

INCREASING ENVIRONMENTAL EFFICIENCY BY REDUCING TRANSPORTATION EMISSIONS ON BUS ROUTES

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Abstract. The article discusses the issues of increasing environmental efficiency by reducing transport emissions on bus routes. The possibilities of rational route planning, reducing fuel consumption, using modern ecological buses, and optimizing the travel interval are analyzed. These approaches serve to reduce air pollution, ensure energy efficiency, and develop sustainable urban transport.

Keywords: bus route, transport emissions, environmental efficiency, fuel efficiency, ecological transport, route optimization.

The sustainable operation of the urban transport system, along with meeting the daily mobility needs of the population, also requires minimizing the negative impact on the environment. In particular, buses are one of the main elements of the urban passenger transport system, and their technical condition, route length, speed, number of stops at stops, congestion and fuel consumption directly affect environmental indicators. Therefore, it is necessary to evaluate bus routes not only from the point of view of delivering passengers to their destination, but also based on environmental efficiency criteria.

Environmental efficiency of transport is understood as reducing the amount of harmful substances emitted into the atmosphere during the transportation of a certain number of passengers, rational use of energy resources and reducing the environmental impact of the vehicle. In this case, the amount of fuel consumed by the bus per kilometer, the number of passengers transported, the level of traffic congestion and traffic conditions are important.

For example, let's take two buses traveling the same distance. The first bus route has a lot of stops, a high number of traffic lights, and frequent traffic jams. The second bus travels along an optimally designed route. The first bus consumes more fuel due to frequent acceleration and braking. As a result, the environmental load of the first route is higher than that of the second.

Based on this, one of the main directions for increasing the environmental efficiency of bus routes is to reduce the idle time of vehicles and optimally organize the movement process.

The amount of emissions from buses depends on many factors. The most important of them are the type of bus engine, fuel quality, technical condition, operating time, route length, road condition, traffic congestion, passenger flow, and driver's driving style.

As the technical condition of the engine deteriorates, the likelihood of incomplete combustion of fuel increases. In this case, the amount of certain harmful components emitted into the atmosphere may increase. Therefore, regular technical diagnostics of bus fleets is an important condition for increasing environmental efficiency[1].

In addition, constant high-speed movement of buses is also not environmentally acceptable. Sharp acceleration, sharp braking, and engine operation under high load increase fuel consumption. On the contrary, the organization of movement in a uniform manner helps to reduce fuel consumption.

Another important problem in urban conditions is traffic jams. During traffic jams, buses can run the engine for a long time without transporting passengers or move at very low speeds. This leads to an increase in the environmental load per passenger.

Therefore, when planning routes, it is not enough to choose only the shortest distance. The level of traffic congestion of the route, the number of traffic lights, road surface, the distance between stops, and the flow of passengers must also be taken into account in a comprehensive manner.

Route optimization is one of the effective ways to reduce transport emissions. An optimal route is understood as a route that minimizes excessive vehicle travel, idling, and unnecessary fuel consumption while meeting passenger needs.

The use of mathematical and information technologies creates great opportunities in this regard. With the help of GPS monitoring, electronic payment systems, passenger flow calculation tools, and digital transport management platforms, it is possible to analyze the real performance of each route.

For example, on a given bus route, the number of passengers may be very high in the morning, but significantly lower in the afternoon. If buses run at the same intervals and in the same quantity throughout the day, the capacity of the vehicles will not be fully utilized at some time intervals. This situation leads to inefficient use of transport resources.

Based on an ecological approach, the number of buses and the interval of their movement can be adjusted to the flow of passengers. By increasing the number of buses during peak times and adjusting the frequency of trips during off-peak times, fuel consumption and emissions can be reduced.

Passenger flow is of particular importance when assessing the environmental efficiency of bus routes. This is because even with the same amount of fuel consumed, a bus carrying more passengers may have a relatively lower environmental impact per passenger.

Let us consider two hypothetical cases. The first bus carries 20 passengers over a distance of 50 kilometers. The second bus also travels 50 kilometers, but carries an average of 60 passengers. If the fuel consumption of both buses is the same, the environmental efficiency per passenger of the second bus service will be higher[3].

