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Research Article

# Changes at mobility space use in the cognitive mobility era

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Abstract: Today's society and one of its main pillars, mobility, is undergoing significant changes due to accelerated technological development. The previous mobility criteria may require revision due to changes. The work presents a study about the urban-rural-highway separation, which is widely used and crucial for the sustainability assessment of road mobility devices. Its characteristics are presented, and the test procedures based on them are considered. By comparing these with mobility trends, these need to be complemented due to the changing mobility use of space. The introduction of a new category, whose main dimensions are indicated, is proposed, and we highlight the areas where further research is needed.

*Keywords: downtown; urban; rural; highway; mobility; sustainability*

## I. INTRODUCTION

Human history is accompanied by urbanization and ever-increasing travel distances. Today, half of humanity lives in cities, and the proportion of the urban population continues to grow. This proportion is expected to reach 60% by the end of the next 10 years and 70% by 2050. In comparison, in 1950, this figure was just 30%. The significant increase in the world's population will undoubtedly take place in cities [1].

The foundations of today's cities and forms of mobility emerged in the modern era. In this era, service to the masses was the main organizing force in the development of urban structures. The main guiding principles were efficiency, mass production, economies of scale and planning. In urban planning and land use, the city meant large urban districts with homogeneous functions (separate residential quarters, industrial areas, and recreational areas).

For this purpose, robust public transport systems (high-speed networks, subways) were built connecting the districts, and public roads became the dominant means of transport during this period. Passenger cars gradually displaced other means of transport from public roads (trams, sidewalks too wide, trees taking up space on the road, etc.). They would have to be removed from the surface or removed: "There is little space, more space for cars." According to his modern understanding, space must be expanded where there is crowding [2].

This guiding principle is overwritten by XX. century. In the last decades, the postmodern approach developed, which mixes instead of separates, integrates instead of dominating. External conditions, the environment, and urban life become important, for which man created them [15].

Systems must adapt. The keywords of this urban organization and mobility organization are cooperation, adaptation, adjustment and networking. According to the postmodern approach, space in the city is given, and crowding indicates poor use of space, overstrain, not lack of space. For this reason, better territorial policy and better service organization become necessary [16]. The increasing dominance of cities affects mobility, its forms, energy consumption and emissions.

In the first half of this paper, the currently used classification of road mobility forms and their characteristics are presented. The impact of urbanization on forms of mobility is showed. In the second half, it formulates a proposal for extending the existing models to consider urbanization and changing land use.

## II. ROAD MOBILITY FORMS

When the forms of use of vehicles in road traffic are examined, the literature distinguishes three broad areas: urban use, rural/mixed-use and motorway use (**Table 1**) [5]. These forms of use differ from each other in their technical characteristics and are often also geographically separated [6].

Due to the name urban traffic, it is typical of urbanized, densely populated areas. It is characterized by the fact that the average speed of the vehicles is low, in many cases below the average of 20 km/h [7]. The maximum speed is 50 km/h, with a few exceptions. Strong, random accelerations and braking characterize the vehicle's longitudinal dynamics [8]. The vehicle's lateral dynamics are also varied and characterized by many lane changes, turns, evasive manoeuvres, and parking manoeuvres. The vehicle and its driver participate in many traffic interactions with other vehicles, including huge vehicles, those driving on a closed route, or with tiny vehicles and even pedestrians. From a vehicle engineering perspective, road users often participate in mobility with a cold engine, and vehicles drive in partial load mode under a wide range of load conditions [9]. The changing loads affect most of the vehicle's subunits: the chassis, the steering, the braking system, the drive chain and the propulsion system.

The lower level shown in ***Fig. 1*** shows the level of engine speed and torque, and the height of the columns shows their frequency in urban traffic. The diagram shows that the use varies greatly across the load range.

