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Optimal Location for Conference Venue in Relation to Transport Emission Sustainability Strategy

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Thousands of conferences held all over the world annually are closely related to the theme of environmental sustainability. Various methods and measures have been presented in the effort to reduce environmental impacts. However, the impact of the conference itself receives relatively less attention. This study proposed a mathematical model to identify the optimal conference locations with minimal environmental footprints in travelling to and from the conference by the participants. The historical data of Conference on Process Integration for Energy Saving and Pollution Reduction (PRES) consisting the origin of the participants is applied to demonstrate the location selection. The model is developed to include air transport for short and long distances where the environmental impact is considered in the form of external cost. Participants are geographically distributed into points considering the capital of countries. Socio-economic and geographic data are used to estimate the expected number of participants through a linear regression model. Population, the absolute difference in religion, the distance between countries (with a positive impact on total attendance) and continent conservation (negative impact) were found to be significant. The result suggests the Czech Republic as the optimal location with the external cost of about 242 € / cap. The subsequent locations are Estonia and Romania. Future studies can cover multi-objective decision making, including price and more problematically quantified features as safety, health issues and attractiveness.

1. Introduction

Conferences bring researchers from different geographical areas together at a place for learning the latest research, exchanging the knowledge and provide ample opportunities for networking. Environmental sustainability is one of the most discussed themes or topics in a conference; however, the own environmental footprint of the conference is yet to be responded (Caset et al., 2018). Holden et al. (2017) found that most of the conference organiser did not think about the environmental impacts of their meeting. Jäckle et al. (2019) estimated that the average emissions per attendee of European Consortium for Political Research general conference were between 0.5 - 1.3 t CO_{2eq} / cap. The greenhouse gases (GHG) footprint is significant considering the high share by taking the value of IPCC where a reduction to 2.5 t CO_{2eq} / cap by 2030 and 0.7 t CO_{2eq} / cap by 2050 is required to keep on track with 1.5 °C goal. Neugebauer et al. (2020) addressed scientific conferences as a source of environmental burdens, with 0.57 t CO_{2eq} / cap. However, it should also be noted that, without the conferences, the environmental footprint would not be necessarily considerably lower. More studies are still needed for verification if the business travel is replaced by leisure travel or other activities which are still inducing GHG footprint. The transportation and hotel are still running sometimes with even a higher CO_{2eq} / cap (e.g. when the capacity is not fully utilised). The differences in CO_{2eq} / cap compared to the baseline scenario would provide a better insight rather than referring to the absolute value. There has been an increasing call for sustainable conferencing (Bossdorf et al., 2010). Some of the efforts included the implementation of the

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paperless conference (distributing electronic materials instead of the printed book) and replacement of plastic cups with paper cups, glasses or bottles. Teleconference/virtual conference has also been proposed to minimise the environmental footprint. However, in enhancing the environmental performance, the effectiveness of the meetings through in-person interaction and discussion (networking) should not be compromised entirely. According to the regression analysis by Mair and Thompson (2009), face to face networking opportunities are one of the significant underlying dimensions in attending a conference.

Desiere (2016) stated that the footprints of non-European participants in a European conference are significantly high, accounted for > 50 % of the total emissions, with only 10 % of total participants. This reflects the importance of selecting the conference venue according to the distribution of participants. Identification of an optimised location for conferences can mitigate the environmental footprints, but it is not a straightforward optimisation. It involves the trade-offs between different factors on top of the environmental concern. Jo et al. (2019) assessed the location selection process and attributes for international association meetings where more than 24 crucial attributes are identified. Available studies on location optimisation usually focus on industry processes and waste management. It has not been properly applied to the study of the conference venue.

This study intends to identify an optimal location for conference organising focuses on environmental aspects, by considering the nature (e.g. distribution of participants) of the conference.

The novel contributions of the presented study are

- The consideration of the different type of emissions in defining environmental performance and selecting an optimal location.
- An improved mathematical model to identify the conference venue based on the regression model from the historical records.
- A demonstration by a real case study where the results could provide higher practical value – suggestions for future conference venues with least environmental footprint.

2. Problem description and simplifications

The core of the proposed problem is the environmental impact of transportation to and from conferences of all participants. It strongly depends on the origin of participants and conference venue – selected location. The total participant's environmental impact should be calculated throughout the whole journey from his home, through some inter-connections, to the final destination. In particular, it may be composed of multiple and different modes of transport (tram, bus, train, boat, aircraft). An exemplary route may be given, starting at home, taking the short tram and then underground to the central train station, where a shuttle bus to an international airport is used. After the flight, shuttle buses/taxis are used to get to the city centre, where local public transport is used to get to the hotel (close or directly at the conference venue). This example might be further extended with inter-connection flights and transfers. Each of the means of transport used relates to some energy, which has to be generated. Depending on the mean of transport, the respective emissions are produced and emitted to the environment. Even tram or underground which are powered by electricity have some impact (depends on the source of energy and respective emission production) unless it is based on cleaner energy (wind, water).

