Urban Mobility Analysis on Efficiency and Sustainability by Means of Transportation

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Abstract. Patterns of urban land use are inherently linked to the predominantly used means of transportation, both generating and being generated themselves. While each mode of transportation shapes a different development typology a clear understanding of their interrelations and dependencies is needed in order to create a comprehensive mobility strategy. The study proposes a 15-criteria analysis framework developed to identify and quantify the main modes of transportation’s key aspects. The analysis framework was applied to a yearlong research on Timisoara, Romania, comprising hard, quantitative data, digital simulations and mobility pattern analysis and soft data, quality assessment and perceived needs and satisfaction levels. The research was carried out in clear opposition to the national trend of official mobility strategies focusing on accommodating increased levels of car traffic on the underdeveloped existing roads infrastructure. By analysing the efficiency and sustainability of all four main modes of transportation the results offer a holistic comprehensive view. While, despite current practices, no mobility strategy can focus on a single means of transportation, the article will only present in detail the research on cycling, infrastructure and use, as it is the most underdeveloped and least discussed at the national level and proven through our study to be the most efficient for a city of Timisoara’s size and characteristics. By identifying a clear link between urban land use patterns, infrastructure quality and perceptions and the most efficient means of transportation for each particular city type mobility strategies could shift the trend of urban development towards a more sustainable one.

1. Introduction
A city’s predominant transportation mode is crucial in determining its type of urban tissue. A denser and more compact urban development is generated through pedestrian, bicycle and public transit while car based developments tend to be dispersed.

Due to their “drive till you qualify” governing principle [1], they have caused the cities’ out of control expansion into the surrounding territory, urban sprawl, characterized by unsustainable low densities, single function areas and a car dependent society [2]. This type of unsustainable development only reached Eastern Europe and Romania at the beginning of the XXI century as opposed to its much earlier start in western, more developed, countries.

The aim of the study was to analyze the efficiency and sustainability of all four major transport modes in order to determine the one most suitable for Timișoara based on its characteristics. With a population of approximately 320.000, Timișoara alongside the similarly sized Cluj are Romania’s largest cities after Bucharest. Situated on a plain Timișoara has a radial concentric urban structure with an 8km radius.
2. Analysis methodology

As part of the research to determine the most efficient and sustainable mode of transportation, 15 criteria were analyzed, chosen from all three pilons, ecology, economy and social: Necessary space per person, Speed/Time, Air pollution, Noise pollution, Health, Fuel consumption/energy, Cost, Route flexibility, Slope, Comfort, Social interactions, Safety, Age restrictions, Pleasure and Ability to transport cargo.

Despite the numerous parameters that influence the decision to choose a particular mode of transport, such as safety, comfort, cost, etc. the most important one remains speed and the time required to reach the destination [3]. Thus, the authors conducted an analysis on Timisoara’s transport opportunities, comparing the maximum distance that can be reached in the amount of time commonly allotted for each destination considering the average speed of each mode of transportation. Based on numerous studies [4, 5, 6, 7, 8, 9, 10, 11, 12] it was identified the average lengths of time one is willing to spend to reach a particular destination: park, shop, playground, school, work, etc. (table 1).

Table 1. Average time allotted for traveling

| Destination            | Average allotted time (min) |
|------------------------|-----------------------------|
| Major public space - square | 10 min                     |
| Small park             | 3 min                       |
| Park                   | 10 min                      |
| Parking                | 2 min                       |
| Local shop             | 3 min                       |
| Neighborhood shop      | 6 min                       |
| Playground             | 2.5 min                     |
| School                 | 10 min                      |
| Public transit station | 5 min                       |
| Workplace              | 30 min                      |

Even though it may vary based on age, weight, height, terrain slope, etc. the average speed of a pedestrian is approximately 5 km/h [13]. Cycling speed varies between 16 and 24 km/h. In order to determine the realistic average speed for cycling in Timisoara, 6 different routes were thoroughly tested for 5 months, August, September, October, November and December, chosen for their array of conveyance for cycling, at different times of day, 7:30, 14:00 and 20:00, and by different subjects, in regards to age and fitness (figure 1). An average speed of 15.25 km/h was determined that illustrates the state and development of Timisoara’s cycling infrastructure.

