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# Peculiarities of Heavy, Oversized and Hazardous Cargo Trasportation

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**ABSTRACT**

The article analyzes the peculiarities of different transport modes indicating the advantages of cargo transportation by motor vehicles. It is shown that the transportation of both dangerous and oversized heavy cargo, especially in mountainous areas, requires strict observance of safety rules, especially when about 20 % of the total cargo transportation includes hazardous cargo. It was also noted that there are tools and equipment (cargos) that requires professional rolling stock for transportation, while for some cases special means should be created for transporting the given cargo, including platform, trailer, trolley, etc.

## Introduction

Cargo transportations have been implemented with ease since the times when a human being invented the wheel and was able to tame some wild animals using them as traction force. Currently, most of the cargo transportation is carried out by water, rail, air, motor vehicles and pipelines. Each of the listed means has its fixed place with its characteristic advantages and disadvantages. Depending on their geographical locations, many countries cannot use all of the abovementioned methods. In this view, the ovrwhelming majority of cargo transportation in the territory of the Republic of Armenia is carried out by motor vehicles and the small part - by the railway transport, as the railway network is not widespread. In this respect car transportation has a number of advantages among which the following are worth to be mentioned (Savin, 2002, Khmelnitski, 2017):

- fast transportation organization with the scheme of "up to the destination point",
- control over the cargo throughout the whole transportation process,
- ad-hoc route modification depending on the situation,
- economic feasibility due to lack of intermediary actions.

On the whole, cargo transportation by motor vehicles is more costly as compared to railway and water transport depending on the ton/dram ratio of transported cargo. However, it is a faster means of transportation, especially for oversized and dangerous cargos. The following types of cargo transportation have been distinguished: intracity, intercity and international. It is apparent that for the first two variants, there is no any alternative for motor vehicle transportation. Meanwhile, in case of international transportation the cargo quantity, its type, time factor and

transportation costs should be considered and then the preferable transportation mode for the specific case should be implemented.

**Materials and methods**

The hazardous cargo can be transported equally by all the abovementioned types of vehicles, and in all cases the safety rules applicable to the transportation for each type of dangerous cargo must be complied with. There are many cargoes under this category, including explosives, ammunition, fireworks, compressed gas, liquefied gas, frozen liquid gas, dissolved gas, other chemicals that cause suffocation, oxidation, easy combustion and poisoning. Nitrogen, argon, helium, xenon, neon and carbon dioxide are among the suffocating gases. Oxygen, air, nitrous oxide and fluoride are the gases that contribute to combustion (fire). Ethylene oxide and chlorine are quite dangerous. This series can be still continued; therefore, when transporting such materials, first, it is necessary to get acquainted with the international agreement - ADR, which coordinates and organizes the process of transporting dangerous cargo in Europe (Pakhno&Shok, 2018). It should be pointed out that the types of dangerous goods have their own logos, which must be posted on the car transporting the given cargo.

The danger of aforementioned cargo types is mainly due to the fact that vehicles loaded with such cargo can leak resulting in explosion or fire due to technical problems (valve opening, cracks, etc.) or, more likely, due to traffic accident, which can cause great damage to the population and the environment. To minimize all these, the cargo/ goods of dangerous class should be transported only by professional transport vehicles. In some cases, it is also preferable to use additional security measures, such as blocking roads for other vehicles, providing escort headed by a patrol with appropriate functions, organizing transportations only at certain times of the day and so on.

A clear example of the large-scale cargo transportation in mountainous conditions is the transportation of the sailing ship “Cilicia”, made by a group of enthusiasts, from the Republic of Armenia through the territory of Georgia to the Black Sea and its return. Special trailers used for transportation of hydro turbines for hydroelectric power plants were also used in this case taking into account the dimensions and weight of the ship’s body (length - 20 m, width and height - 5 meters each, weight - 25… 28 t before navigation and afterwards as a result of water absorption). If we take into account the dimensions of the towing car as well, the total length of the motorail makes about 30 meters, and such a giant had to pass through Dilijan, Pushkin mountain pass and the other roads with abrupt bends. It should be mentioned that according to the traffic rules, the maximum height of vehicles is 3.8 m and the length is 24 m. The difference is very significant, regarding the height, as there is a problem of passing under many bridges. In such cases, a specially designed trailer is definitely used. We have participated in the transportation of 2 oversized cargos, which are shown in figures 1 and 2.