The problem is formulated as where to hold a conference to have a minimal environmental impact caused by necessary participants' transportation to and from the venue. In the first step, the problem is simplified, and only air transportation is considered. It is likely that different results can be obtained when the train and other transport modes are taken into account. Each of the historical participants is represented by an international airport situated at the capital city of his state of origin. Direct flights are then assumed to all candidate conference venue locations. A notable simplification is underlying in this assumption, because large countries may benefit from small ones. For example, China, with almost 10,000,000 km^2, and a huge number of large cities, is considered in a single point as also the Czech Republic with less than 80,000 km^2. This means that all participants from one country are represented by only one point. Researchers attending the conference should begin their journey from their university, with the possibility to choose from various available international airports. However, the problem presented here reflects only one centrally selected international airport.

The considered airports corresponding with five past conference participants' country of origin are depicted in Figure 1. Red labelled marks denote the international airport assigned to recent venues. This network of airports and respective distances between them can be used for the calculation of optimal conference location. Historical participation data is required to calculate a suitable location. However, these are only available for venues where the conference has already taken place. In some places, it is a traditional meeting of the academic community and is repeated regularly. Since for many candidate locations, no data of attendance are available; it is necessary to make an estimate for the potential number of participants in each country considered. The origin of participants is key for the calculation of environmental impact. This work focus on the first step of the elaborate assessment approach.

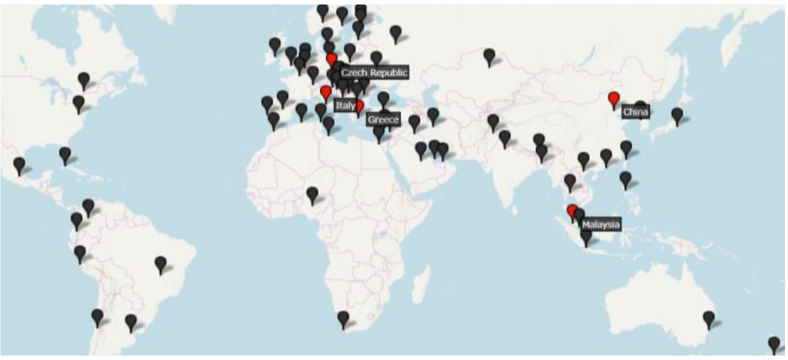

Figure 1: Illustration of the problem and the scope of the proposed approach. Red labels indicate the Czech Republic, Italy, Greece, China and Malaysia, where the previous conferences were located.

3. Mathematical model

Emissions from air transport are a major contributor to GHG production (Amizadeh et al., 2016). One of the parameters that affect specific values is the type of aircraft, but also the age of aircraft and time in service influence fuel consumption and emission. The use of the type of aircraft depends on the distance of the flight and the territorial classification of the transport (internal / external traffic). Depending on travelled distance, the aircraft produces a different amount of emissions. Two options were decided to be included in the model corresponding with the short and long haul. Integer linear programming techniques are used to formulate the model. The notation of the model attributes is described in Table 1.

Table 1: The notation

Type	Symbol	Description
Sets	$i \in I$	Nodes of the network representing participants University origin
	$j \in J$	Nodes defining candidate locations for the conference venue
	$p \in P$	Set of pollutants
Parameters	$n_{i,j}$	Number of participants from node i attending location j
	$d_{i,j}$	Distance from participant's node i to candidate location j
	$e_{i,j,p}$	Pollutant p produced by transport from i to j
	a_p^S, a_p^L	Pollutant production for short and long distances
	t	Threshold dividing short and long-distance
	c_p	Metric for pollutant's p impact
	M	Upper bound – total number of candidate sites j
Variables	$\delta_{i,j}$	Binary variable

It is assumed that emitted pollutants depend on the travelled distance. The shorter the trip is, the higher is the production of emission per kilometre. The pollutants' production is considered as in Eq(1), where the threshold distance t plays the distribution point.

$$e_{i,j,p} = \{a_p^S d_{i,j} \quad if\ d_{i,j} \le t, a_p^L d_{i,j} \quad otherwise, \qquad \forall i \in I, \forall j \in J, \forall p \in P. \tag{1}$$

The model of the described problem is formulated by Eq(2)-Eq(6). The objective function Eq(2) summarises the impact of all considered pollutants produced by the transportation of participants to the conference location. Multiplier 2 stands for the return journey. The equation is normalised by the number of participants attending the respective location so that it is comparable. The crucial part of the objective function is the parameter c_p, which defines the selected criterion for pollutant impact.

