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Design of a Unified Algorithm to Ensure the Sustainable Use of Air Transport during a Pandemic

Stanislav Szabo , Sebastián Makó *, Michaela Kešeľová and Stanislav Szabo, Jr.

Department of Air Traffic Management, Faculty of Aeronautics, Technical University of Košice, 040 01 Košice, Slovakia; stanislav.szabo@tuke.sk (S.S.); michaela.keselova@tuke.sk (M.K.); stanislav.szabo.2@tuke.sk (S.S.J.)
* Correspondence: sebastian.mako@tuke.sk

Abstract: The COVID-19 pandemic has had a significant impact on air transport in various parts of the world. The impact of the pandemic has been and still is significant within the Member States of the European Union. The introduction focused on identifying and monitoring the pandemic spread in the individual Member States. The research focused on two periods that were compared with each other based on key indicators, i.e., reproduction rate, hospitalized patients, or ICU patients. Identification and monitoring of the above-mentioned periods were performed by an observational study of collected data mentioned below. Subsequently, an algorithm was proposed, which was to determine an index number of a given country based on key indicators mentioned earlier. The index number is an assessment of the pandemic situation in a given country. The index number calculation in the monitored periods divided the countries into two groups: countries with the index number higher than one and countries with the index number lower than one. The latter can continue using air transport by pandemic situation assessment conducted by the algorithm. The air transport utilization rate depends on the second part of the algorithm, where the allowed number of routes is calculated for individual airlines. The use of an algorithm for calculating the index number of individual countries and at the same time monitoring the development of key indicators every 14 days is a suitable method for ensuring the sustainable use of air transport to minimize financial losses.

Keywords: algorithm; pandemic; air transport; routes

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1. Introduction

The coronavirus disease 2019 (COVID-19) is a transmissible and infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The disease was first diagnosed in December 2019 in Wuhan, the capital of China's Hubei province, and has expanded globally, resulting in the ongoing coronavirus pandemic [1,2]. The virus can be spread between humans by contact with biological fluids (for instance, through coughing and sneezing), mainly through close contact from person to person and between people who are physically near each other. Thus, the disease is highly contagious [1]. In February 2020, data from the World Health Organization (WHO) had confirmed that more than 43,000 cases had been recognised in 28 countries/regions, with >99% of patients being identified in China [3]. The WHO declared COVID-19 as the sixth public health emergency of international concern. SARS-CoV-2 is closely related to two bat-derived severe acute respiratory syndrome-like coronaviruses, bat-SL-CoVZC45 and bat-SL-CoVZXC21. The infection has been estimated to have a mean incubation period of 6.4 days and a primary reproduction rate of 2.24–3.58. Among patients with pneumonia caused by SARS-CoV-2, fever was the most common symptom, followed by cough [4,5]. Originating from China, COVID cases quickly spread worldwide, urging world governments to implement stringent measures to isolate patients and limit the transmission rate of the virus [6]. All nations and countries have implemented various strategies to handle emerging issues [7].

Governments in the European Union have used travel bans, the closure of borders, and limitations on people's mobility to decrease the spread of the virus [7,8]. Intense government measures, including travel restrictions and travel bans, have been implemented to limit the spread of COVID-19 worldwide. Throughout the early stages of the pandemic, global mobility modulated the initial outbreak pattern. Global mobility, including tourists, business people, sportspeople, and many others, increases the chances of a virus outbreak in different places in a very short time due to worldwide connections between various destinations that can be traveled to within hours. Multiple studies have shown a close relationship between mobility and the spreading of contagious disease, particularly during the early stages of an outbreak [9,10]. Many authors [11–14] claim that travel restrictions are beneficial in the early or initial stage of an outbreak when confined to a certain area that is a major source of the spread. However, travel restrictions may be less efficient once the outbreak is more widespread [15]. With a limited medical capacity to treat the disease, non-pharmaceutical interventions (NPI) are the primary strategy to contain the pandemic. Unprecedented global travel restrictions and "stay-at-home" orders are causing the most significant disruption of the global economy. With international travel bans affecting over 90% of the world population and widespread restrictions on public gatherings and community mobility, tourism largely ceased in March 2020 [16]. Most airlines decided to operate a regular schedule until drastic mobility restrictions stopped them. This caused unexpected drops in flight numbers from mid-March 2020, when lockdowns, border closures, and travel bans began to be the principal policy response across Europe and America [17,18]. According to IATA [19], it is possible to categorize flights into three groups: high-risk flights, medium-risk flights, and low-risk flights. Prevention and control measures are implemented after a thorough and complete evaluation of the outbreak at the flights' area of origin [20]. Amongst the restrictive measures and rules, international air traffic and flight suspension are undoubtedly effective in reducing mobility globally in the short term. Still, it also has a major long-term and short-term socioeconomic impact [21]. The aviation industry and airports face a considerable decline in revenues due to the lower number of flights [22,23]. Airliners, especially in the European Union, were also forced to cancel charter flights. Tourism which is directly connected to Airliners and their performance indicators is also one of the central aspects of achieving economic growth and one of the world's largest and fastest-growing economic activity industries. Many developing countries also see tourism as a large part of economic growth and sustainability policies and as a source of limited financial services, employment, foreign exchange gains, and technological assistance [24,25]. Beyond this, in an era of enormous change, reflecting the outcomes of the COVID-19 pandemic, the essence of sustainable transport in the continual development of tourism is of critical importance. Air transport, as the large propagator of global tourism via fast, safe, long-distance travel, has, of course, changed significantly [26]. Research conducted shows that air transport is directly connected to state policy in terms of restrictions during COVID-19. However, no key or pattern is currently known as a universal solution to ensure sustainable use of air transport during the pandemic.

