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# Accessibility for money? An evaluation of subsidized air transport services in Europe and the United States

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ABSTRACT

The United States Essential Air Service (EAS) programme and Europe's imposition of Public Service Obligation (PSO) air services are nationally funded and intended to increase access to remote areas. In 2018, the programmes together, involved subsidy payments in excess of US$590 million. Applying a generalized travel-cost-based methodology, this paper analyses to what extent 264 subsidized air services in 12 countries contribute to the locational accessibility of remote regions. It also assesses the routes' viability in the presence of transport alternatives at nearby airports. The results indicate that the accessibility contributions of subsidized services vary considerably across countries. More than 45 routes are identified for which no measurable accessibility improvements are found. In total, only 15% of all services appear to yield accessibility contributions sufficient to justify the corresponding subsidies. The implications of the findings for future policymaking is discussed.

## 1. Introduction

Given the well-established link between access to air transportation and regional economic development (Baker et al. 2015; Brugnoli et al., 2018; Zhang and Graham 2020), public authorities around the world subsidize air transport to channel its alleged benefits to remotely located parts of their jurisdiction. One way of incentivizing airlines to serve peripheral destinations that are otherwise not commercially viable, is to purchase air-transport services through competitive tendering.

The United States Essential Air Service (EAS) programme (e.g. Matisziw et al. 2012; Wittman 2014) and Europe's imposition of public service obligation (PSO) air services (e.g. Calzada and Fageda 2014) are two such initiatives. They account for around 320 routes and annual subsidy payments in excess of US$590 million (USDOT 2018b; EC 2019) in total. Likely due to the high diversity in routes' characteristics (e.g. geography, policy goals), the route-specific, per capita compensation rates for both programmes vary considerably, ranging for example in Europe from $5 to more than $1000 per passenger (EC 2019). Regardless of specific cases, it appears reasonable that subsidized air services should generate gains — here improving the accessibility of remote locations — larger than the underlying subsidy payments. Otherwise, the subsidized air services may be ill-advised, and alternative policy initiatives may be more promising.

Despite the obviously high relevance of this cost benefit aspect to policymakers, literature concerning the accessibility contribution of subsidized air services in light of their cost is scarce. A comprehensive analysis of the value of such services for network-wide journeys and in the presence of alternative transport options, appears to be still lacking. The objective of this paper is to fill this gap and provide the first assessment that (i) systematically measures the accessibility of remote airports served by subsidized air services across geographies, (ii) estimates the extent to which existing EAS/PSO arrangements contribute to this accessibility level and (iii) compares the accessibility effects with the corresponding costs to generate them.

To this end, this paper develops a recently introduced airport connectivity metric (Mueller and Aravazhi 2020) into a measure of locational accessibility. Traveller's monetized disutility from the air and surface based transport legs of a journey are integrated into one framework. Accessibility values for 264 EAS/PSO airports in 12 countries are calculated, treating air services operated from nearby airports as potential substitutes. The counter-factual (the termination of a subsidized route) is simulated, and the reduction of accessibility for the corresponding airport is estimated.

The remainder of this paper is structured as follows. Section 2 provides the background for this analysis in terms of relevant literature. There follows a presentation of the methodology in Section 3. In Sections 4 and 5, the results are presented, and their policy implications are discussed. Section 6 concludes the paper.

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## 2. Background

### 2.1. The EAS programme in the United States and the PSO regime in Europe

Established after the deregulation of the air-transport industry, the EAS scheme in the US and Europe's PSO system share the overarching goal of preventing an undersupply of air services to remote regions. While procedures differ in detail, in both programmes airlines enter into contractual agreements with governments to serve EAS/PSO routes in line with predefined service standards (e.g. daily departure frequencies). The airlines, in return, receive subsidies granted on the federal level in the US or by national or regional governments within Europe. A detailed discussion and a comparison of the two programmes are provided in Bråthen and Halpern (2012), Calzada and Fageda (2014) and most recently in Fageda et al. (2018). A few notable differences in the two programmes relevant to this study are highlighted below.

The funding of EAS-services is conditional on several eligibility criteria, such as that communities served by EAS routes should have had air services before the liberalization. Further, demand for such routes is to meet a minimum threshold of 10 enplanements a day, but can not be high enough to make the route economically viable to operate. In an attempt to reduce total programme costs, a distance criterion was established, requiring, for example, communities located closer than 40 miles to the nearest small-hub airport to finance a share of the subsidies from their own funds. Accordingly, subsidies are generally limited to US $200 per traveller if hub airports are within 210 miles and to a maximum of US $1000 per passenger regardless of the circumstances (USDOT 2018b).[1]

In contrast, the appraisal of a poor region or thin route as being vital for the economic and social development of a peripheral region and the absence of suitable ground transport alternatives are sufficient to qualify in Europe's PSO regime. As they are abstract in formulation and not quantitively defined, the detailed interpretation of these criteria remains to the individual national governments. This permits the consideration of other policy objectives, such as, for example, the promotion of tourism by subsidized air services (Williams 2005), and consequently leads a substantial heterogeneity among PSO services (Williams and Pagliari 2004). Further, no generally agreed constraints are specified within the European framework, such as, for example, maximum subsidy payments per enplanement or a minimum distance to alternative airports (Fageda et al., 2018). Finally, an important distinction between the programmes relates to the required network integration of a subsidized route. While EAS routes, by regulation, have to link an eligible community to a hub airport, no such restrictions apply in Europe's PSO initiatives (EU 2008).

### 2.2. Literature on the assessment of subsidized air transport

Research has focused on many significant dimensions of EAS/PSO regimes, such as their social and economic contributions (e.g. Bråthen and Halpern 2012), differences in objectives and implementation across nations (e.g. Fageda et al., 2018) and the incentive governing the actions of various stakeholders (e.g. Merkert and O'Fee, 2016). Three streams of literature are of particular interest to this study and hence are considered in this review.

First, there are a number of methodologically relevant publications on how to adequately measure the locational accessibility provided by air-transport services. Accessibility, here, refers to the extent to which land use and transport systems enable individuals to reach destinations by means of a combination of transport modes (Geurs and van Wee 2004). Following this definition, two dimensions determine accessibility in the context of this paper: (i) the level of service available to travellers within the air-transport network and (ii) the existing opportunities to enter the air-transport network.

Considering the first dimension, various so-called 'airport connectivity metrics' have been proposed in literature (e.g. Veldhuis 1997; Veldhuis and Lieshout 2009; Allroggen et al. 2015). These are intended to capture the degree to which an airport facilitates network-wide air travel and hence generates network accessibility for travellers. Building predominantly on supply-side attributes, the merits and limitations of different methodologies are distinct (ITF 2018). As they have gradually improved over time, recent metrics are capable of measuring airport connectivity based on the combination of available direct and indirect travel options, and the temporal coordination of flights within the network. A shared limitation of this literature is that features of airport access are usually not considered, hence the second dimension of accessibility.

Closely related, the second relevant strand of literature highlights the importance of airport leakage for the assessment of regional air-transport services. Airport leakage is a well-documented phenomenon (Fuellhart 2007; Ishii et al., 2009). It is defined as travellers having access to nearby local airports and still preferring to start their air journeys at larger, more distant 'out-of-region' airports (Suzuki et al. 2004). Travellers' willingness to trade higher access costs for more convenient flight schedules, lower fares and other amenities has been identified to be the main motivation behind airport leakage (Grubesic and Wei 2012; Kim and Ryerson 2018). Literature on the spatial structure of the US airport system, for instance, suggests a high potential for leakage from EAS-airports (Grubesic and Matisziw 2011; Grubesic et al. 2012; Grubesic et al., 2016).

Third, and conceptually most relevant, is a small number of contributions concerning the evaluation of the costs and accessibility outcomes of subsidized air-transport services. Wittman, Allroggen, and Malina (2016) estimate the airport connectivity contributions of some 230 individual EAS/PSO routes in 12 different countries and compare them with route-specific subsidy payments. The authors find the 'cost/impact'-ratios to substantially vary across the countries and relate this finding to the existence of diverging policy objectives. The methodological limitations of the underlying point-based connectivity metric (Allroggen et al. 2015) however, do not allow ultimate conclusions to be drawn on the 'value' of an EAS/PSO service relative to scenarios in which the services would be terminated.

