Analysis of the taxis' operating conditions in the city and determination of the technical parameters of the electric vehicles

VELIZARA PENCHEVA, ASEN ASENOV, DIMITAR GROZEV, EMIL SAVEV, PLAMENA GAGOVA
Department Transport
University University of Ruse
Address 8 Studentska, str., Ruse, 7017
BULGARIA
vpencheva@uni-ruse.bg; asasenov@uni-ruse.bg; dgrozev@uni-ruse.bg; Emil_g.s@abv.bg; pgagova@uni-ruse.bg, http://www.uni-ruse.bg

Abstract: - The work has been done to study the operation of taxi vehicles in an average European city - Ruse. Referring to the strategic tasks in the White Paper till 2050 to the use of environmentally friendly road transport, had been made an evaluation of the qualities necessary for electric vehicles to be used as an alternative to the traditional taxi vehicles.

Key-Words: - taxis, electric vehicles, operating conditions, city passenger transport, optimization, ecology

1 Introduction
The establishment of the cities as an attractive centers for work and life has led to their expansion and increasing their population. Due to the large distances between the residential areas, workplaces, public attraction centers and various opportunities to the citizens, they have to move within the city in various ways. In the smaller towns generally the residents travel on foot, by bicycle/moped or car. In the medium-sized towns is used the public transport which includes buses, trolley buses and taxis. In the large and the largest cities, due to exhausted possibilities of the other types of transport, is used ground railway transport - trams, and underground - metro transport.

Of all the types of public transport only the taxi transport allows flexibility and choice of random destination, pick up and drop off point and the client is served at the highest level. The taxi services are operated by vehicles with diesel and gasoline engines, which most often can work with LPG or CNG. According to the determined in the White Paper transport development by 2050 one of the main tasks is to limit the use of such cars in the city centre areas and replace them with alternative, [3, 11]. At this stage the alternative vehicles can work with fuel cells, electricity and LPG or CNG. From these alternatives, at this stage, most suitable is the use of electric vehicles.

2 Operation of taxis in the conditions of an average city - Ruse, Bulgaria

2.1 Characterization of Ruse
Ruse is one of the biggest cities in Bulgaria. According to the last census in 2011 it takes the fifth place. With about 146 000 residents, it falls into the group of medium-sized cities with population of 50 000 to 350 000. During the day the residents do not travel large distances because both the length and width of the city does not exceed 20 km. They use public transport - buses and trolley buses, taxis and private vehicles - bicycles, motorbikes, cars. In recent years traveling by car has come up as the most preferred way to travel. Therefore, taxi transport is still well developed in the city. In 2011 the town has 130 taxi service companies registered as sole proprietors or limited companies (LTD and LLPC). They have a fleet of 650 cars. This shows that there are 4.45 taxis average per 1,000 residents in the city.

2.2 Characteristics of the taxis
The fleet mainly consist of new cars with prices up to 30 000 euro, brands Chevrolet, Dacia, Škoda, Daewoo, and Renault with four and five-door, according to the regulations in the country, (Table 1). They mainly work in 12 hours shifts with two drivers. There are also taxis with one driver who works selective or with regular customers. The work scheme is organized this way because 70% of cars...
are owned by large companies (leasing companies) and are rented/sold by instalments to the taxi drivers. The remaining cars are owned by the taxi drivers.

Table 1

<table>
<thead>
<tr>
<th>Brand</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dacia</td>
<td>21.0</td>
</tr>
<tr>
<td>Shevroilet</td>
<td>25.2</td>
</tr>
<tr>
<td>Skoda</td>
<td>16.8</td>
</tr>
<tr>
<td>Daewoo</td>
<td>16.8</td>
</tr>
<tr>
<td>Renault</td>
<td>8.8</td>
</tr>
<tr>
<td>Lada</td>
<td>4.2</td>
</tr>
<tr>
<td>Opel</td>
<td>4.2</td>
</tr>
<tr>
<td>Others</td>
<td>2.9</td>
</tr>
</tbody>
</table>

According to Bulgarian legislation, vehicles used for taxis must be aged 10 years or less from the first registration. Complying with this requirement and with its own capabilities the ongoing taxi cars in the city are 16% new and 84% second-hand purchased up to 5 years old.