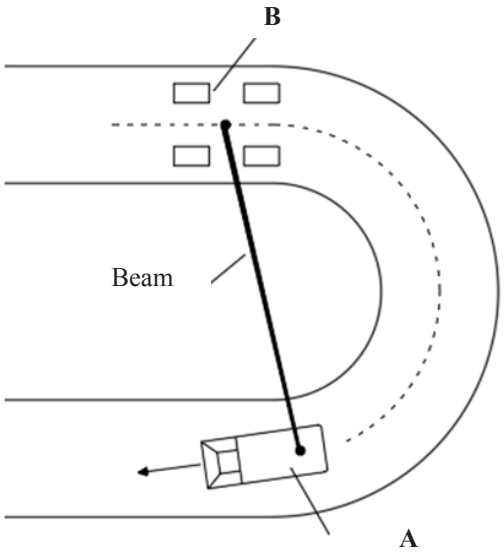


**Figure 1.** Diagram of semitrailer motion designed for transporting the shovel of the wind power plant (*composed by the author*).

Figure 1 clearly shows that two equivalent approaches can be used to move along such trajectory: a) - “B” trolley has its own engine and steering system driven by the second driver sitting there and b) - when the trolley is automatically controlled, during which the trolley moves in the direction of the traction motor. The transported oversized cargo can be a wind power plant shovel, elements of archs for field irrigation, bridge structures, etc. Surely, the structure of the beam must contain telescopic elements so that it is aligned with the length of the specific cargo. The turning radius of the motorail with a semitrailer of classic structure is formed according to the following scheme:

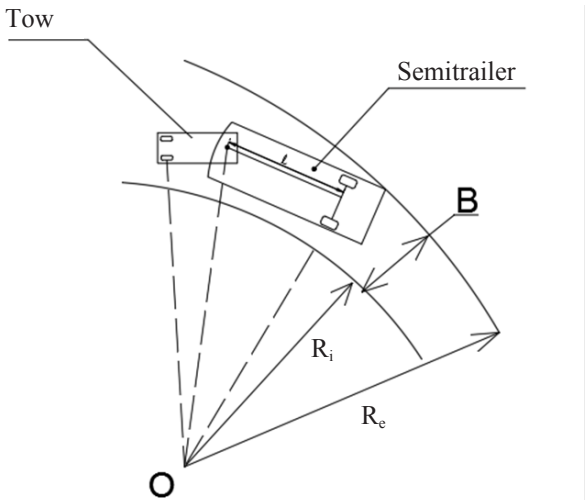


**Figure 2.** Diagram of motorail turning (*composed by the author*).

Depending on the "l" size and the needed turning radius, the "B" size of the passage occupied by the motorail undergoes significant changes causing a great difference between the motion trajectories of the wheels in the tow and semitrailers.

We also see the similar picture when transporting the sailing ship "Cilicia":

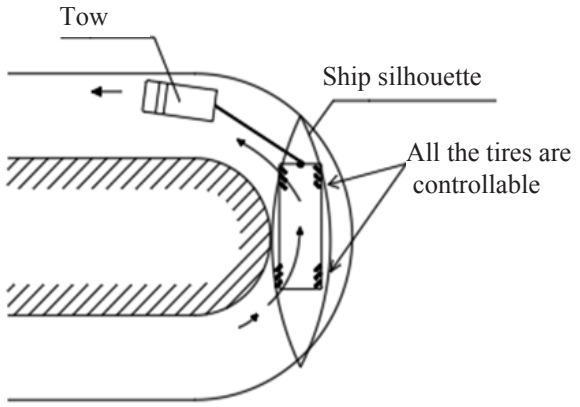


**Figure 3.** Passage of "Cilicia" ship through "Dilijan" bends (*composed by the author*).

**Results and discussions**

As it was previously mentioned, about 20% of all cargo transportations include different types of dangerous cargo (Pakhno&Shok, 2018). In order to correctly and safely organize transportation of dangerous and oversized cargo it is necessary to follow the changes taking place in the legal area of the sector, as well as to plan serious preparatory works aimed at the preparation and selection of the rolling stock, trainings of the driving staff, labeling the vehicles with special labels based on the type and peculiarities of the transported cargo. It is not ruled out that even without a traffic accident, fires, explosions and other incidents may happen to dangerous cargo by other reasons. It is noteworthy that the United Nations (UN) has compiled a list of hazardous substances (more than 3 000 names), each of which has its own four-digit code, according to which the transportation of the cargo type must be organized and implemented. According to these rules, each type of dangerous cargo is transported by a special professional vehicle and the drivers receive special instructions. In order to ensure the safety of cargo transportation, the corresponding vehicles must be equipped as proper, the drivers must take additional professional training courses and obtain a relevant certificate, based on which they are allowed to transport such types of dangerous cargo. In this case, the comprehensiveness of the documentations related to the cargo transportation is also quite essential. It is noteworthy that since 2013 all vehicles carrying dangerous goods must have a satellite control system via GLONASS (Information and Analyses Center for Positioning, Navigation and Timing). For safety purposes, drivers carrying such cargos must be completely informed about the hazardous properties and consequences of the transported cargo, be ready for rendering the needed assistance during accidents and be aware of the options for eliminating the consequences.

