MAPS REFLECTING POPULATION DISPLACEMENT CAUSED BY WAR

Doina VASILCA, Dr. Eng. Lecturer, Technical University of Civil Engineering, Faculty of Geodesy, Romania, doina.vasilca@utcb.ro

***Abstract**: Using a series of maps rendered via ArcGIS Pro, the present article aims to make a comparison of the number of Ukrainian refugees fleeing the war between Russia and Ukraine during 2022 and the number of Arab refugees who left their countries between the years 2011 and 2021, following the so-called "Arab Spring" conflicts. The techniques used for creating the maps included dot and bivariate dot density mapping, as well as a bivariate color and chart symbol mapping. For an improved highlighting of the represented phenomenon, it was proposed to have it symbolized by dots of similarly colored shades, from the lightest to the darkest, depending on the number of refugees hosted by each country. The resulting maps are intended for the general public to provide an overview of the population displacement caused by war.*

***Keywords:** Ukrainian refugees, Arab refugees, dot map, bivariate dot map, bivariate colors map*

1. Introduction

One of the major problems facing Europe today is the war between Russia and Ukraine, which has forced millions of Ukrainian citizens to flee their country in search of shelter. A similarly serious situation has occurred in the last decade when the bloody anti-government protests known as the "Arab Spring" forced part of the population to flee to European Union countries.

In this paper we used thematic maps to present the total number of refugees, both Arabs and Ukrainians, who have sought refuge throughout the European Union states, and in the case of Ukrainians also in other neighboring countries such as Russia, the Republic of Moldova and Belarus, so as to highlight the extent of the population displacement.

Representing the number of refugees by host country is important for assessing the extent of the phenomenon as well as for applying coordinated measures at a European level in order to better manage the situation and also make evident the population displacement caused by the ongoing war to the general public.

For comparing the number of Ukrainian and Arab refugees hosted by European Union countries we have created dot and bivariate dot density maps, including one bivariate color map and one chart symbols map.

2. Materials and Methods

In order to represent the total values of a phenomenon produced in certain enumeration units, an easily applicable method that is also readily understandable by end-users is *dot density mapping*. First introduced more than a century ago, this method uses dots featuring a certain shape, dimension and value, placed randomly within enumeration units and having variable density depending on the number of the object represented [1]. The dots can

be placed more precisely within the enumeration units using ancillary information, and in this case the method is called *dasymetric mapping* [2], but this technique was not applied in the present study since it would not have contributed to the final purpose of the maps.

The data used for creating said maps referred to the total number of Ukrainians who have taken refuge in 2022 throughout neighboring countries such as Belarus, Hungary, Poland, Romania, Russia and Slovakia, but also other European Union states as well. Additionally, we have used the total number of refugees from the Arab countries where street demonstrations took place during the “Arab Spring”, namely Algeria, Egypt, Iran, Jordan, Libya, Morocco, the Syrian Arab Republic and Yemen, with the data corresponding to the period of 2011-2021.

To better highlight those countries where the number of refugees was higher, a bivariate dot density map was created, symbolizing the number of Arab refugees and the number of Ukrainian refugees, respectively, using differently colored dots [3].

Furthermore, bivariate dot mapping was also employed for representing the above-mentioned data using dots featuring the same value and size, but with different shades of the same color so as to better highlight the countries according to the number of refugees that arrived there. The European Union states were thereby classified into five groups according to the number of Ukrainian refugees taken in, using the Natural Breaks (Jenks) method, similar to classification applied in the choropleth mapping method. The Reds Cynthia Brewer's single-hue scheme was used in this sense [4], and the following classes have been created:

Table 1. Classification of EU states hosting Ukrainian refugees

Class number	Class breaks	Countries belonging to the class
I	303 - 25,000	Malta, Belgium, Slovenia, Croatia, Finland, Greece, Ireland, Latvia, Netherlands, Denmark, Spain
II	25,001 - 45,000	Sweden, Portugal, Estonia, Lithuania, Austria, France
III	45,001 - 152,340	Italy, Bulgaria
IV	152,341 - 678,081	Czech Republic, Germany, Slovakia, Republic of Moldova, Hungary, Romania
V	678,082 - 2,564,994	Poland

A separate layer was created for each class, and all of them belonged to a group layer. The countries belonging to each class were selected from the table of attributes defining a query and were symbolized with dots of the chosen color shade. For example, for selecting countries belonging to the third class, the following clause was built: *Where Country includes the value(s) Italy, Bulgaria.* Then, in the Symbology pan, for the Ukrainian refugees field the dot color was defined as follows: Red - 251, Green - 106, Blue - 74.

