TIME-SPACE ASYMMETRY VERSUS TIME-SPACE SYMMETRY

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Abstract
The interpretation and the analysis of physical spaces is generated from the symmetry axiom which is valid in geographical spaces but might not be valid in other forms of spaces, the so called non-geographical ones. In the case of such spaces which can be expressed by time, network and cost, the opposite of symmetry can be found: distance asymmetry which means that the distance from one object to another and back are not equal. This research is motivated by the fact that while distance symmetry has been widely studied distance asymmetry has been not investigated in suburban areas of Győr. The purpose of the study is to give a typology of the sources of distance asymmetry, especially with regard to time-spaces, to demonstrate some real life practices and finally, to present measures of time-space asymmetry.
Keywords: time-space, distance asymmetry, spatial modelling

1. INTRODUCTION

In today's accelerated world, the role of accessibility is accepted as a vital element of everyday life and due to this concept worldwide it has become a key element in research, especially in regional science. In the past decades there has been a movement towards the time-based approach instead of the traditional, space-based view, as today it is no longer important what the distance between two spatial points is, as today the geographical distance between two spatial points becomes less important than the amount of time and cost of moving from one place to another. As such, the advantages or disadvantages of a given location are shown as well compared to other ones, since it is confirmed that the location of a place is unfavourable if it is difficult to reach (Ahmed & Miller, 2007; Dusek & Szalkai, 2017; Győrffy, 2011). To

Theoretical and Empirical Researches in Urban Management
Volume 17 Issue 4 / November 2022

Theoretical and Empirical Researches in Urban Management
Volume 17 Issue 4 / November 2022

examine the connection between time-space and accessibility is nowadays especially relevant. This is because there is also a demand for fast and convenient transport for travellers, as it has already been highlighted in several studies (Colesca et al., 2017; Sabir & Ali, 2021).

"Geographical space is continuous, each point of a topographic map can be interpreted as an element of space" (Dusek, 2014, 19). In geographical space, the distance between point A and point B is the same as the distance between point B and point A, that is, the symmetry axiom applies. The geographical model with symmetry axiom often determines the way of thinking about other types of spaces where the symmetry axiom is not valid. The network, time and cost spaces contain nodes and lines and therefore they are not continuous. Several factors threaten symmetry axiom in these spaces, for example the different types of streets in cities, traffic jams and its direction, timetable effect, or the weather conditions.

Mental and cognitive perception of geographical space is symmetric neither, only the two-dimensional representations, the mental maps have to be symmetric. Directional judgements are also enforced by the hierarchical organization of the space elements. Ordinary elements are judged to be closer to landmarks than landmarks to ordinary elements (Sadalla et al., 1980; McNamara & Diwadkar, 1997).

Theoretical and empirical spatial research pays surprisingly little attention to the consequences of distance asymmetry. Disregarding by the theoretical side it can be explained both by the disturbing problems in model building and by the implicit assumption, that this feature has a negligible effect on the validity of models. 50 years ago empirical disregard might have been explained by the lack of easily available databases (distance matrices), but today it is an invalid argument. It is interesting, that the distance asymmetry of non-geographical spaces, such as human distance perception, cultural, institutional distance of institutions, countries and other aggregate entities, psychological distances between people, psychological evaluation, and citation data matrix of journals, disciplines or authors are more intensively investigated areas than the asymmetry of network, time and cost spaces (Burroughs & Saddala, 1979; Codol et al., 1989; Goldstone, 1994; Hakanson & Ambos, 2010; Hakanson et al., 2016; Holman, 1979; McNamara & Diwadkar, 1997; Selmer et al., 2007; Shenkar, 2001).

The asymmetry may have different meanings:

- The entity A (which may be a person or a group of people) is dissimilar to the entity B and it is not the same as the degree to which the entity B is dissimilar to the entity A.
- In the context of cultural distance moving from location A to location B, different problems may occur as when moving from location B to location A.

- According to another definition, cultural distance between two countries may yield an asymmetric impact on the target's evaluation, depending on who, in the pair, performs the evaluation (Lim et al., 2016).
- Asymmetry of distances and other conceptual and methodological deficiencies lead some researchers to questioning the distance as an appropriate metaphor that international management phenomena can be described and analysed with (Shenkar et al., 2008).

Inherent conceptual problem of many models and empirical analyses are the failure to take into account of asymmetry of distances.