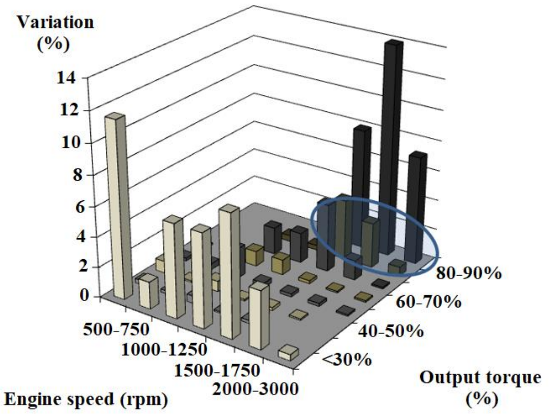


***Figure 1.*** *Speed-torque variation of the urban vehicle [10]*

Motorway traffic is an important part of the road network with at least two lanes, but in many cases more. Divided carriageways are roads with two separate lanes for the two traffic directions - separated by a pavement island, vegetation, closed tram tracks or similar [11]. This is the highest-rated public road suitable for the fast movement of very large volumes of vehicles. The main characteristic of traffic here is homogeneity. The average speed of vehicles here can even exceed the highest average of 110 km/h [12]. This value obviously depends on whether and to what extent a speed limit exists in the given country. In addition, on most motorways there is a minimum speed that excludes slow-moving vehicles and promotes homogeneous mobility [13]. A constant speed characterizes the vehicle's longitudinal dynamics, but intensive braking is not excluded occasionally. The vehicle's lateral dynamics, although more intense due to lane changes, are far behind urban traffic dynamics [14]. Due to the divided lanes and railway crossings, as well as the support of traffic entry and exit by a separate lane, there are fewer interactions between vehicles and these potential encounters are limited. Due to the speed, size and pedestrian bans, the number of vehicles is also significantly more homogeneous. These properties also affect vehicles from an automotive engineering point of view, especially when you think of heavy trucks driving one behind the other with cruise control; the drive unit works in a reasonable approximation at one operating point [15]. This is also facilitated by the construction of highways, which avoid the construction of significant inclines and declines [16].

In the diagram (***Fig. 2***), the lower level is the engine speed and torque field, and the height of the columns indicates the frequency of use of the respective point. The figure clearly shows that the use of the highway and its statistics are clearly recognizable in commercial vehicles.

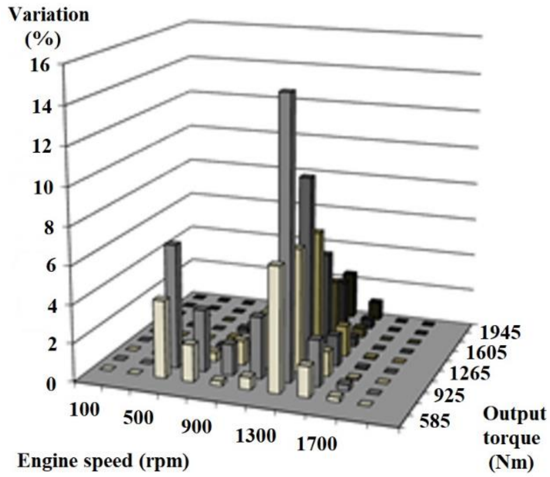


***Figure 2.*** *Speed-torque variation of the highway engine [10]*

In terms of the characteristics of suburban/rural traffic, it is somewhere between urban and highway traffic. The place where the main road network typically passes is twice with single-lane roads. Intersections are rare, but they are flat and affect traffic. The fleet's composition is mixed, because in addition to the vehicles on the highway, agricultural vehicles and bicycles also travel on certain road sections. Longitudinal vehicle dynamics vary more than on the highway, but the average speed is closer to the highway (75 km/h, [12]). Lateral vehicle dynamics are similar to highway use [17].