The dot density method was also used to represent the number of Ukrainian refugees in countries bordering Ukraine, but for clarity, their depiction featured different colors. To give the maps a more pleasant appearance, YlOrBr transition hues given by Brewer’s scheme were chosen [4]. For correctly comparing all of the maps rendered using the dot method, the dot value was set to 2000 refugees and the dot size to 2 points for all maps. These particular values selected so that the dots begin to coalesce in those countries with the largest number of refugees, while throughout the regions with the lowest number of refugees we aimed to have at least two to three dots [1]. The same data was represented using the bivariate color mapping technique. Using two hues, namely blue for Arab refugees and magenta for Ukrainian

refugees, each one with four shades of different saturation and value, the Union European states were divided into 16 classes depending on the number of Arab and Ukrainian refugees hosted, each class having thus been assigned a different color and shade. The data was classified using the Natural Breaks (Jenks) method. In order to highlight the same two variables, a map was created via the chart symbols method.

An equal-area projection was used for all maps, namely the Europe Albers Equal Area Conic, in order to represent country surfaces without distortion, with the density of the represented dots being in close connection with the area of the enumeration surface. Finally, all maps were designed using ArcGIS Pro and a polygon layer containing the Nomenclature of Territorial Units for Statistics [5].

3. Results and Discussion

The maps created via the dot density method (i.e. Fig. 1, Fig. 2 and Fig. 3), as implemented in various GIS, provide an overview of the magnitude distribution of a certain phenomenon throughout the area of interest. In order to clearly represent each enumeration unit, the method can be further improved by using dots of different hues for each enumeration unit (Fig. 4).

We consider that using dot mapping with shades of the same color brings an improvement upon the traditional dot density method because if the enumeration unit (e.g. a country) has a large area, then the distribution of dots may be rare even when they are present in large numbers (i.e. a very large number of refugees), whereas a unit of enumeration with a smaller surface area may appear to have a higher dot density although their total number represents a smaller number of refugees. Therefore, the units represented by the dots with the darkest hue, even if they are rarer, represent the countries with the highest number of refugees, while the units with the lightest hued dots, even if their density is high, represent those countries with the lowest number of refugees. This means that, by comparing the shade of the color being used, one can highlight the magnitude of the phenomenon represented in the studied area (Fig. 5).

Not only that, but should one want to represent two phenomena occurring within the same area, one can use dots of the same value and size but of different colors, meaning one for each depicted phenomenon (Fig. 6). The resulting map thus becomes easy to interpret by its end-users.

The bivariate color map method can also be used to represent the quantitative relationship between two similar phenomena (Fig. 7), but the result is more complex and it is not as easy to interpret by an inexperienced user. Looking at the sides of the square in the legend of this map, one can see the different shades depending on the number of Arab and Ukrainian refugees hosted, respectively. Thus, it can be seen that Poland hosts the largest number of Ukrainian refugees, while Germany has the largest number of Arab refugees. On the diagonal of the square, as a third attribute, there are those colors with which the host countries are represented, from the smallest to the largest number of both Arab and Ukrainian refugees. Given this fact, on the same map it can be seen that the countries represented with neutral light colors such as Portugal, Spain, Ireland, Finland and the Baltic States host the smallest number of both Ukrainian and Arab refugees. Bulgaria, represented with a diagonal color from the square in the legend, host a similar number of Ukrainian and Arab refugees. On the other hand, Germany hosts the largest number of Arab refugees, as well as a number corresponding of the second largest class of Ukrainian refugees. A third method used for representing the relationship between two variables was *chart symbols mapping*, where the size of the pie charts is proportional to the total number of Arab and Ukrainian refugees.