Simulating such route closures, Lowell et al. (2011) analyse the potential changes in the cost structure resulting from the hypothetical replacement of subsidized air services to 38 EAS communities in 2011 by coach or bus services. The analysis yields the interesting finding that the potential savings in operating costs outperform travellers' additional disutility due to the increase in ground-travel time on all the analysed routes. Likewise, Mundy et al. (2015) estimate how many subsidized coach round-trips could theoretically be funded by the current EAS subsidies. Their findings suggest that switching to a subsidized bus service would on average allow an additional five daily round-trips in addition to the required minimum EAS-service frequencies. This could potentially yield additional benefits for travellers by a reduction in layover times at connecting hub airports.

O'Kelly (2012) and Park and O'Kelly (2016) develop an empirical trip-based accessibility measure and apply it to the US system to determine the distinct role of EAS airports in the network. The analysis is premised on a comparison of the length of a traveller's trip (i.e., greater circle distance) from an origin airport $v$ to a destination airport $d$ with the length of a traveller's trip from other airports to $d$. In this manner, the authors identify two distinct roles of EAS airports. These airports are either regionally oriented, serving predominantly short-haul travellers, or they act as network entrance points, ensuring network-wide connectivity. The authors further suggest that the geographical heterogeneity of airports and their dynamics are subject to factors that are external to the EAS regime, such as changes in the routing strategies of

[1] Constraints are relaxed for communities outside the 'contiguous' United States.

airlines.

Bråthen and Eriksen (2018) suggest a method for assessing the socio-economic profitability of PSO routes in Norway. The technique is grounded in a comparison of the generalized travel costs (GTC) for air travel on a PSO route with the corresponding cost to travel the distance by surface transport or via a nearby alternative airport. If the former costs are higher than the latter, a termination of the route may be considered. In the opposite case, the method proposes that the difference in costs should be at least as high as the corresponding subsidy payment to justify the public funding of the services. In line with Lowell et al. (2011) and Mundy et al. (2015), the method focuses on journeys between the two endpoints of a subsidized route without considering the temporal coordination of services beyond the route. Hence it does not assess accessibility effects on network-wide journeys.

In summary, this review identifies a very limited body of literature dedicated to the assessment of EAS/PSO route contributions to locational accessibility. As airport leakage constitutes proven behavioural pattern of travellers, publications suggest that subsidized air-transport services should be evaluated using an integrated perspective, considering aspects of airport access and air-transport network travel in combination. Literature applying this perspective in the context of global air travel, though, and analysis related to the cost-benefit viability of such routes and across different geographies appears lacking. This paper aims to close this gap and to contribute to policy decision-making by establishing evidence for 264 subsidized air routes in Europe and the United States.

## 3. Methods

### 3.1. Deriving the accessibility contribution of EAS/PSO services

Building on the Generalized Travel Cost Connectivity (GTCC) metric proposed by Mueller and Aravazhi (2020), this paper estimates the degree to which subsidized air services generate locational accessibility. It compares the average generalized travel costs of journeys from an EAS/PSO airport with the costs of a counterfactual scenario in which a subsidized service is terminated. Extended to incorporate potential travel options from nearby alternative airports and mapping the related costs of airport ground access, the GTCC metric for an airport $v$ as applied in this paper takes the following form:

$$GTCC_v = \sum_{\substack{d \in V \\ d \neq v}} \omega_d * \sum_{m=1}^{1008} \varphi_m * \min_{p \in P_v} \left( SD_{p,m} + TCS_p + TCA_p \right) \quad (1)$$

where $V$ is a set of global airports and $P_v$ the set of travel paths connecting an EAS/PSO airport $v \in V$ to a destination airport $d \in V$. $TCA_p$ and $TCS_p$ denote the path-specific costs for air- and surface travel and $SD_{p,m}$ represents schedule delay costs. The method employed in this paper isolates the specific travel path between $v$ and $d$ that minimizes total generalized travel costs for each 10-min interval $m$ of a representative week. The weighting parameters $\varphi_m$ and $\omega_d$ are scaling with respect to travellers' assumed arrival time preferences and the relative destination importance of $d$. Mueller and Aravazhi (2020) outline the metric's parameterization and constraints, with the following details applying:

(1) Set $P_v$ contains all feasible direct and indirect travel paths available to a traveller at $v$ who wants to reach destination $d$. An algorithm is used to create paths by stringing together individual links (i.e. surface transport and flights). A path is considered feasible if it does not violate established constraints on maximum travel time and minimum connection time. This includes multimodal paths in which an alternative nearby departure airport $a \in V$ is used to access the air-transport network and the distance between $v$ and $a$ is covered by car. An airport is considered an alternative access point if (i) air-transport services are provided from this airport, (ii) it is located within a radius of 260 km (Matisziw and Grubesic 2010) of an EAS/PSO airport $v$ and (iii) the necessary road infrastructure exists to facilitate ground movements between $v$ and airport $a$. To manage the computational complexity, a maximum of 10 geographically closest alternative access points per EAS/PSO airport $v$ were considered. No matter the distance, though, an EAS/PSO route's endpoint (i.e. the hub airport) is always classified as an alternative access point.

(2) Set $V$ contains all airports that (i) can be reached by direct flight from at least one airport located in Europe or the United States, (ii) are served at least 10 times per week from Europe or the US, and (iii) are accessible from all EAS/PSO airports considered in this study, given the path-constraints. There are two important implications that are unique to this methodology. First, using a quasi-global network definition allows the assessment of the accessibility contribution of subsidized air services from a network-wide perspective and beyond a route's local network embeddedness. Second, keeping set $V$ constant for different EAS/PSO airports ensures that their results are comparable irrespective of geographical location and topological integration.

(3) Cost term $TCA_p$ denotes a function of air travel specific cost components, such as the path-specific airfare, the monetized value of in-vehicle time and waiting time at transfer airports, and a penalty factor related to possible inconveniences caused by transfers. An airfare model obtained from Mueller and Aravazhi (2020) was used to express path-dependent one-way airfares as a function of block-time, airline type and the competitive situation on the travel path. This model was calibrated to better reflect US airfares (USDOT 2018a), which were found to be systematically underestimated in the original version. Further analysis suggested a smaller aircraft size in the US and, therefore, higher per-seat costs as one potential explanation for this deviation. In-vehicle travel time (*IvT*) was valued in line with the individual national guidelines of the countries each EAS/PSO airport is located in, adjusted for potential changes in per capita income for the year 2018 (WorldBank 2020). The transfer penalty corresponds to 10 min *IvT* for each transfer on a travel path (Ramjerdi et al., 2010).

(4) Cost term $TCS_p$ reflects expenses incurred by travellers accessing nearby alternative departure airports (i.e. *IvT* and vehicle operating costs). Data on overland travel distances and timings were sourced from Google (2020) and valued at country-specific prices.

(5) Schedule delay costs $SD_{p,m}$ reflect travellers' disutility resulting from a mismatch between the preferred and scheduled arrival times. For each minute deviation, a value equal to 0.4 times the country specific *IvT* was applied (Ramjerdi et al., 2010). Integration of $SD_{p,m}$ with $TCS_p$ and $TCA_p$ to form the so-called rooftop models (Douglas et al. 2011) made it possible to estimate the generalized travel costs a traveller bears for a journey between $v$ and $d$, related to a specific arrival time at $d$.

