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KATARZYNA KRAWCZYŃSKA, IZABELA KARSZNIA
University of Warsaw
Faculty of Geography and Regional Studies
km.krawczynsk2@student.uw.edu.pl
https://orcid.org/0000-0001-5510-8770; i.karsznia@uw.edu.pl

An analysis of the functionality of selected websites presenting data on air traffic

Abstract. The subject of the article is the assessment and comparison of the functionality of websites presenting flight data and the current location of aircraft on the map. The following websites were assessed: Flightradar24 (flightradar24.com), RadarBox24 (radarbox24.com), Flightaware (flightaware.com) and Planefinder (planefinder.com). The credibility of the presented data and the range of functions available on the websites were analyzed in detail. A number of functions included in data sets were compared to the examined websites. Additionally, the possibilities of expanding the analyzed websites and extending the scope of their functions were determined. The issue of using data from air traffic data websites for scientific research was also examined.

Keywords: functionality, websites, air traffic, flights, Warsaw Chopin Airport

1. Introduction

The result of the development of air traffic and maps appearing on the Internet are websites presenting the location of planes on maps. They are primarily used by ordinary users who want to view the current position of a plane flown by a family member or a friend, or check a plane which they currently see in the sky. They can also look up the volume of air traffic at a selected location on Earth. Apart from amateur users, such websites are also used by aviation professionals such as airport operators and pilots. In addition to the current location of the aircraft, such websites also provide flight data from previous days along with their routes. Also, the websites provide a range of functions facilitating browsing by the user and obtaining additional information. Some functions and data are also available after purchasing the paid version.

This article analyses the functionality of four websites: flightradar24.com, radarbox24.com, flightaware.com and planefinder.com. The aim of the research was to determine the functionality of the examined websites and their credibility. Their functions and data were analyzed, as well as their compatibility, also between the four websites.

2. The functionality of online maps

Today, there is an increasing tendency to make maps available online and thus increasingly used in everyday life. Today, everyone uses maps on the Internet, as they visualize a wide variety of content.

The definitions of the terms defining various types of maps on the Internet are not precise. What is more, there are many different classifications (M. Kukułka 2011). Despite the differences in defining them, it is easy to notice some common elements. Depending on the author, the division is more or less detailed. M. Kukułka (2011) distinguishes between online maps, data sets, and geoportals. A more detailed division includes: electronic versions of paper maps, electronic maps, electronic atlases, Internet mapping services and mobile solutions (T. Nowacki, T. Opach 2010). In both of these classifications, the important differentiating factors are interactivity, the number of functions and their advancement, as well as the scope and variety of data.

Currently, the functionality of websites is one of the important elements indicating their quality (A. Fernandez et al. 2011). This means that problems related to functionality may significantly hinder the recipient from fully taking advantage of the options offered on the websites. It should also be noted that the topic of website functionality has been insufficiently explored in relation to the aspects of cartographic visualization (A.M. Nivala et al. 2008).

The concept of functionality can be defined in two ways. On the one hand, it can be defined as a science aimed at developing websites in such a way that their use is not complicated for the user (P.J. Kowalski 2006 after M. Pearrow 2002). Within this definition, P.J. Kowalski (2006) distinguished three features of functionality. They are:

– usability,
– accessibility,
– practicality.

At the same time, functionality can be defined as all the functions of a given application. Usability then becomes a concept with a broader meaning, and functionality (as a whole of functions) is its essential element (P.J. Kowalski 2012). This article focuses primarily on the functionality of websites in the context of the included functions.

The use of data sets is closely related to the use of their interactive functions, i.e. those that enable interaction with the map user. Therefore, functionality and interactivity are interdependent (A. Macioch, G. Malmon 2010). The very concept of interactivity is not easy to define because it is not fully clear, which can be seen in the works of many authors. In the context of visualization, it can be translated as "a system that changes its visual data display in response to user input" (J.W. Crampton 2002, p. 88). The interactivity associated with the use of data sets creates a relationship between the user and the map, which is expressed in mutual interaction (A. Macioch, G. Malmon 2010).

The functionality of websites with online maps can be equated with the sum of interactive functions, which are, in a way, a combination of interactivity and functionality (A. Macioch, G. Malmon 2010). Therefore, these functions should be classified into the most relevant categories. M. Okonek (2010) distinguishes six types of these functions:

– navigation functions,
– identification functions,
– orientation functions,
– cartometric functions,
– analytical functions,
– external communication functions.

The second way to classify interactive functions is to divide them into:

– general functions,
– navigation functions,
– didactic functions,
– cartographic and visualization functions,
– GIS functions (A. Macioch, G. Malmon 2010).

An important element of examining the functionality of data sets is the user and the adaptation of the application interface to his competences, because the user does not need to have cartographic knowledge of cartographic information systems. When the website is thus tailored to the needs of users, it can be defined as "user-friendly" (M.H. Tsou, J.M. Curran 2008). "User studies" or "user-centered design" focus on making the use of websites as easy as possible for the user. In order to obtain knowledge that will be useful in the development and expansion of data sets, tests are carried out among users (R. Roth et al. 2015, R. Roth et al. 2017).

3. Visualizing the dynamics of phenomena

The dynamics of phenomena are presented on a map showing an element changing over time, assuming either interaction with the user or its absence, while the user entering into such interaction does not take control and does not determine the visualization of dynamics (T.A. Slocum et al. 2001). One of the elements distinguishing a map presenting the dynamics of phenomena from other maps is the appearance of an additional variable – time (D. DiBiase et al. 1992).

The dynamics of phenomena can be divided into three categories: motion dynamics, state dynamics, and complex dynamics. Motion dynamics means the movement of a given object over time. State dynamics is a situation of changing certain characteristics of an object – qualitative or quantitative. On the other hand, complex dynamics are when both factors occur simultaneously (M.W. Meksuła 2001). M.W. Meksuła additionally distinguishes two types of visualization of the dynamics of phenomena – indirect and direct methods. Indirect methods are divided into single maps and series of maps.

