Urban transport – the virtual source for sustainability of a city

V.N. Bougromenko & E.G. Myasoedova
Research and consulting company Geogracom, Russia

Abstract

Strategic planning (of sustainable development) implies a shift from technical, branch indices to humanitarian ones characterizing standards of living. In context of urban transportation the solution is urban transport standard, which is an aggregate of the indices of end consumption of transport services minimally required to sustain normal living conditions, such as mobility, level of transport discrimination, level of ecological safety, net contribution of urban transport to GDP.

Introduction

What is sustainability in a broad meaning of this word? Let's remind ourselves that the main sense of sustainability, defined in Rio de Janeiro in 1992, is "a way of life", and that means such consumption of resources today that will allow the future generations to breath a cleaner air.

Eight years later it became obvious that sustainability implies not only environmentally friendly attitude, but it also covers socio-economic, geopolitical, cultural and even purely financial aspects. The key issue of indices-orientations of sustainable development put forward the same questions with respect to the above stated aspects, especially in connection with the needs of the future generations. From the point of view of environmental protection finding forecast parameters of the environmental evolution was not the most difficult task. What was difficult is finding a way to reduce to a "common denominator" the needs of the future generations in the socio-economic sphere. We have made some efforts trying to solve the encountered problems on the example of sustainable
development of a city, to be more exact – sustainable development of urban transport.

This article sets out two interconnected problems:

1. Needs of the future generations, as an vision of the desired state of city life that our grandsons and great grandsons will lead, bear a virtual character and depend on forecast period, as well as on specific features of a country and general world organisation;

2. The city of the future will survive mainly due to its communications. And here we are speaking chiefly about telecommunications, not transportation. However, the life of at least three more generations is going to depend on the level of development of urban transportation. That is why a sustainable city is a city with sustainable urban transportation.

Minimal urban transport standard

The advent of the new millennium necessitates new conceptions of social development reflecting modern tendencies. With regard to the specific character of transportation as an infrastructure, it can be said that its role in sustainable development of the society is rather ambiguous. And it is even more so with urban passenger transportation.

Transport policy in the countries with social market economy aims at revival of public transportation and curb on the number of individual vehicles. The 90-s were marked by increasing role of rail transport in the infrastructure. It was mainly due to ecological problems in the cities. Efforts to privatise urban passenger transport (UPT) were reduced to nothing, the reason being low profitability of UPT or its absolute unprofitable nature. Thus, UPT falls under more and more active patronage of the state authorities. However, the methods of state “intervention” should be controlled by the end goals of its existence – a universal well-being, including concern about the future generations. Therefore, there is a connection between this process and sustainable development in its broader meaning. This connection is the very essence of UTS.

The future of public urban transportation depends on the degree of significance that will be attached to the following three major tasks:

- fulfilment of social duties with regard to those sections of the population that do not have individual vehicles;
- maintenance or improvement of economic stability in the districts where services are provided;
- minimal damage to the environment.

The most important component of the social sphere functioning is the state social regulation, implying legal regulation of social development with application of the most significant social norms and standards. Economic expediency consists in effective provision of the population with the needed passenger communications to the extent when the cost of the system (in its broad meaning) is still offset by the contribution to the well-being of the society.
To achieve this goal, urban transport system should meet the following requirements:
- to be a balanced combination of public and private transport with consideration of local, socio-economic, technical and ecological abilities and limitations;
- to be convenient, reliable and safe, while using limited resources of energy, land, etc. more rationally.

In the context of urban transportation social norms are scientifically grounded qualitative and quantitative characteristics of the optimal state of business and household activity, which depend on passenger transportation.

Urban transport standard (UTS) is a combination of target indices (norms) of end consumption of transport services, achievement of which guarantees sustainable development. UTS ensures that the citizens will receive minimally required level of transport services.

Unlike purely branch indices (such as volume of passenger conveyance, average trip distance, coefficient of transport pool on line, prime cost of conveyance), characterising the work of urban transport, the indices that constitute UTS are the results of UPT functioning, reflecting normal transport conditions of business and household activity.

