressed fluid. This technology was developed for the use of heavy trucks, heavy trailers and special machinery. Some of the trucks were equipped with a system for this before the war but in the 1950s it became a must for heavy trucks. This technology is behind many of the following technologies.

The brake system

Originally the brakes were a mechanical system with a wire from the brake to the two back wheels. It was sufficient to use this system when the trucks were small and driving at a low speed. When there was a trailer behind the truck this trailer had to have brakes too. This problem could be solved with building a house on the trailer where the brake man could sit and brake when it was necessary.

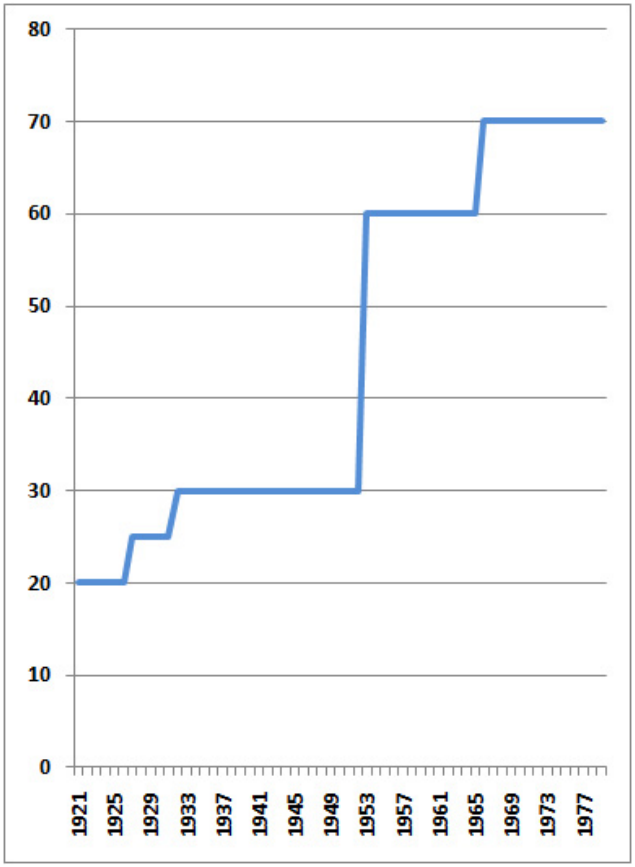
The mechanical brake was efficient enough at a low speed to brake a rather heavy truck. In Denmark, in 1950, a mechanical brake was used at trucks up to six-ton total weight but without any regulation the truck owners could drive with trailers with a higher weight. The new trucks—especially those from Germany—came equipped with a pneumatic system at that time.[21]

With the new rules about weight in 1955 and speed in 1953, better brake systems became necessary and mandated. In 1956 a claim was introduced that a truck with a total weight of 3.5 tons should have this new brake system. This new rule claimed a special pressure system, and the very old system with vacuum brakes became illegal to use for trailers; if the brake tube to the trailer was demolished the brakes should be activated when the pressure was felt. While the truck itself was allowed to use the direct brake, the brake system at the trailer had to be indirect. The system at that time in Denmark and Germany was the single string brake system while the trucks from England and the U.S. were two–stringed.

The trucks loading and discharging systems

Mechanical handling of the cargo became very important in this period. Mechanization had started, but with a functioning pneumatic system all the mechanical parts could be moved quickly. The loading systems in particular have been around for a while where harbors and gravel pits had their own loading mechanisms.

Fig. 3 The maximum speed for a 4-ton truck, Denmark



One of the most important systems for trucks was the dump body. It was used foremost for dumping gravel, earth, sugar beet, coal and sand in construction. With the short distances in this trade the discharging time was of extraordinary importance.