Multiphase, balance, and type maps are single maps, while comparative, overlay and double-sided maps are series of maps. Direct methods are animated maps (M.W. Meksuła 2001).

It is animated maps that seem to be an important tool for presenting the dynamics of phenomena today. By showing various types of changes, they help the user to understand the essence of the presented phenomenon (M. Harrower 2001). Moreover, they show movement or development directly, and animation of phenomena refers to dynamics (M. Harrower 2001, J.B. Morrison 2000). The development of such maps is facilitated by the possibilities offered by the Internet, which then also creates conditions for sharing them (M. Harrower 2004).

The construction of animated maps may cause some difficulties in reading them. According to M. Harrower (2003), four such problems can be distinguished. In a situation where the user is not able to note key information on a changing map, it can be referred to as a "disappearance" error. In such a situation, it is best to give the viewer control, e.g. to pause and play the animation at any pace or repeat it. Another problem is the matter of attention. The user, looking at the map, should have no doubts where he needs to focus his attention, i.e. where a given phenomenon occurs, and he should not have difficulties finding important functions. It is therefore necessary to ensure a logical layout of the map and its functions or use attention-grabbing symbols or sound effects. Another difficulty for the user may be an attempt to provide too much information on a single map. The solution seems to be the use of relatively simple symbols and providing the option to filter the data. The fourth challenge is the fact that users have less confidence in animations than in static maps. Therefore, a short instruction on how to use the map can be included (M. Harrower 2003).

The studied websites use basic animations. The user can view the movement of planes in real time or recreate the route of a given flight that has already taken place, within the time range in which such data is available on a given website. This is due to the fact that the analyzed websites focus mainly on the presentation of up-to-date flight data, which does not require the use of more advanced animations.

4. Selected websites presenting data on air traffic

The analyzed websites present data on air traffic. Their main elements are maps showing the current location of planes in the airspace. In addition, the websites contain information on the route of completed flights, flight duration, flight schedules, and much more. The websites listed below have been selected because they present current flights directly on the map. They

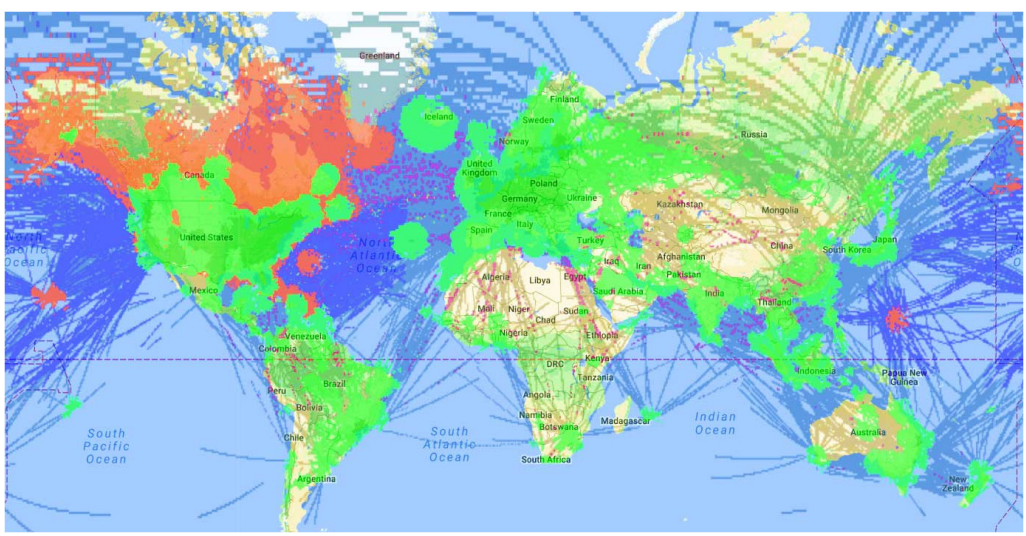

Fig. 1. A map of the airspace monitored by RadarBox24

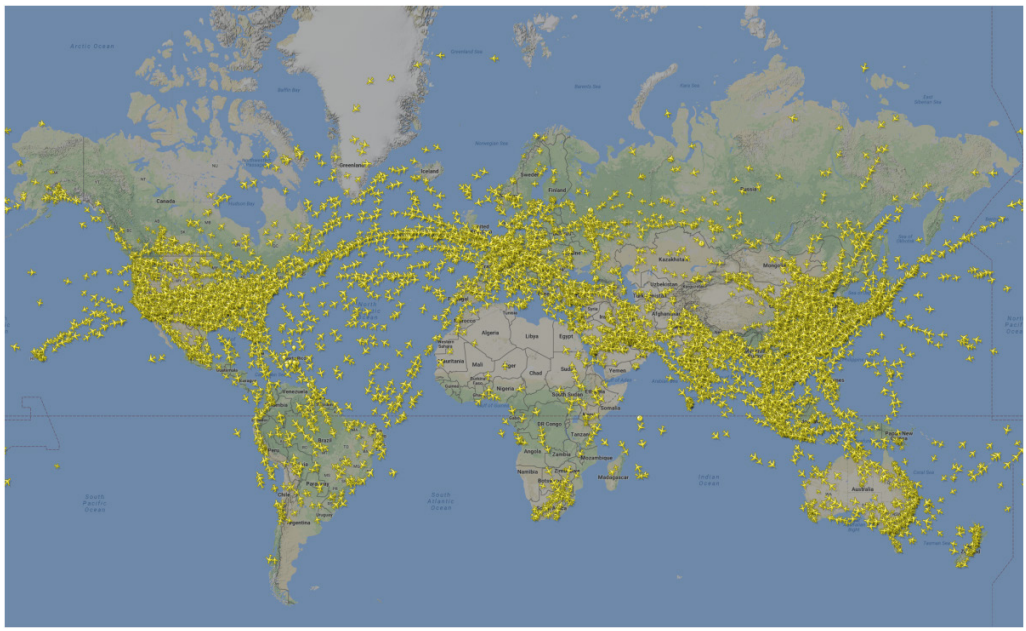

Fig. 2. A map of the airspace monitored by Flightradar24

are also the most popular websites of this type on the Internet, as reflected by their position in the Google search engine.