The value of social norms cannot be considered constant. It is subject to complex dynamic modifications, because any normative requirement should have "an open-ended structure", which means capability to change quantitative parameters and the list of these characteristics.

The range of the indices and qualitative characteristics of their parameters are determined by:
- current level urban development (population size, level of real income per capita, features of architectural planning, life expectancy, level of social expenditures in the city budget);
- potential development of a city (industrial potential, type of the demographic structure of the population);
- city size.

On the whole UTS should reflect value orientations of the society that can be translated into reality in 5-20 years and used for the following issues:
- strategic planning of urban development with regard to town-planning, economic and social features;
- creation of a new mechanism of procuring financial support for development of urban passenger transportation (shift from paragraph-by-paragraph financing to per capita financing) leading to a more effective use of budget means.

The following sets of norms can be singled out:
- direct quantitative expression of degree of various requirements, or norms expressing the absolute degree of a certain requirement;
- norms expressing a relative degree of a certain requirement.

Each city receives its own set of indices developed with consideration of its architectural planning features, level of real income per capita a year, level of
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social expenditure in the city budget, level of ecological safety, and planning period, which can be 5.5 – 10 or more than 10 years.

The goal of urban transport policy is establishment of the required end state that can range from a very high standard of living to a very specific threshold value. Elimination of difference found between the actual and designed (normative) values of UTS is the end goal of urban passenger transport development from the point of view of sustainable development.

UTS can consist of the following main indices:

1. Transport mobility of the population.
   Transport mobility is one the main indices describing the transportation system of a city. It is an integral index reflecting a contradictory set of factors:
   - rhythm of the city life;
   - town-planning features and planning structure;
   - current state and development of the transportation system;
   - city economy.

   Taking into consideration complexity and contradictory nature of this index, only one part of it can be incorporated in UTS – transport mobility with social and cultural purposes (trips/person a year). In other words, minimal level of travelling with the above-mentioned purposed in mind, the level that is guaranteed to each citizen given present state of the urban transport system.

   Social and cultural trips have been set aside with a purpose, because the rest of the trips (to work, college) is obligatory and unavoidable. In the future telecommunications will help us to study and work without leaving our respective homes, however, seeing friends, going to theatres, museums, etc. is a free choice of our own, and it requires a "live" trip. Thanks to the technical progress unavoidable trips are supposed to decrease in number, while "free will" ones should continually increase.

2. Ratio of public to private transport means.
   Ratio of development level of public urban transport (PUT) to individual transport (IT) greatly influences the parameters of the road network, as well as the economic characteristics of the system in general.

   Low density of geographical distribution and locations of work places and service centres favours development of individual transportation, while PUT is economically justified by a higher density of building and concentration of production. Decision in favour of predominant development of IT deteriorates conditions of PUT functioning, making it not always economically justifiable, because the number of users decreases. PUT and IT should not be competing, but exist in harmony and complement each other.

   PUT is an important factor of urban economic development. The future of this type of transportation should be connected with the solution of such problems as:
   - fulfilment of social duties with regard to those sections of the population that do not have individual vehicles;
   - maintenance or improvement of economic stability in the districts where services are provided;
abatement of pollution caused by PUT.

Thus, the optimal ratio of PUT to IT guarantees that each and every citizen will enjoy normal transport conditions.

3. Reliability of UPT (Level of Integral transport accessibility).

Integral transport accessibility (ITA) is the index reflecting the quality of urban transport environment. It is given in the form of average weighted loss of time spent on passenger conveyance. An urban transport network should be considered reliable if it makes it possible for one to get from any place to any other place within the period called normative time inclusive time needed to reach an embarkation place, waiting time and changes on the way. Note that ITA norm is determined with respect to functional peculiarities of each location in the city. Level of transport accessibility is measured in % as ratio of actual average weighted loss of time spent on passenger conveyance to normative loss.

4. Level of transport discrimination of the population.

Level of transport discrimination of the population shows in % what part of the citizens live outside the zone of normative accessibility. Similar to index 3, it is calculated with the help of expert system Geograd.

5. Convenience of transportation by UPT.

Convenience in PUT system is determined by a set of heterogeneous factors, technical equipment, technologies, transport organisation and management influencing passengers' physical and mental state during transportation.