2. Materials and Methods

The COVID-19 pandemic has affected the aviation industry worldwide. The influence of the COVID-19 pandemic persists within the European Union, mainly because the Member States of the European Union have not applied the same restrictions. Restrictions were different in each Member State, which was caused by the unequal spread of the pandemic in the Member States. Overall, restrictions were applied to travel, sport, education, and leisure activities to prevent the spread of the pandemic by restricting contact between large groups of people.

2.1. Monitoring the Spread of the Pandemic in the Member States of the European Union

At the beginning of the research, it was important to collect the necessary data on the development of the pandemic in each country [27,28]. These data show the spread of the pandemic during selected periods in chronological order [29,30]. The particular periods point to the speed and diversity of spread of the pandemic in the individual Member States of the European Union. Not all Member States of the European Union specify the exact number of beds with oxygen support and ICU units. For research purposes and based on the data mentioned above, the number of beds with oxygen support was estimated to be 1/10 of the original number of all hospital beds in the Member States of the European Union. The number of ICU units was estimated to be 15 thousandths of the actual number of all hospital beds in the Member States of the European Union. It should be noted that the spread of the COVID-19 pandemic also affected the number of beds with oxygen support and ICU units.

The basic reproduction rate was used to measure the transmission potential of a disease. It was the average number of secondary infections produced by a typical case of an infection in a population where everyone is susceptible [31]. In Europe, the second wave of the pandemic started to get serious at the end of September and the beginning of October (Figure 1), when there was a significant increase in the reproduction rate.

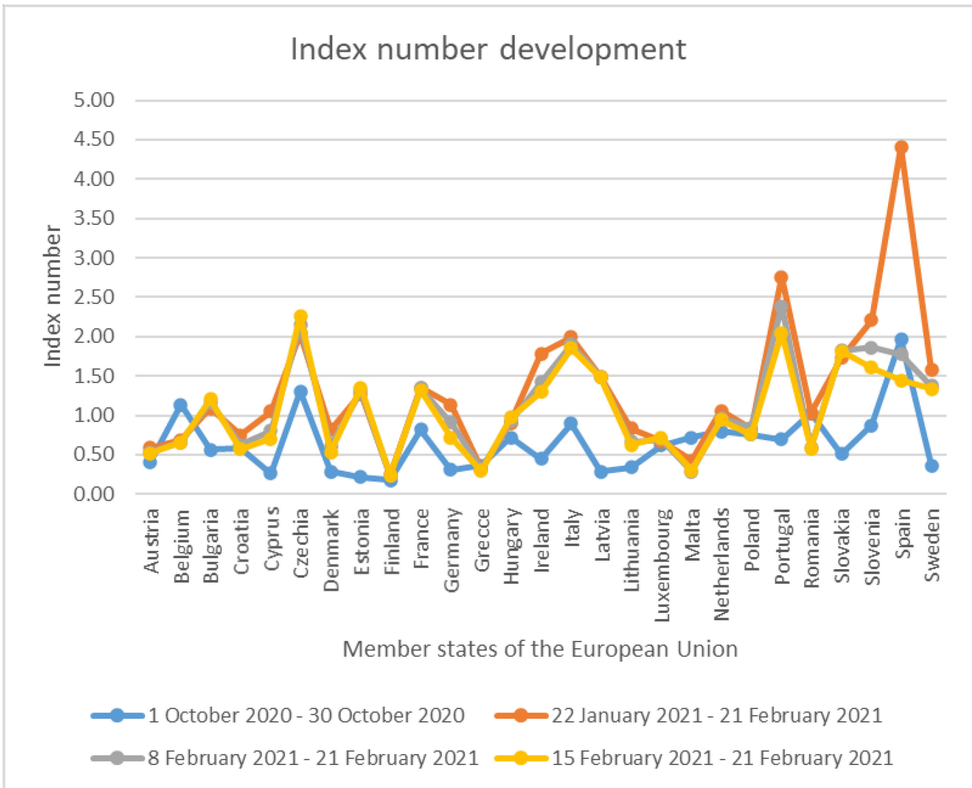

Figure 1. Index number development.

As was stated in (Table 1), the numbers of hospitalized patients or ICU patients were not high enough to force the Member States of the European Union to stop air traffic completely. At that time, individual states began to take steps to limit the spread of the pandemic. Spain and the Czech Republic were higher among the surveyed countries. The pandemic spread during October 2020 was chosen as a reference sample when comparing other pandemic spread data in January and February. The values given in all tables were the average values of individual days of the observed period.

In further monitoring of the pandemic, research was focused on monitoring changes in key indicators of the pandemic spread in January and February. From 22 January 2021 to 21 February 2021 (Table 2), a significant increase in hospitalized patients and ICU patients were seen compared to data from October 2020. The reproduction rate had a decreasing tendency. After applying the algorithm and considering all the variables, it was clear that most countries should not have been connected by air transport during this period (Figure 1).

Table 1. Key indicators for monitoring the spread of a pandemic in the period from 1 October 2020 to 30 October 2020 [27–30].