4.1. Radarbox24

The company was founded in 2007 and is based in the United States and Europe. Radarbox24.com, like the other websites, is based on the ADS-B (Automatic Dependent Surveillance-Broadcast) system, which is used to track aircraft equipped with a transmitter of this system. Additionally, other systems are also used. The ADS-B system transmits the position of the aircraft and other flight data using radio waves. The signal is received by a network of receivers on the ground owned by Radarbox24 volunteers. For this reason, the range of the area where the planes are "tracked" does not cover the whole Earth (fig. 1). According to the information available on the website, an average of about 40,000 people from over 150 countries use the website each day[1].

4.2. Flightradar24

Flightradar24.com was established in 2006. It is also based on receivers given to private individuals – volunteers. In addition to various systems, it also uses radar data and satellite systems. According to the data available on the website, Flightradar24 has the largest network of ADS-B receivers – over 20,000. Thanks to this, it provides data on over 180,000 flights used by over 2 million users daily. Figure 2 shows the extent of the airspace monitored by Flightradar24[2].

4.3. Flightaware

Flightaware is the oldest of the described websites, and is also the first site that provided access to data on the current position of aircraft around the world, since it was created in 2005[3]. Flightaware retrieves data from air traffic control

[1] https://www.radarbox24.com/about (access 16.03.2019)

[2] https://www.flightradar24.com/about (access 13.04.2019)

[3] https://www.reuters.com/article/us-airlines-flightradar24/flightradar24-finds-not-just-planespotters-flockingto-its-website-idUSKBN0O31Q720150518 (access 11.04.2019)

Fig. 3. A screenshot of an interactive airspace map monitored by Flightaware

systems in 45 countries, from its own ADS-B ground stations in over 190 countries, and from a satellite system[4]. The extent of the area monitored by Flightaware is shown in figure 3.

4.4. Planefinder

The website was created in 2009, initially as an application for iOS[5]. It is this fact that distinguishes it from the other sites. They were first created as websites, and then applications were developed on their basis. This is why the way the data is presented is slightly different. It is more useful and clear when used on mobile devices. Planefinder also has its own network of receivers. It is shown in figure 4.

5. Research methodology

Four websites presenting data on air traffic were selected for the analysis (flightradar24.com, radarbox24.com, flightaware.com, and planefinder.net). The choice of websites was determined by the fact that they presented the current location of planes on the map and their popularity on the Internet.

The functional analysis covered three basic steps. After reviewing the content of research and studies published by various authors, a table was created to determine the presence of individual interactive functions in the analyzed websites. The scheme of the research methodology is presented in figure 5.

The table was developed on the basis of the description of the electronic map functions proposed by A. Macioch and G. Malmon (2010). First, a list was made that presented all the functions listed in their article, excluding a few that were considered unhelpful in the context of the analyzed websites. Ultimately, however, the table presents only the functions that were available in at least one website. In relation to the proposal by A. Macioch and G. Malmon (2010), the name of one of the functions "access to a table with statistical data" was also changed to "access to statistical data" to take into account also other methods of data presentation. The table uses a score according to which each website received 0 or 1 point for each function. 0 means that the function is absent, and 1 means that the function is present. However, its quality was not assessed. 0.5 points were awarded when a given function is available in the paid version of the website. It was also granted in one case, when the function appeared partially on a given website, as a query for location (coordinates and height).

[4] https://flightaware.com/about/ (access 11.04.2019)

[5] https://planefinder.net/about (access 27.04.2019)

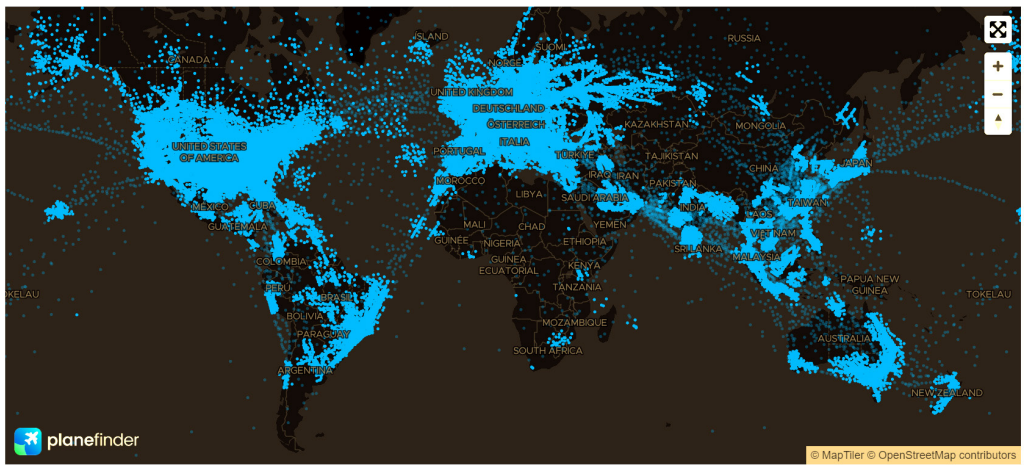

Fig. 4. A screenshot of an interactive airspace map monitored by Planefinder

The next step was to design a database in which information available on the websites was collected and organized. The database has been divided into two parts: a list of flights taking place on particular days during the week and a summary of detailed information on flights over two days. The following information about flights is compiled in the first part: flight date, departure airport, arrival airport, days of the week of the flight, and flight number. In the second part, they also include the following data: flight duration, departure time according to schedule, time of arrival according to schedule, actual departure time, actual time of arrival, airline, and distance travelled. The analyzed websites were the sources of this data. The database includes flights from one point of departure – the Warsaw Chopin Airport, located in the Warsaw district of Okęcie. This choice was determined by the fact that it is the largest and most important airport in Poland. Only departures from Chopin Airport were analyzed, arrivals were not taken into account.