From the point of view of convenience a specific character of PUT is defined by the following circumstances:

- in PUT system the notion "convenience" refers to the whole trip – "from door to door", and not only to transportation;
- relatively short period of time taken up by transportation proper if compared with other phases of a trip;
- day-by-day multiple use of PUT system.

In general, it can be said that inconvenience of PUT system increases passengers' physical and mental tiredness. Therefore, the degree of quality called convenience should be measured in the units of passengers' physical and mental tiredness.

In the course of study of the convenience issue it is necessary to subdivide the notion of convenience into measurable attributes. Keeping in mind that certain characteristics of convenience can be set apart as independent indices or reflected in other indices, the main criterion of convenience can be the index giving number of people standing on one square meter of the salon of a vehicle.

6. Specific lost free time fund.

Total unproductive loss of time spent on chase after transport services of socially guaranteed minimum by each city-dweller a day (measured in hours). Quantitative representation of this standard makes it possible to assess the quality of UPT functioning and evaluate its social (public) usefulness.

7. Share of UPT in total pollution.

Development of urban transport systems has brought forth a problem of evaluation of influence of transport functioning on the ecological situation in a
The problem can be solved by establishing strict norms that would determine the level of ecological safety and encouragement of muscular transport modes. The main negative results of influence of the transport on the urban environment are air and noise pollution. Share of UTP in total pollution is estimated in % of total pollution from all sources. Moreover, there can be additional standards:

- level of noise pollution (decibels per 1 vehicle);
- level of toxic fumes (million ton/million pass.-km).

8. Level of development of muscular transport modes.

Share of muscular transport modes (e.g. bicycles) in total number of trips undertaken by city-dwellers (%).

9. Accident level due to UPT.

Traffic safety during passenger conveyance is the challenge for all transport modes. Emergency situations on roads are a phenomenon accompanying the motorization of the society and leading to significant losses.

Traffic safety is the criterion of choice made in favour of this or that means of conveyance.

On the basis of analysis of safety issue in Russia and abroad some specific indices-criteria were established:

- number of accidents involving fatal injuries per $10^5$ passengers;
- number of accidents involving fatal injuries per $10^4$ vehicles.

10. "Effectiveness" of UPT.

This index is calculated as ratio of results to costs. Results are monetary estimation of the share of transport in the gross domestic product of a city (or the gross added value) calculated on the basis of the methodology developed by Geogracom company. Costs are the whole sum allotted for development of the urban transport system (subsidies from the city budget, taxes and other sources). If the value of this index is more than 1, then financial support of the urban transport system is expedient.

All 10 parameters of UTS are determined for a concrete city on the basis of the following factors:

1. Current level of development and structure (number of citizens in a city (N), city surface (F), characteristics of architectural planning structure (K));
2. Potential level of development and period of strategic planning.

Type of architectural planning structure influences the average distance of a trip undertaken by one citizen in a given city. It is believed that average trip distance ($L_{av.}$), city surface (F) and coefficient of town-planning structure (K) are interconnected by the following formula (Velmozhin & Gukov [1]):

$$L_{av.} = 1.2 + 0.25 \sqrt{F}. \quad (1)$$

Coefficient of town-planning structure (K) depends on the type of this very structure:

1 – linear with cross-distribution with regard to the mains of major gravity centres of the population, $K=0.6-0.9;$
2 – compact town-planning structure with centripetal distribution of major gravity centres of the population, K=0.7-1.1;

3 – compact with lengthwise distribution with regard to the mains of major gravity centres of the population, K=0.9-1.2;

4 – linear with lengthwise distribution with regard to the mains of major gravity centres of the population, K=1.2-2.0.

This connection between mobility of the population and town-planning structure is conditional. However, it is sufficient for the purposes of strategic planning.

Besides, there are some strategic parameters characterising the potential level of city development and defining normative parameters of the UTS indices:

- real income per capita
  1000-5000; 5001-10,000; over 10,000 (dollars a year);
- index of economic provision of social guarantees – expenditure on social needs (% of the city budget)
  less than 20%; 20-40%; over 40%;
- level of ecological safety – specific pollution (carbon monoxide), mg/m³
  less than 1; 1-3; over 3;
- determination of strategic planning period
  up to 5 years; 5-10 years; more than 10 years.