Country	New Cases	Reprod. Number	Hospit. Patients	ICU Patients	Hospital Beds with Oxygen Support *	ICU Beds *	People Vaccinated	Population
Austria	1939	1.36	726	142	6637	996	N/A	9,046,000
Belgium	10,025	1.43	2793	473	6537	981	N/A	11,589,616
Bulgaria	1033	1.50	1478	89	5179	777	N/A	6,948,445
Croatia	1056	1.52	562	56	2274	341	N/A	4,105,268
Cyprus	84	1.51	18	2	298	45	N/A	875,899
Czechia	8527	1.38	3768	592	7100	1065	N/A	10,708,982
Denmark	593	1.16	119	17	1448	218	N/A	5,792,203
Estonia	49	1.17	35	4	622	93	N/A	1,326,539
Finland	197	1.20	51	8	1817	273	N/A	5,540,718
France	26,080	1.26	11,939	2010	39,033	5855	N/A	65,273,512
Germany	7706	0.38	12,013	863	67,027	10,055	N/A	83,783,945
Greece	670	1.27	530	70	4388	659	N/A	10,423,056
Hungary	1576	1.24	1764	325	6782	1017	N/A	9,660,350
Ireland	816	1.20	245	32	1461	219	N/A	4,937,796
Italy	11,760	1.57	8629	785	19,227	2885	N/A	60,461,828
Latvia	131	1.42	87	8	1051	158	N/A	1,886,202
Lithuania	327	1.43	254	11	1786	269	N/A	2,722,291
Luxembourg	278	1.46	67	8	282	42	N/A	625,976
Malta	96	1.24	47	10	198	30	N/A	441,539
Netherlands	7473	1.27	1233	349	5689	854	N/A	17,134,873
Poland	8749	1.56	7843	980	25,054	3758	N/A	37,846,605
Portugal	2121	1.34	1144	166	3457	792	N/A	10,196,707
Romania	3670	1.26	6872	716	13,259	1988	N/A	19,237,682
Slovakia	1533	1.36	581	76	3176	477	N/A	5,459,643
Slovenia	923	1.52	300	50	936	141	N/A	2,078,932
Spain	13,435	1.18	12,958	1848	13,886	2084	N/A	46,754,783
Sweden	1016	1.33	274	32	2242	336	N/A	10,099,270

* Estimated value.

Table 2. Key indicators for monitoring the spread of a pandemic in the period from 22 January 2021 to 21 February 2021 [27–30].

Country	New Cases	Reprod. Number	Hospit. Patients	ICU Patients	Hospital Beds with Oxygen Support *	ICU Beds*	People Vaccinated	Population
Austria	1470	0.98	1294	287	6637	996	121,216	9,046,000
Belgium	2182	1.03	1728	312	6537	981	232,861	11,589,616
Bulgaria	736	1.14	3141	283	5179	777	21,496	6,948,445
Croatia	407	0.85	1148	56	2274	341	64,951	4,105,268
Cyprus	117	0.86	117	26	298	45	15,322	875,899
Czechia	7606	1.03	6032	1098	7100	1065	189,566	10,708,982
Denmark	494	0.83	490	91	1448	218	180,625	5,792,203
Estonia	594	1.10	465	36	622	93	23,523	1,326,539
Finland	393	1.10	130	21	1817	273	91,260	5,540,718
France	19,946	1.01	26,841	3223	39,033	5855	959,716	65,273,512
Germany	9214	0.88	49,050	3249	67,027	10,055	1,526,605	83,783,945
Greece	946	1.16	539	54	4388	659	141,298	10,423,056
Hungary	1528	1.10	3800	240	6782	1017	143,184	9,660,350
Ireland	1069	0.73	1272	186	1461	219	143,000	4,937,796
Italy	12,291	0.98	21,855	2183	19,227	2885	1,326,263	60,461,828
Latvia	734	1.00	1100	49	1051	158	16,779	1,886,202
Lithuania	650	0.82	1166	26	1786	269	59,170	2,722,291
Luxembourg	144	1.08	69	13	282	42	7309	625,976
Malta	149	1.00	26	6	198	30	17,767	441,539
Netherlands	4041	0.91	1506	586	5689	854	135,000	17,134,873
Poland	5839	1.00	13,073	776	25,054	3758	638,798	37,846,605
Portugal	6528	0.72	5662	797	3457	792	210,734	10,196,707
Romania	2449	0.97	5945	975	13,259	1988	374,681	19,237,682
Slovakia	1965	1.01	3422	253	3176	477	99,455	5,459,643
Slovenia	983	0.90	917	157	936	141	52,340	2,078,932
Spain	21,821	0.94	28,967	4599	13,886	2084	1,097,369	46,754,783
Sweden	2846	1.21	1613	246	2242	336	221,504	10,099,270

* Estimated value.

The reproduction rate should not be the only and determining factor. A comprehensive assessment of the situation was needed. Spain has had the worst results in research, and a nationwide lockdown, including air traffic, was to be applied in the country to limit the spread of the disease. The 30-day average of key indicators was a long period for monitoring changes in the spread of the pandemic, and, therefore, in the next section, a 14-day average and a 7-day average were presented.

Subsequently, the research was focused on the period from 8 February 2021 to 21 February 2021 (Table 3). While conducting the research and utilizing the algorithm, it was agreed that the 14-day average of the pandemic spread key indicators were more crucial for ensuring sustainable air transport. When comparing the values of Tables 2 and 3, relatively minor changes could be noticed.

Table 3. Key indicators for monitoring the spread of a pandemic in the period from 8 February 2021 to 21 February 2021 [27–30].