***Table 1.*** *Summary of existing road mobility form characteristics*

| ***Criteria*** | ***Urban*** | ***Rural*** | ***Motorway*** |
|---|---|---|---|
| Nr. of paralel lines | 1-4 | 1 | 2+ |
| Sepearation of lines | none | none | physical separation |
| Crossing types | all possible types | limited | no same level crossing |
| Nr. of crossings | high | moderate | no (separate lines) |
| Average speed | under 30 km/h | app. 75 km/h | app. 110 km/h |
| Minimum speed | no | no | 70 km/h |
| Longitudnal vehicle dynamics | turbulent | moderate | simple |
| Lateral vehicle dynamics | turbulent | simple | simple |
| Interaction numbers between parcticipants | very high | moderate | low |
| Homogenity of participants | inhomogen | moderate | homogenous |
| Vehicle technology effects | turbulent | moderate | stable |

## III. Measuring vehicle behaviour

Emissions from road mobility account for a large share of pollutant and carbon dioxide emissions. The European Environment Agency’s 2018 air quality report [18] confirms that air pollution is the main environmental health risk. Road transport is responsible for 39% of nitrogen oxide emissions, 28% of particulate emissions and 20% of carbon monoxide emissions. For this reason, road vehicles placed on the EU market since 1970 are subject to type approval, which has been part of the Euro 1 standard since its introduction in 1992. Currently, the active pollution control standard applies to passenger cars from Euro 6d onwards [19].

As a result, road transport has reduced its emission rate since 1990. However, the continued growth of the EU fleet and in particular, the increasing share of diesel vehicles (which traditionally have higher $NO_x$ and PM emissions than petrol vehicles) have reduced the scope for improving air quality. Note that recent studies have confirmed the critical aspects of old diesel vehicles (Euro 0 to Euro 3) but have reduced the impact of modern diesel compared to modern petrol vehicles, at least to the extent that this applies to particulates. In addition, the deviations between expected and actual pollutant reductions also increased due to the emission differences between the vehicles tested in the laboratory and on the road. With different rolling resistance and aerodynamic drag, free gear shift strategy and driving style, non-zero positive altitude gain and unregulated environmental conditions, emissions on the road are expected to vary compared to those in controlled vehicles—laboratory experiment following the prescribed speed curve. In 2007, the JRC started a series of experimental activities to investigate real-world emissions using on-board instruments such as PEMS. In particular, for light commercial vehicles (i.e. passenger cars), large differences between laboratory and road vehicles were found in terms of $NO_x$ emissions from diesel cars [20]. These findings and other elements led to regulatory efforts: In 2016, the EU adopted the first RDE package [21], establishing procedures, equipment requirements and assessment. Since then, RDE has undergone three major legislative changes. A non-exhaustive chronology of the EU RDE legislation is presented in **Table 2**, which includes the relevant JRC reports. Currently, the 4th RDE legislative package [22] is active and valid for Euro 6d-TEMP vehicles from January 2019.

The main scientific link between road mobility splitting and transport sustainability is vehicle emissions testing. Since the three categories presented described most of the vehicle use in the last century, the test methods were developed for them [23].

During the tests, the qualification tracks consist of three separable sections: highway, urban and mixed, which map the previously presented categories. Figure 3 shows that the test sections' characteristics are separated in terms of acceleration*speed indication and acceleration while driving. The results of the tests are used in many places, for example in the emission assessment of new vehicles or in the determination of catalog consumption.

The data set was characterized by a speed in the city of ≈ 30 km/h, a speed in the countryside of ≈ 75 km/h and a speed on the highway of ≈ 110 km/h.

## IV. Current data on urban mobility

According to the survey, most people still travel by car on their daily journeys: 45 percent mainly use their private car, 23 percent use public transport, 16 percent use a micro-mobility device and 14 percent reach their destination on foot. According to previous data, 16 percent of the Hungarian population cycles on weekdays, and four thousand designated cycle paths now serve this purpose. The data also show that micromobility in Hungary is mainly used for shorter distances: 60 percent of electric scooter riders and 50 percent of cyclists travel less than five kilometres per trip; the accident rate of e-scooters is three times higher than that of cyclists. According to the survey, many people see cycling in traffic as a stress factor. At the same time, other new means of transport have recently emerged as part of the mobility transition: electric bicycles, Segways and electric scooters. These vehicles already participate in traffic every day, but on public roads they often appear in disorderly conditions [24].