The ports of departure and arrival are defined by the names of the cities they belong to and the IATA (International Air Transport Association)

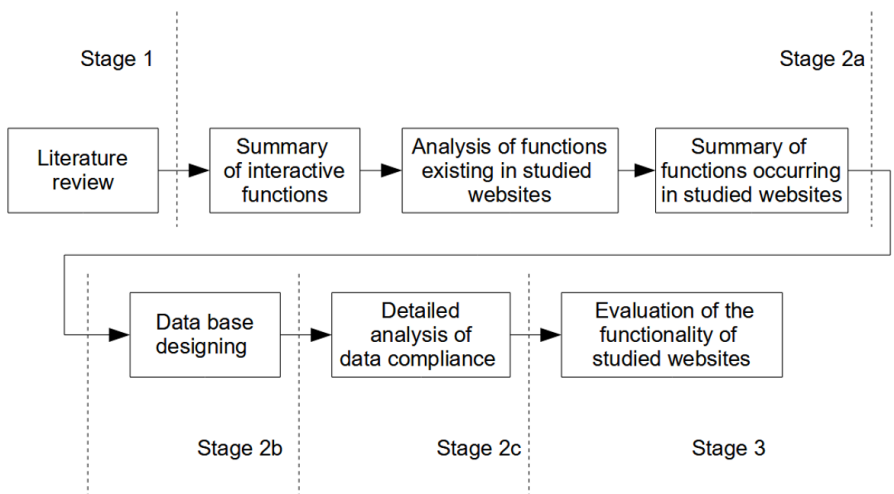

Fig. 5. Research methodology (source: own study)

codes for each airport. Flightradar24 was selected as the main data source for developing the database because it presents data in the most clear and complete way. The development of the database on the basis of data obtained mainly from one website ensured its consistency. Data on distance travelled available from Flightaware was also used. However, in the absence of data on the Flightradar24 website, Flightaware or RadarBox24 were used. The database was attached to the work by K. Krawczyńska (2019), on the basis of which this article was prepared.

In the final stage, a detailed analysis was carried out to compare the compliance, completeness and consistency of the information of the four websites. For this purpose, flight information was obtained, which is available in each of the analyzed websites, and its compliance with other websites was compared. 40 flights were randomly selected, diversified in terms of space and time, taking into account the most important airports and areas important for aviation. Then, the compliance of the most important data between the websites was analyzed. Among the 40 selected flights, 10 flights were analyzed during their duration, and 30 were analyzed after they were completed. In the case of the former, the current location of flights on the map was compared at the same time in each of the websites and it was determined which of them represents the most accurate position of the aircraft, and in relation to completed flights, their routes were compared. All the above stages allowed for drawing conclusions on the evaluation of the functionality of the analyzed websites.

6. Results

The result of the analysis of the functions provided by the studied websites is a summary in the form of a table. The dominant types of functions were defined (general, navigation, didactic, cartographic and visualization, GIS functions). The results are presented in Table 1.

The websites also include other functions that have not been analyzed, because the above list was prepared on the basis of a set of functions included in the article by A. Macioch and G. Malmon (2010). It should be noted that another way to analyse functionality may be to record all the functions contained in each of the websites. However, this method would make it impossible to compare to some extent with other electronic maps relating to other issues and would limit the scope to the functions that were included in the analyzed websites, which could result in the lack of an important function being overlooked.

The presented list is subjective because due to the specificity of websites and their narrow scope, some functions have a different form than in typical map websites.

According to the summary, Flightradar24 received the highest number of points, which indicates its highest functionality in accordance with the methodology adopted in this research. Flightaware and RadarBox24 obtained similar results, while Planefinder received the lowest number of points.

It is also important to analyse the partial results in each category, where there were slight differences from the final score. In the case of navigation functions, the same highest score was achieved by Flightradar24 and RadarBox24. On the other hand, the number of didactic, cartographic and visualization functions was the same for all the websites and they were the same functions. In the GIS function category, the analyzed websites had the lowest number of functions (from 2 to 0.5 points).

Summing up, Flightradar24 showed the greatest functionality. RadarBox24 and Flightaware had a comparable number of analyzed functions with slight deviations in terms of their types used in these websites. Planefinder turned out to be the least functional in this comparison. The analysis showed that the analyzed websites do not differ significantly in terms of functionality and often have similar functions. This is also reflected by the total number of 57 functions included in the analysis and the 18,5-24 points scored by websites.

Another element of analysing the websites was the development of the database. It covers one week (March 25–31, 2019). As mentioned earlier, the detailed analysis was done for two days in the analyzed week. It included Monday, due to the highest number of flights, and Saturday, with the fewest flights. The database was attached to the work by K. Krawczyńska (2019). After the database was developed, the obtained results were analyzed. The number of all flights from Warsaw Chopin Airport was 1,556. The number of flights is summarized in a diagram showing the division by consecutive days of the week (fig. 6.).