Geogracom has developed a methodology of automated calculation of UTS. For example, Table 1 represents parameter values that are suggested, depending on the desired (strategic) level of income per capita, for a city with up to 500 thousand citizens (group 3 according to the conventional classification, Vaksman [2]) and a linear architectural planning structure with cross-distribution with regard to the mains of major gravity centres of the population.

<table>
<thead>
<tr>
<th>Indices</th>
<th>Real income (US$ per capita)</th>
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<tbody>
<tr>
<td>1. Transport mobility of the population with social and cultural purposes, trips/person a year</td>
<td>150 200 250</td>
</tr>
<tr>
<td>2. Ratio of public and individual transport, %</td>
<td>75:25 50:50 20:80</td>
</tr>
<tr>
<td>3. Reliability of urban transportation, %</td>
<td>over 80 over 90 over 95</td>
</tr>
<tr>
<td>4. Level of development of muscular transportation, %</td>
<td>over 5 over 15 over 35</td>
</tr>
<tr>
<td>5. Level of transport discrimination of the population, %</td>
<td>less that 5 less than 2 less than 1</td>
</tr>
<tr>
<td>6. Level of comfort and convenience of conveyance, persons/sq. m</td>
<td>less that 5 less than 4.5 less than 3.5</td>
</tr>
<tr>
<td>7. Specific lost fund of free time a day, hours a day per person</td>
<td>less that 0.3 less that 0.15 less than 0.15</td>
</tr>
</tbody>
</table>
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8. Share of transport pollution in the total pollution, including public urban transport

<table>
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<tr>
<th></th>
<th>60</th>
<th>65</th>
<th>75</th>
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<tbody>
<tr>
<td></td>
<td>10</td>
<td>8</td>
<td>5</td>
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</tbody>
</table>

9. Accident level through fault of transport:
- number of fatal injuries per 10^6 passengers;
- number of fatal injuries per 10^4 vehicles.

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<th>less than 12</th>
<th>less than 12</th>
<th>less than 10</th>
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<tbody>
<tr>
<td></td>
<td>less than 10</td>
<td>less than 10</td>
<td>less than 6.5</td>
</tr>
</tbody>
</table>

10. Efficiency of urban passenger transportation

|     | 1.12 | 1.2  | 1.2 |

The obtained values served as a basis for perspective UTS indices that should be corrected with regard to the following factors:
- economic provision of social guarantees (level of expenditure on social needs in the city budget);
- level of ecological safety.

Final values of the indices depend on the potential of general development of a city (low, medium, high) that is determined in the expert mode on the basis of two indices – industrial potential of a city and demographic structure of the population.

Industrial potential of a city is determined by possible expansion of the economy (increase in output volumes of products and services) – advantageous location, availability of materials, labour and capital resources, possible change of the city status.

Demographic structure of the population, depending on the ratio (%) of the age groups (up to 14 years of age, 15-49 years, over 50 years), can be progressive (30-50-20), stationary (25-50-30), and regressive (20-50-30).

Study of works on development and functioning of urban transport by home and foreign authors ([1-5]) has led to systematisation and application of some already formed tendencies and dependences that can be used as limitations during calculation of the UTS indices. As a result of multiple comparisons between simulated situations, we have succeeded in determining a possible range of values for indices-orientations (see Table 2), and that confirms their trustworthiness. For example, the extreme situations for the second index are as follows: in 1997 the ratio of the public to private transport in Kazakhstan was 78 to 22%, while Australia demonstrated the ratio of 29 to 71%.

