Identification of the similarity of urban mobility country patterns during the period of COVID restrictions: methodology and results

Artur Petrov[1*] and *Dmitrii* Zakharov[1]

[1]Industrial University of Tyumen, 72, Mel'nikaite, 625027 Tyumen, Russia

Abstract. The term "Black Swan" by N. Taleb (Taleb, 2007) well illustrates a sudden, negatively manifesting itself in relation to the surrounding world factor. Actively used since 2015, this concept implies a shock impact on economic and production systems, which include transport and logistics systems. COVID-19 and its negative manifestations are a good example of such a 'black swan'. The serious crisis of the world economic system, which began in February-March 2020 and lasted about 450-600 days, was caused by a total restriction of elementary physical contacts between people and any manifestations of their pedestrian and transport mobility associated with it. The widespread lockdowns served this very purpose. However, lockdowns varied across countries in terms of timing, duration, methodological approaches, the strength of restrictions, and control measures. As a result, the mobility of the urban population varied with the influence of the external environment and was not identical in different cities. This paper presents the results of comparative studies of the urban population mobility dynamics in three European cities: two cities of one country – Moscow and St. Petersburg, and another European capital – Amsterdam. At the same time, the goal was to identify the urban mobility country patterns similarity during the period of COVID restrictions. Two tasks were solved: a cross-country comparison of trends in urban population mobility during 2020-2021 and a comparison of trends in population mobility in two cities of the same country. Keywords: urban population, mobility, COVID-19, country differences, trends over time, similarity.

1 Introduction

Without considering the details of the economic problems due to the impact of COVID-19, the author of this paper notes the extremely negative impact of the lockdowns introduced in the spring of 2020 in almost all cities of the world on changing the usual modes of citizens' life. First of all, this was expressed in the restriction of pedestrian and transport mobility of urban residents (Corazza and Musso, 2021). The scale of these restrictions varied across countries (Simović et al., 2021; Sidorchuk et al., 2020). Much in this area depended on the resource provision of public health systems, on the speed of their prompt response to the

[*] Corresponding author: ArtIgPetrov@yandex.ru

sharply increased needs for medical care for the sick (Lessa and Lobo, 2021). At the same time, politics also had an impact on the scale and form of operational response. Thus, in the Scandinavian countries, especially in Sweden (Bohman, 2021), this reaction was much more restrained than in the countries of Southern Europe. There was practically no lockdown in Sweden; in other Scandinavian countries the restrictions were relatively loose.

The psychological shock of people at the beginning of the COVID-19 pandemic (spring 2020) was quite strong. No one knew how serious the scale of loss of life would be, what the economic losses would be, how long the lockdown would last. All this has had a major impact on people's behavior and, as a result, on their adoption of health-saving behavior patterns. In particular, the activity of all species was reduced. In the spring-summer of 2020, road traffic dropped sharply in almost all cities of the world. Then, with the growth of understanding of the nature of the disease and the development of measures to combat it, people gradually began to return to their usual patterns of behavior. Mobility, both pedestrian and transport, began to grow again.

This paper presents data characterizing the trends in time (spring 2020 – autumn 2021) of the Citymapper Mobility Index, which characterizes the transport mobility of citizens. These data are considered in the context of studying the transport mobility of citizens from the standpoint of assessing the degree of similarity of cross-country patterns.

2 Methods and problem statement

Citymapper Mobility Index (CMI) (according to data of Website of Citymapper Limited. Citymapper-mobility-index) is the most convenient tool for solving the set tasks. *CMI* is an Internet application based on the use of Big Data and GIS technologies.

Citymapper Limited, the developer of this application, was established in 2011 to develop and promote a software product designed to help citizens choose travel patterns in the urban environment of more than 100 cities around the world (71 European, 27 American and 9 Asian cities) (according to data of Website of Citymapper Limited).

In the context of COVID restrictions, Citymapper Limited took care of the issue of assessing the transport mobility of citizens and already in May 2020 provided access to the Citymapper Mobility Index section. This index is based on a comparison of the actual transport mobility observed in the city on a particular day with a certain model level (corresponding to this day of the base (2019, pre-Covid) year).