First we provide an overview on different spaces and the sources of asymmetrical distances. Then, real examples for the time-space asymmetry are given. We deal only with georeferenced objective spaces and do not discuss the cognitive spaces and other types of spaces, where the concept of distance is used mainly metaphorically.

In this paper the existence of time-space asymmetry is investigated through Győr, defined as a large city based on both population and functionality. Győr, the seat of Győr-Moson-Sopron county is one of the most dynamically developing cities located in Hungary, in the Western Transdanubia region. The proximity of the Austrian and Slovakian border, as well as the relative closeness and development of the network connection to Budapest makes the geographical location of the city favourable. Together with the Vienna-Bratislava-Győr-Budapest urban region, one of the most developed core areas and agglomerations in Eastern Europe is formed by these cities (Rechnitzer & Kecskés, 2015). Being the sixth largest city in Hungary, Győr covers an area of 175 km2 with a population of 132,735 (KSH, 2021). Győr has the second largest agglomeration with the most settlements (68) in the country, with an area of 1607 km2 and a population of 227,704.

According to the data of the 2011 census, 30.3 thousand of the 79.8 thousand employees working in Győr commuted to the city from other settlements, including seven-tenths of them from the settlements of the agglomeration. Consequently, Győr with significant industrial potential is able to integrate not only the labour force of the attracted settlements, but also employees of more distant areas. In contrast, only 12% of the employees went to work in other settlements from Győr (KSH, 2015).

The city's suburbia is characterized by intense population growth. The commute of the large number of workforce, which has moved to the suburban areas in the last decade, mainly caused an increase in car traffic (KSH, 2014). Hardi et al. (2021) based on traffic counting data, describe the transport of Győr as a typical suburban pattern.

Theoretical and Empirical Researches in Urban Management
Volume 17 Issue 4 / November 2022

Theoretical and Empirical Researches in Urban Management
Volume 17 Issue 4 / November 2022

2. LITERATURE REVIEW

Distance is one of the basic concepts of spatial sciences (geography, regional science). Today it is an extremely complex notion and it is examined from many perspectives. Interpreting distance, geographical distance is the basic term, by which spatial non-identity, or the degree of difference between two places is determined. In general, distance can be defined as the length of the shortest way between two places and spatial points (Nemes Nagy, 1998). This distance can be interpreted, measured and expressed in numbers in several ways (L'Hostis, 2020).

Depending on whether the extent of the spatial difference or closeness are emphasized by the researchers, the concept of distance and proximity are used (Kecskés, 2018; Kecskés, 2019). Proximity clearly refers to the small distance, the physical nearness and the direct neighbourhood (Nemes Nagy, 1998). Geographical proximity is the most commonly used dimension of proximity in the literature, although according to Knoben & Oerlemans (2006), the notion 'geographical' is often neglected, and only the term 'proximity' refers to the location. The use of the term proximity has become widespread mainly with the development of info-communication devices being able to bridge geographical distances and the appreciation of the role of information and knowledge (Boschma, 2005; Kecskés, 2018).

The dimensions of the traditional proximity or distance create different spaces, such as geographical, transport network, time and cost space (Table 1).

TABLE 1 – CHARACTERISTICS OF DIFFERENT DISTANCES AND SPACE CATEGORIES

Proximity/distance	Space category	Characteristic
Geographical	Geographical space	Shortest distance between two geographical points
Transport network	Transport network space	The shortest distance between two geographical points on the elements of the transport network
Time	Time-spaces	The shortest (or average) time required to reach from one geographical point to another
Cost	Cost-spaces	The lowest (or average) cost of bridging two geographical points

Source: The authors' own compilation based on Dusek & Szalkai (2017)

According to Table 1, space of transport networks are originated from the shortest routes between the different particles of any network, time-spaces involve the average time which is necessary to take from point A to point B of a network and cost-spaces cover those average costs that are spent to reach one specific point from another one (Ahmed & Miller, 2007; Dusek & Szalkai, 2017). The collective name of the latter three distances is economic distance (Mazurek, 2012; Kecskés, 2018).

The order of the different economic distances in the first table shows the sequence of how the calculation of these distances can be carried out. The first is the space of transport network and its attributes that has to be counted related to which we can specify time-spaces and at last the costs and the cost-spaces can be determined.

Time- and cost-spaces contain nodes and lines. The geographical space has metrical characteristics, i. e. prevail these axioms:

1. "The distance between two points is zero if and only if the two points are identical (the separation axiom).
2. The distance between two points is positive if the two points are different.
3. The distance from point A to point B is identical with the distance from point B to point A (symmetry axiom).
4. The distance from point A to point B cannot be larger than the sum of the distance from point A to point C and the distance from point B to point C (axiom of triangle inequality)" (Dusek, 2010, 4–5).