In mountainous conditions, the safety-related problems in the transportation of hazardous materials become even more complicated. The steep descents and ascents, winding roads, abrupt changes in external atmospheric conditions that adversely affect drivers, need to be adjusted. Taking into account the aforementioned, we find it expedient to have a second driver for such cases and to equip the car with the automatic facilities transmitting the appropriate warning signal (regarding the cargo type, its quantity and the place of accident) to the department responsible for the emergency management. There is apparently a great demand for the transportation of oversized cargo by motor vehicles. Oversized cargo is usually a structure of specific designation or equipment of the energy sector (nuclear power plant reactor, turbine, generator, transformer, wind power plant pillars and shovels, ships, etc.). Oversized cargoes include those which are super heavy, but the sizes of which are not very large or those relatively not heavy, but large in geometric sizes, as well as those in which both the sizes and weight are large. There is an individual

approach towards each abovementioned variants which consists of the selection of corresponding vehicle with tows (if necessary) and determination of the transport route. It is evident that apart from merely technical issues that arise during the transportation of both heavy oversized and hazardous cargo, which are solved by the cargo transportation company, many other problems come forth, the solutions of which are provided by other relevant departments. Among such issues we can single out the following ones: passing ability under the air power networks and bridges, passing ability under the tunnels, the cargo loads of the bridges, passing ability under the gas pipelines or other pipes, the traffic suspension of other vehicles in the route, etc.

When studying the auto transport means designed for transportation of oversized and heavy cargo, we see a great variety. However, depending on the specific road conditions, occasionally it is impossible to use them and in some cases platforms have to be designed for the transportation of the heavy or oversized equipment (Gromakovski, 2009). Here semitrailers transporting the wind turbine shovels can be involved. The length of such shovels in some cases amounts up to 80-100 m. The transportation of oversized cargo becomes rather complicated on the mountain roads due to abrupt ascents, descents and bends, in particular. The latter have fairly small curve radius, especially in mountain passes, and for the majority cases in such locations it is also impossible to build a temporary alternative road.

To avoid the problem, a controllable trolley is used. Uninterrupted motorail driving on a twisted road presumes combined trajectories for the motion of the tow and trolley wheels, which can be ensured by the second driver sitting in the trolley. Anyhow, it is more expedient to use an automatic steering system that will ensure identification of the trolley trajectory in accordance with the trajectory of the leader (tow). It is known that currently motor vehicles moving without any driver are being used according to the selected route, the automatic control system of which operates based on the data received on location, road network, traffic organization in the given sector and on many other online data. In this case, there is only one baseline datum, which is related to the trajectory of the leader's motion. Now let us see how to interrelate the trajectories of the leader and the trolley.

The motion is observed only on the x, y plane. The leader in position $O_1$ has the coordinate ($x_0$; $y_0$) and $\alpha_0$ angle against the meridian. Each $i$ position of its trajectory is definite (the data are obtained from an electronic gyroscope and a locating device) and is entered into an on-board computer, based on the signals of which the wheels of the trolley are operated so that the $O_1^u$ point passes through the same $O_i$ point. The towing power of the trolley wheels is provided by electric motors.

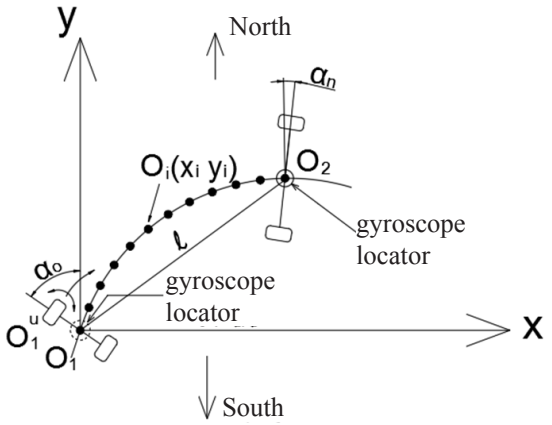


**Figure 4.** Trajectory marking diagram (*composed by the author*).

*The scientific novelty of the current research*

Simultaneous use of the virages in the curved sectors is the standard adopted in road construction. The structures viewed as oversized are very often transported through direct fields, which have transverse slopes with ($\varphi$) angle (figure 5).