Accordingly, the value for a specific *i*-th day of 2020 or 2021 CMI_i is defined as (1):

$$CMI_i = Mobility\ Index_{2020\text{-}i} / Mobility\ Index_{2019\text{-}I} \quad (1)$$

where: $Mobility\ Index_{2020\text{-}I}$ assessment of the actual transport activity in the city on a specific *i*-th day of 2020;
$Mobility\ Index_{2020\text{-}i}$ assessment of the actual transport activity in the city on the same *i*-th day of 2019.

Given the global decline in mobility of all types during the lockdown period, the numerical values of CMI_{2020i} during 2020 and 2021 are almost always below 1.

Research objectives are set as follows:

- Based on the data of Citymapper Limited (according to data of Website of Citymapper Limited) on the corresponding values of *CMI*, build time series (during 02.03.2020…27.10.2021 – 605 days in total) *CMI = f(Time)* of changes in this indicator for three cities – two capital cities of European countries and two cities of one country (the capital and the second largest city of the country).
- Build regression models $CMI_{1\ city} = f(CMI_{2\ city})$ for two databases. The first database combines data on *CMI* values of two capital cities of different European countries.

 https://doi.org/10.1051/e3sconf/202337604032

The second database combines data on the *CMI* values of two cities in the same country (the capital and the second largest city in the country).

- Analyze the obtained results from the point of view of comparing features from trends over time and identifying the degree of their similarity.

3 Results

3.1 Time series CMI = f(Time)

Figures 1…3 present *CMI* values in dynamics (02.03.2020…27.10.2021) for the following cities: Moscow (the capital of Russia), Amsterdam (the capital of the Netherlands) and St. Petersburg (the second largest city in Russia).

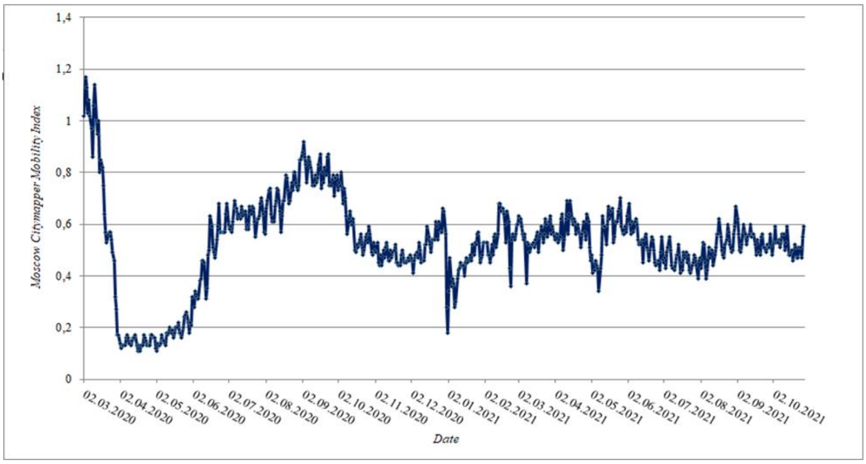

Fig. 1. Time series (02.03.2020…27.10.2021) of *CMI* values for Moscow.

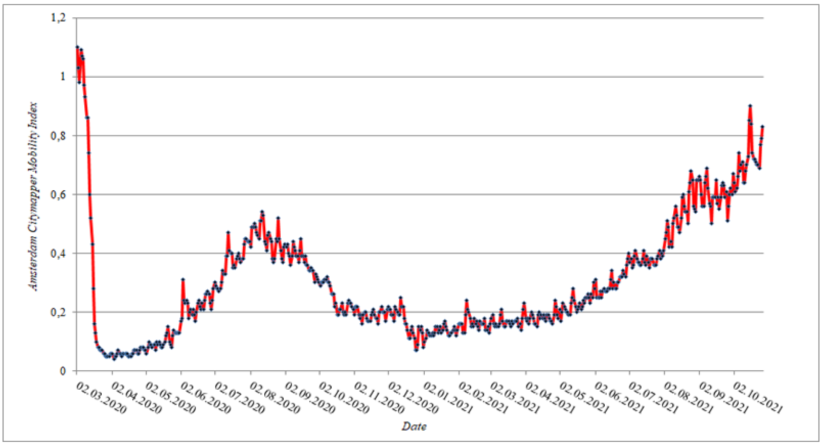

Fig. 2. Time series (02.03.2020…27.10.2021) of *CMI* values for Amsterdam.