Table 1. Comparison of the functionality of studied websites

Function type	Function	Flightradar24	Radarbox24	Flightaware	Planefinder
General functions	Mode selection	1	0,5	1	1
	Data export	0,5	0	0	0
	Language selection	0	0	1	0
	Bookmarks posting	0,5	0	0	1
	Labels	1	1	1	1
	Settings	1	1	1	1
	Tool tips	1	1	0	0
	Help	1	1	1	0
	Home page	1	1	1	1
	Sum	**7**	**5,5**	**6**	**5**
Navigation functions	Spatial object selection	1	1	1	1
	Zooming in and out of the map	1	1	1	1
	Map moving	1	1	1	1
	Map rotation	1	1	0	0
	Geographic names index	1	1	1	0
	Geographic names searching	1	1	1	1
	Position tracking	1	1	1	1
	Time selection	1	1	1	1
	Animation	1	1	1	1
	Sum	**9**	**9**	**8**	**7**
Didactic functions	Photos	1	1	1	1
	Texts	1	1	1	1
	Graphics	1	1	1	1
	Sum	3	3	3	3
Carthographic and visualization functions	Layer display/conceal	1	1	1	1
	Graphical form/data visualization modification	1	1	1	1
	Data selection	1	1	1	1
	Sum	**3**	**3**	**3**	**3**
GIS functions	Location query (coordinates and altitude)	1	1	1	0,5
	Access to statistical data	1	0	1	0
	Sum	**2**	**1**	**2**	**0,5**
	Total	**24**	**21,5**	**22**	**18,5**

source: own study based on A. Macioch, G. Malmon (2010)

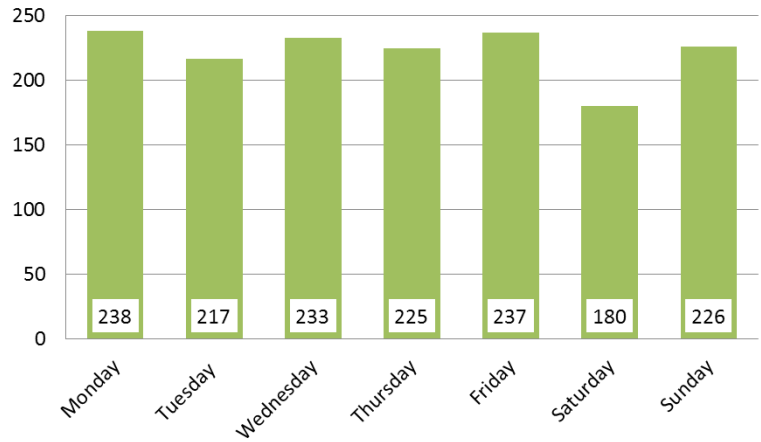

Fig. 6. The number of flights on particular days of the week from Warsaw Chopin Airport (25–31.03.2019) (source: own study based on data from flightradar24.com, flightaware.com, and radarbox24.com)

Most flights took place on Monday (238 – 15.3% of all flights during the week). Next was Friday (237 – 15.2%), Wednesday (233 – 15%), then Sunday (226 – 14.5%), Thursday (225 – 14.5%) and Tuesday (217 – 13.9%). The smallest number of flights took place on Saturday (180 – 11.6%).

In the next stage, the most important destinations for flights from Chopin Airport were determined. They are presented in figure 7. The main destinations are London (67 flights). Frankfurt and Cracow (49 flights each), as well as Amsterdam and Kiev (47 flights each) also turned out to be important destinations from the Warsaw airport. Among the 15 important destinations, there were also: Prague (45 flights), Munich and Wrocław (42 flights each), Moscow and Paris (41 flights each), Gdańsk (40), Brussels (39) Copenhagen and Vienna (38 each), and Budapest (37). Based on the graph (fig. 8) it is also worth noting that the dominant flight destinations are mainly foreign destinations (80%), while domestic flights are less important (20%).

The next element of the analysis was airlines that most often fly from Chopin Airport (fig. 9). LOT Polish Airlines is of the greatest importance.

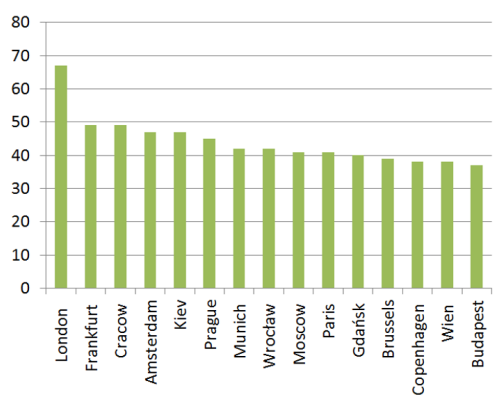

Fig. 7. The main destinations of flights from Warsaw Chopin Airport (25–31.03.2019)

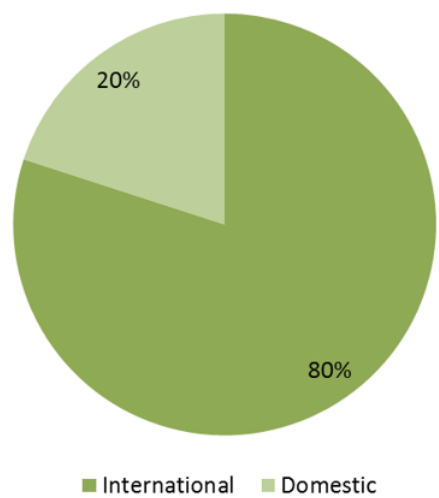

Fig. 8. The main destinations of flights from Warsaw Chopin Airport (25–31.03.2019) – division into domestic and foreign destinations

This carrier handles over 70% of all departures from the analyzed airport. Other important airlines are WizzAir, i.e. Hungarian low-cost airlines (almost 7%) and the German national carrier Lufthansa (over 3%). The top five carriers also included Russian Aeroflot and Dutch KLM. Each of these operators handles approximately 1.4% of flights from the Warsaw airport.

In addition, flight delays were analyzed, which was achieved thanks to a detailed analysis that took into account two days of the week – Monday and Saturday. The delays have been calculated based on the difference between the planned and actual departure times. On Monday, the average delay was 26 minutes and on Saturday it was 19 minutes. On the basis of this comparison, it was found that there were longer maximum delays on Monday than on Saturday. There were delays of more than two hours on Monday, while on Saturday the maximum delays were between one and two hours. On both days, delays ranging from 15 to 30 minutes were the most common. Over 35% of flights were delayed on each of the days. On Saturday, more flights began before the scheduled departure. Tables 2 and 3 present the delays recorded on Monday and Saturday.

In addition, 40 flights were compiled for a more detailed analysis, including 30 that had already taken place and 10 that were ongoing at the time of the study. The comparison in the form of a table is attached to the work by K. Krawczyńska (2019).