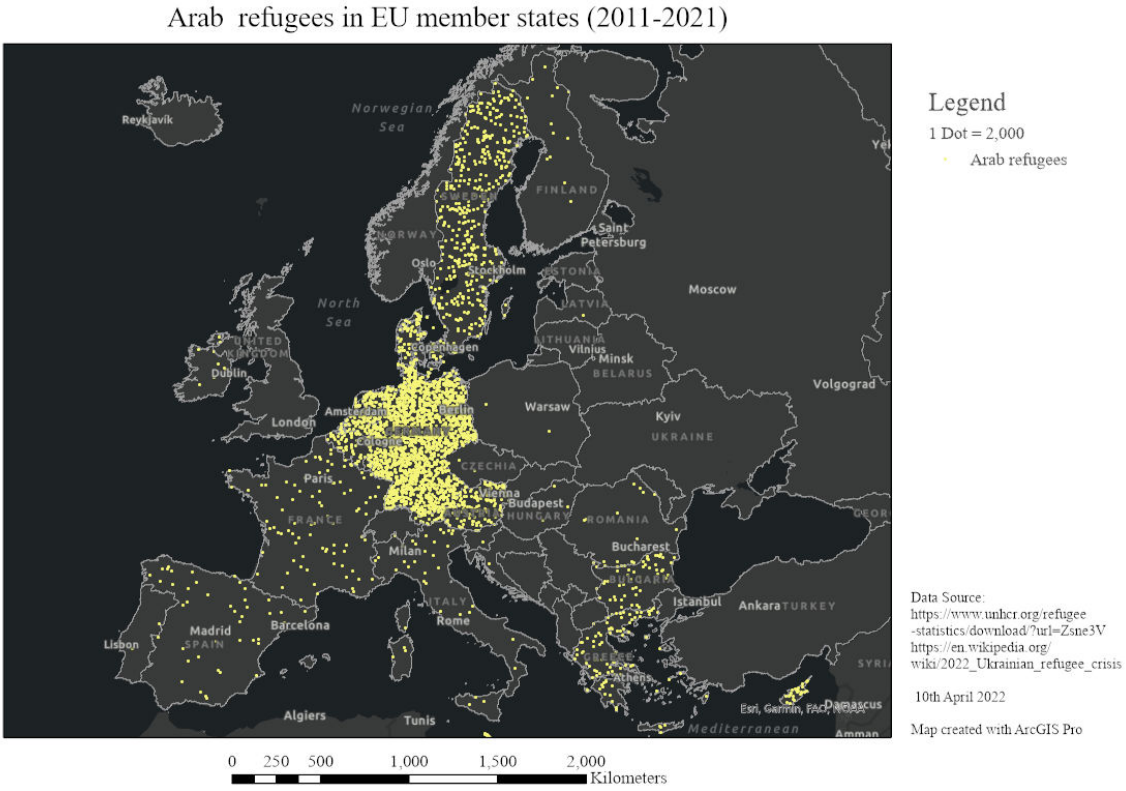

Fig. 1. Arab refugees – dot density map

Fig. 2. Ukrainian refugees in EU member states not bordering Ukraine – dot density map

Fig. 3. Ukrainian refugees in states bordering Ukraine – one colour dot density map

Fig. 4. Ukrainian refugees in states bordering Ukraine – multiple colour dot density map