The toy network in Panel A of Fig. 1 exemplifies the GTC calculations at this stage for journeys between an EAS/PSO airport $v$ and a destination airport $d_2$. Flights $A_1$ and $A_2$ denote subsidized services originating at $v$. At airports $d_1$ or $a$, there are connections to commercial services ($A_3$, $A_4$, $A_5$), with the traveller required to access airport $a$ by car ($S$). Assuming that the depicted airports are located in the US, that all flights are provided by non-low-cost carriers and that it takes 60 min to travel the 80-km distance of $S$, the flight schedule information provided (Panel B) can be used to derive four feasible travel paths $p \in P_{v,d2}$. The algorithm sequentially strings together individual links (e.g. $S$ and $A_5$) until the full set of paths is created and their path specific travel-cost components ($TCS_p + TCA_p$) can be calculated. Given these details, flight path

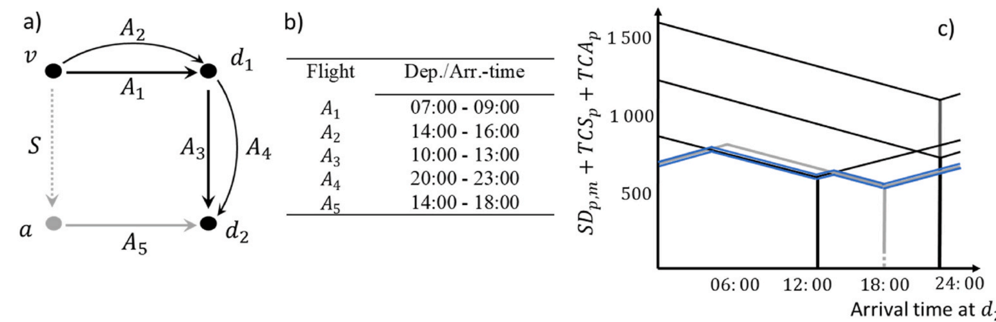


**Fig. 1.** Toy network illustrating the methodology
Note: Panel a) Potential flights between $a$ and $d_1$ or $v$ and $d_2$ not shown to reduce complexity; Panel c) Stylized, based on a 24-h period.

$\{A_1, A_3\}$, for example, costs \$615 ($TCS_{A1,A3} = 0$), whereas travel path $\{S, A_5\}$ costs \$535 ($TCS_{S,A5} =$ \$75 + $TCA_{S,A5} =$ \$480). Mapping these costs with respect to arrival time at $d_2$ as vertical lines in Panel C and adding the costs of schedule delay ($SD_{p,m}$) as sloping components creates the rooftop model. Assuming the traveller to behave in a cost-rational manner, a minimum cost curve (blue line Panel C) can be derived which represents for each arrival time interval the lowest possible costs a traveller can face on journeys between $v$ and $d_2$. This curve is used as a proxy for the locational accessibility of $v$ with respect to $d_2$. The procedure is repeated with respect to all other network destinations.

(6) Assuming that travellers have a preference for arriving at their final destination airport at a specific time of the day, parameter $\varphi_m$ scales each minimum-cost curve with respect to each 10-min interval $m$ of a representative week. Applying the approach presented by Brey and Walker (2011) to empirical data from high-frequency city pairs in Norway, a two-peak formation preference pattern (Koppelman et al. 2008; Brey and Walker 2011) was identified and $\varphi_m$ was estimated. Consequently, periods of high arrival time preference (e.g. mid-morning and early evening) contribute more to the final accessibility-value of an airport than periods of low arrival time preference do (e.g. midnight).

(7) Destination importance weight $\omega_d$ is intended to discriminate for different levels of interaction potential (Hansen 1959) between an airport $v$ and all $d \in V$ (i.e. their hinterlands). That is, the degree to which the costs for travel between $v$ and an individual destination $d$ count in the overall assessment of accessibility-generation at airport $v$ reflects the relative importance of $d$ in regard to all other destination airports. Building on the concept that the 'potential' of a location is a function of its market size and the inverse of the cost to reach the location (Harris 1954), $\omega_d$ was derived. This was based on the economic output within a 75-km radius around the destination airport $d$ (GEcon4.0 2011; WorldBank 2020) and the transportation costs necessary to travel to this airport. This implies that destinations with higher economic output or relatively close proximity to an EAS/PSO airport or both contribute more to an airport's accessibility-generation than lower importance destinations do.

To estimate the accessibility contribution of a subsidized service to an EAS/PSO airport, this methodology was applied to two different network definitions. Establishing the base case first, $GTCC_v$ was derived by using the full path set $P_v$, including any services on a subsidized route from $v$. Simulating the counterfactual of terminating an individual EAS/PSO route, a second run was performed on a path set $P'_v \subseteq P_v$, which did not contain the specific subsidized services at $v$. The difference between the scenarios then reflects the average improvements in GTC for journeys starting at airport $v$ due to the funding of the subsidized service and allows a comparison with the underlying subsidy payments.

### 3.2. Data and summary statistics

The analysis was conducted based on three main sources of data. First, the inventory of active EAS/PSO routes in 2018 and their subsidy payments were sourced from the latest versions of databases maintained by the US Department of Transportation and the European Commission (USDOT 2018b; EC 2019), which were publicly available, and on request from the Norwegian Ministry of Transportation. These records itemized in total data for around 360 observations.

Second, the Distance Matrix of Google (2020) was accessed using Dorman (2020) to identify the set of nearby alternative airports for each EAS/PSO airport and to gain information on travel distance and travel time by car to reach them. An EAS/PSO airport was omitted from further analysis if (i) an enquiry did not yield at least one nearby alternative airport that could be reached by means of surface travel (e.g. the majority of Alaskan airports) and (ii) the individual EAS/PSO route analysed was the only service available from this airport. For such 'lifeline' services, the methodology suggested in this paper cannot be applied, as no feasible counterfactual case can be simulated.

Third, data provided by the SRS-Analyzer Flight Schedule Database (SRS) was used to model the global air-transport network in detail. The last week of September 2018, was selected as the representative week, as it was identified as a non-holiday period, with traffic statistics being close to average for 2018. If no flight activity was recorded for an individual EAS/PSO route in this week (e.g. the majority of Swedish PSO routes) or a route belonged to a disconnected subgraph of the network (e.g. PSO systems in the Shetlands and Northern Portugal) the route was dropped from the analysis, as no accessibility contribution could be derived.

The resulting air-transport network, given the constraints established, includes 1241 destination airports (see Annex A for a graphical illustration), of which 200 were identified as EAS/PSO airports. The network further consists of some 365,000 individual flights, with 6700 of them directly allocable to EAS/PSO operations in 12 different countries. Fig. 2 maps the geographical location of the 264 EAS/PSO routes analysed in this paper and Table 1 provides related summary statistics. With respect to the objective of this paper - the assessment of an EAS/PSO route's accessibility contribution - several heterogeneities in route characteristics should be noted.

First, Fig. 2 highlights the existence of different types of spatial network organizations. While star-like configurations seem to dominate in the US, line- and grid-type layouts exist in some European areas (e.g. Croatia and northern Norway). The former appears to be a direct consequence of the US regulation that subsidized air services have to link to hub airports. Interestingly, though, several US communities link to more distant hub airports than necessary, despite the fact that nearby EAS peers connect to much closer hub alternatives (e.g. Central