The fleet of taxis consists mainly of gasoline cars with engine capacity up to 1600 cm3 and diesel with engine capacity up to 1900 cm3, (Table 2), [8]. The most preferred fuel is CNG, due to its lowest price and availability of CNG stations spread across the city. The use of LPG has decreased in the recent years because of the higher prices and lower mileage traveled by taxis in the city. Vehicles operating only with diesel or gasoline fuel has almost none except the new cars without LPG equipment purchased with a lease warranty

Table 2

<table>
<thead>
<tr>
<th>Fuel</th>
<th>% taxi cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline/CNG</td>
<td>66</td>
</tr>
<tr>
<td>Gasoline/LPG</td>
<td>18</td>
</tr>
<tr>
<td>Gasoline А95Н</td>
<td>2</td>
</tr>
<tr>
<td>Diesel</td>
<td>14</td>
</tr>
</tbody>
</table>

2.3 Taxi stands/parking features

Ruse Municipality has provided special places for taxis to stop and to meet their clients without being in conflict with the other drivers involved in the city traffic. The places are considered with the attractive centers as hospitals, schools, railway and bus stations, shops and city centre. The total number of the taxi ranks and parking places is 50 with a total 219 parking spaces, [8]. Therefore 33.6% of taxis are provided with places to stay and meet customers. This means that there are 1.5 taxi parking spaces per 1000 residents.

The offered places from Ruse Municipality meet the organization of the taxi business in several European countries, where there are between 1 and 2.5 taxis per 1,000 residents.

3 Traffic researches in Ruse

Despite of the large number of taxis in the city, in the work had been done a research under realistic conditions, by a laboratory car with research equipment video VBOX (Racelogic) to record the main operating indices of the vehicle, [5,6,13]. The study took place in Ruse during the working days of the week. A random taxi had been chosen which work involves the transport of regular and occasional customers for daily work period. After the end of the study the data were transferred to a PC and processed with the program video VBOX.

The results from the study with one and two passengers are presented in Figure 1 and Figure 2.

For the whole study had been made a summary of the amount of passengers travelled by taxi (Figure 3).

Figure 3. Amount of passengers in the taxi during the day

The results show that most of the runs had been made with one passenger - 79%, then with two passengers - 19% and on rare occasions by more than two passengers (3 or 4) - 2%.

After processing the information about the operating parameters recorded by the research equipment, the following results occur:
- Shift duration - 12 h;
- Average time per run - 15,2 min;
- Average length of passenger run - 3,38 km;
- Average travel speed - 21,3 km / h;
- Average stay for a run - 80 sec;
- Request awaiting stay time - 60% of the shift duration;
Figure 1. Results from the study with one passenger

Figure 2. Results from the study with two passengers
Driving with a passenger - 24% of the shift duration;
Driving without a passenger - 16% of the shift duration;
Average run for a shift - 163 km;
Maximum speed within the town - 77 km/h;
Maximum speed outside the city - 93 km/h.

4 Technical features for an alternative fleet of electric vehicles.

4.1 Main features of both parks.
The use of internal combustion engines in taxis is
convenient in terms of rapid refueling, maintenance
of proper temperature for the customer (heating
during the winter and cooling by air conditioning
during the summer), the opportunity to run higher
mileage per charge - over 200-250 km with CNG,
about twice more with LPG and about 500-600 km
with liquid fuels (gasoline, diesel).

In recent years has begun mass production,
promotion and implementation of electric transport
in the cities. The technical characteristics of the
electric vehicles allow them to travel average about
140-160 km per charge of battery, top speed - 130-
140 km/h; noise - less than 65 dB; capacity - most
often two people, but the larger ones - 4 people;
charging time - normally - 4-8 h; fast charging 20-
30 min; accelerating time - the same as the
traditional cars, [1,7,14,15,16].

4.2 Scheme of the replacement of the taxi fleet with alternative fleet of electric vehicles.
Comparing the values obtained of the technical
and operational indicators with the road conditions
of Ruse and the technical characteristics of the
alternative park of electric cars show a hypothetic
possibility of exchanging the currently used
automobile park for taximeter transports with an
alternative park of electric cars to reduce fuel
expenses and CO2 emissions in the cities, [1,16].
The key aspects in assessment of effectiveness of
exchanging used automobile park for taxi transport
with park of electric cars are:
- energy efficiency;
- environmental impact;
- economic efficiency;
- safety;
- charging, preserving and maintaining the
alternative vehicles.