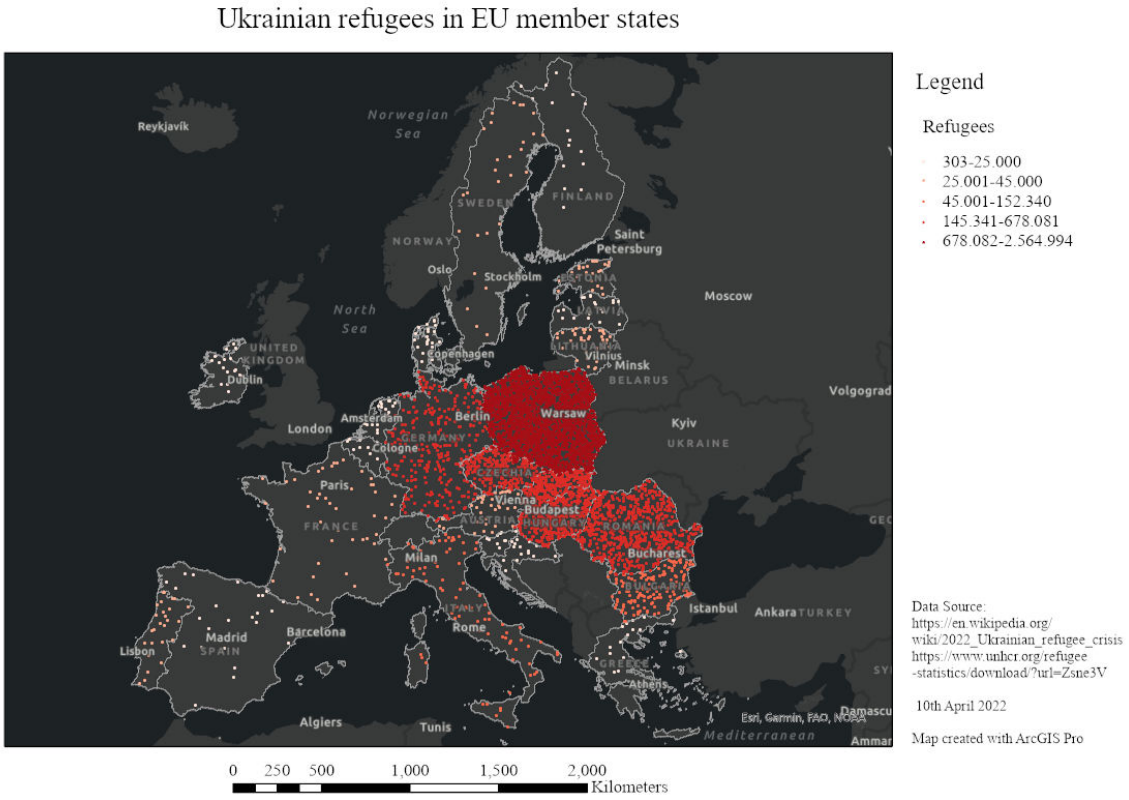

Fig. 5. Ukrainian refugees in EU member states – dot density map

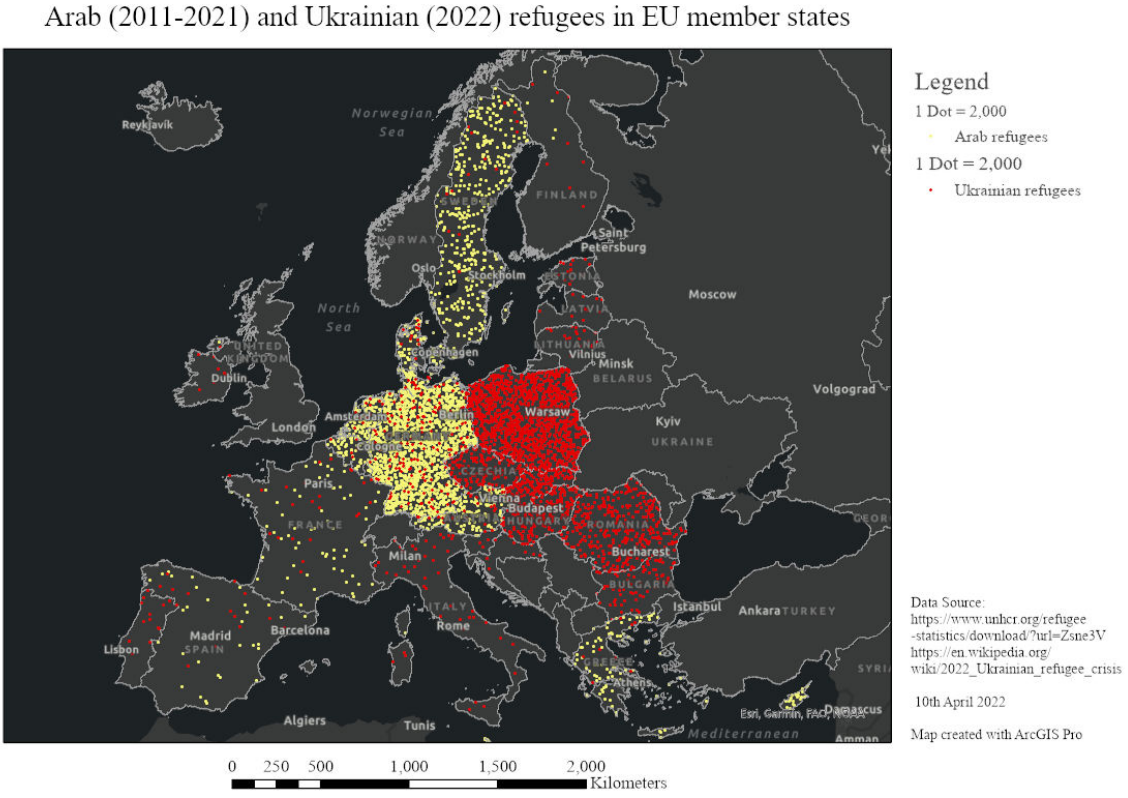

Fig. 6. Arab (2011-2021) and Ukrainian (2022) refugees – bivariate dot density map