 https://doi.org/10.1051/e3sconf/202337604032

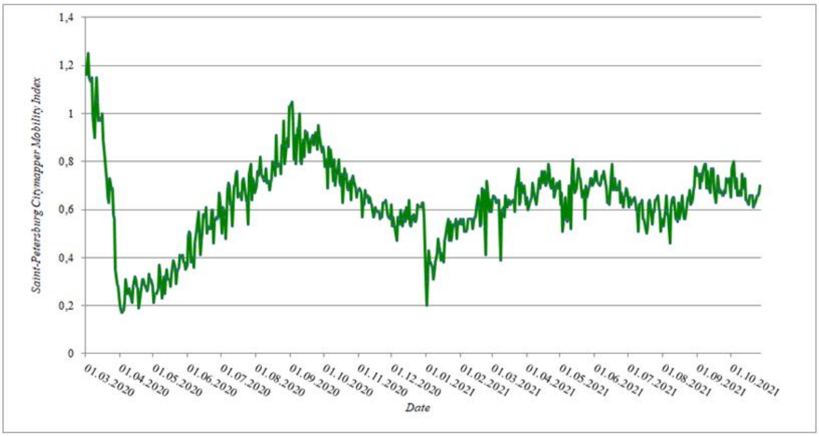

Fig. 3. Time series (02.03.2020…27.10.2021) of *CMI* values for St. Petersburg.

3.2 Regression models CMI1 city = f(CMI2 city)

Figures 4…5 show the regression models $CMI_{Amsterdam} = f(CMI_{Moscow})$ and $CMI_{Saint\text{-}Petersburg} = f(CMI_{Moscow})$. Moscow is taken as the base city (variable *X*), because it is with respect to the mobility of the citizens of this city that the mobility of residents (variable *Y*) of other cities (Amsterdam, St. Petersburg) is compared.

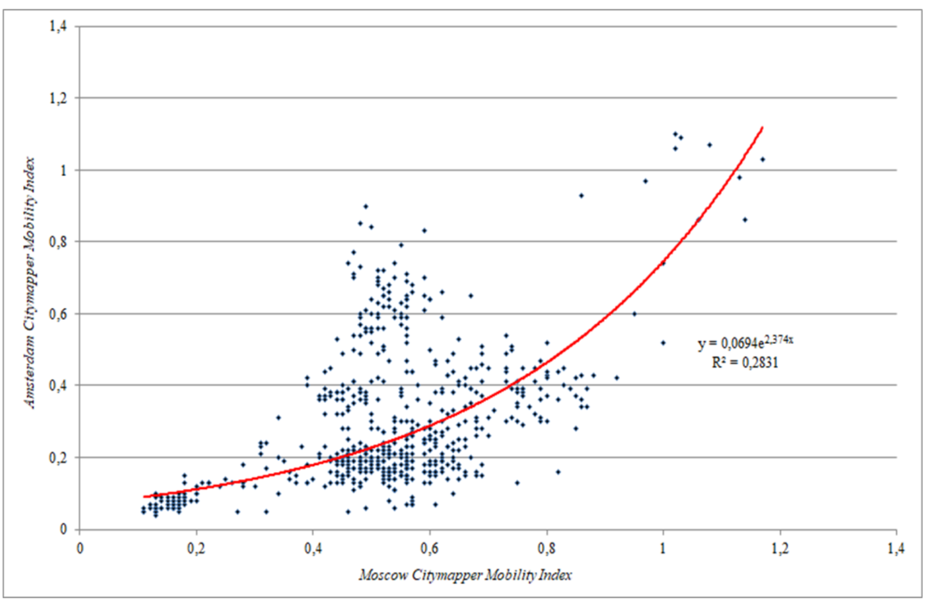

Fig. 4. Regression model $CMI_{Amsterdam} = f(CMI_{Moscow})$.