Its history is long. The first dump bodies were made circa 1907. The German factory F.X. Meiller made a dumper where two men had to turn a handle. The first pneumatic system was made in 1925 probably by this firm or by Scania in Sweden. The introduction lasted many years because it was rather expensive and labor at that time was cheap.[22]

Around 1950 many firms started to buy dump systems. There were two main systems. One could only dump back and another system could dump to all three sides. A dump could take less than 10 seconds and was controlled by buttons on the instrument table. The dumping systems were rather expensive. In 1950 a system could cost 3.450 Dkr. while a new truck of average size cost approximately 40.000 Dkr. The haulage contractor would only buy such a system if he had a large use

for it. It had to be included in the calculation of a trucks weight because mechanical tools like this have a high weight that had to reduce the overall weight of the truck.

Combined loading and discharging systems were also important tools. Several systems were introduced around 1950. Cranes became important tools for many haulage contractors. With cranes, heavy weights could be carried that would not have been possible before or only could have been handled with a lot of trouble, including more men.[23]

For example a crane with a capacity of 1.5 tons could fill a truck in four loads. The crane itself weighed 425 kg, giving a lesser load and an increased tax (calculated of the weight of the truck). Its price was approximately 7.000 Dkr. in the early 1950s, but it had such a large advantage that it only saved three hours of work a week. When the trucks became larger over the years, the crane's advantages became more obvious.

Special built trucks came into action during this time and tank trucks became common. For example, a truck with 20 tons fuel could be discharged at a rate of approximately 1 ton per minute.[24] A concrete mixer with a load of 1.5 m^3 (3 tons) could be emptied in 20 minutes. A few years later a larger concrete mixer with a load of 2.5 m^3 (6 tons) could be empty in six minutes.

The engine

The motor is important for drawing the load, the speed, the economy, reliability and a lot of other matters around truck driving. The most important technical development in this period was the introduction of the diesel engine. Rudolf Diesel obtained his patent on the engine in 1892 but it took many years before it was possible to construct a small engine with a higher rotation than the slow large engines. When a solid injection pump was developed in 1921 it became possible to introduce a commercial motor for trucks, which was done in 1924.[25] When the German firm Bosch marketed an injection pump in 1927, the time was ripe. Many other firms are using the Bosch system but only two firms in the U.S., Cummins and General Motors, are using another system with a pump at each cylinder.[26]

It took nearly 10 years before the diesel motor was introduced in the first truck in Denmark, but the introduction went slow thanks to technical problems with the engine. Slowly the engine became more common but in 1952 only 4 per cent of all the trucks in Denmark had this engine. In 1959 the share of diesel engines rose to 8 per cent.

The diesel engine was suited for the long trips. In 1958, trucks with this engine drove in average 40.000 km a year while the trucks with the gasoline engine only drove approximately 16.000 km.

In the first years there was another advantage—there was no tax on the diesel oil. In 1948 the price was 0.78 Dkr. for a liter of petrol and the haulage contractors could do it with a liter diesel for 0.26 Dkr.

In 1964, 13 per cent of trucks had diesel motors but the majority of larger trucks weighing more than 3 tons were diesel driven. In 1956, the majority of heavy duty trucks weighing more than 7 tons had diesel engines.[27]

The diesel engine has a higher efficiency than the petrol engine, and a liter of diesel oil contains more energy than a liter of petrol. In the 1950s, a diesel engine could save 35–40 per cent of fuel expenses.[28]

The motor was larger and more expensive. In 1948 it was 8.000 Dkr. more expensive, but in 1956, the difference decreased to 6.000 Dkr.

Before the war the difference in weight was approximately 500 kg, but in 1956 the difference decreased to 250 kg for trucks with a load of 6 tons and only 100 kg for a truck with a 3-ton load. The costs of maintenance were lower when there came repair shops with special instruments for this engine. Therefore a more expensive engine at 6.000 Dkr. would have been an advantage when the truck was driving 30.000 km a year or more. However, those calculations were not valid because in 1956 the state taxed this engine at a rate of nearly four times the ordinary vehicle excise tax, but diesel oil itself did not have a tax like petrol.

A new technology, *turbo,* was introduced around 1960. In 1953, Mercedes began producing a little serial but Volvo began building the first mass produced turbo systems in 1954. In 1966 only a few brands delivered turbo engines to Denmark. Those companies were Volvo, Scania-Vabis and DAF/Leyland.