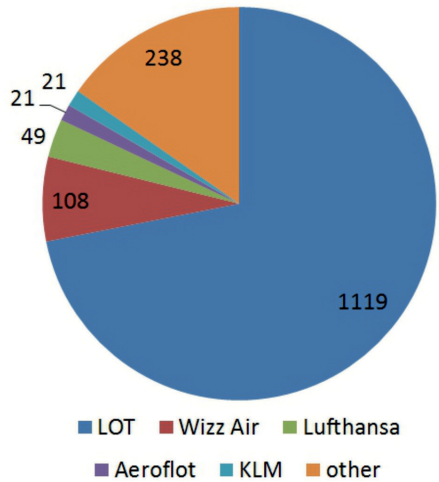

Fig. 9. The dominant airlines for flights from Warsaw Chopin Airport (25–31.03.2019)

The tables include flight numbers according to IATA and ICAO (International Civil Aviation Organization), place of departure and arrival (city names) with IATA codes for the airport, departure time according to the schedule and actual departure time and time of arrival according to the schedule, as well as the name of the airline. In addition, the tables for ongoing flights include: estimated time of arrival, flight

Table 2. Delays on Monday 25.03.2019

Delay	Number of flights	Percentage share of all flights [%]
>2 h	3	1.26
>1-2 h	9	3.78
>30 min - 1 h	49	20.59
>15-30 min	88	36.97
>10-15 min	50	21.01
>5-10 min	29	12.18
<5 min	8	3.36
flight ahead of schedule	1	0.42
canceled flight	1	0.42
Sum	**238**	**100.00**

source: own study based on data from flightradar24.com, flightaware.com, radarbox24.com

Table 3. Delays on Saturday 30.03.2019

Delay	Number of flights	Percentage share of all flights [%]
>1 h	4	2.22
>30 min - 1 h	22	12.22
>15-30 min	68	37.78
>10-15 min	36	20.00
>5-10 min	27	15.00
<5 min	16	8.89
flight ahead of schedule	6	3.33
canceled flight	1	0.56
Sum	**180**	**100.00**

source: own study based on data from flightradar24.com, flightaware.com, radarbox24.com

duration, remaining flight time, distance travelled and distance remaining, altitude, latitude and longitude, as well as a comparison of information on the position of the aircraft presented on the maps on the analyzed websites. The tables for completed flights include: flight (departure) date, actual arrival time, flight duration and a comparison of the routes presented on the maps on the analyzed websites.

There were differences between the sites, such as a five-minute delay in aircraft location data (altitude and latitude) on Flightaware compared to other sites. It was also noticed that some websites present additional flight data. The duration of flights was calculated by each of the websites in a different way, hence there are differences between them. In addition, on the Planefinder website, it was not possible to find exact data on arrival and departure times, scheduled times, as well as the exact duration of a specific flight.

After a detailed analysis of ten selected flights during their duration, different in terms of time and range, certain regularities were noticed. First of all, usually the websites did not differ significantly in terms of the geographical location of the aircraft. There were situations when a website presented a location that differed significantly from the others, but no regularity was found here. The times of departure and arrival usually overlapped either for all websites or were repeated simultaneously on two websites. Often, there were also differences of several minutes between the sites. Taking into account the duration of the flight and the estimated time remaining to complete the flight, it can be seen that even half an hour differences were noted.

There were quite significant differences in latitude or longitude values that could reach 1.5 degrees or even a maximum of almost 2.5 degrees. In some cases, this was the difference between Flightaware and RadarBox24 / Flightradar24.

The time remaining until the end of the flight usually differed between the data on the websites of the selected websites, with the maximum difference being around 50 minutes. Usually, the height value did not differ significantly. There were also individual errors, for example in the case of altitude or arrival/departure times. When analysing 30 completed flights, it was noticed that Planefinder does not provide arrival and departure times according to the schedule and the actual arrival and departure times, while the flight duration is generally given for all flights with a given number. Between the other sites, the flight duration often differed by up to an hour.

Considering the function of presenting the position of aircraft on the map (in the case of 30 analyzed flights), it was noticed that in areas such as Europe and the United States, accurate flight route data is usually complete. The situation is different over the oceans and seas, as well as over Africa and some regions of Asia, where routes are usually marked according to predictions. Sometimes complete location data for flights over Australia and South America are also missing. Over the oceans, in areas close to islands, the flight path is recorded – possibly within the range of the receiver.

It can be generally assumed that the flight routes presented on the websites usually coincided to a large extent. It was also noted that Flightradar24 usually has the most complete data in terms of routes, while Flightaware presents just slightly less complete data. RadarBox24, on the other hand, often contains very limited data. It is most difficult to find complete routes on Planefinder. While the rest of the sites present much more complete route information, this site does not contain much of the data.

7. General conclusions

7.1. Functionality analysis

Based on the functionality table and the small number of points obtained by each of the websites, it can be concluded that the examined websites cover a narrower scope than a typical data set for which a set of functions has been developed. At the same time, some of the unused functions, for example the function of importing and exporting data, could enhance these sites with additional possibilities. To facilitate access and increase the number of users, it would suffice to add a language selection feature, which is only available on Flightaware.

Tool tips, i.e. information about a given function explaining how to use it, are available only on two websites. Introducing them could make it much easier to use the maps and understand the functions. The map rotation function, which enables 3D visualization, could be omitted because in the websites where it is available, it is in the authors' opinion inaccurate and useless,

and therefore unnecessary. It makes the website more attractive visually but is not informative.

A significant difficulty is also the lack of geographical plane coordinates on Planefinder. Adding it would increase the credibility to the website, as it displays the position of the aircraft. The possibility of adding identification points could also appear on the described websites. This would make it easier to adapt the map to different studies or observations. On the other hand, the function of selecting and changing the thematic content would certainly simplify the visual perception of the map and expand the scope of data presented on the websites.