Country	New Cases	Reprod. Number	Hospit. Patients	ICU Patients	Hospital Beds with Oxygen Support *	ICU Beds *	People Vaccinated	Population
Austria	1538	1.07	1121	264	6637	996	212,062	9,046,000
Belgium	2062	1.02	1621	309	6537	981	349,992	11,589,616
Bulgaria	923	1.22	3416	292	5179	777	41,407	6,948,445
Croatia	325	0.89	941	43	2274	341	61,241	4,105,268
Cyprus	107	0.99	87	19	298	45	22,813	875,899
Czechia	8442	1.12	6168	1188	7100	1065	266,445	10,708,982
Denmark	423	0.90	341	67	1448	218	199,439	5,792,203
Estonia	692	1.17	495	35	622	93	35,917	1,326,539
Finland	438	1.11	125	21	1817	273	170,641	5,540,718
France	19,194	0.97	26,453	3342	39,033	5855	1,922,706	65,273,512
Germany	7346	0.89	30,401	3936	67,027	10,055	2,380,609	83,783,945
Greece	1133	1.17	539	71	4388	659	332,812	10,423,056
Hungary	1895	1.25	3908	242	6782	1017	291,396	9,660,350
Ireland	821	0.79	906	162	1461	219	154,900	4,937,796
Italy	12,322	1.03	20,626	2089	19,227	2885	1,464,945	60,461,828
Latvia	694	1.00	955	71	1051	158	18,075	1,886,202
Lithuania	520	0.87	901	23	1786	269	79,268	2,722,291
Luxembourg	162	1.10	71	14	282	42	14,089	625,976
Malta	158	1.07	16	4	198	30	30,235	441,539
Netherlands	3679	0.98	1395	531	5689	854	414,858	17,134,873
Poland	6322	1.12	12,329	956	25,054	3758	1,291,569	37,846,605
Portugal	2294	0.51	4724	771	3457	792	291,758	10,196,707
Romania	2456	1.03	4999	267	13,259	1988	661,062	19,237,682
Slovakia	2058	1.03	3576	281	3176	477	193,218	5,459,643
Slovenia	790	0.90	737	137	936	141	55,684	2,078,932
Spain	13,652	0.81	16,236	1094	13,886	2084	1,328,459	46,754,783
Sweden	3079	1.21	1337	222	2242	336	326,607	10,099,270

* Estimated value.

However, after applying the algorithm these changes were significant enough to limit some countries using air transport. As was shown, it was possible to ensure air transport sustainability within the restrictions in countries with low key indicators.

The last period was focused on the period from 15 February 2021 to 21 February 2021 (Table 4). Changes between the 14-day average and the 7-day average were minimal. This fact was also reflected in the calculated values by applying the algorithm. For optimal operation of the algorithm, it was necessary to work with average values for the last 14 days. As was pointed out in Tables 2 and 3, other periods were too long or too short to actively monitor changes in the pandemic spread.

Table 4. Key indicators for monitoring the spread of a pandemic in the period from 15 February 2021 to 21 February 2021 [27–30].

Country	New Cases	Reprod. Number	Hospit. Patients	ICU Patients	Hospital Beds with Oxygen Support *	ICU Beds *	People Vaccinated	Population
Austria	1698	1.12	1048	261	6637	996	298,199	9,046,000
Belgium	2263	1.06	1604	318	6537	981	423,946	11,589,616
Bulgaria	998	1.23	3614	300	5179	777	92,381	6,948,445
Croatia	327	0.96	851	39	2274	341	87,169	4,105,268
Cyprus	107	1.05	81	16	298	45	37,570	875,899
Czechia	9307	1.17	6381	1273	7100	1065	341,687	10,708,982
Denmark	459	0.94	289	62	1448	218	320,891	5,792,203
Estonia	743	1.20	512	37	622	93	61,904	1,326,539
Finland	489	1.13	132	26	1817	273	287,998	5,540,718
France	20,056	0.96	25,794	3368	39,033	5855	2,564,530	65,273,512
Germany	7538	0.93	23,690	3029	67,027	10,055	3,335,830	83,783,945
Greece	1096	1.17	539	57	4388	659	467,656	10,423,056
Hungary	2223	1.33	4043	273	6782	1017	453,457	9,660,350
Ireland	782	0.82	799	153	1461	219	222,073	4,937,796
Italy	12,481	1.06	20,149	2067	19,227	2885	2,201,756	60,461,828
Latvia	686	1.00	828	91	1051	158	29,288	1,886,202
Lithuania	475	0.90	861	22	1786	269	122,410	2,722,291
Luxembourg	178	1.11	74	15	282	42	23,259	625,976
Malta	158	1.10	24	4	198	30	43,888	441,539
Netherlands	3955	1.04	1382	524	5689	854	778,744	17,134,873
Poland	7116	1.18	12,332	667	25,054	3758	1,785,194	37,846,605
Portugal	1681	0.49	3917	703	3457	792	429,020	10,196,707
Romania	2533	1.06	4831	266	13,259	1988	803,098	19,237,682
Slovakia	2066	1.05	3623	278	3176	477	276,535	5,459,643
Slovenia	755	0.91	638	119	936	141	95,070	2,078,932
Spain	11,012	0.78	13,020	925	13,886	2084	1,893,290	46,754,783
Sweden	3251	1.21	1288	217	2242	336	398,092	10,099,270

* Estimated value.

2.2. The Effect of the Pandemic on Air Transport in the European Union

The impact of the pandemic on air transport was significant and persisted. The following subchapter presents the pandemic's impact on European airlines and airports by comparing 2020 and 2019 key performance indicators.

