An analysis of traffic flow distribution on roads

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Abstract Traffic intensity is the main parameter determining the road category and all other road design and construction requirements. The aim of this article is to study patterns of traffic intensity on the example of a local highway Egorovshchina – Ryazanovshchina in Irkutsk region. The article presents results of traffic intensity measurements by hours and calculation of reduced traffic intensity taking into account the traffic flow depending on the number of axles and load capacity. Diagrams of the hourly dependence of traffic intensity and traffic flow distribution were created taking into account the traffic flow mix. Traffic intensity reduced to a passenger car was calculated. The research result is patterns of traffic intensity distribution by the traffic flow mix required for calculating reduced traffic intensity.

To ensure safe traffic on roads with permitted speed, it is necessary to know characteristics of the existing and predicted traffic intensity, taking into account the traffic flow for a specified period.

According to the Technical Regulations of the Customs Union, “traffic intensity” is the number of vehicles passing through the section of a road per unit of time (day or hour) \cite{1}. The traffic flow composition is the share of vehicles simultaneously involved in traffic.

Existing regulatory documents \cite{2} establish methods for calculating traffic intensity and traffic flow composition.

The methods used to calculate the traffic flow are divided into two groups: automated and visual. In terms of duration, accounting for traffic intensity is divided into long-term and short-term. With any method, the data should contain information that is a multiple of no more than 1 hour \cite{2}.

There are the following groups of vehicles in the traffic flow: cars, trucks and buses.

The trucks are divided depending on the number of axles and load capacity. The number of trucks is a decisive indicator when determining reduced traffic intensity.

By the number of axles, there are biaxial, triaxial and four-axle trucks; four-axle and five-axle road trains; three-axle, four-axle, five-axle and six-axle truck trains; cars with seven or more axles.

By load capacity, there are the following vehicles:
- trucks with a capacity of up to 2 tons, over 2-6 tons, 6-8 tons, 8-14 tons, 14 tons;
- road trains with a capacity of up to 12 tons, over 12-20 tons, 20-30 tons, 30 tons;
- buses with a small, medium or large capacity;
- articulated buses and trolleybuses \cite{3}.

The initial road design and construction stage is the substantiation of a road category. This stage is relevant both for construction and reconstruction of roads. The category of roads is determined depending on functions and the maximum traffic intensity for a passenger car. The classification by load capacity and types of vehicles is used for calculating the reduced traffic intensity (hourly or daily).
A calculation unit is equal to a passenger car. It accounts for other types of vehicles on the road, their dynamic properties and sizes in order to average averaging them to determine traffic characteristics (intensity, estimated speed, etc.) [3].

The estimated traffic in both directions is:
- average annual daily traffic intensity for the last year of a 20-year period;
- hourly reduced traffic intensity achieved or exceeded for the last year of a 20-year period for 50 hours.

The category of a road is a criterion characterizing the importance of the road in the transport network of the country determined by traffic intensity. In accordance with the road category, all technical parameters of the road are set [7].

Traffic intensity for a passenger car is calculated by formula (1).

\[ N_r = N_{\text{pass}} \times K_{\text{pass}} + N_{\text{tr}} \times K_{\text{tr}} + N_a \times K_a \]  

(1)

The factors reducing traffic intensity to a passenger car are recommended for countries of the Customs Union (Table 1).

| Types of vehicles                  | Reduction coefficient |
|------------------------------------|-----------------------|
| Cars and motorbikes, minibuses     | 1.0                   |
| Trucks with load capacity, t:      |                       |
| up to 2                            |                       |
| more than 2 “ 6 ”                  | 1.3                   |
| “ 6 “ 8 ”                          | 1.4                   |
| “ 8 “ 14 ”                         | 1.6                   |
| “ 14 ”                             | 1.8                   |
|                                    | 2.0                   |
| Road trains with load capacity, t:  |                       |
| up to 12                           |                       |
| more than 12 “ 20 ”                | 1.8                   |
| “ 20 “ 30 ”                        | 2.2                   |
| “ 30 ”                             | 2.7                   |
|                                    | 3.2                   |
| Small capacity buses               | 1.4                   |
| Medium capacity buses              | 2.5                   |
| High capacity buses                | 3.0                   |
| Articulated buses and trolleybuses | 4.6                   |

When designing a road, the type of a road surface, traffic intensity and traffic flow composition should be taken into account.