The technique presses more air into the cylinders through a turbo-charger with air from the exhaust. The performance of an engine can be improved 30 per cent; with a special build engine the improvement can be larger.[29]

With these technologies, truck factories could deliver a broad range of specially-built engines for different purposes. One important factor is the torque that rotates the engine. An engine for a construction truck should have its highest

performance at a low speed while long distance trucks should perform best at higher speeds so they can handle mountain roads.[30]

An engine is often designated by its effect, which is measured in HP. This is not the same as torque—the formula is HP=torque (in kgm) x rotations per minute/716.2. Each engine is indicated by its HP number. This is important especially for trucks driving through Germany because a heavy goods vehicle should have at least 6 HP per ton (in 1972 that number increased to 8 HP). This regulation could reduce the tailback after slow trucks; that effect never could come close to that for personal cars with 50-150 HP per ton.[31]

The engine builders wanted to help drivers with an optimized engine with higher torque when they came to a rise. The high speed became lower and trucks had higher torque. The French firm Berliet (Renault) and the American company Mack made engines with these characteristics.

One of the new technologies was the intercooler that cooled the exhaust air and gave the truck a higher torque. In 1976 Scania introduced its slow hauling engine and other manufacturers soon followed.[32]

An engine with a high rotation is not always a good solution. It is necessary to look at the maintenance too, because slow engines have less wear and tear. If a high rotation engine often has to be repaired, a slow and more stable engine might be a better solution.

Gears and gear boxes

Gears have to be mentioned in conjuction with engines. The high rotation of an engine has to be transformed to a lower rotation through a gear. There are often 10 gears or more for heavy trucks. I will not tell the whole story about gears but I will mention some of the most important developments in this period. Remember that trucks grew in size and the need for complicated gears also increased, especially at slow speeds on soft and rugged ground at construction sites, for example, where several gears are necessary.

For small cars, the ordinary four-step gear box and the later five-step gear box were sufficient, but larger trucks needed more gears. It is difficult to build gear boxes with more than five steps, which brought about a longstanding solution. In 1933, the American firm Eaton started production of its rear-axle second gear. Add a five-step gear box and the truck had 10 gears.[33]

The construction has changed very little. Original the shift was mechanical through wires or an operating lever device but in this period shifting through electricity or pneumatics began. Many truck factories still used the Eaton-made gears but Bedford, Mercedes and Volvo made their own constructions.

This rear-axle second gear has some drawbacks; especially in heavy trucks this gear would be too big. Therefore, companies developed ordinary gear boxes with many gears, or a splitter gear box. For example, the German ZF has an eight-step gear box from an ordinary four-step gear box combined with a reduction gear.[34]

One of the many improvements was the *torque amplifier* introduced originally in automatic gear boxes for personal cars. The torque amplifier came into production for manual gears for trucks in 1970 at Volvo and German truck producers. Its main advantage is its nearly-zero wear and tear and a reduction in gear shifts.[35]

The truck chassis and construction

The beginning of the paper discussed developments in truck weight. This chapter will give more details about truck construction.

Denmark had only a few small factories for trucks. In this period only small factories were still in action. In 1950, General Motors, Ford and some foreign firms still had large assembly plants, but for the most part, trucks were imported.[36] A large part of the trucks were imported as bare chassis even without the driver's cab. The trucks were completed at body shops.

With this system there was a unique possibility to tailor the truck to the exact need. The platform could have the desired length and a special build, closed or open in many variations. The engine and the gear could be ordered for specific needs. In the 1960s companies began building trucks with three or more axles.

Besides the traditional truck, a lot of specially built trucks came along such as tankers, wrecking cars, cement mixers, etc. A rather special type became the drawer to the special trailer, the hanger or semi-trailer that will be mentioned later.

In 1968 there were 314 basic types offered on the Danish market, and with many possible variations of each type there could be thousands of different combinations.[37] In all there were 17 different marks offered on the Danish market, each with their own profile. Some marks such as Ford offered small standard trucks, while others like Scania offered large trucks.