By comparing the key performance indicators of European airlines for the years 2020 and 2019, the authors were able to obtain a comprehensive view of the impact the pandemic had on individual companies. Results showed (Table 5) a decrease in sales, passengers, and load factor for all airlines. The only airline that did not report a loss in 2020 was the Hungarian Wizz Air, which increased its net profit by 79 mils. €. The total losses of the airlines amounted to tens of billions of euros. Airlines are currently dependent on government assistance and are compensating for financial losses by laying off staff.

Due to the decrease in the number of flights (Table 6) in 2020, airports recorded a decline in passengers' number compared to 2019. The reduction in the number of passengers was accentuated by regional policy decisions mentioned in Section 2.1, which resulted in the closure of the airports to reduce the risk of the spread of the pandemic. The average decrease in passengers in 2020 compared to 2019 was 74.24%. Airports without aircraft and passenger handling did not make a profit, which only created further financial losses in this sector.

Table 5. Comparison of key performance indicators of European airlines.

Airliner	TR 2020 [1]	TR 2019 [1]	Net Income 2020 [1]	Net Income 2019 [1]	PAX 2020 [2]	PAX 2019 [2]	LF 2020	LF 2019
Ryanair Holding [32]	340	1.91	−306	88	25,200	121,600	72.0%	96.0%
Lufthansa Group [33]	13,589	36,424	−6725	1213	36,354	145,299	63.2%	82.6%
Air France-KML Group [34]	11,088	27,189	−7078	290	5211	87,624	41.4%	87.9%
International Airlines Group [35]	7806	25,51	−6923	1715	31,275	118,253	63.8%	84.6%
Austrian Airlines [35]	460	2108	−381	15	3114	14,613	61.9%	80.8%
Brussels Airlines [35]	414	1473	−332	−32	2362	10,285	68.3%	81.5%
Wizz Air [36]	2761	2319	344	265	40,027	34,566	93.6%	92.8%
SAS Group [18]	2009	4517	−908	60	12,610	29,761	60.5%	75.2%
Tap Portugal [37]	N/A	3345	N/A	−105	N/A	17,052	N/A	80.1%
Aegean Airlines [38]	N/A	1308	N/A	78	N/A	14,900	N/A	85.0%
Finnair [39]	829	3097	−523	74	14,645	34,856	63.0%	81.7%
TUI Group [40]	7952	18,928	−3139	532	8057	21,075	N/A	N/A
Air Baltic [41]	120	392	−578	−640	1179	3875	55.6%	76.6%
Norwegian Air [42]	897	4293	−2272	−158	6870	36,200	75.2%	86.6%

[1] in millions, [2] in thousands.

Table 6. Comparison of passenger statistics at major airports in Europe [43].

State	IATA Code	Airport	PAX Statistics 2019 [1]	PAX Statistics 2020 [1]	Change
Austria	VIE	Vienna International Airport	31.6	7.8	−75.3%
Belgium	BRU	Brussels Airport	26.3	6.7	−74.0%
Bulgaria	SOF	Sofia Airport	7.1	2.9	−58.7%
Croatia	ZAG	Zagreb Airport	3.3	0.9	−72.0%
Cyprus	LCA	Larnaca Airport	8.2	1.6	−79.5%
Czechia	PRG	Václav Havel Airport Prague	17.8	3.0	−79.4%
Denmark	CPH	Copenhagen Airport	30.1	7.5	−75.0%
Estonia	TLL	Tallin Airport	0.8	0.2	−73.6%
Finland	HEL	Helsinki Airport	26.0	5.0	−76.8%
France	CDG	Paris Charles de Gaulle Airport	76.2	33.1	−69.4%
Germany	FRA	Frankfurt am Main Airport	70.6	18.8	−73.0%
Germany	MUC	Munich Airport	47.9	11.1	−76.8%
Greece	ATH	Athens International Airport	25.6	8.1	−68.4%
Hungary	BUD	Budapest Ferenc Liszt International Airport	16.2	3.8	−76.0%
Ireland	DUB	Dublin Airport	32.9	7.4	−78.0%
Italy	FCO	Rome–Fiumicino International Airport	43.5	11.4	−76.8%
Latvia	RIX	Riga International Airport	7.8	0.5	−91.0%
Lithuania	KUN	Kaunas International Airport	1.2	0.4	−68.0%
Luxembourg	LUX	Luxembourg Airport	4.4	1.4	−68.0%
Malta	MLA	Malta International Airport	7.3	1.7	−76.0%
Netherlands	AMS	Amsterdam Airport Schiphol	71.0	20.8	−71.0%
Poland	WAW	Warsaw Chopin Airport	18.2	5.0	−69.0%
Portugal	LIS	Lisbon Portela Airport	31.0	N/A	N/A
Romania	OTP	Henri Coandă International Airport	14.7	4.4	−69.0%
Slovakia	BTS	Bratislava Airport	2.3	0.4	−82.0%
Spain	MAD	Madrid-Barajas Airport	61.7	17.1	−79.7%
Sweden	ARN	Stockholm Arlanda Airport	25.6	6.5	−74.0%

[1] in millions.

Figure 2 shows the estimated development of air traffic volume in the European Region for 2021 compared to 2020. The baseline values with which the values of 2020 and 2021 were compared were from 2019. The graph shows that Eurocontrol estimates a possible slight improvement in the Q2 of 2021. Air traffic percentages were low compared to 2019 and in 2021, and several organizations expected this trend to continue until individual states managed the fight against a pandemic. At the moment, the biggest concern was the speed of vaccination in the individual Member States of the European Union.