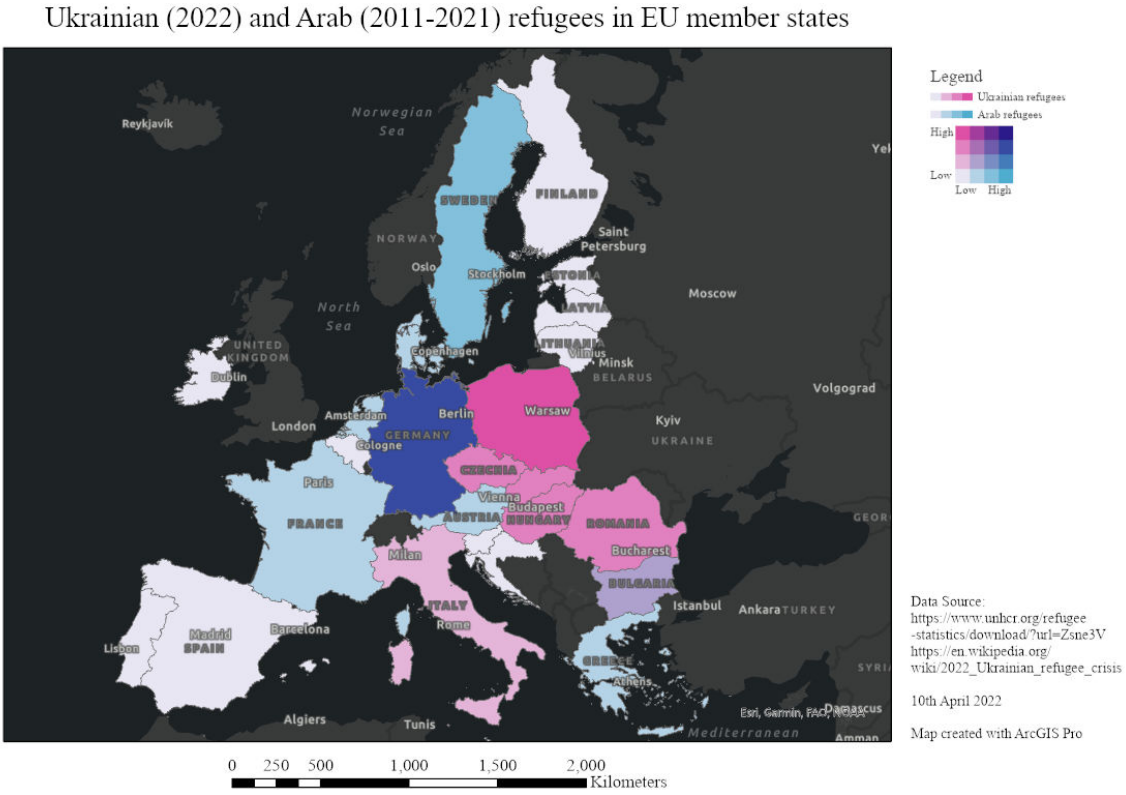

Fig. 7. Ukrainian and Arab refugees - bivariate color map

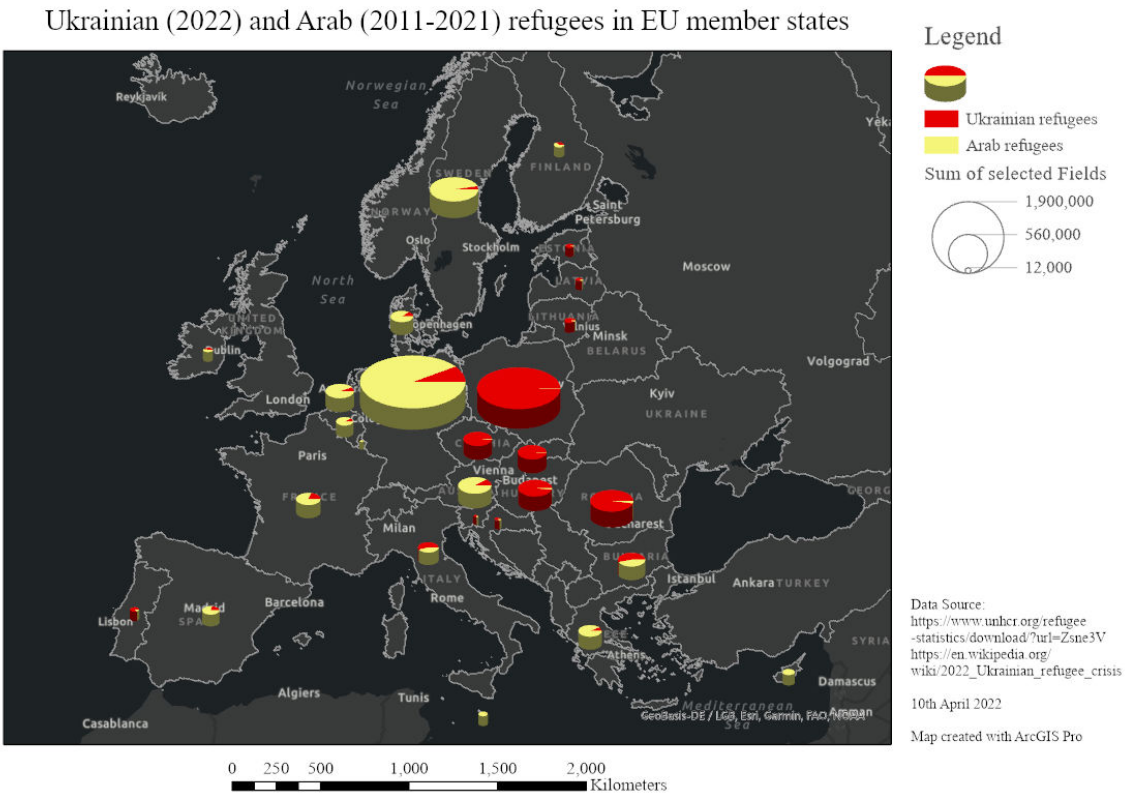

Fig. 8. Ukrainian and Arab refugees – chart symbols map

4. Conclusions

In the current article, we used several maps to present the phenomenon of population displacement due to the war within the European Union states, but also in other countries neighboring Ukraine. For the technique employed in generating the maps, we chose the simplest and easiest method to interpret by the map users, namely the dot density method, but for comparison we also used the bivariate color map method and a 3D chart symbols map.

In order to bring about an improvement on the dot density method, we have proposed classifying the host countries according to the number of refugees via the Natural Breaks (Jenks) method, and as a way of symbolizing the resulting classes, we proposed different shades of the same color. Thus, states belonging to the class with the lowest number of refugees are symbolized by the lightest shade, whereas those states belonging to the class with the higher number of refugees is symbolized using the darkest shade. In doing so, the phenomenon represented by the dot density method, which is suitable for the representation of total values, can be more suggestively symbolized, because even if the number of dots represented in a unit of enumeration is rare on account of its large area, the depicted points bear a dark shade, thereby meaning that the actual number of represented elements is large. Otherwise, if all dots are represented using the same color, the impression created solely by considering the density of the depicted dots may be erroneous.

5. References

1. *Dent B, Torguson J, Hodler T, Cartography: Thematic Map Design, Sixth Edition. McGraw Hill Higher Education, New York, 2009, pages: 119-125.*
2. *Slocum T, McMaster R, Kessler F, Howard H, Thematic Cartography and Geovizualization, Third Edition, Pearson Prentice Hall, Pearson Education, New Jersey, 2010, page: 272.*
3. *Field, K., Experiments with dot density - Part One-in https://www.esri.com/arcgis-blog/products/arcgis-pro/mapping/experiments-with-dot-density-part-one/, accessed on 5th March, 2022.*
4. *Brewer, C. A., Designing better maps: a guide for GIS users, ESRI Press, Redlands, California, 2005, pages: 188-189.*
5. *https://www.arcgis.com/home/item.html?id=bdcb40c0b6124f6d99f10b9b23647712, accessed on 10th March, 2022.*