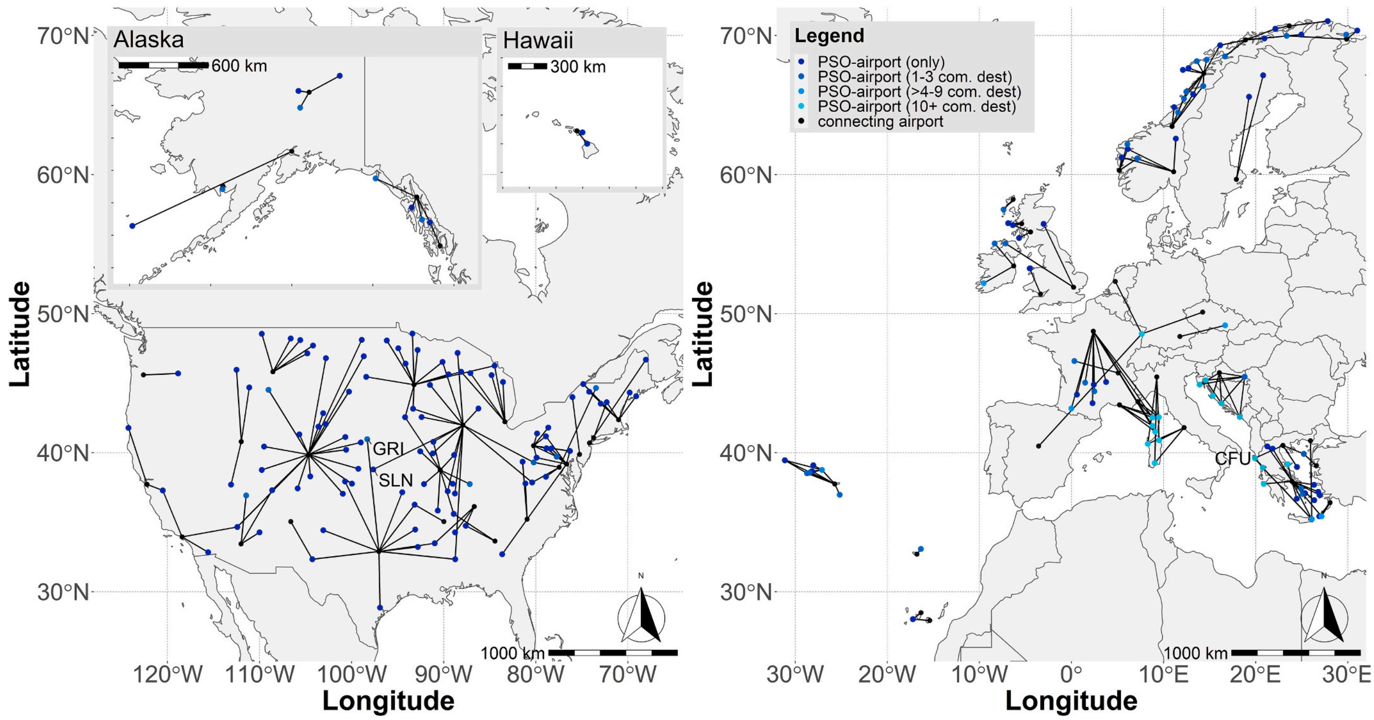


**Fig. 2.** Geographical location of PSO routes and types of airport
Note: An airport is defined as commercial destination (‘com. dest.‘) if it is not the remote endpoint of EAS/PSO route.

**Table 1**
Summary statistics by country.

| Country | PSO airports | City-pairs | Avg. stage length[a] | | Flights per route[c] | | | Per passenger subsidy (US $2018)[d] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | km | STTEq.[b] | median | min. | max. | median | min. | max. |
| Croatia | 6 | 11 | 301 | 4.7 | 3.5 | 1 | 34 | 289 | 28 | 1330 |
| Czech Rep. | 1 | 1 | 370 | 5.7 | 10 | 10 | 10 | 121 | 121 | 121 |
| France | 13 | 23 | 540 | 16.4 | 16 | 3 | 34 | 31 | 7 | 225 |
| Greece | 19 | 23 | 209 | 8.2 | 6 | 2 | 53 | 80 | 22 | 1857 |
| Ireland | 2 | 2 | 242 | 3.5 | 14 | 14 | 14 | 103 | 72 | 134 |
| Italy | 3 | 6 | 475 | 12.6 | 28.5 | 21 | 70 | 19 | 11 | 30 |
| Norway | 24 | 33 | 185 | 5.0 | 12 | 5 | 42 | 83 | 13 | 470 |
| Portugal | 8 | 13 | 180 | 8.0 | 14 | 4 | 49 | 62 | 14 | 344 |
| Spain | 1 | 2 | 140 | 6.0 | 14 | 14 | 14 | 30 | 19 | 41 |
| Sweden | 2 | 2 | 664 | 9.5 | 11 | 11 | 11 | 137 | 137 | 137 |
| UK | 7 | 8 | 285 | 6.1 | 10.5 | 2 | 13 | 179 | 67 | 296 |
| US (AK, HI, PT) | 12 | 13 | 141 | 7.5 | 7 | 2 | 28 | 89 | 4 | 359 |
| US (cont.) | 102 | 127 | 365 | 4.4 | 12 | 3 | 36 | 195 | 11 | 599 |
| Total | 200 | 264 | 330 | 6.9 | 12 | 1 | 70 | 129 | 4 | 1857 |

Note.
[a] Weighted for flight frequency.
[b] Surface Travel Time Equivalents in hours (Google 2020).
[c] One way, week 39/2018 (SRS 2020) - may deviate from minimum requirements specified in EAS/PSO inventories.
[d] Purchasing power parity adjusted.

Nebraska Regional (GRI) and Salina Regional (SLN)).

Fig. 2 also reveals that several EAS/PSO airports offer services to destinations other than the end point of their subsidized services (indicated by shades of blue). This phenomenon is more pronounced in Europe than in the United States. In Northern Europe, for example, operators often choose network layouts that combine multiple PSO routes and occasionally also integrate non-PSO airports into their networks. At Southern European PSO airports, subsidized and commercial operations often coexist, with the latter regularly linking to other domestic and major airports in Central Europe. The Greek PSO airport of Corfu (CFU), for instance, provides services to more than 70 different destinations. Assuming that commercial routes themselves create onward connectivity, a PSO route from such an airport may yield relatively low global accessibility gains, and therefore, may be plausible only with corresponding low subsidy levels.

Further, while in some European countries PSO routes are on average shorter than 200 km (e.g. in Norway and Portugal) subsidized services in the contiguous US typically span distances around 365 km. However, accounting for topographical and regulatory conditions in the different countries, Table 1 suggests that potential travel-time savings by EAS/PSO services as compared to road travel can be substantial even on some relatively short routes. For example, despite the fact that PSO routes in Norway are typically half the length of US routes, the average time to cover the corresponding distances by car is higher in Norway than in the US. This suggests that short-haul EAS/PSO routes may also yield considerable accessibility contributions. The same may account for EAS/

PSO routes that link airports located on islands with destinations on the mainland and where surface transport options imply time-consuming maritime legs (e.g. Italy and France).

Table 1 also displays strong heterogeneities in the number of frequencies offered on different EAS/PSO routes. While routes on average are served around 12 times a week (one-way), individual routes - for example in Croatia and Alaska - have much lower service frequencies, with 1–2 rotations per week. In contrast, a few routes in Italy or Greece are operated up to 10 times a day.

Last, it can be seen that strong variations exist in the routes' per passenger subsidy payments. Adjusted for differences in purchasing power, values range in the extreme from around $4 to more than $1850 per passenger. The cross-country median subsidy per passenger is approximately $129, with the corresponding value for the US being higher and approaching the $200 limit specified in the US regulations. Heterogeneities in route characteristics, such as varying levels of supply and demand, may explain this finding. The wide range of subsidy values suggests that the plausibility of the EAS/PSO routes differs greatly. While many low-subsidy routes need to generate only minor accessibility gains to be considered rational, routes with high-subsidy payments may require accessibility gains in excess of what may be realistically achieved.

## 4. Results

### 4.1. Locational accessibility at EAS/PSO airports

The calculation of the locational accessibility scores for all analysed EAS/PSO airports with the full set of travel paths available (i.e. EAS/PSO, commercial and multimodal options) yields the results summarized by country in Fig. 3. The corresponding route-based values are provided in Annex B.

Fig. 3 indicates a strong heterogeneity in accessibility scores across the EAS/PSO airports. Values range from around US$650 for the British airport of Dundee (DND) to almost $2100 for the isolated Alaskan EAS-community of St. George Island (STG) and the Azorean airport of Flores (FLW). Interpreted in terms of generalized travel costs, these scores indicate that journeys between these latter airports and the average network destination are more than three times as expensive as an average journey from DND. In a cross-country perspective, the mean score is approximately $1115, as represented by the US airport of Del Norte County (CEC).

Substantial variations in accessibility scores also exist within the individual nations. For example, journeys from the least accessible airport in Norway and the contiguous US, Mehamn (MEH) and Glasgow Valley County airport (GGW), are more than 70% more expensive than a typical journey from the best performers in both countries, Roeros (RSS) and Lancaster airport (LNS). This considerable cost-penalty for journeys starting at one of the former airports can be understood as a relative competitive disadvantage for the corresponding regions. It suggests that, even governed by one central authority per country, subsidized air services do not necessarily lead to an equality of accessibility across a jurisdiction.

Further, some airports, such as the Portuguese airport of Flores (FLW) and the French airport of Strasbourg (SXB), appear to lie clearly outside a reasonable national range. Case-specific characteristics explain their outlier positions. According to flight-schedule data, the Azorean airport FLW does not provide any services leaving the archipelago. Instead, journeys to any continental destinations require transfers at one of the other Azorean airports. The temporal coordination between the corresponding flights seems rather weak, driving the costs of waiting for transfers upwards. Strasbourg on the other hand, reports some 1200 weekly commercial departures, which leads to high levels of accessibility. As such, SXB can not be characterized as rural or remote. The corresponding PSO routes seem rather vested in Strasbourg's role as home to the European Parliament.