In determining the average speed for public transport the authors added the average wait time to the travel speed as opposed to the local authorities’ sole use of travel speed for urban mobility strategies [14]. In 2014 the reported average speed for public transit was 16.9 km/h (including, however, the much faster express and metropolitan routes), 13.8 km/h for trolleybuses and 14.9 km/h for trams [14]. The average public transit speed was 15.2 km/h with a wait time of 16 minutes and 24 seconds, as illustrated in figure 2, calculated based on the minimum and maximum wait times for the three modes of transportation reported by the local transit authority and verified through field tests at various times of the day by the authors.

The legal speed limit in Romanian cities is 50km/h, but due to traffic and climate conditions, the average speed is much lower. In the major European Western cities, the average speed is 30.1 km/h, with the lowest being registered in London of only 19 km/h and the highest in Barcelona 35 km/h [15]. Four routes were tested for 5 months at various times of the day, 7:30, 12:00 and 18:00 determining an average of 22 km/h (figure 1). The lowest speed registered was 9 km/h while the highest 37 km/h.
Figure 1. Bicycle and car routes tested for 5 months to determine the average speed

Figure 2. Comparison of average speed and distance covered by the four main modes of transport for Timisoara

In order to determine the efficiency of the various modes of transit the authors analyzed the maximum distance that can be covered in 30 minutes, namely the maximum time a person is willing to spend traveling to their workplace. The starting point was selected at Timisoara’s Southern city limit on ‘Calea Martirilor 1989’ boulevard, one of the eight major access routes, to also take into consideration possible travel times inside the city for those living in its suburbs or surrounding villages. For each mode of
transport, the data was used to create two maps, one illustrating the covered area in 5 minutes’ increments while the other the accessible blocks.

The area covered on foot in 30 minutes can be observed in figure 3, divided in 5 minutes’ segments, namely a total of 2.5 km, 9.44% of the city’s total area. Figure 4 illustrates the area covered cycling. In 30 minutes, a distance of 7.62 km can be reached, 93.74% of the city’s administrative territory and 98.32% of its total built area.

**Figure 3.** Distance and area covered by pedestrian transit in 30 minutes

**Figure 4.** Distance and area covered cycling in 30 minutes

Taking into consideration the study’s starting point at the edge of the city, 2.5 minutes are required to reach the nearest public transit station. Adding the average wait time, the earliest the journey can start is after 19 minutes and despite the many connections available along the line an additional wait time would make the journey by public transit impractical, thus limiting the passengers’ options.
In the remaining time 10 stations can be reached given the 15.2 km/h average speed. A mere 11.21% of the city’s total area can be reached as illustrated in figure 5.

Taking into consideration the disadvantages created by the wait time for public transit, Timisoara’s citizens’ preference for private cars is substantiated. A distance of 11 km can be reached in 30 minutes 100% of the city’s total area, outside of infrequent traffic jams, as can be noted in figure 6.

![Figure 5. Distance and area covered using public transit in 30 minutes](image1)

![Figure 6. Distance and area covered by car in 30 minutes](image2)

3. Results and discussions

For longer distances the most efficient modes of transport for a city of Timisoara’s urban tissue and landscape type proved to be cycling and private cars. The inconvenience of the wait time for public transit caused by the infrastructure network, its development and lack of dedicated lanes, number and distribution of vehicles on each route and the scheduling inflexibility related to traffic conditions and rush hours has a negative effect on its efficiency and use. Table 2
Table 2. Percentage of Timisoara’s total area covered by mode of transit in 30 minutes

| Time     | Pedestrian | Bicycle | Public transit | Car    |
|----------|------------|---------|----------------|--------|
| 5 minutes| 0.25%      | 2.30%   | 0.25%          | 4.55%  |
| 10 minutes| 0.85%     | 7.79%   | 0.85%          | 20.94% |
| 15 minutes| 2.04%     | 26.19%  | 2.04%          | 49.79% |
| 20 minutes| 3.99%     | 45.93%  | 3.99%          | 78.58% |
| 25 minutes| 5.93%     | 68.03%  | 5.93%          | 99.99% |
| 30 minutes| 9.44%     | 93.74%  | 11.21%         | 100%   |