An interesting question is the quality, where a difference between the brands can be seen. Some marks like Bedford were meant for modest yearly driving lengths while Volvo was of a normally

higher quality (and more expensive cost) for export trucks.

One part of the construction of the truck became important—the drivers cap. A new type of cab became common, with the cab situated over the motor. It was a better place for the driver to sit and navigate in narrow roads in towns but the most important reason for this type was a different weight distribution. The steering axle could have a higher weight and because of the rules for the distribution of weight this type of truck could carry a total weight of 10-10.5 tons while the ordinary cab type with a nose for the motor could handle approximately 9 tons. The platform could be 40 per cent longer and was easier to turn around.[38] This cab often was necessary because of a rule on the maximum length of a truck with a trailer. By taking the "nose" away there could be more room for the load.

The trailers and semi-trailers

As long as there have been trucks, there have been trailers. Today, this use is regulated and in opposition to Sweden only a single trailer is allowed behind a truck. The idea with a trailer is to spread the weight on several axles. New kinds of trailers have seen the light. The semi-trailer is one of those types. In Denmark in the 1970s, export trucks were not allowed to have a length of more than 12.9 m from the drawers front axle to the last axle on the semi-trailer and an overall length of 15 m while the ordinary trailer could have an overall length of 18 m and a distance between the first and last axle of 18.9 m.[39]

The relatively large popularity of the semi-trailer can be explained by the rather small distances in Denmark. In a small country the load and discharging time is a large part of the total transport time. Therefore it is appropriate to drop the semi-trailer and drive away with another full or discharged semi-trailer.

There are other advantages. The costumer can fill the semi-trailer and the load does not need to be unloaded before arriving at the final destination, reducing the risk for theft and destruction.

Those semi-trailers soon became popular on the roll-on, roll-off ferries. After 1964, the ferries to England organized by Ferrymaster were filled with semi-trailers and the ferries did not need to carry the semi-trailer truck. At first, the loads were of general cargo and later bacon came on the ferries from Esbjerg. In 1966, a Danish bacon export company bought 400 semi-trailers with cooling facilities and 70 drawers.[40]

In the 1960s, an effort to standardize the saddle began so a semi-trailer could be linked to any semi-trailer truck.

As with trucks the semi-trailer can be built for all special purposes including the container carrier, curtain, flat, general cargo, isothermal, tanker, textile and tipper semi-trailer. In 1980, the total transport work was 7,850 billion tons km, with nearly two-thirds of this driving with trailers and only 2,722 billion tons km on solo trucks.41

Containers

Containers often are used for transport between different transport forms. The Danish shipping line DFDS introduced small containers in the late 1930s. The containers had the same base but had different shapes, with the largest at 3 m^3 and a maximum weight of 2.5 tons. In the late 1950s, the company also could deliver isolated containers. It lent the containers to its customers for a small fee and most were transported by trucks. The company's new boats were built for this new transport system with hatches in nearly their full length, with lock handles to fix the containers and other features in some of the world's first container boats.[42]

The European railways have used containers for many years. In 1962 the Danish State Railroads had three different sizes of containers—an A container with 1 m^3 of content, a B with 2 m^3 of content and C container with 3 m^3 of content.[43] For transportation of deep-frozen goods there were isolated containers in the A and B size and small isolated containers too that held 165 liters.

In 1966 a new transport system came into when the first container boat crossed the Atlantic. To this points, there had been a lot of container systems but soon this system became a worldwide standardized reality. It became a door-to-door service with truck transportation in at ends nearly always.

In 1967, container sizes were standardized. First came an ISO standard for how a container should be built with fittings for lifting, how stable the container had to be for driving with forklifts, etc.[44]

The standardized 10', 20', 30' and 40' containers became very important for the transportation to and from foreign countries far from Denmark. They could be transported on special semi-trailers, but occasionally two could be transported on a truck and its trailer. The maximum weight allowed in 1970 for at 10' container was 10 tons and for most common 20' container, the weight was 20 tons. Those 20 tons could not be transported on an ordinary truck but if the containers were filled with

lighter goods the semi-trailer was not necessary.[45] Soon the infrastructure was established with heavy cranes at railways and large harbours.