### 4.2. Accessibility contributions of EAS/PSO routes

Based on a comparison of the accessibility scores with the results of a simulation of the closure of the EAS/PSO routes, the accessibility contribution of an individual service is estimated next. Note that if an EAS/PSO airport is served by multiple EAS/PSO routes, only one EAS/PSO route at a time is omitted from the network in the counterfactual. Further, an EAS/PSO route is always omitted completely in the simulation, including frequencies that an airline may provide in excess of the level specified in the EAS/PSO inventory. Last, no consideration is given to the operational coordination of different EAS/PSO routes. If, for

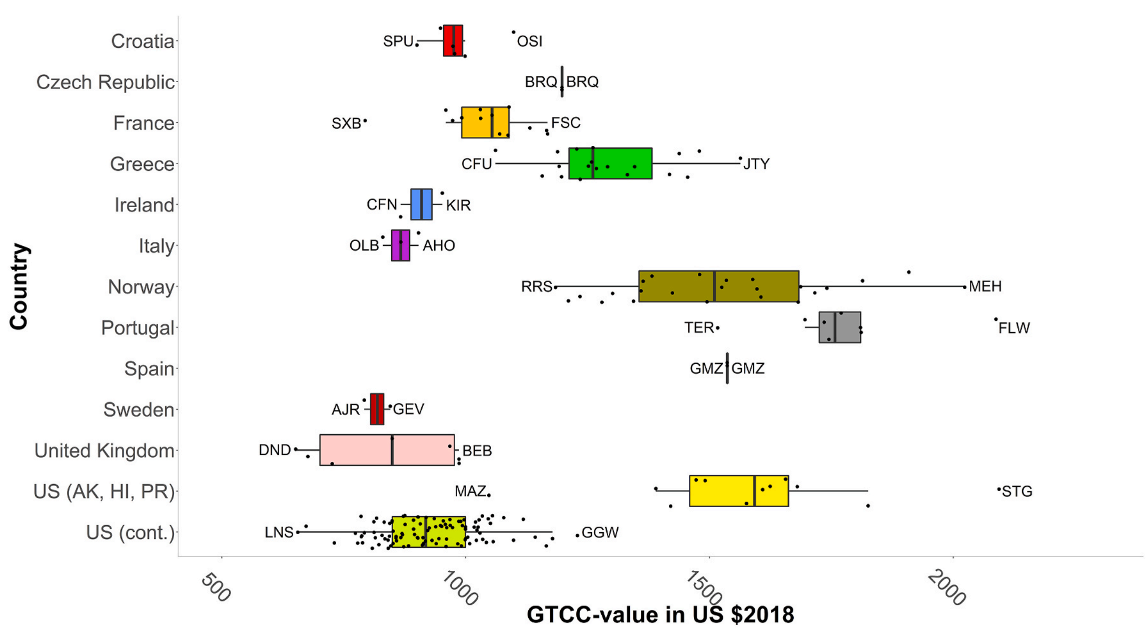


**Fig. 3.** Location accessibility EAS/PSO airports by country
Note: Dots are jittered to increase perceptibility and the vertical distance is random. Minimum and maximum value airports per country are indicated by IATA designations.

example, as in northern Norway, multiple PSO routes are integrated into line-type networks by means of intermediate stops, the simulation omits only frequencies on the first leg. It cannot consider the complexities of frequency changes beyond the first transit airport.

Fig. 4 visualizes the accessibility contribution of the routes in a global network context (see Annex B for numerical values), with darker shades of green representing relatively high and orange indicating marginal accessibility contributions.

Assessed from a cross-country perspective, a mean EAS/PSO route generates savings in generalized travel costs equal to $25 per one-way trip, although route-specific values vary widely. While 46 routes (18% of the sample) appear not to provide any accessibility gains (e.g. Croatia), others reduce travellers' costs substantially (e.g. Scandinavia, Alaska). In fact, the most beneficiary EAS/PSO route in the sample, the Alaskan service St. George – Anchorage (STG–ANC) generates gains in excess of $670 per trip. St. George Island's geographical isolation and the general lack of additional air services from the island explain this high value. At the opposite end of the spectrum, multiple routes in Croatia and the service between DND and London Stansted (STN), for example, do not provide sizeable global-accessibility gains.

For the Croatian airports, on the one hand, such as Rijeke (RJK), the offering of an array of domestic and international direct destinations (e.g. Frankfurt) in addition to the subsidized service (see Fig. 1) may explain this finding.

For DND, on the other hand, detailed analysis reveals that its geographically close proximity to the airport of Edinburgh (EDI), and therefore, the relatively low cost to access EDI, explains the result. The methodology applied in this paper compares potential savings from Edinburgh's higher service levels (e.g. 1250 departures per week, 132 direct destinations, 30 different airlines) with costs incurred for accessing EDI. For the overwhelming majority of destination airports, it was found that the most cost-efficient travel paths starting at DND involve surface-transport legs to EDI. The same phenomenon applies to several other, only marginally contributing routes. The US service between Middle Georgia Regional (MCN) and Baltimore–Washington International (BWI), for instance, is negatively affected by intensive services available at Atlanta International (ATL), which is only 80 min surface travel away from MCN.

Fig. 4 also indicates that multiple US services with relatively short distances to their respective hub airports also do not provide sizable accessibility contribution. As short surface travel distances imply low airport-access costs, these EAS routes are often found not to be competitive in a generalized travel-cost context. Travellers also benefit from being able to avoid potential waiting costs related to transfers at the hub airport. This phenomena exists for many services linking EAS airports to Pittsburgh (PIT) or BWI, for example. In addition, the presence of multiple additional hub airports in close proximity limits the relevance of the corresponding EAS routes further.

It could be claimed that the motivation behind subsidizing individual air services is not to improve accessibility from a global air-transport perspective but to increase national cohesion or to improve the connectivity between only the two endpoints of the EAS/PSO route. In such scenarios, these results may be biased downwards, as travellers' cost savings from EAS/PSO routes may vanish on the way to long-distance destinations. This is because any network constraints beyond the specific EAS/PSO city pair may limit the accessibility contribution of the EAS/PSO route. To cover such scenarios, two separate simulation runs were conducted, in which for every EAS/PSO route the set of destinations $V$ were constrained to the airports located in the same country as the EAS/PSO airport or to the destination airport of the route itself. A service's accessibility contribution was thus considered in a domestic or a purely route-based context. The latter is referred to as 'local' perspective in the remainder of this paper.

A comparison of the global with the domestic accessibility contributions of EAS/PSO routes reveals some interesting patterns. In Fig. 5, a route's contribution in terms of domestic accessibility generation is subtracted from the route's benefits in the global context. Blue colour indicates that global gains are higher than domestic gains and yellow highlights the opposite. Distinct differences by country may be noted. In the US, contributions are rather balanced; global gains only occasionally