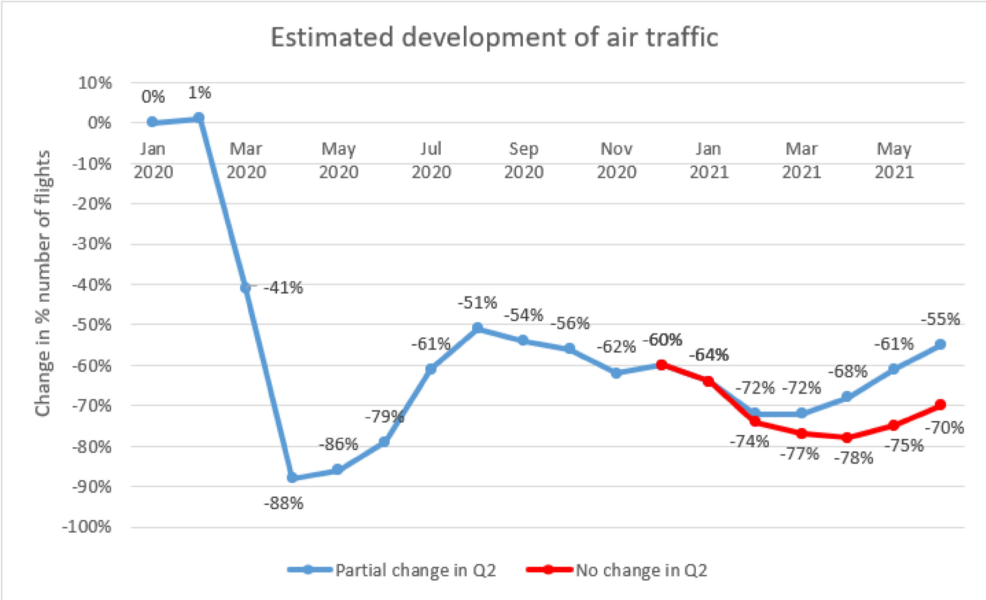

Figure 2. Estimated development of air traffic in Europe in Q2 of 2021.

This article was proposed to monitor changes in key performance indicators and design a unified algorithm, which was presented in Section 3, which would simplify airlines' operation by unifying the air transport rules. Unified rules for air transport within the Member States of the European Union would help to increase the number of passengers and speed up the recovery of air transport that experienced financial losses, as is shown in Tables 5 and 6.

3. Results

An algorithm (Figure 3) was proposed to unify the procedures for the use of air transport. The algorithm was focused on the evaluation of key indicators of individual countries and the calculation of the use of air transport within pandemic measures. The result of the algorithm was an index number of a particular country. The index number is an assessment of the pandemic situation in a particular country, and it determines whether the given country should operate air transport at all in a specific situation and, if so, to what extent.

Variables and constants: H_{1i}—hospital beds with oxygen support, H_{2i}—hospitalized patients, H_{3i}—ICU patients, H_{4i}—people vaccinated, H_{5i}—new cases, H_{6i}—ICU beds, H_{7i}—reproduction rate, P_i—country population, P_k—total number of countries, P_{cm}—number of passengers in 2019, L_{cj}—number of airline's routes within EU, L—total number of airlines, H_i—country index number, A_i—country index number shown at the end, P_1—counter of countries with index number higher than 1, P_2—counter of countries with index number lower than 1, H_x—country index counter with an index number lower than 1, x—counter of total number of countries, C—index number of all countries involved with index number lower than 1, L_j—total index number for airline, L_x—counter of airlines, K_j—maximum number of passengers, P_{cj}—average estimated number of passengers, D_j—maximum permitted number of passengers, M_j—maximum number of passengers in 2019, i—auxiliary variable, j—auxiliary variable, m—auxiliary variable.

The authors developed the algorithm based on the theory of maximization of the utilization of air transport during the pandemic to ensure a controlled and sustainable environment for customers and airliners.