Other than this, many rules should be made. One of them was the national authorization of containers in 1980 when Denmark approved an international convention from 1972 to secure the containers. A lot of rules for the strength, charging, control and much more were mandated.[46]

Pallets

Wood packaging always has been used, and this is the case of the pallet, used as a platform for assembling, storing, handling, and transporting materials and products in a unit load.[47] In the 1930s, companies began using pallets with forklifts. The Danish shipping line DFDS started using small containers in the late 1930s, along with small platform trucks.[48]

The pallets were used on a large scale during World War II by the military. Between 1941 and 1945 more than 50 million pallets were made in the U.S. In 1946 the food-processing industry, among others, recommended 40" x 32" and 40" x 48" pallets, with other recommendations later.

The idea of pallets is best when standardized pallets can be reused. The first pallet pool in the U.S. was formed in 1945 in the brick industry, and the first national pallet pool started in Sweden in 1947. Thirteen national pallet pools operated in Europe, managed mainly by the railroads.

Since 1962, the Danish State Railroads became a member of the European pallet pool. The pool had been underway for many years, but the railroads could not come to an agreement about the size. Germany and the Netherlands used a pallet of 1 m x 1.2 m, while other countries used pallets that were 0.8 m x 1.2 m.[49]

At last Germany agreed with the smallest pallet and in 1959 a thorough specification was stated. The EUR pallet was born with this dimension and in a quality that could handle 1-ton goods. Later it was stated that this EUR signature and the name of the national railroad should be on the pallet. There is a freedom to choosing wood. In Denmark and most other countries the pallet is made of pine or fir, but in Italy and France the pallet is often made of hard wood.

The design of the pallet gave it many advantages. It could be taken by the forklift from all four sides and it could be handled by a sling in a harbor, and a box for transporting loose artifacts can be placed on a pallet.

After some years the pool came in action and by 1962, nine countries were members. In 1966, 14 countries were members, and Denmark had 17,000 pallets owned by the State Railways and 23,000 owned by private firms; on average there were nine pallets per 1,000 inhabitants.[50] The pallets were made to standards and the International Road Transport Union recommended to truck and van producers that they build their vehicles to the measure of the EUR pallet.

With this pallet the conceptions of logistics became real. The transport system was no more only a matter of transportation from A to B, but there was something before A and after B. The pallets became an important part of the storage facilities at factories and in storehouses.

The truck producers and the body builders soon made vehicles and truck bodies according the pallet measures. The maximum width of a vehicle was 2.5 m, according the European rules; because there should be place for hinges and locks, the largest German truck factories, Henschel, Krupp, Faun, and Kässbohrer, made their vehicles 2.42 m wide. Often the traditional wood sides were replaced by thinner materials such as aluminum or glass fibre.[51]

The forklift and the one-story building

After the war the haulage business could read stories in its trade journals about how the forklift was used in the U.S. Large warehouses had forklifts to handle the goods, and they could be used to fill and empty semi-trailers. One of the articles was illustrated with a picture from the freight center in Copenhagen with a queue of trucks waiting to be discharged and loaded; this tool could help the business.[52]

The forklift was not a new invention. It was developed from small platform trucks and got its important final design with forks in 1923, when Yale launched a series of forklift trucks.[53] In World War II the forklift and pallets were important tools.

In Denmark it probably was introduced before the war; it could be seen in action in the harbor of Copenhagen very early. The shipping company DFDS started using containers and platform trucks in the late 1930s, and after the war the company bought forklifts as soon as trade became possible.[54]

DFDS was the leading shipload company in Denmark for general cargo and it soon had forklifts in all of the harbors it sailed to, 39 forklifts in all. A truck could be loaded or discharged in few minutes thanks to them.