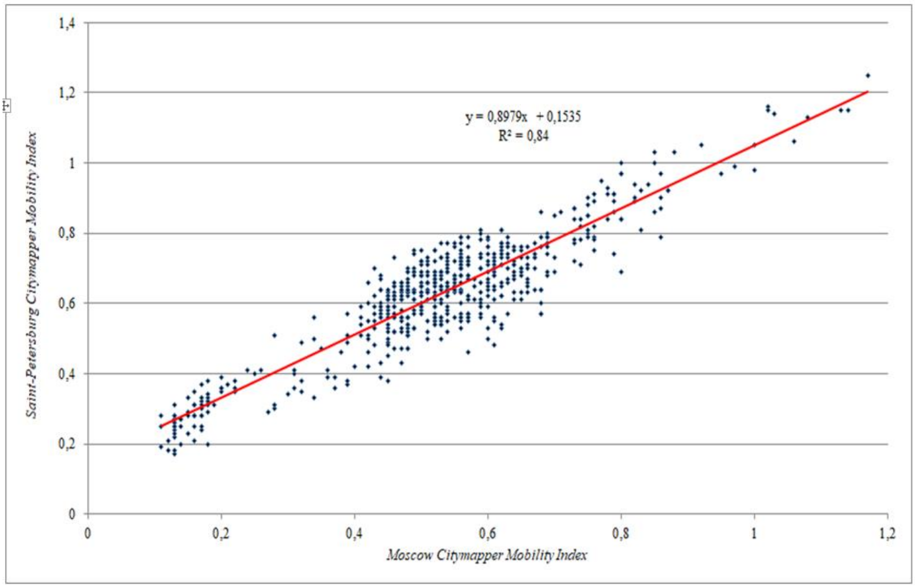

Fig. 5. Regression model $CMI_{Saint\text{-}Petersburg} = f(CMI_{Moscow})$.

4 Conclusions

Analyzing figures 1…3, the following conclusions can be drawn.

1. At the beginning of the period of COVID mobility restrictions, the residents of all three cities were in a psychological shock. The transport mobility of citizens in all three compared cities at the beginning of April 2020 dropped a lot. However, the parameters of this decline in the compared cities varied significantly. In Amsterdam in April 2020, the *CMI* index reached *CMI* = [0.04…0.06]. In Moscow, the minimum values of the *CMI* index reached *CMI* = [0.11…0.13]. In St. Petersburg, the minimum values of the *CMI* index reached *CMI* = [0.17…0.18]. Thus, in Russian cities (Moscow, St. Petersburg), the shock from the introduction of the lockdown in terms of the consequences for transport mobility was much weaker than in Amsterdam.

2. The processes of returning to the initial positions $CMI \rightarrow 1$ in all three cities also proceeded differently. In St. Petersburg, the rollback process began quite quickly and proceeded evenly. By the beginning of September 2020, the *CMI* index reached the level of *CMI* = [0.98…1.03]. In Moscow, this process dragged on in time, and the maximum values of the *CMI* index reached *CMI* = [0.88…0.92] in September 2020. In Amsterdam, the rate of recovery of mobility parameters was even lower than in Moscow, and the maximum value of the *CMI* index in autumn 2020 did not exceed the level of *CMI* = [0.50…0.55].

3. In September-October 2020, the autumn-winter decline in mobility characteristics began again in all three cities. This process was the result of an increase in the number of cases of COVID-19, and, as a result, the repeated restriction of the citizens' mobility. And again, in Amsterdam, this process was expressed more clearly. By the end of December, the *CMI* index in Amsterdam reached $CMI \approx 0.2$. At the same time, in Moscow and St. Petersburg, $CMI \rightarrow 0.5 \cdots 0.6$.