If the application of the above mentioned axioms is examined, it can be found that the first and the second can also be used to describe time-spaces beside geographical space. It takes time to reach a point in geographical space – i.e. to overcome physical distance – from another point, thus these points will be diverse in both geographical and time-spaces as well. However, the identification of these points with different methods is problematic. If cost-spaces and the first two axioms are taken into account, the picture is more complex.

In case of the symmetry axiom, it can be found that it is not valid in time- and cost-spaces. Several different factors influence this statement both in practice and theory – such factors can be the direction of the wind which can have a great impact of travelling in terms of flying times or the intracity and intercity transportation where the street types or the vertical characteristics of the roads will result the invalidity of the symmetry axiom in these cases. The time-space of hitchhiking is also direction dependent: thumbing from small settlements to big centres is significantly easier and faster than hitchhiking from big centres to small settlements. In the time-space of public transport, the differences are also larger between directions than in the case of individual transport.

Nowadays, time-space is becoming more and more important as transport infrastructure is being improved (L'Hostis, 2016). This paper illustrates the existence of the asymmetry of the time-space through three practical cases: first, the asymmetry of time space of the Hungarian rail traffic is measured, the

Theoretical and Empirical Researches in Urban Management
Volume 17 Issue 4 / November 2022

second case is the asymmetry that can be identified between the chosen suburban areas and the city centre. The last practical example discusses the rail traffic asymmetry of the suburban areas and the city centre.

3. RESEARCH METHODOLOGY AND RESULTS ANALYSIS

Asymmetry can be measured with various global and local indices on different spatial level of analysis. Global indices show the asymmetry of the whole network under study, local indices show the asymmetry of a point or a smaller area inside a bigger network. For example, you can analyse the asymmetry of world air traffic or air traffic of Europe, or air traffic of Italy (these are different levels of a global analysis) or asymmetry of an airport compared to many airports.

This paper introduces three practical cases of time-space asymmetry using local indices on three different spatial levels. In the first example to present the time-space asymmetry of the Hungarian rail traffic only a very simple and well interpretable measure of asymmetry is used, namely the sum of differences of inbound and outbound distances between two locations divided by the total distance of the network. In case of symmetry, this statistic is equal to zero. In case of perfect asymmetry, the value of this statistic is 1 (100%). Perfect asymmetry means that one direction has zero distance; the opposite direction is non-zero, in each pair of locations. It is evident that perfect asymmetry is impossible in georeferenced networks.

In the second case of this study, we investigate the time-space asymmetry of travelling by car between a Hungarian city, Győr, and its six suburban regions by comparing the inbound and outbound travel times calculated by the Waze application. Waze is a navigation application based on community collaboration, launched in 2009. The aim to create Waze navigation application was is to build a database based on the real data of vehicles in traffic and to provide as exact information as possible about the length of the expected travel time, as well as the best routes that avoid current traffic jams (Hoseinzadeh et al., 2020). Regarding the spatial level in the second case, six suburban regions of Győr are chosen, three suburban areas which are located outside the administrative border are Vámosszabadi, Pér and Abda, while within the administrative border we examine Sárás, Győrszentiván and Gyirmót. The choice of these settlements is justified by the fact that the access to the city centre, Győr is achieved from different directions, and the population growth of these suburban areas is also significant. The data of the six routes examined show a pre-calculated average time, but conclusions can be drawn regarding the trend. In order to demonstrate the asymmetry of time-space, time differences between the inbound and outbound paths between the city centre and the suburban areas are described, which is zero in case of symmetry, while the positive values

represent the longer time of the inbound travel, and the negative values express the longer time of the outbound travel.

Finally, the third example of the paper investigates the time-space asymmetry of the train transport between Győr and its six suburban regions. For this analysis, a small database was formed based on the schedule times of these inbound and outbound routes. Time differences, i.e. the existence of asymmetry of time-space, are presented with a simple comparison of these schedule times.

The three different practical examples show different findings towards the asymmetry of time-space. In our first case we present the asymmetry of time-space of the Hungarian rail traffic. Table 2 shows the time asymmetry of the 23 biggest Hungarian towns and cities.