In the early 1960s, the trade journals were filled with stories about how much help the forklift

was in internal transport and loading and unloading trucks. In 1963, Danfoss, the large machine works, built its transport system around the use of forklifts. Approximately 3,000-4,000 tons could be handled each day with only 14 forklifts, five electric stackers and three electric lifting trucks. In 1957, it had five forklifts and two lifting trucks and they were all slower and smaller.[55]

The trucks alone could not do it alone. Approximately 20 per cent of the money invested in the transport system was for the transport vehicles mentioned, while 80 per cent for the 12,000 containers, 10,000 pallets and 50,000 steel boxes. There is an obvious advantage in using such a transport system. At a grocery warehouse, with a truck could be emptied with a forklift in 15-20 minutes; by manual work this would have taken two hours.[56]

With those advantages it is surprising that the introduction of the new transport system did not happen faster. The graph shows that the introduction went rather slow and had first its fullest adoption in the late 1970s.

The investments in forklifts, pallets and containers naturally were a large investment but with the promised advantages those investments alone should have been paid back in few years.

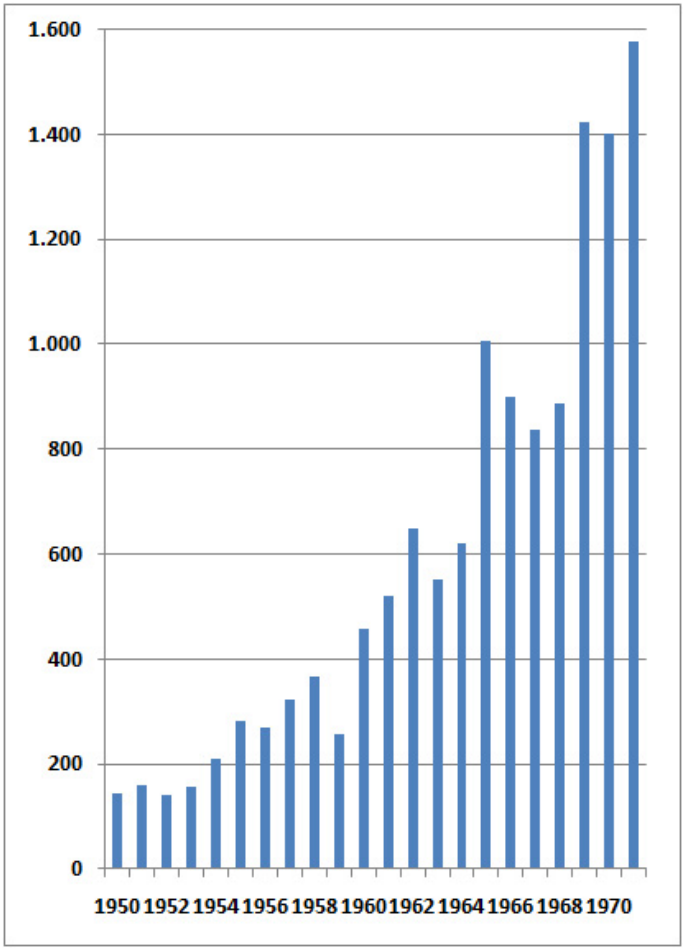
The purchase of a new semi-trailer that was perfect for the new transport system was another hindrance to the introduction. However, this was not the main reason for the delay of the system because road equipment had a rather low life cycle of approximately 4-8 years. Within this cycle, the introduction would have been faster if it depended only on this factor.

The new transport system was hindered by a special internal need for truck driving. Whole warehouses or factories had to be one-story if the total potential of the transport system should be exploited. The floor had to be made of a very durable surface with only small leveling differences. Especially in factories the whole system of internal transport roads needed to be reorganized, including a change of the whole machine layout with often very heavy machinery and matching foundations. Approach ramps were necessary for trucks so forklifts could drive directly into the semi-trailers or truck body. Those investments were so extensive that it delayed rapid change.