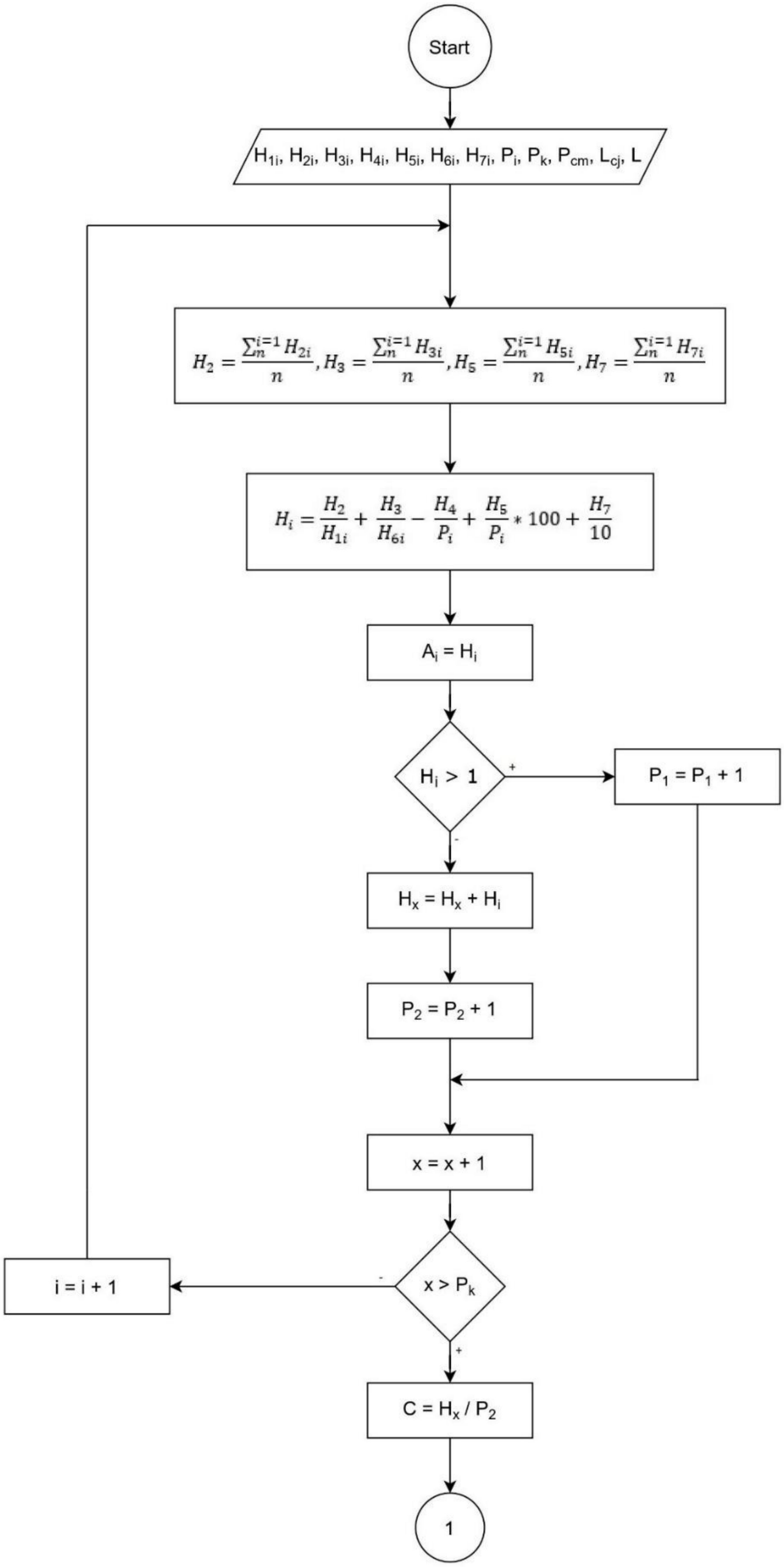

Figure 3. *Cont.*

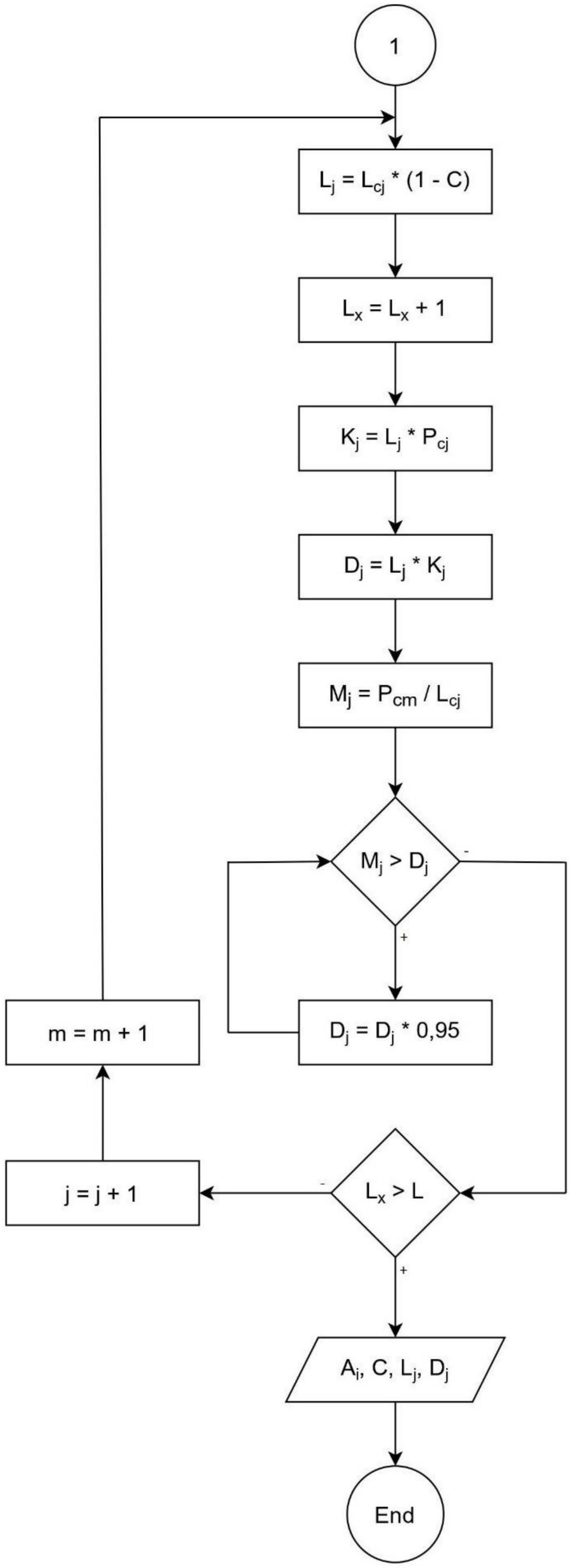

Figure 3. Unified algorithm for calculating usable capacities of air carriers with regard to the spread of a pandemic.