TABLE 2 – ASYMMETRY OF RAILWAY TIME-SPACE IN HUNGARY

Name of settlement	Asymmetry (%)
Békéscsaba	3.7
Budapest	2.2
Debrecen	1.6
Dunaújváros	3.5
Eger	1.4
Győr	4.6
Hódmezővásárhely	2.2
Kaposvár	3.9
Kecskemét	2.8
Miskolc	1.8
Nagykanizsa	3.8
Nyíregyháza	2.0
Pécs	2.9
Salgótarján	4.1
Sopron	3.4
Szeged	1.8
Székesfehérvár	2.9
Szekszárd	2.8
Szolnok	3.3
Szombathely	2.7
Tatabánya	4.5
Veszprém	5.2
Zalaegerszeg	3.1
Total network	**3.0**

Source: Authors' own compilation 2022

The origin of the asymmetry is mostly the schedule effect. Directional difference of speed is only important in Budapest (the capital) because the direction to Budapest is longer with only one or two minutes compared to the direction from Budapest. The maximum value of the pair wise difference is 19.4%. This

Theoretical and Empirical Researches in Urban Management
Volume 17 Issue 4 / November 2022

is larger than road traffic differences, which is almost negligible on this level of analysis (network of settlements with large distances). Road traffic asymmetry can be very large inside the cities.

In our second example, Figure 1 illustrates the difference between the road traffic of a Monday morning inbound (from the suburban area to the city centre) and outbound traffic (from the city centre to the suburban area). It shows that the difference is positive for all locations, i.e. the length of the inbound road is bigger than the length of the outbound road, despite the same geographical length of the examined road. Figure 1 also illustrates that there is a particularly large time difference in the morning hours, since the majority of the inhabitants of the suburban regions work in the city, and schools and other services can be accessed there as well.

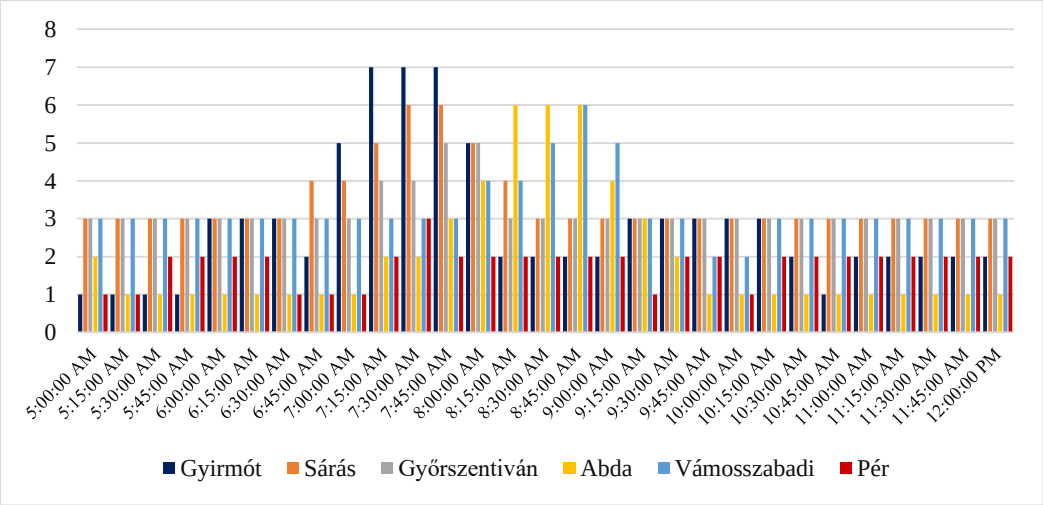

FIGURE 1 – TIME DIFFERENCE BETWEEN THE INBOUND AND OUTBOUND TRAFFIC OF THE ROAD BETWEEN THE SUBURBAN AREAS EXAMINED AND THE CITY CENTRE OF GYŐR (MONDAY MORNING)
Source: Waze application 2022. The authors' own compilation

However, the result is less clear in the afternoon (from 12:15 to 22:00 p.m.) (Figure 2). While Hardi et al. (2021) point out that in the afternoon the time of the outbound travel is greater, it is only proven by the settlement Gyirmót, because here the difference between 16:30 and 17:00 has taken a negative value, i.e., the time of the outgoing travel is longer than the time needed to access the city centre of Győr. In the case of the other areas, although the length of the road from the city centre increases by 1-2 minutes (in the case of the settlements Sárás, Vámosszabadi and Pér), this value does not exceed the length of the traffic to the city centre. While in the case of Győrszentiván, the travel to the suburban region does not increase at all in the afternoon hours, according to Waze data. The reasons for explaining this (which exploration goes beyond the purpose of the study) can vary from the type of road given, the operation of traffic lights to the number of users of the application.