Specialized vehicles such as a refrigerator truck

Transportation is more than moving something from a point A to point B. In the above formula transport is a simple value but in reality there are also additional qualitative values. Tankers can provide secure transportation for fluids and for food they can deliver a high level of hygienic treatment. A truck for transporting cement is also a cement mixer. One of the most important special vehicles, the refrigerator van, will be discussed and described in more detail.

Figure 4 New forklifts in Denmark



For many years the transportation of perishable food such as fish was done with ice cooled boxes with ice from ice factories. The insulated closed truck body was introduced for longer distances. There were not many of this kind compared to the railroads with many reefer cars.

While stationary refrigerators have been used in the U.S. 1915—60 per cent of U.S. households had a refrigerator in the 1930s—they were not introduced in Europe until later. Therefore, refrigerated trucks were introduced as "rolling refrigerators." The cooling machinery was of American origin from the brands *Thermo-King* and *Therm-O-Matic*. The invention of a stable system suited for trucks was made by Thermo Control (later Thermo King) in 1938 and was soon marketed to the American army.[57]

In Denmark the new method was offered after the war but installations did not begin until the 1950s. The refrigerated body meant a higher quality in many ways. For instance, melted ice would not cause the problems it did in the summer when trucks transported fish and where the stench from the fish water on the road caused problems.

In the 1950s, the car body often was built from new materials such as aluminum and polystyrene. With

increasing exports to foreign destinations, the return freight became important and the refrigeration system was made in such a way that it also could be used as a warming tool. After freight with meat in -25º the heater could heat the car body and a load of bananas to 20º, for example.[58]

Radio communication

In the long row of new technologies, radio is one of the important. It provided a connection between the haulage administration and the driver. Before the radio, the driver had to phone the office several times a day to hear about upcoming jobs or a haulage contractor had to drive out in his local area to contact his drivers when he got new jobs for them. It is obvious that this system has not been the most efficient or fast.

This possibility of communication was especially important for handling return freight. The office could make an agreement with a customer if they knew their truck would be ready for this return freight. Without contact the truck could be delayed or there could be other problems with the acceptance of new freight.

After World War II, radio systems could be installed in trucks. The technology was based on a base station with its own mast connected with a cable and with a receiver in the car. In 1949 such a system was installed at a company for gathering meat. Its eight trucks could get information about new places to visit thanks to the radio and it meant that the firm could spare 1-3 trucks.[59]

The National Post and Telecompany could deliver a service but it was expensive and slow. The worst part of its use was its limited coverage of only Copenhagen and 20 km from the town in 1955.[60]

Through a radio station it was possible to have a duplex connection but most users were content to use the walkie-talkie system with the "shifter; over" message. The distance from the antenna to the cars was 10 km to 70 km, depending on the placement of the mast. This distance was acceptable for local services such as taxi-cabs and haulage companies with local traffic; long distance driving could not use the system yet.

While radio communication could reduce the empty return driving by approximately 65 per cent for local haulage companies, it took longer for long distance transportation to get the same service.[61] The National Post and Telecompany expanded its service throughout the 1960s and in 1969 had approximately 1,250 customers connected to its service.[62]

In 1979 it was only possible to have a radio connection to Denmark, Sweden and southern Norway. No other international connections were possible. The statistics show that there were 12,254 costumers at the Post and Telecompany's radio service with more than 10,700 from haulage, factories and similar costumers. More than 26,000 companies among the total 58,085 customers had their own radio station.[63]

Computation, lubricating oil, infrastructure and much more

The haulage business had a lot of new technologies besides those mentioned earlier. This section will mention some of the more important technologies.

The use of computers began slowly in the business. The first contact with this new technology was when haulage contractors could book a place on a ferry owned by the national railway company in 1957. The company decided to introduce this service at its new ferry between Sealand and Funen, and it chose to use a system based on the counters at telephone centrals and with a telex to make the reservations. Those telex machines were installed in offices around the country and the haulage companies could reserve a space two months in advance.[64]

The regular use of computers began in the 1960s. EDP was effective to handle warehouses and most of the largest wholesale dealers and large companies handled their stocks with computers. Long lists of endless computer prints were made in the machine rooms.