The long-term mobility visions also point in a similar direction. On the one hand, individual transport in cities, especially in traffic-calmed zones, will be pointless due to the strengthening of alternatives such as micromobility, bicycle, walking, and on the other hand, the increase in the price of new vehicles will not make sense, so it is possible to own them [25]. The car-free inner cities with few parking spaces being introduced in more cities will also facilitate this [26].

## V. Results

The changing road mobility is less and less described by the triple use of city-country-road-highway, which has been well suited until now, because urbanization has reached such a level that a new area of use has emerged: the city center.

Its peculiarity is that it is located in metropolises and in many cases is identical to the historic city center. The existing road network is not suitable for the transit function it will take on once the residents have moved out, so from a car traffic perspective it can be characterized as a traffic-calmed or closed area. In these areas, the use value of private cars is reduced due to restrictions on pollution classification or powertrain and the limited number of parking spaces. At a system level, the objective is to reduce emissions. This can be achieved by prioritizing public transport, even public transport with fixed tracks, footpaths and - in many cases shared - micromobility devices. Vehicle dynamics can only be interpreted for the remaining vehicles in these areas. There is a lot of interaction with pedestrians, typically the speed is low, averaging 10 km/h. The further development of cognitive mobility significantly influences inner-city mobility, the participants are equipped with sensors, location sensors and occupancy sensors, thus promoting highly efficient mobility through networking with the help of mobile devices.

The introduction of the new form of use opens up new scope, especially for urban mobility planning, and opens up the possibility of using economic means to contribute to the most sustainable mobility possible. The new category is in symbiosis with the other categories, since the difference does not consist of a unit jump at the interfaces, but in a fuzzy system. The solutions observed here are partially and spatially to a lesser extent shifted to the surrounding areas.

***Table 2.*** *Proposal for the introduction of a new mode of transport*

| ***Criteria*** | ***Downtown*** | ***Urban*** | ***Rural*** | ***Motorway*** |
|---|---|---|---|---|
| Nr. of parallel lines | 1/none | 1-4 | 1 | 2+ |
| Separation of lines | none | none | none | physical separation |
| Crossing types | merging | all possible types | limited | no same level crossing |
| Nr of crossings | very high | high | moderate | no (separate lines) |
| Average speed | app. 10 km/h | under 30 km/h | app. 75 km/h | app. 110 km/h |
| Minimum speed | no (walking) | no | no | 70 km/h |
| Longitudnal vehicle dynamics | limited by the speed | turbulent | moderate | simple |
| Lateral vehicle dynamics | dynamic | turbulent | simple | simple |
| Interaction numbers between parcticipants | very high, pedestrians | very high | moderate | low |
| Homogenity of participants | moderate | inhomogen | moderate | homogenious |
| Vehicle technology effects | to be determined | turbulent | moderate | stable |
| Energy consumption per participants | very low (tbd) | high | moderate | very high |
| Emission per participants | very low (tdb) | very high | moderate | high |

## VI. Conclusion

The social music of the 21st century and one of its main pillars, mobility, is changing thanks to the accelerated technological development. The criteria by which we have characterized mobility so far may need to be revised. In our work, we study the urban-rural-highway-based separation, which is widespread and crucial from the perspective of sustainability assessment of road mobility devices. We present its characteristics and consider the testing procedures based on them. By comparing these with the mobility trends, we point out the need to complement them and propose the introduction of a new category, indicating its main dimensions and highlighting the areas where further research is needed.

## VII. Acknowledgement

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## Author contributions

**M. Zöldy**: Conceptualization, Experiments, Theoretical analysis, Writing, Review and editing.

## Disclosure statement

The author declare that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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