The calculation should be performed using average daily traffic intensity in both directions, calculated as the sum of intensities in each direction. When the difference between intensities is more than 10%, the calculation can be performed for each direction separately, taking into account actual traffic intensity for each direction [4].

For designing and calculating the road surface, the following characteristics reflecting intensity of the impact of a moving load are used:
- average daily load (at the end of the overhaul period), the number of driveways of all wheels located on one side of the calculated vehicle within one lane of the carriageway (traffic intensity reduced to the calculated load);
- the total number of applications of the reduced design load to a point on the surface over the overhaul period.

There are objective difficulties in determining actual intensity on a specific section of the road. Automated methods are used for roads of high categories. They often do not capture individual sections.
The categorization of vehicles by load capacity is difficult when visually accounting for traffic intensity. It is necessary to know the car model, its load capacity or specify its characteristics. The second option is impossible without an employee of the State Inspectorate for Road Safety and leads to traffic jams, congestion.

The video surveillance and subsequent cameral processing of video files can be used as an alternative.

The authors performed recorded the traffic flow on the local Egorovschina-Ryazanovschina road in Irkutsk region. The traffic intensity was being determined during one day in September 2019. The actual traffic intensity was 74 cars per day. When determining traffic intensity, the flow composition was taken into account and trucks were categorized by load capacity and the number of axles.

Then cameral processing of field intensity data was carried out.

The hourly distribution of traffic intensity on the Egorovshchina-Ryazanovshchina road is presented in Figure 1.

![Figure 1. Distribution of traffic intensity by hours on the Egorovshchina – Ryazanovshchina road](image)

The distribution of cars and trucks by traffic flow composition depending on the number of axles and load capacity is presented in Figure 2.

Tables 2 and 3 show the calculation of traffic intensity reduced to a passenger car. The flow contains 38% of trucks and 62% of cars.
**Figure 2.** Distribution of cars by traffic flow composition (depending on the number of axles and load capacity of trucks)

**Table 2.** Traffic intensity reduced to a passenger car (depending on load capacity of trucks)

| Types of vehicles                      | Number of cars per day | Reduction coefficient | Traffic intensity reduced to a passenger car, cars per day |
|----------------------------------------|------------------------|-----------------------|-----------------------------------------------------------|
| Passenger cars                         | 46                     | 1.0                   | 46.0                                                      |
| Trucks with a capacity of up to 2 t    | 6                      | 1.3                   | 7.8                                                       |
| Trucks with a capacity from 5 to 8 t   | 0                      | 1.4                   | 0.0                                                       |
| Trucks with a capacity of more than 8 t| 7                      | 1.6                   | 11.2                                                      |
| Trucks with a capacity of more than 8 t| 14                     | 1.8                   | 25.2                                                      |
| Road trains                            | 1                      | 1.8                   | 1.8                                                       |
| Buses                                  | 0                      | 2.5                   | 0.0                                                       |
| **Total**                              | **74**                 |                       | **92**                                                    |
Table 3. Traffic intensity reduced to a passenger car (depending on the number of axles)