Other cartographic and visualization functions, such as adding your own objects or changing the cartographic projection, could also increase the functionality of the websites and allow people involved in various types of research related to the thematic scope of these pages to use them in various research. GIS functions are not necessary for such websites, but one of them – distance and area measurement – could be useful.

7.2. Database analysis

On the basis of the created database, it can be concluded that the analyzed websites can be used to analyse traffic at Warsaw Chopin Airport. However, this assessment is largely general and in order to be able to conduct comprehensive analyses, it would be necessary to obtain data from a longer period, which would be difficult due to the short time of data availability (from about a week to 10 days depending on the website) and its quantity. For these reasons, and because of errors and gaps in the data, the creation of a large, comprehensive database for one period is significantly difficult. The research described in this article was intended to show the possibilities of such analyses and their subsequent use. Nevertheless, it was possible to notice certain regularities and draw conclusions.

The main destinations of flights from Warsaw, determined using the database, are partially in line with the statistics provided by the Civil Aviation Authority[6]. However, the data of the Civil Aviation Authority concern the whole of Poland and only foreign flights, and also include departures and arrivals, unlike the developed database, which only includes departures. In addition, the Civil Aviation Authority data presents the number of passengers, while the developed database shows the number of flights.

In the study on the number of passengers served at Polish airports by city in international regular traffic in 2017 and 2018, London was mentioned as the most important destination, followed by Frankfurt. This is in line with the data compiled from the database. Also in the top fifteen cities to which planes fly from Chopin Airport there are 8 destinations given in the statistics of the Civil Aviation Authority. Thus, 8 out of 12 foreign destinations listed in the data compiled on the basis of the database coincided with the statistical data of the Civil Aviation Authority. They were: London, Frankfurt, Amsterdam, Kiev, Munich, Paris, Brussels and Copenhagen. This may mean that other airports in Poland handle flights to other destinations listed in the Civil Aviation Authority statistics more often than Chopin Airport.

When comparing the most important carriers operating flights from Chopin Airport, determined on the basis of the created database with the main airlines operating in Poland, it can be seen that 3 out of 5 airlines from the top five are the same (LOT, Wizz Air and Lufthansa). Data for the whole of Poland was also prepared by the Civil Aviation Authority and concerns the number of departing passengers by carriers, served at Polish airports in domestic and international regular traffic in 2017 and 2018[7]. In these statistics, Ryanair is the most important airline in Poland. However, it does not operate from Chopin Airport and therefore does not appear in the summary in this article. On the other hand, LOT Polish Airlines operate here, which handle over 70% of flights from Chopin Airport.

The research carried out by M.P. Peterson, P. Hunt and K. Weiß (2017) can be cited here. They carried out analyses to determine the number of people using air transport traveling over a given area. The authors counted the so-called Air Population on the basis of current data on the location of aircraft and data on the

[6] http://www.ulc.gov.pl/_download/regulacja_rynku/statystyki/2018/4-kw-2018/wg_metropolii_regularne_kw42018.pdf (access 26.04.2019)

[7] http://www.ulc.gov.pl/_download/regulacja_rynku/statystyki/2018/4-kw-2018/wg_przew_out_regularne_kw42018.pdf (access 26.04.2019)

aircraft model, on the basis of which the number of seats for passengers was determined. Then, using the flight load indicators for the given airlines, the searched values were calculated.

One common conclusion can be drawn from the cited article and this paper that the websites presenting air traffic data can be used for quantitative analyses and examining the regularities of air traffic, and the data can be presented by means of maps and charts.

7.3. Detailed analysis

Detailed analysis showed that the data from the analyzed websites is usually consistent, but there are situations when they differ significantly.

In conclusion, we find that the websites seem to be very helpful as a compatible single source of data in specific cases where the data does not contradict each other. The websites offer various options, data, studies and data search possibilities. Therefore, if users encounter a problem finding information on one site, they can usually find it on another and then use the former again. An example may be the fact that on Flightradar24 the register of flights departing from a given airport allows viewing the register of flights only up to one day back. RadarBox24, on the other hand, allows users to roll back up to 8 days. Therefore, when users find the flight they are looking for on RadarBox24, they can search for it on Flightradar24 by taking its number from RadarBox24. This is just one of the ways to combine data from these sites.

An additional argument is the fact that the examined websites are usually compatible with each other and their data do not differ from each other. Each of the websites differs in terms of the data presented, which means that instead of using just one website, users can use several at the same time. For example, route data can be taken from Flightradar24, and route data or altitude data can be sourced from Flightaware. In this way, the websites can complement one another. Some websites have more precise data (e.g. location data) or simply have more data available (e.g. they may show most of the routes).

It should also be noted that this article is not an exhaustive study of the analyzed websites. Only some of the functions available on the websites have been analyzed, and the developed database covers a specified period of time and data useful for the purpose of this study.

8. Conclusions

This research shows that the presented websites (flightradar24.com, radarbox24.com, flightaware.com and planefinder.com) are useful for examining air traffic and its regularities. The functionality test was carried out in three stages, consisting of the development of a functionality table, designing a database, and detailed analysis of the websites.

This study uses a ready-made set of functions developed for electronic maps (A. Macioch, G. Malmon 2010). When examining the scope of functions of the described websites, it can be noticed that it is narrower than in typical map websites, which are usually not so specialized and concern more general issues. Some of the examined functions would not be useful in air traffic sites. When using a specific range of functions, it was also noticed that there were no functions that could increase the functionality and make it much easier for users to use the websites.

Since functionality may also concern the scope of data that the websites have and the possibility of using them, a database was also created and the possibilities of its subsequent use were established. The collected data and their elaboration can be used to create various maps in order to better visualize the studied issue, the more so as such data is not easy to obtain due to its strategic nature. For example, you can create a map of the most important destinations of flights from Chopin Airport, grading their importance using a route diagram that would specify the number of flights per week. This can also be represented by a point diagram map, however, a route diagram map better shows the movement that is visualized on the basis of these maps.