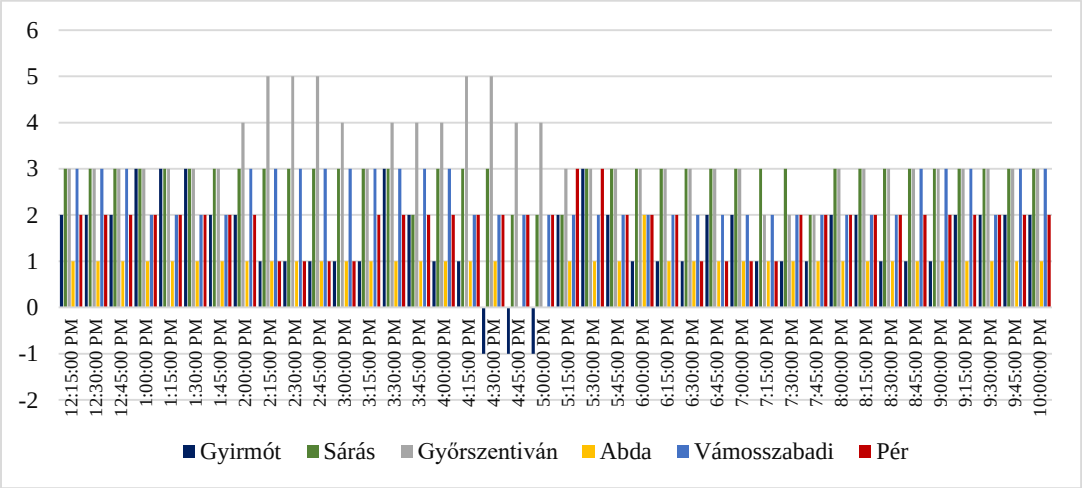

FIGURE 2 – TIME DIFFERENCE BETWEEN THE INBOUND AND OUTBOUND TRAFFIC OF THE ROAD BETWEEN THE SUBURBAN AREAS EXAMINED AND THE CITY CENTRE OF GYŐR (MONDAY MORNING)
Source: Waze application 2022. The authors' own compilation

On weekends there are no big differences like on weekdays, but it can be concluded that the time length of the inbound and outgoing travels are different (the former is longer than the latter) as well, so the time length of the two travels did not take a zero value in any cases.

The third example of the study presents the asymmetry of the time-space for train transport between Győr and six suburban regions of the city (Table 3).

TABLE 3 – TRAIN TRANSPORT BETWEEN GYŐR AND THE SUBURBAN REGIONS (IN MINUTES)

Suburban region – downtown	Time	Downtown – suburban region	Time
Ménfőcsanak – Győr	**13**	Győr – Ménfőcsanak	**11**
Ikrény – Győr	**8**	Győr – Ikrény	**7**
Győrszentiván – Győr	**8**	Győr – Győrszentiván	**6**
Abda – Győr	**8**	Győr – Abda	**5**
Nyúl – Győr	**21**	Győr – Nyúl	**18**
Rábapatona – Győr	**15**	Győr – Rábapatona	**12**

Source: Authors' own compilation 2022

It is clear that this example also refutes the existence of symmetry axiom in time spaces, since the length of the journey from suburban areas to Győr is greater than the length of the road from Győr to the suburban region. Although exploring the origin of the inequality in length of time of the journey exceeds the scope and goals of the study, the source of the time asymmetry may be for example the schedule effect, and the acceleration and deceleration of arriving and departing trains.

Theoretical and Empirical Researches in Urban Management
Volume 17 Issue 4 / November 2022

4. DISCUSSIONS

Asymmetry is an interesting and important descriptive characteristic of spaces. Measure of asymmetry is an indicator of non-metricity and a sign of space distortion, compared to the Euclidean space. Local measure of asymmetry is related to the accessibility of different locations. Asymmetry plays an inspiring role in the theory as well as in model building.