As a rule, after loading the oversized structures, the "$h_g$" size of the gravity centre in the motorail considerably increases and there is a need to study and estimate the changes affecting the transverse stability of the motorail at that time from the prospect of the circumstance that the trolley rotates with $\alpha$ dimension against the semitrailer body, depending on the location. The "*C*" point of the tire rotates around the "*O*" point along the "*R*" radius:

$$R = \sqrt{\left(\frac{lu}{2}\right)^2 + \left(\frac{B}{2}\right)^2}.$$

As a result of the trolley rotation, the removal size of "*C*" point from the motorail axis will be:

$$\Delta B = R\cos\alpha - B,$$

which shows that "*D*" point moves inwards with equal sizes. Therefore, equivalent changes take place in the loads of "*C*" and "*D*" wheels. In other words, if $P_C = P_D$ interrealation occurs on the horizontal road, where Ps are the loads on the corresponding tires, then the following occurs on the curve:

$$PC + \Delta P > PC - \Delta P \text{ dependence.}$$

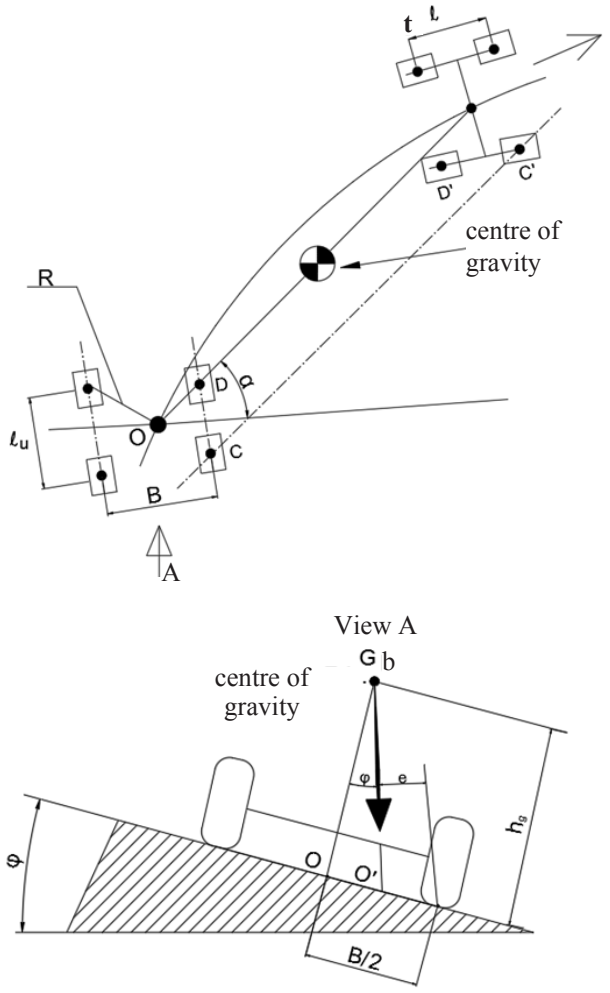


**Figure 5.** Redistribution of the load weight of the oversized cargo during the virage turning (*composed by the author*).

Due to such change in forces, the tires respond by modifying their initial characteristics, basically, in "*C*" wheel the support angle increases. Thus, to ensure a constant situation we find it necessary to apply an automated tire pressure adjustment system, where in each case "*O*" static load of the support point accepts the nominal pressure limit of the tires as a basis, which is subject to the dynamic changes based on the following relation for *C* and *D* tires respectively:

$$\Delta q = \pm f(\alpha).$$

The same regularity is true for the other tires as well.

**Conclusion**

The transportation of oversized cargo requires detailed planning for work organization, in particular:

- selection of appropriate vehicle,
- recruitment of the drivers with relevant qualification upon the instructions on cargo characteristics,
- optimal (safe) route development,
- marking the stops and fuel filling stations,
- additional cargo-related functions (labeling, illumination, etc.),
- legal functions (insurance, etc.),
- other organizational issues related to transportation.

In order to make the transportation of the cargo under the mentioned category safer and more efficient, we suggest installing video cameras and radio-communication in the driver's cabin so as to get in contact with the maintenance personnel. The analysis introduced in the current article can be also beneficial for agricultural sector, particularly for the transportation of special systems for orchard and field irrigation, the length of the details of which can reach up to 60 m.

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