Another example is the map of the actual flight time from Warsaw to other airports in Poland. For this purpose, it would be necessary to calculate the average flight duration to all Polish cities on the list, and then develop a map using the isochrones method. This is obviously not an exhaustive list of maps that can be developed.

The concept of functionality is complex and may also apply to the general functioning of websites and their suitability for use, also in

research. One of the factors that make websites useful is their credibility and accuracy. It was examined through a detailed analysis in which data from particular websites were compared. Typical errors and inconsistencies included variations in flight duration, no exact data on part of the route, and no data of any kind on the route.

Summing up, it is not easy to determine the most functional website in all the examined areas. However, as mentioned above, to increase the likelihood of data accuracy and the range of functions and data, several websites can be used simultaneously to collect and compile data.

Literature

Crampton J.W., 2002, *Interactivity types in geographic visualization*. "Cartography and Geographic Information Science" Vol. 29, no. 2, pp. 85–98; DOI: 10.1559/152304002782053314

DiBiase D., MacEachren A.M., Krygier J.B., Reeves C., 1992, *Animation and the role of map design in scientific visualization*. "Cartography and Geographic Information Systems" Vol. 19, no. 4, pp. 201–214; DOI:10.1559/152304092783721295

Fernandez A., Insfran E., Abrahão S., 2011, *Usability evaluation methods for the web: A systematic mapping study*. "Information and Software Technology" No. 53, no. 8, pp. 789–817.

Harrower M., 2001, *Visualizing change: Using cartographic animation to explore remotely-sensed data*. "Cartographic Pespectives" No. 39, pp. 30–42; DOI: 10.14714/CP39.637

Harrower M., 2003, *Tips for designing effective animated maps*. "Cartographic Pespectives" No. 44, pp. 63–65; DOI: 10.14714/CP44.516

Harrower M., 2004, *A look at the history and future of animated maps*. "Cartographica" Vol. 39, no. 3, pp. 33–42; DOI: 10.3138/7MN7-5132-1MW6-4V62

Kowalski P.J., 2006, *Problem funkcjonalności prezentacji kartograficznych w internetowych serwisach informacyjnych.* In: *Społeczna i edukacyjna rola kartografii w Polsce*. "Materiały Ogólnopolskich Konferencji Kartograficznych" T. 26, Warszawa, pp. 103–127.

Kowalski P.J., 2012, *Mapa jako praktyczny interfejs serwisu internetowego*. "Archiwum Fotogrametrii Kartografii i Teledetekcji" T. 23, pp. 159–168.

Krawczyńska K., 2019, *Analiza funkcjonalności wybranych serwisów internetowych prezentujących dane o ruchu lotniczym.* University of Warsaw, Faculty of Geography and Regional Studies.

Kukułka M., 2011, *Nowe aspekty metodyczne projektowania serwisów map internetowych*. "Polski Przegląd Kartograficzny" T. 43, nr 3, pp. 239–251.

Macioch A., Malmon G., 2010, *Funkcje interaktywne współczesnych map elektronicznych.* "Polski Przegląd Kartograficzny" T. 42, nr 4, pp. 331–353.

Meksuła M.W., 2001, *Kartograficzne sposoby prezentowania dynamiki zjawisk*. "Polski Przegląd Kartograficzny" T. 33, nr 4, pp. 329–338.

Morrison J.B., 2000, *The complex nature of animation.* In: *Does animation facilitate learning? An evaluation of the congruence and equivalence hypotheses*. Doctor's thesis, Stanford University, pp. 1–12, https://www.learntechlib.org/p/115900/ (access 2.01.2019).

Nivala A.M., Brewster S., Sarjakoski T.L., 2008, *Usability evaluation of web mapping sites*. "The Cartographic Journal" Vol. 45, no. 2, pp. 129–138; DOI: 10.1179/174327708X305120

Nowacki T., Opach T., 2010, *Mapy i atlasy elektroniczne*. In: J. Pasławski (ed.), *Wprowadzenie do kartografii i topografii*, Wrocław: Nowa Era, pp. 386–406.

Okonek M., 2010, *Lokalizacyjne serwisy mapowe w Polsce – zakres treści, geowizualizacje, funkcje interaktywne*. "Polski Przegląd Kartograficzny" T. 42, no. 3, pp. 211–226.

Peterson M.P., Hunt P., Weiß K., 2017, *Mapping air population*. "Journal of Geovisualization and Spatial Analysis" Vol. 1, no. 4; DOI: 10.1007/s41651-017-0005-3

Pearrow M., 2002, *Funkcjonalność stron internetowych*. Gliwice: Helion.

Roth R.E., Çöltekin A., Delazari L., Filho H.F., Griffin A., Hall A., Korpi J., Lokka I., Mendonça A., Ooms K., van Elzakker C.P., 2017, *User studies in cartography: opportunities for empirical research on interactive maps and visualizations*. "International Journal of Cartography" Vol. 3, (Sup. 1), pp. 61–89; DOI: 10.1080/23729333.2017.1288534

Roth R.E., Ross K.S., MacEachren A.M., 2015, *User-centered design for interactive maps: A case study in crime analysis*. "SPRS International Journal of Geo-Information" Vol. 4, no. 1, pp. 262–301; DOI: 10.3390/ijgi4010262

Slocum T.A., Blok C., Jiang B., Koussoulakou A., Montello D., Fuhrmann S., Hedley N., 2001, *Cognitive and usability issues in geovisualization*. "Cartography and Geographic Information Science" Vol. 28, no. 1, pp. 61–75; DOI: 10.1559/152304001782173998

Tsou M.H., Curran J.M., 2008, *User-centered design approaches for web mapping applications: A case study with USGS hydrological data in the United States*. In: M.P. Peterson (ed.), *International perspectives on maps and the Internet*. "Lecture Notes in Geoinformation and Cartography", Berlin, Heidelberg: Springer, pp. 301–321; DOI: 10.1007/978-3-540-72029-4_20