In a similar fashion, 14 other criteria were analyzed for each mode of transportation based on hard and soft data obtained from the authors’ field studies and observations, discussions with experts in the field, by analyzing the local authority’s official reports and strategies [16] and questionnaire surveys of Timisoara’s citizens [17].

For each criterion, a score from 1 to 5, 5 being the highest, was assigned, based on the results from the above-mentioned sources. Thus, the efficiency and sustainability of each mode of transportation is clearly illustrated. From the total possible score of 75 points, cycling and pedestrian transit obtained the highest scores, 62-61, proving themselves to be the most sustainable. Despite its many infrastructural flaws, public transit earned 47 points, while the most unsustainable one was the private car with 38, as can be noted in table 3.

Table 3. Sustainability and efficiency analysis of the main transport modes in Timisoara

| Time     | Pedestrian | Bicycle | Public transit | Car    |
|----------|------------|---------|----------------|--------|
| Necessary space per person | 5 | 4 | 3 | 1 |
| Air pollution | 5 | 5 | 3 | 1 |
| Noise pollution | 5 | 5 | 2 | 1 |
| Health | 5 | 5 | 3 | 1 |
| Fuel consumption/energy | 5 | 5 | 2 | 1 |
| Cost | 5 | 4 | 3 | 5 |
| Speed/Time | 1 | 5 | 1 | 2 |
| Route flexibility | 5 | 5 | 1 | 5 |
| Slope | 5 | 5 | 5 | 5 |
| Comfort | 1 | 2 | 3 | 1 |
| Social interactions | 5 | 5 | 5 | 3 |
| Age restrictions | 5 | 4 | 5 | 3 |
| Safety | 3 | 2 | 5 | 3 |
| Pleasure | 5 | 4 | 3 | 3 |
| Ability to transport cargo | 1 | 2 | 3 | 5 |
| Total | 61 | 62 | 47 | 38 |

4. Conclusions

The study proved that pedestrian transit is sustainable and the most efficient for short distances, under 2.5 km, having problems in the comfort criterion in case of rainfall and extreme temperatures and for transporting cargo. At the neighbourhood level, pedestrian accessibility is crucial in shaping a community. Cycling is both sustainable and efficient for distances up to 7.6 km, making it the perfect fit for Timisoara’s 8 km diameter. Its problems are related to inadequate citywide infrastructure that instills unease concerning safety in traffic and with the high chances of bicycle theft. Climate conditions can affect travel comfort but the harsh circumstances created by both them and the state of infrastructure development help form a tight knit cycling community. Public transit is relatively sustainable but due
to Timisoara’s long wait times is only practical for single line travel. Travel by car, despite the low sustainability scores offers undeniable advantages in efficiency for distances over 8 km, in comfort and ability to transport cargo.

In creating a citywide mobility strategy all modes of transport must be taken into consideration and implemented and facilitated according to an area’s and situation’s particular characteristics. The city center should, in most cases, accommodate cycling due to its high sustainability and efficiency on short distances, however, in Timisoara’s case its infrastructure is underdeveloped and flawed. The local authorities’ official development and mobility strategies only facilitate car traffic, in a passive reactive manner, thus encouraging sprawl type urban development. In Romania’s case, except the capital’s 1.9 million inhabitants, all other cities have a population similar or lower than Timisoara’s resulting in a need to focus most mobility strategies on cycling.

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