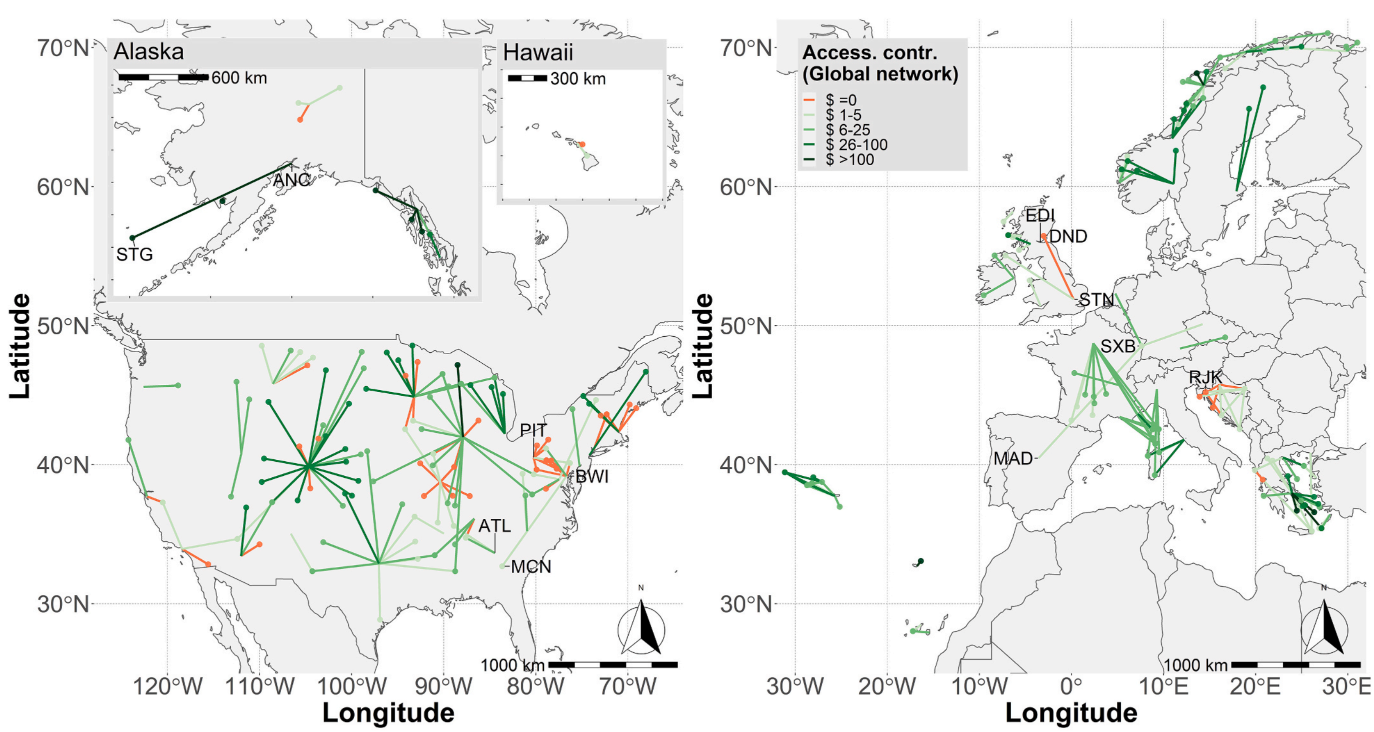


**Fig. 4.** Global accessibility contributions of EAS/PSO routes
Note: GTC savings per traveller one way. Colour scale truncated at $100 to improve graphical representability. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

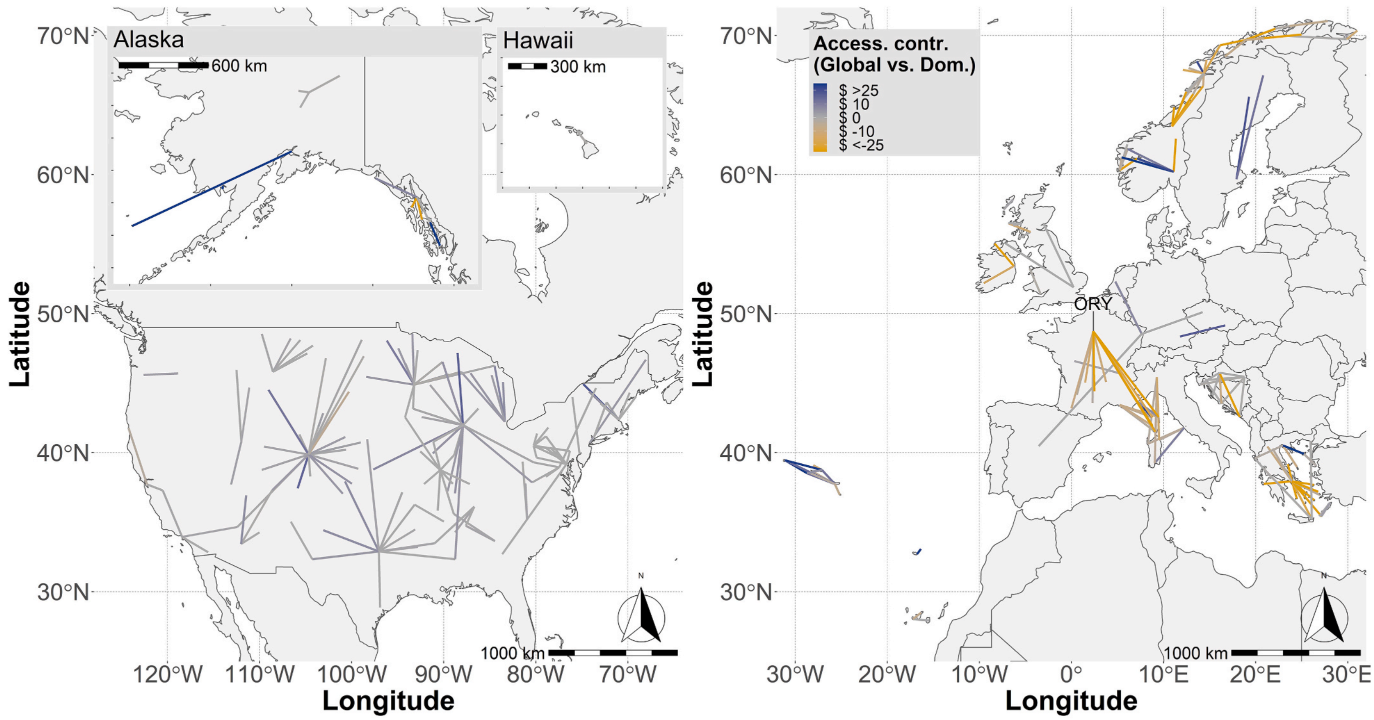


**Fig. 5.** Global vs. domestic accessibility contributions of EAS/PSO routes
Note: Colour scale truncated at $25 to improve graphical representability. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

seem to outweigh domestic contributions.

In contrast, French, Greek and most Norwegian PSO routes generate higher benefits for domestic than for international travellers. In the former two countries, PSO airports are often linked to additional destinations (see Fig. 1), of which many are categorically international. Omitting an individual subsidized service from such an airport, therefore, has smaller global than domestic effects. In contrast, PSO routes in the northern part of Norway typically link to regional airports that are highly integrated into the domestic network but which lack high-frequency international links. The domestic effect of omitting a PSO service in northern Norway is, therefore, more pronounced than its impact on the global-accessibility gains.

The local contribution of an EAS/PSO route is typically found to be higher than its domestic and global gains. This relates to the fact that any network constraints beyond the specific EAS/PSO city pair may limit the accessibility contribution of the route. If, for example, a distant destination airport is only served twice a day, the benefits of having five daily subsidized PSO departures vanish, because only two reasonable travel paths exist in total. Omitting these five subsidized departures from the network causes the loss of only two global paths as compared to five local paths. The exception to this rule relates to EAS/PSO airports that are located in relatively close proximity to their hub destinations but are still sufficiently distant to generate minor local gains. Relatively low access costs by car - no matter the time of the day - limit the local value

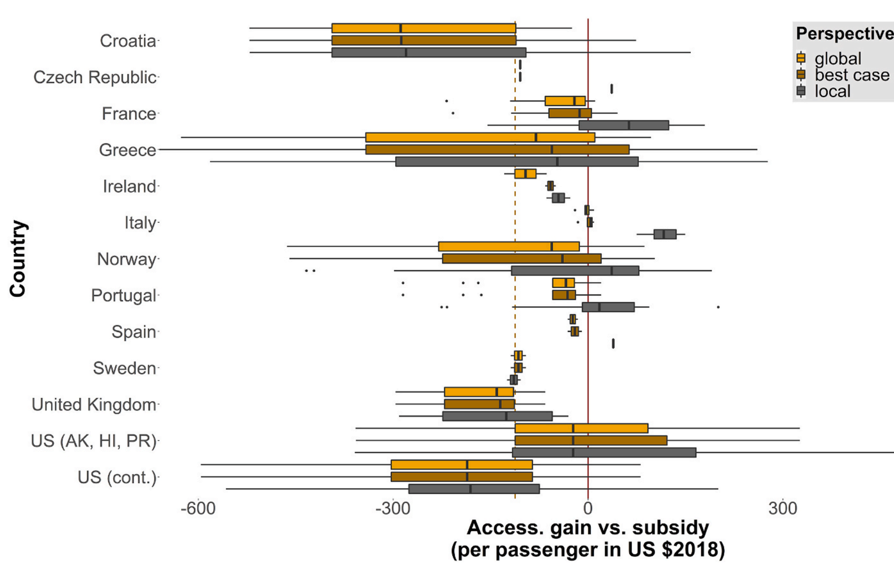


**Fig. 6.** Per capita cost/benefit comparison of EAS/PSO routes by country
Note: Scale truncated {-600,600}.

of a service, as schedule delay is no longer a relevant cost factor. In a long-distance context, however, the determination of a temporally well-coordinated EAS/PSO route may have rather strong cost impacts.