The main reason for creating the algorithm was to unify the procedure for assessing air transport possibilities during a pandemic. The European Union has not acted unanimously in this direction, which has caused heavy losses in the airline industry, especially in the European market. The proposed algorithm was divided into two parts. In the first part, based on the primary parameters H1–H7, the index number of a specific country was calculated. If the interval values were $0 < Hi < 1$, the country was included in the overall average of the assessed countries. If the value of $Hi > 1$, the country was not included in the assessed countries' overall average and was excluded from further calculations. Countries with an index number higher than 1 had a higher risk of transmitting the disease, which was no longer acceptable for air transport. The next step was the calculation of the C value, which was the ratio of countries with an index number lower than one to the number of these countries.

The second part of the algorithm focuses on calculating the air carrier's routes within the COVID-19 restrictions. The first important factor is how many routes, out of the original number of routes from 2019, can an air carrier use. To calculate this value, the original number of routes from 2019 was used along with the C value. This calculation was the value of Lj, which precisely defines the number of routes that the air carrier can use. A check calculation of the maximum number of passengers and the estimated number of passengers was presented in the algorithm to ensure compliance with hygienic and epidemiological measures. From the relationship $Mj > Dj$, the estimated number of passengers must not exceed the actual number of passengers from 2019, considering the number of lines.

The inconsistent approach to the COVID-19 restrictions by the individual Member States of the European Union continues to cause significant problems for air carriers. Other forms of transport have not been so significantly affected by the restrictions of individual countries. The algorithm considers all the necessary information to ensure the sustainable use of air transport, even considering the risks of a pandemic.

Testing and validation of the algorithm are based on data mentioned in Section 2.1 where all key indicators of the spread of the pandemic are mentioned as well as data from airliners about their lines and passengers in Member States of European Union.

By applying the algorithm for each period, the index numbers of individual countries within the European Union were calculated. To ensure sustainable air transport, all countries aim to have an index number value lower than 1. From the graph (Figure 1), it can be seen that in the first research period (Table 1) from 1 October 2020 to 30 October 2020, most countries had an index number value lower than 1, which creates an assumption for the sustainable use of air transport within the region. The reproduction rate was higher in this period than in the other periods examined, but the other key indicators examined were significantly lower.

Other research periods divided the countries into two groups. In the first group, there are countries with an index number higher than 1. Air transport should not be operated in these countries due to the higher risk of disease transmission. In the second group, some countries have an index number of less than 1. In these countries, part of the air transport operation as calculated in Figure 1 should be allowed. According to the proposed algorithm (Figure 3), countries such as Portugal, Spain, or the Czech Republic should not operate air transport, and the risk of spreading the disease is exceptionally high in these countries. Countries such as Austria, Finland, Greece, and Croatia should operate air transport with the constraints arising from Figure 1. By dividing the countries within the European Union, it is possible to ensure the sustainable use of air transport given the current state of pandemic spread in each country.

4. Discussion

The study points to the spread of a pandemic in the individual Member States of the European Union and at the same time suggests the use of a unified algorithm to ensure the sustainable use of air transport.

In the first phase, the research focused on specific pandemic spread periods in individual states. The reference point in the research was October when the pandemic was on the rise, but several indicators did not reach a critical value. Subsequently, they may compare these values with the values from January and February, thus the study focused on a 30-day, 14-day, and 7-day average. The research shows that the best explanatory value for applying the algorithm is exactly the 14-day average and the changes in it are relevant and suitable for the application of the calculation using the algorithm.

Due to the inconsistent approach of the Member States of the European Union to individual restrictions to reduce the spread of COVID-19, the unified algorithm was created. The design of the algorithm was based on pandemic spread evaluation in each Member State of the European Union conducted by monitoring of key indicators as well as monitoring the need for sustainable utilization of air transport. The algorithm was divided into two parts. The first part was focused on calculating the index number of individual countries. If the index number was lower than 1, the air traffic should be operated in the given country with the second part of the algorithm's restrictions. If the index number in a given country was higher than 1, air transport should not be operated in that country. The second part of the algorithm evaluates the possible usable capacity of air carriers concerning the index number. The evaluation of possible usable capacity was performed by calculation of index number and original capacity of the air carrier from 2019 in the specific country. The result of the evaluation process was certain percentage of possible usable capacity for the air carrier. Thus, the air carrier can provide air transport in the specific country to a certain level. At the same time, a check calculation was presented in the algorithm to ensure that the maximum number of passengers is never exceeded.

In the long run, the situation, especially in air transport, is critical. As is shown in previous chapters, the impact of the pandemic has caused many airlines billions of euros in losses. Research shows that the European Union could have approached all Member States uniformly, and the application of the same rules could have provided a better environment and sustainable utilization of air transport without restriction performed by individual governments.

Thus, it can be concluded that for the successful application of the algorithm in air transport, both airliners and the Member states of the European Union have to co-operate in terms of providing necessary information to ensure sustainable utilization of air transport during the pandemic. The application of the unified algorithm as proposed would help in this matter.

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Abbreviations

i.e.,	id est
Reprod.	Reproduction
Hospit.	Hospitalized
ICU	Intensive care unit
TR	Total revenue
PAX	Passengers
LF	Load factor
IATA	International Air Transport Association

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