The first practical example of the paper, in which differences in the railway time space in Hungary were examined, illustrates the existence of asymmetry, since zero value is not a result in any cases. The second example of the study also allows important conclusions to be drawn i.e. the suburbanization is one of the most noteworthy processes of the post-socialist urban development in Hungary. The phenomenon of suburbanization, i.e. the extension and spatial spread of the cities' built-up across boundaries, is caused by the fact that the inhabitants of the city move to the outer parts of the city (suburbanization within the administrative boundaries) or beyond (suburbanization outside the administrative boundaries). It means that the resulting suburbanization remains organically connected to the city, so the traffic between the two regions is high (Kovács et al., 2019; Hardi et al., 2021, Vasárus & Lennert, 2022). The process is more complex by the urban sprawl phenomenon, which is regarded as one of the most prominent challenges facing European cities today (Suditu et al. 2010). The process, common inherent part of appeared mainly through suburbanization, which means the quantitative growth and functional transformation of urban areas by spreading the city and its suburbs to rural and undeveloped land areas (Szirmai, 2011; Grigorescu et al., 2012; Kovács et al., 2019). Consequently, the rapid expansion of built-up areas and the large-scale displacement of the urban population have significant negative social and environmental consequences. Such negative effects are caused, for example, by traffic loads, such as increased risk of accidents, road congestion and increased air pollution (Johnson, 2001; Hardi et al., 2020; Sprikova et al., 2020). However, as the two processes are relatively rapid and the phenomena is not followed by coherent urban development policies, furthermore, urban development does not even seek to optimize the location of these areas in terms of transport, the inflexible, slowly changing transport infrastructure has fallen short of new needs (Batty et al., 2003; Grigorescu et al., 2012). The problem is further strengthened by the fact that transport between the examined two places is mostly one-way (flow from agglomeration to city) and that households living in suburban areas often have more than one passenger car. The situation is not improved by public transport either (at least by bus), as it uses the same routes. As a result, traffic to the city in the morning and out of the city in the afternoon hours is crowded, and this incorporates the concept of symmetry axiom into our thought process (Comi & Polimeni, 2020; Hardi et al., 2021).

It can be stated that the time distance of the inbound and outbound roads (despite examining the same section of road) is not equal in the morning or afternoon hours, so the asymmetry of the time space is proven. In all cases, the length of inbound traffic is greater than the outbound traffic, except for one suburban region (Gyirmót) for an afternoon half-hour interval. There are no significant differences on Sundays but the travel time of the two roads is not the same here either, the length of the traffic to the city centre is always higher.

The third example of the study, the examination of rail transport between a Hungarian city, Győr and six suburban regions, also refuted the symmetry axiom. However, in relation to the previous example, the practical aspect is clear: while access to the city centre from the direction of the suburban areas is difficult in the morning and afternoon due to traffic congestion, including transport by bus as the only possible means of public transport, the third example shows an opportunity for travellers. Although the length of travel by train varies on the inbound and outbound sections, the degree of asymmetry is less than that of road transport. Androniceanu (2016) comes to similar conclusions by examining urban transport in Bucharest. As a weakness his SWOT analysis, it is mentioned that congestion increases travel time and reduces service reliability (in parallel with the second example of our study, where buses run on the same congested roads as cars), but he mentions as an advantage the availability of different modes of transport that in our study the third example also shows. Of course, rail transport is limited, some suburban areas of Győr are not connected by rail to the city centre, but where available, it can be a solution to transport and commuting problems.

6. CONCLUSIONS

Although in recent years the road network has been developed, many regions are still disadvantaged in terms of accessibility. Suburban areas of large cities can also be classified as areas with significant traffic problems, which are also disadvantaged in terms of accessibility, but there are also time differences in the case of rail transport. During suburbanization and urban sprawl the mass relocation has resulted in an extremely high volume of traffic in the direction of the city, as a significant portion of the jobs and other services are still available in big cities. Although the need for the development of transport is becoming increasingly important, suburban settlements, which are otherwise close to the city with regard to geographical distance, are still lagging behind optimal transport times. The high extent of city expansions, the increasing traffic problems as well as the appreciation of accessibility are confirming the importance of studying the time-spaces and the asymmetry arisen in it.

The study had two purposes: on the one hand, to give a typology of the sources of distance asymmetry, especially with regard to time spaces, and on the other hand, to demonstrate some real life cases and to

Theoretical and Empirical Researches in Urban Management
Volume 17 Issue 4 / November 2022

present measures of time space asymmetry. The study used two simple methods to illustrate the existence of the asymmetry of time space and its consequences through three practical examples.

The results can serve a basis for further research involving even more settlements and modifiers (e.g. traffic lights, one-way roads). From a practical point of view, it aims to raise awareness, highlighting, for example, the need to optimize the transport network connections of suburban areas with the city and the use of public transport.

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