### 4.3. Comparison of accessibility contribution and subsidy level

In this section, the gains in locational accessibility due to subsidized air services are compared with the route-specific, per-passenger subsidy payments to gauge the viability of the routes. For this purpose, the per-passenger subsidy payments for each EAS/PSO route are subtracted from the route-specific accessibility contributions. Fig. 6 summarizes the results by country and Fig. 7 provides a route-specific visualization.

From a global network perspective first (Fig. 6, yellow colour), it may be noted that the vast majority of all analysed routes yield lower benefits than costs. The cross-country median profitability per passenger-value (dashed line) is negative approximately -$112 making the overwhelming majority of EAS/PSO routes analysed unprofitable. In fact, generalized travel-cost savings are higher than subsidy payments for only 38 routes. The heterogeneity in values is substantial, ranging from -$1850 for the Greek route between Sitia (JSH) and Preveza (PKV) and $326 for the Alaskan service STG–ANC. The profitability of the former suffers from the combination of very high subsidy levels, alternative commercial services available at nearby airports and low service frequencies on the PSO route. The extreme remoteness of St. George Island and relatively modest subsidies of $350 per passenger drive the result for the latter route.

Heterogeneities can also be identified in outcomes for EAS/PSO routes in the same country. For example, EAS routes in the contiguous US appear to have lower cost/benefit-ratios on average compared to subsidized services in the non-contiguous US states. This dichotomy reflects the different degrees to which nearby substitute airports are accessible and dissimilar subsidy levels (see Table 1).

As argued earlier, increasing global accessibility may not be the main rationale for each EAS/PSO route; instead the focus is on enhancing regional coherence. To avoid underestimating a route's profitability by deriving it based on global scores alone, Fig. 6 also compares the level of subsidy with a best case accessibility score: a route's global or domestic accessibility contribution, whichever yields higher benefits. In this best-case scenario (brown colour) also, the overwhelming majority of the routes remain non-profitable. Minor adjustments in the distributions of, for example, Norway reflect its high share of PSO routes with a dominance of domestic over global gains.

The corresponding geographical distribution of this best case scenario is shown in Fig. 7. On the one hand, it is noticeable that a few clusters in Alaska, central Norway, the Mediterranean area and the core of the Greek domestic system account for the majority of all profitable routes. A detailed analysis reveals that most of these routes involve rather modest subsidy payments (median $25). Driven by intensive remoteness, many Alaskan routes, on the other hand, generate high enough accessibility gains to compensate for higher costs. In the contiguous US, no clear geographical pattern can be identified. Instead, the distribution of profitable routes appears quite random. Case specifics explain the results. For instance, the EAS-routes connecting Butte (BTM), Cedar City (CDC) and West Yellowstone (WYS) with Salt Lake City (SLC), are homogenous in terms of flight distance, operating airline, flight frequencies and aircraft type. Their relatively low accessibility contributions are also comparable in size ($6–$20), but the required subsidy payments differ dramatically, ranging between $18 (BTM) and $92 (CDC) per passenger.

Last, if travellers are assumed to travel on EAS/PSO routes only to cover the distance between the routes' end points (Fig. 6, grey colour), the benefits of several EAS/PSO routes (e.g. those in Croatia and the US) still do not exceed their costs. Several factors apply, such as the presence of nearby alternative services, short surface-travel times between the end points of an EAS/PSO route and the fact that car travellers are unaffected by constraints set by the flight schedule at the EAS/PSO airport. In contrast, where no fixed links to the destination airport exist (e.g. the island routes of Italy, Portugal, Spain and Sweden) or overall surface travel durations are long (e.g. Norway, Alaska), routes may be profitable under this restrictive assumption.

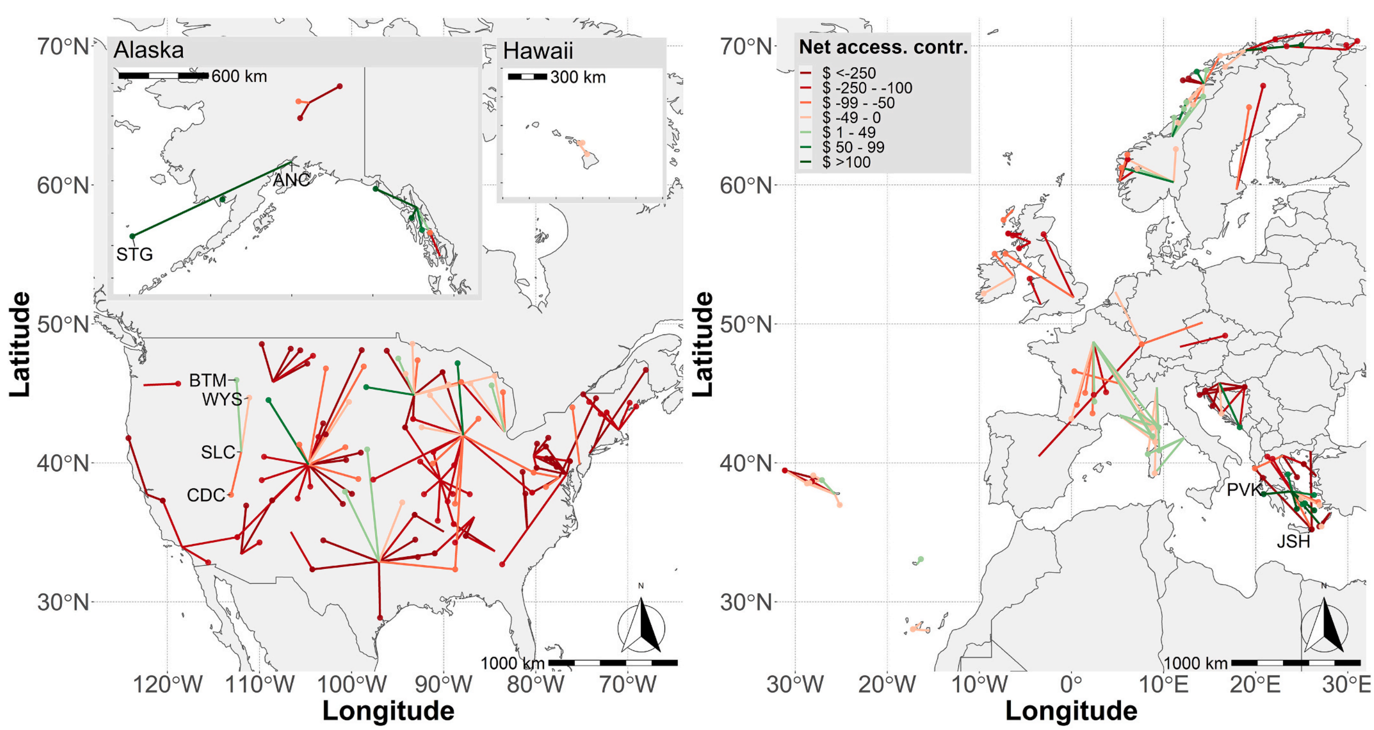


**Fig. 7.** Net accessibility contribution of EAS/PSO routes
Note: Best case accessibility gains minus subsidy payments per traveller.