To determine the energy efficiency it is
necessary to define the average consummation of
energy for both parks (l/km and kWh/km). The
basic factor which exercises influence on the
average energy consumption are the characteristics
of the vehicle (speed, maintaining, exc.) and the
operating conditions (traffic, density of population,
profile of the road, exc.)

When we are comparing the economic
efficiency, it can be started with counting the cost per trip i.e. the amount the customer pays per trip
which is determined whether it is for an electric
car(1) or an automobile(2) with an engine.

For calculating the environmental impact of the
alternative vehicles, two basic factors must be taken
into account: greenhouse gases emissions during the
utilization of the vehicles; noise emissions.

In defining the economic efficiency fixed and
variable costs are valued.
Safety is defined by risk assessment for both
alternative parks, [9,10,12].

Charging, preserving and maintaining the
alternative vehicles is connected with, [2,4,12]:
- assessment of possible options and
infrastructure for charging. For example a colon for
charging electric cars (with normal charging of an
electric car being 8 hours) can be used a day for full
charge of three cars.

- defining the place for preserving. There must
be taken into account all elements which are
necessary for integrating the infrastructure such as:
mains supply, charging systems, fire alarm systems,
cocks, fire extinguishers and others.

- maintaining is connected with strict
enforcement of the prescribed norms for vehicles as
well as with the places for charging and their
preserving.

When we are comparing the economic
efficiency, it can be started with counting the cost per trip i.e. the amount the customer pays per trip
which is determined whether it is for an electric
car(1) or an automobile(2) with an engine.

\[ C_p = C_{Le} + L + C_{Te} T + C_{tax}, \text{ euro;} \]  
\[ C_a = C_{La} + L + C_{Ta} T + C_{tax}, \text{ euro,} \] 

where \( C_{Le} \) and \( C_{La} \) are the costs for one traveled
kilometer by the customer with an electric car and
an automobile with an engine, euro/km;
\( C_{Te} \) and \( C_{Ta} \) - costs for a one-minute stop be
the customer with an electric car and an automobile
with an engine, euro/min;

\( C_{tax} \) is the initial fee that the customer must
pay when he gets into the taxi, euro;

\( L \) and \( T \) are the traveled paid mileage and the paid
stop with a customer on the route, in km and min.

The tariff for the paid mileage and stop are
accounted the fixed and variable costs in taxi
activity which can be expressed as follows:

- Fixed costs

\[ P_{Fix} = P_{pfr} + P_{legis} + P_{r} + P_{Adm}, \text{ euro.} \] 

where are:
where are:

- Variable costs

\[ P_{Va} = P_{\text{acq}} + P_{\text{ins}} + P_{\text{reg}} + P_{\text{fuel}} + P_{\text{en}} +
\quad + P_{\text{ser}} + P_{\text{ot}} + P_{\text{ac}} \text{, euro} \]  (4)

- General costs for an automobile and park with n cars

\[ P = \sum_{i=1}^{n} (P_{\text{fix}} + P_{\text{var}} + \sum D_{\text{exp}} )i \text{, euro} \]  (7)

Comparing the costs for an electric car (5) and automobile with an engine (6) we get:

\[ \Delta = P_e - P_a \text{, euro} \]  (8)

If \[ \Delta > 0 \] the automobile with an engine is more effective, because the costs per trip are less. If \[ \Delta = 0 \] costs per trip in both vehicles are equal their efficiency is the same. In the third case \[ \Delta < 0 \] the electric car is the most effective.

So if we get\[ \Delta \leq 0 \], then the electric car turns out to be economically and ecologically more effective and can be successfully used as an alternative to taxis. Otherwise a compromise can be made because of the better ecological and noise indicators.

### 5 Conclusion

An analysis has been made to the taxi activity in medium town in Bulgaria, Ruse, in which are evaluated the operational indicators for work of the taxis. Taking into account the requirements, set in White paper 2011 Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system and the existing on the market electric cars, the possibility of exchanging the used automobile park for taximeter transports with alternative park of electric cars is evaluated. As a result is proposed a method for comparing the efficiency between two park vehicles.

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