| Types of vehicles                                         | Number of cars per day | Reduction coefficient | Traffic intensity reduced to a passenger car, cars per day |
|----------------------------------------------------------|------------------------|-----------------------|-------------------------------------------------|
| Motorcycles                                              | 0                      | -                     | 0.0                                             |
| Cars, small trucks (vans) and other cars with and without a trailer | 46                     | 1.0                   | 46.0                                           |
| Biaxial trucks                                          | 6                      | 1.5                   | 9.0                                            |
| Three-axle trucks                                      | 19                     | 1.8                   | 34.2                                           |
| Four-axle trucks                                       | 0                      | 2.0                   | 0.0                                            |
| Four-axle road trains (two-axle lorry with a trailer)   | 1                      | 2.2                   | 2.2                                            |
| Five-axle road trains (three-axle truck with a trailer) | 2                      | 2.7                   | 5.4                                            |
| Three-axle truck trains (two-axle truck tractor with a semitrailer) | 0                      | 2.2                   | 0.0                                            |
| Four-axle truck trains (two-axle truck tractor with a semitrailer) | 0                      | 2.7                   | 0.0                                            |
| Five-axle truck trains (two-axle truck tractor with a semitrailer) | 0                      | 2.7                   | 0.0                                            |
| Five-axle truck trains (three-axle truck tractor with a semitrailer) | 0                      | 2.7                   | 0.0                                            |
| Six-axle truck trains                                   | 0                      | 3.2                   | 0.0                                            |
| Cars with seven or more axles and others                 | 0                      | 3.2                   | 0.0                                            |
| Buses                                                   | 0                      | 3.0                   | 0.0                                            |
| **Total**                                               | **74**                 |                       | **97**                                          |

The reduced traffic intensity allows us to attribute this road section to category V.

Observations of the traffic flow composition were carried out on other sections of Irkutsk roads. The distribution of the traffic flow composition is presented in Table 4. The traffic flow includes: cars - 60-82%; trucks - 17-38%; buses (including minibuses) - 1-8%.

The results show a large number of passenger cars, which indicates a slight increase in traffic intensity compared with actual traffic intensity.

Table 4. The composition of the traffic flow in Irkutsk region

| Road section                                           | Traffic flow composition, % | Traffic intensity, vehicles per day |
|--------------------------------------------------------|-----------------------------|-------------------------------------|
|                                                        | Passenger cars | Trucks | Buses | 2019                      |
| Irkutsk - Bolshoy Goloustnoye, Irkutsk - Pivovarikha section | 81 | 16 | 3 | 8057                      |
| Irkutsk - Osa - Ust-Uda, Irkutsk - cemetery approach section (2.6 km) | 76 | 18 | 6 | 21993                      |
| Irkutsk - Osa - Ust-Uda, Irkutsk - cemetery approach section (km 2.6) - dump cite approach section (4.7 km) | 68 | 24 | 8 | 18606                      |
| Irkutsk - Osa - Ust-Uda, dump site approach (4.7 km) - Razdolie (8 km) | 75 | 20 | 5 | 13 452                     |
| Irkutsk - Osa - Ust-Uda, dump site approach (4.7 km) - Razdolie (8 km) Ust-Kuda approach (17.2 km) | 74 | 21 | 5 | 13 452                     |
| Irkutsk - Osa - Ust-Uda approach (17.2 km) - Moskovskchina (24.6 km) | 76 | 19 | 5 | 2 737                      |
| Irkutsk - Iskra                                         | 76 | 22 | 2 | 727                        |
| Access to Malaya Elanka                                 | 76 | 21 | 3 | 3011                       |
| Access to Elovy                                         | 62 | 36 | 2 | 2150                       |
| Urik - Stolbovo                                         | 60 | 38 | 2 | 552                        |
The analysis allows us to draw the following conclusions.

When calculating traffic intensity reduced to a passenger car, the categorization of trucks by the number of axles or load capacity is not significant.

According to the regulatory documents [3], [6], traffic intensity reduced to a passenger car is calculated on the basis of reduction factors depending on a load capacity.

In accordance with GOST 32965-2014 "Public roads. Methods of accounting for traffic flow intensity", the calculation of traffic intensity reduced to a passenger car takes into account the division of trucks by the number of axles. Thus, traffic intensity is used to determine the throughput of roads and transport hubs.

According to PNST 265-2018 “Public automobile roads. Non-rigid pavement design” for calculating pavement, freight vehicles are divided by the traffic flow composition depending on the number of axles.

Therefore, when conducting economic surveys, a comprehensive analysis of the composition of the traffic flow is required to determine traffic intensity. It is necessary to distinguish the following groups of cars: cars, trucks and buses. Trucks should be subdivided according to the number of axles and load capacity.

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