4. The situations describing the *CMI* trends in the compared cities during 2021 were very different. In Amsterdam, a gradual, smooth, but steady increase in the mobility of citizens was recorded throughout the year to the levels of *CMI* = [0.7…0.9]. In Russian cities, the *CMI* index fluctuated in the range *CMI* = [0.4…0.8]. Moreover, the level of *CMI*

index values in Moscow was lower than in St. Petersburg, and its seasonal fluctuations were relatively synchronous in the two compared cities. In general, the mobility index in Moscow was lower than in St. Petersburg by approximately $\Delta CMI \approx 0.05 \ldots 0.10$.

5. Comparing the mobility trends in three cities (Moscow, St. Petersburg, Amsterdam), certain qualitative conclusions can be drawn. It is obvious that the organizational and managerial discipline and consciousness of Russians (in relation to the implementation of recommendations to limit mobility) is at a lower qualitative level compared to Europeans. And if in Moscow, with all its organizational and managerial resources and control capabilities, the processes of restricting mobility still more or less worked, then for St. Petersburg this conclusion is less obvious. As a result, by the fall of 2021 (one and a half years after the start of the COVID epidemic), the restoration of transport mobility was largely manifested in Amsterdam.

Analyzing figures 4…5, the following conclusions can be drawn.

6. The similarity degree of the country patterns was identified through regression analysis and building the models $CMI_{Amsterdam} = f(CMI_{Moscow})$ и $CMI_{Saint\text{-}Petersburg} = f(CMI_{Moscow})$. This analysis showed that it can be stated that there is a relative intra-country similarity (Fig. 5; $R^2 = 0.84$) of the behavioral reactions of residents of two cities of one country to limited mobility (lockdown). Comparison of the trends in the *CMI* index of two capital cities of different countries – Amsterdam and Moscow, allows us to assert more about the absence of cross-country similarity (Fig. 4; $R^2 = 0.39$) than about its presence.

7. The conclusion that there is no cross-country similarity of urban mobility patterns during the period of COVID restrictions is also confirmed by different types of corresponding models $CMI_{1\ city} = f(CMI_{2\ city})$. In the case of comparing the similarity of urban mobility patterns of two Russian cities, it is adequate to use the linear model $CMI_{Saint\text{-}Petersburg} = 0.1535 = 0.8979 \cdot CMI_{Moscow}$. In the case of comparing the similarity of urban mobility patterns of two capital cities – Amsterdam and Moscow, it is adequate to use the exponential model $CMI_{Amsterdam} = 0.0694e^{2.374 \cdot CM\ IMoscow}$.

So, the main conclusion is that it can be stated that in crisis situations (under the influence of the ‘black swan’ factor), there is an intra-country similarity of urban population mobility patterns and that there is no corresponding cross-country similarity.

Acknowledgements

The research was funded by RFBR and Tyumen Region, number 20-48-720006 “Model for the transformation of urban transport systems with considering account the impact on society and the economy of the Covid-19 coronavirus pandemic”.

References

1. N. Taleb, *The Black Swan. The Impact of Highly Improbable* (Random House, New York, 2007)
2. M.V. Corazza, A. Musso, Transport Policy **103**, 31-44 (2021) DOI: 10.1016/j.tranpol.2021.01.010
3. S. Simović, T. Ivanišević, B. Bradić, S. Čičević, A. Trifunović, Sustainability (Switzerland) **13(15)**, 8398 (2021) DOI: 10.3390/su13158398
4. R. Sidorchuk, A. Lukina, I. Markin, S. Korobkov, N. Ivashkova, S. Mkhitaryan, I. Skorobogatykh, J. Open Innov. Technol. Mark. Complex **6(4)**, 150 (2020) DOI: 10.3390/joitmc6040150

5. D.A. Lessa, C. Lobo, Sustainability (Switzerland) **13(15)**, 10128 (2021) DOI: 10.3390/su131810128
6. H. Bohman, J. Ryan, V. Stjernborg, D. Nilsson, Transport Policy **106**, 109–119 (2021) DOI: 10.1016/j.tranpol.2021.03.013.
7. Website of the Citymapper Limited company. Citymapper-mobility-index, URL: https://citymapper.com/citymapper-mobility-index/
8. Website of the Citymapper Limited company, URL: https://citymapper.com/