Therefore, it is appropriate to assess environmental efficiency not only in terms of the total amount of emissions from the bus, but also in terms of the number of passengers transported and the distance traveled.

Such an assessment allows comparing bus routes with each other. As a result, routes that create the greatest environmental load are identified and optimization measures are developed for them.

Another important direction for reducing transport emissions is the use of more environmentally friendly buses. Along with traditional diesel buses, there are options for using buses that run on compressed natural gas, electricity or hybrid technologies.

The use of electric buses can help reduce local air pollution in city centers. However, when introducing such transport, it is necessary to take into account not only the bus itself, but also the source of electricity generation, charging infrastructure, battery life and operating costs.

It is also important to gradually modernize the existing bus fleet along with the purchase of new buses. Simple measures such as improving engine and fuel systems, improving maintenance, and monitoring tire pressure can also help reduce fuel consumption.

The environmental efficiency of a bus route is also related to speed. Driving too slowly or stopping too often can increase a bus's fuel consumption. Therefore, coordinating traffic lights, creating separate bus lanes, and reviewing the location of stops can be effective in improving bus traffic conditions.

The distance between stops is also an important factor. If the stops are located too close together, the bus will stop and start again more often. This will lead to an increase in the number of accelerations and braking. However, placing the stops too far apart can cause inconvenience to pedestrians. Therefore, the location of the stops is determined taking into account the requirements of both traffic and pedestrian traffic.

Several indicators can be used to determine the environmental efficiency of a bus route. In particular:

- fuel consumed per kilometer;
- fuel consumption per trip;
- number of passengers transported;

fuel consumption per passenger;
estimated amount of transport waste;
idle time;
average speed along the route[1].

To summarize environmental efficiency, the following indicator can be conditionally used:

$$E = Q / (Y \times L)$$

Where E is the environmental load per passenger-kilometer; Q is the transport waste generated over a certain period of time; Y is the number of passengers transported; L is the distance traveled.

A decrease in this indicator indicates an ecological improvement of the route. For example, if, as a result of reducing traffic congestion on the route, the fuel consumption of buses decreases, while at the same time maintaining the flow of passengers, the environmental efficiency indicator improves[2].

Today, digital technologies create a wide range of opportunities for monitoring the environmental performance of bus transport. GPS devices can determine the real-time location, speed, stops and travel time of the bus. By analyzing this data, ecologically problematic sections are identified.

For example, if buses are stuck at a certain intersection for 10–15 minutes every day due to traffic jams, special traffic management measures can be developed for this area. The idle time can be reduced by revising the operation mode of traffic lights or creating a separate lane for buses.

In addition, real-time monitoring of passenger flow allows you to manage the number of buses according to demand. As a result, unnecessary trips are reduced and the efficiency of using transport resources increases.

The driver's driving style is also an important factor in reducing transport emissions. Sharp acceleration, sudden braking and prolonged engine idling can increase fuel consumption.

Therefore, it is advisable to organize special training on environmental management for bus drivers. The training can develop skills such as maintaining a stable speed, assessing road conditions in advance, reducing excessive braking and rational engine control at stops.

Evaluating drivers' performance based on environmental indicators can also yield positive results. For example, drivers who keep fuel consumption within limits and drive carefully can be encouraged.

To improve the environmental efficiency of bus routes, it is advisable to use an integrated approach. This approach can be implemented in the following sequence:

- Step 1 - collection of transport and environmental indicators of existing routes;
- Step 2 - analysis of passenger flow and speed;
- Step 3 - identification of sections with congestion and excessive stops;
- Step 4 - optimization of route length, stop spacing and travel interval;
- Stage 5 — gradual introduction of ecological vehicles;
- Stage 6 — monitoring of results using GPS and other digital monitoring tools;
- Stage 7 — comparison of environmental indicators before and after optimization[4].

The main advantage of this system is that it evaluates not only one indicator, but also transport, economic and environmental factors in an interconnected manner.

In general, reducing transport emissions on bus routes should be carried out not by a single measure, but by scientifically planning routes, taking into account passenger flow, reducing traffic jams, improving the technical condition of vehicles, using ecological buses and introducing digital monitoring. Such an integrated approach, while reducing the environmental load of urban transport, will allow reducing fuel consumption, improving the quality of service provided to passengers and improving the overall efficiency of the transport system.

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