## 5. Discussion

Given the findings presented above, there are several aspects worthy of further discussion. First, this paper clearly demonstrates that accessibility levels at EAS/PSO airports vary considerably even under a common federal EAS/PSO regime. With regard to a supposed correlation between a region's level of accessibility and its potential to impact the locational decisions of people and businesses, these heterogeneities imply the existence of substantial location-specific advantages of high-accessibility over low-accessibility regions. On the one hand, policymakers concerned with aspects of regional development should be aware of this as a relevant competitive dimension. For policymakers aiming for national coherence, on the other hand, this suggests that EAS/PSO schemes in their existing form achieve only a limited degree of nation-wide equality in accessibility levels.

Second, the results suggest that travel-cost savings due to subsidized air services in many cases are rather limited. Average accessibility gains often amount to less than $100 per journey, which is often inadequate to justify the corresponding subsidy. The unique approach applied in this study, measuring an EAS/PSO route's accessibility contribution on the assumption that travellers also consider other airports as potential network-access points, may have enabled this finding. The policy implications are profound. For instance, consider the EAS-service Middle Georgia Regional-Baltimore (MCN-BWI) for which an accessibility contribution of $1 and a profitability of -$168 was identified. If the fact that travellers have access to and potentially use multiple nearby airports, such as Atlanta Hartsfield, is ignored the value that some 9000 weekly, nearby departures bring to the traveller is omitted. Applying this restrictive assumption under the framework of this paper, the accessibility contribution of MCN-BWI increases to $463 and the benefits now exceed the subsidies by $294, indicating high profitability. That is because in the counterfactual scenario, travellers now can no longer divert to nearby services, which artificially reduces the accessibility at MCN and ultimately exaggerates the significance of the EAS-service.

Third, this paper proposes that the profitability of a route is at its highest if it is assessed from a purely local perspective, but that benefits diminish if a domestic or global perspective is applied. The local scenario inherently assumes, however, that all demand on an EAS/PSO route is strictly limited to journeys between the route's end points. Disregarding a few special purpose EAS/PSO routes, such as Strasbourg–Madrid, this assumption is hardly applicable to the majority of all routes. The divergence between local and global outcomes identified in this study, therefore, highlights that methodologies assessing the viability of subsidized services exclusively on local trade-offs are likely to overestimate the benefits of an EAS/PSO route. The method presented in this paper, therefore, provides a tool for policymakers and planners to make better-informed decisions and to avoid an unintended misallocation of resources for subsidized air services.

On the same grounds, the results provide reasons to critically assess the existing design of a nation's EAS/PSO system and its overall efficiency. As Fig. 7 suggests, many non-profitable EAS/PSO routes are located in relatively close proximity to each other, potentially creating cannibalization effects. While some of them link to the same hub airport (e.g. in north-western US and southern France), others are connected to more distant hub airports than their geographically closest EAS/PSO peers are (e.g. mid-western US) and a third group is highly integrated with each other but does not link to hub airports directly (e.g. in northern Norway). Governmental agencies could use the proposed methodology to optimize their existing EAS/PSO structures in line with their underlying objectives and to assess the effects of corrective initiatives. The consolidation of subsidized air services at fewer airports and the complementary establishment of subsidized surface transport options constitute only one possible scenario. Testing the implications of modified eligibility criteria (e.g. linking to the nearest hub airport) could be another promising application of the method.

Furthermore, this study did not yield evidence of systematic differences in accessibility outcomes and route profitability between routes administered under the EAS scheme and the European PSO regime. This suggests that neither of the two regulatory frameworks produces better cost/benefit ratios or higher accessibility contributions per se. Instead, results appear to be highly dependent on individual route characteristics across all of the geographies that were covered in this study. Given these heterogeneities, this paper applies the same methodological approach to all assessed routes so as to generate transparent, transferable results. The change in travellers' generalized travel costs due to subsidized air-transport is estimated and compared in magnitude to the subsidy payment on the basis of the monetary valuation of travellers' disutility, which is expressed in the correspondent national guidelines. Additional considerations which may be used to promote an EAS/PSO route on a case-by-case basis are intentionally omitted because they are often highly context-dependent. For example, suppose that a route is found to yield no accessibility gains. Therefore, the subsidy that it requires is higher than the GTC savings that it generates. This should motivate funding agencies to assess the extraneous benefits that the route in question offers and to decide whether its existence is justified. An above-average valuation of travel time for politicians (e.g. Strasbourg-Prague) or academics (e.g. Morgantown routes) or a non-monetizable policy objective to sustain remote settlements (e.g. Norway) are two potential factors for such an assessment. However, the identification of the motivational constructs that underlie every route is beyond the scope of this study. The matter lends itself best to discussions between funding bodies and stakeholders. Nevertheless, the results of this paper might facilitate such exchanges by establishing a consistent baseline profitability of each route.

Last, this study suggests that the overwhelming majority of the analysed EAS/PSO routes do not yield accessibility contributions sufficient to cover the corresponding subsidy payments. Accordingly, policymakers may want to critically assess the imperatives behind the need for these routes. It follows to ask which of the services are the most obvious candidates for such a reassessment. Addressing that issue, it must be noted that this paper's methodology measures the value of an EAS/PSO service exclusively based on changes in consumer surplus. This implies that several of these routes may still be justifiable, for example, if they yield benefits additional to the effects identified in this study. The literature, in fact, advocates the existence of such 'wider economic benefits' in the presence of market failure in secondary markets (e.g. Laird and Venables 2017). A negative net contribution of an EAS/PSO service (Annex B) alone may, therefore, not be a sufficient ranking criterion. However, the emergence of wider impacts is generally dependent on a transport initiative yielding consumer surplus change (Laird and Mackie 2018). That is, an EAS/PSO route identified in this paper as only marginally reducing travellers' generalized travel costs will produce minimal wider economic impacts. Based on this logic, apparent candidates for critical reassessment are those EAS/PSO routes that combine high per-passenger subsidy payments with marginal accessibility contributions from both the global, domestic and local perspectives. This includes, for instance, multiple US services linking to the hub airports of Pittsburgh and Baltimore, and several Croatian routes.

## 6. Conclusion

This paper estimates the extent to which 264 EAS/PSO routes in 12 different countries generate accessibility gains for travellers and compares them with corresponding subsidy levels.

The results suggest that accessibility gains at EAS/PSO airports due to subsidized air services vary considerably. While some routes improve locational accessibility to a large extent, others show no or only marginal improvements. The findings further indicate that the majority of all EAS/PSO routes analysed here do not yield generalized cost savings high enough to fully compensate for the route subsidies involved. It must be noted, however, that multiple lifeline services had to be excluded from analysis in this paper (see Section 3.2). As these routes are generally characterized by the absence of access to services from nearby airports, their accessibility contribution and hence profitability may be much higher than suggested by the sample of routes analysed in this paper.

The study has further limitations, as it applies some simplifying assumptions. It relies, for instance, on existing literature for model parametrization in terms of country-specific valuations of travel time. The comparability of the accessibility values in this paper is, therefore, greater between routes of the same jurisdiction than between subsidized services in different countries. Further, travellers are assumed to be fully informed about all air-transport services available within a radius of 260 km around an EAS/PSO airport and as to choose between them purely on a rational cost basis. If these conditions do not hold, an individual traveller's subjective valuation of an EAS/PSO route could be higher than indicated here. However, if travellers regard services at airports beyond the 260 km-boundary as viable options, the accessibility contribution of an EAS/PSO route in this paper may be too high.

Considering these limitations, the accuracy of future accessibility studies would benefit from more research exploring factors that determine the PSO traveller's travel path choices in the presence of competing nearby subsidized and commercial air services. As a result, the size of EAS/PSO airports' catchment areas could be modelled more precisely, and additional preferences not considered in this study (e.g. travellers' loyalty to local EAS/PSO airports) could be incorporated. Research could also explore the extent to which other route attributes (e.g. the motives behind their installation) should be considered and whether their implementation would strengthen the case for subsidized air services.

Future model extensions could also incorporate additional surface-transport modes, such as short- and long-distance coach and train services. Their contribution to locational accessibility may be sizeable for some EAS/PSO communities and may reduce the value of the subsidized air service. As mass transportation options are also often subsidized, their inclusion would enable a more comprehensive assessment of subsidized transport services and their optimization across transport modes.

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## Author statement

Falko Mueller: Conceptualization, Methodology, Software, Formal analysis, Writing.

## Declaration of competing interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tranpol.2021.03.023.

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