**Table 2: Range of values for indices-orientations.**

<table>
<thead>
<tr>
<th>Indices-orientations</th>
<th>Range of values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Transport mobility of the population with social and cultural purposes, trips/person a year</td>
<td>100 ≤ 1 ≤ 350</td>
</tr>
<tr>
<td>2. Ratio of public and individual transport, %</td>
<td>80:20 ≤ 2 ≤ 20:80</td>
</tr>
<tr>
<td>3. Reliability of urban transportation, %</td>
<td>0 ≤ 3 ≤ 100</td>
</tr>
<tr>
<td>4. Level of development of muscular transportation, %</td>
<td>0 ≤ 4 ≤ 45</td>
</tr>
<tr>
<td>5. Level of transport discrimination of the population, %</td>
<td>0 ≤ 5 ≤ 35</td>
</tr>
</tbody>
</table>
6. Level of comfort and convenience of conveyance, persons/sq. m
   \[ 3 \leq 6 \leq 9 \]

7. Specific lost fund of free time a day, hours a day per person
   \[ 0.1 \leq 7 \leq 1.5 \]

8. Share of transport pollution in the total pollution, including public urban transport
   \[ 10 \leq 81 \leq 80 \]
   \[ 5 \leq 82 \leq 30 \]

9. Accident level through fault of transport:
   number of fatal injuries per \(10^5\) passengers;
   number of fatal injuries per \(10^4\) vehicles.
   \[ 3 \leq 91 \leq 25 \]
   \[ 2 \leq 92 \leq 20 \]

10. Efficiency of urban passenger transportation
    \[ 1 \leq 10 \leq 1.5 \]

With the help of the methodology of calculation of the UTS parameters we received the indices-orientations for Nalchik. They can be used for the purposes of strategic planning and creation of a new financing mechanism for development of urban passenger transportation. Table 3 contains UTS for Nalchik. The following strategic parameters were chosen: real income per one citizen is from 1000 to 5000 dollars a year, level of social expenditure is from 20 to 40% of the budget, level of ecological safety is medium. These strategic norms will be valid for more than 10 years given medium potential of development according to the industrial potential and demographic structure of the population.

**Table 3: Urban transport standard of Nalchik (UTS).**

<table>
<thead>
<tr>
<th>Indices-orientations</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Transport mobility of the population with social and cultural purposes, trips/person a year</td>
<td>150</td>
</tr>
<tr>
<td>2. Ratio of public and individual transport, %</td>
<td>70 : 30</td>
</tr>
<tr>
<td>3. Reliability of urban transportation, %</td>
<td>over 85</td>
</tr>
<tr>
<td>4. Level of transport discrimination of the population, %</td>
<td>less than 13</td>
</tr>
<tr>
<td>5. Level of comfort and convenience of conveyance, persons/sq. m</td>
<td>less than 4.5</td>
</tr>
<tr>
<td>6. Specific lost fund of free time a day, hours a day per person</td>
<td>less than 0.2</td>
</tr>
<tr>
<td>7. Share of transport pollution in the total pollution, including public urban transport</td>
<td>50</td>
</tr>
</tbody>
</table>
| 8. Accident level through fault of transport:
   number of fatal injuries per \(10^5\) passengers;
   number of fatal injuries per \(10^4\) vehicles. | 11 |
| 9. Efficiency of urban passenger transportation | 1.17 |
As a matter of fact, Table 3 can be called a "profile" of the transport system of Nalchik as it will be in 10 years. In other words, it gives us an idea of the future transport conditions in Nalchik.

As soon as the strategy of sustainable development by means of transport is outlined, the expert system itself (on the basis of the database) generates proposals that will make achievement of the given ten UTS parameters possible. Thus, now we are speaking not so much about effectiveness of separate transport projects, but about efficiency of life in the city in general. Such a shift is due to the fact that every generated technical proposal (increase in traffic frequency on routes, enlargement of the transport pool, reconstruction of tracks, construction of a motor-transport depot, set up of a "green line") is transferred directly into the indices important to each and every citizen-taxpayer. Reports about reduction of specific consumption of fuel or quantitative indices of transport functioning are of little interest to taxpayers, but UTS indices are of great importance to them. Every department in charge of urban transport development should report back to the citizens through the indices of UTS increase.

Later, expert system Geograd will combine heterogeneous proposals into a satisfactorily substantiated investment programme and will add up some financial scenarios of its implementation with regard to its multiple peculiarities.

References