The containers mentioned earlier were gathered in pools and they could not have existed without computer controls. The international transport organization ICHCA planned a container pool in 1968. If each company used its own containers it was calculated that the need was 1,600 containers. If the companies pooled their containers the need was only 1,000 containers. This new information system kept track of the location of each container, when it was released and where it should be sent.[65]

In 1970 the big companies began to use computers to plan their distribution in detail. At that time the computer systems were based on a few central computers that "drove" the punch cards or paper tape once a day. The systems were very stiff and a good plan could be destroyed by few unforeseen incidents if an urgent matter should be executed or if drivers became sick.[66]

Technological progress can come in small but important areas. The use of new lubricating oil is one of those. In the late 1970s, the new multigrade oils came to diesel engines. This kind of oil had been used in personal petrol cars for years but it had been a challenge to construct such oils for the diesel engine with its higher temperature. They were made with several advantages where a better fuel economy was important. Another advantage was their better lubrication characteristics that meant less wear and tear and reduced oil shifts.[67]

New technology could have an organizational side, too. When the new long distance diesel trucks could drive through Europe it became necessary to have service stations across Europe for those brands. Therefore, only the biggest companies could secure their customers at a short wait if technical problems arose.

The economy then

For many years was the economy very simple. If the haulage contractor had money in his pocket when all his expenses were paid he had a surplus. Most of the haulage contractors were small family-owned companies. In the beginning of our period they were not forced to make accounts. Around 1950 it became mandated to file their income and the situation changed dramatically. The companies had to keep track of everything. The driver's time was recorded through tachographs and a lot of reports were made to a lot of new public offices. The economy became more scientific. Education in transport economy came into the business schools and in 1969 an organization for transport economy was formed. Though they were aware of the importance of the economy there were no established theories and practical accountancies that could be used in this paper. The analyses were not detailed enough yet.

Can we say anything about technology and economy?

Yes. New technology means a better economy, but it is not possible to give exact amounts of each new technology. The reality is too complicated. This complicated picture was realized by Thomas Thorburn and he tried to improve his formula. The new expanded formula became:[68]

$$C(x, w) = 2\ A_1(w)(j/w + 1/t)/gi + x(A_1(w)\ (F(w)\ (1+m)/w)/gis_1w$$

A_1=wages, provisions, depreciation, interest, taxes and profits, etc., per year and vehicle
g=hours in service per year
j=initial time at terminals in hours per call
m=length of empty trip in proportion to previous trip
s_1=speed in kilometers per hour in normal service
i=effective time as proportion of time in service

The first part of the formula is the terminal cost and the last is the underway cost. If there is a return load, the cost price will be the first part of the formula because the second part has already been paid.

The formula seems rather reasonable. The new factor j is interesting because it tends to be reduced because of *organizational* matters. An effective organization will tend to reduce this, but by this there became an increase in the overall expenses to pay for the organization that will expand A_1, which is therefore a trash can (or a black box) where many different factors can be placed.

With caution I will try to make a loose judgment on the influence of single technological factors on the economy as shown in Table 3. For each of the factors mentioned earlier, I have made a qualified estimate from the empirical knowledge of the change between 1950 and 1980.

Table 3
Improvements caused by technological innovations

weight	500%
speed	100%
tires	100%
fuel	100%
loading and discharging	900%
empty trips	10%

By those numbers, the calculation will be pretty near the situation in 1973 as stated by Thorburn. Further studies will show more exact data about the improvements. The black box should be opened a little for covering the formula. The "A" factor should be split up into the following factors:

Driver's wage
Haulage company administration
Public investments in infrastructure
(paid by the tax):

a) roadbuilding
b) technical control of trucks
c) control of trucks and traffic by the police
d) environmental issues, etc.

The old formula was suited for a society where the haulage business was driven by family-owned small firms. Therefore it was not necessary to include administration in the formula. The formula was suited for a very weak society without support to this part of the transport sector. For today, the state has become a necessary player in the transportation sector.

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