$$\sum_{i \in I} \sum_{j \in J} \sum_{p \in P} \frac{c_p e_{i,j,p} n_{i,j} 2\delta_{i,j}}{\sum_{k \in I} n_{k,j}} \tag{2}$$

The constraints take the following form:

$$\sum_{j \in J} \delta_{i,j} = 1 \qquad \forall i \in I, \tag{3}$$

$$\sum_{i \in I} \delta_{i,j} \le M\gamma_j \qquad \forall j \in J, \qquad (4)$$

$$\sum_{j \in J} \gamma_j = 1 \qquad (5)$$

$$\delta_{i,j} \in \{0,1\} \qquad \forall i \in I, \forall j \in J. \qquad (6)$$

Eq(3) ensures that for all candidates, a single location is selected. In Eq(4), the choice of venue locations is activated, while Eq(5) specifies the number of conference venues. Eq(6) states variables as binary. The goal of the presented model is to minimise the environmental impact per participant. The distance $d_{i,j}$ between airports is calculated based on the GPS coordinates and the following Eq(7), which defines the distances on the sphere. Parameter r is the sphere radius and [ψ_i ; λ_i], [ψ_j ; λ_j] are coordinates of the points (airports). The distance calculation is simplified and could be further edited according to real air routes.

$$d_{i,j} = r \cdot arccos(sin\, sin\, \psi_i \;\; sin\, sin\, \psi_j \;\; + cos\, cos\, \psi_i \;\; cos\, cos\, \psi_j \;\; cos\, cos\, (\lambda_j - \lambda_i)\,) \qquad (7)$$

The presented simple model demonstrates the choice possibility of conference venue location from an environmental point of view, where only air transport is considered. Based on obtained results related to the most important parameters, it could be enhanced in order to reflect reality more credibly. Extension options are transfers possibility, new infrastructure (network) corresponding with road and/or rail transportation, and densely designed network of nodes (participants' university / city, country division, multiple airports).

4. Case study – PRES conference

The mathematical model is applied to a real case study to suggest a location for the upcoming PRES conferences. The estimation is based on the participation data of PRES conference (Klemeš et al., 2017), which is having a history for more than 20 y. A total of 72 countries which have attendance history were considered as candidate locations for the venue. The transportation mode in this case study is limited to air transport (plane), where the major airport of the countries' capital is set as the reference point. The considered aviation emissions include CO_2, CH_4, N_2O, NO_X and SO_X, and the emission factors applied are in Table 2. Emission factors are divided with a threshold distance of 463 km, according to LISPASTO (2017) in defining short distance and long-haul flight. Values in Table 2 are normalised per passenger and km. The total external cost has been selected to represent the environmental impacts and as the criterion in the objective function to be minimised. It is calculated according to Eq(9), where c_p is the cost coefficient of the emission type (e.g. CO_2, CH_4, N_2O, SO_2, NO_X) in €/t and value e_p is the emissions amount (e.g. in g or t). Variables e_p and c_p correspond with $e_{i,j,p}$ and c_p in Eq(2). Considered values of environmental prices are in Table 2.

Table 2: Emission factors depending on distance (LIPASTO, 2017) and environmental prices (CE Delft, 2017)

Emission Type	Short Distance (<463 km) [g / (p×km)]	Long Haul [g / (p×km)]	Environmental Price [€ / t]
CO_2	257	113	56.6
CH_4	0.0018	0.00078	175
N_2O	0.0070	0.0031	15,000
NO_X	1.1	0.45	34,700
SO_X	0.084	0.036	24,900

$$T_{externalcost} = \sum_{p \in P} e_p c_p \qquad (9)$$

A linear regression model was used to estimate the number of participants for all candidate locations. The chosen independent variables are gross domestic product, population, the distance between countries (airports), percentage distribution of faith, the absolute difference in religion, the number of tourist per capita and continent conservation. Historical data regarding the number of participants served as the dependent variable. Participants from the organising country were excluded from the regression model. Data of factors were taken from the database of the World Bank Open Data (World Bank Group, 2018). According to the formulated model, only four independent variables were found significant, according to the p-value supporting the null hypothesis. The resulting linear model includes population (P_i), the absolute difference in religion ($R_{i,j}$), the distance between countries ($d_{i,j}$) and continent conservation ($C_{i,j}$), while it describes 45 % of the variability in data. The expected number of participants from country i to candidate location j is estimated, according to Eq(8).

$$n_{i,j} = 1.57788 \cdot 10^{-8} P_i + 4.744224171 R_{i,j} + 0.00077018 d_{i,j} - 6.316886133 C_{i,j} \quad (8)$$

The regression model indicates that the size of the population has a positive effect on the number of participants which was expected. The difference in religion and distance increases the number of participants, which can be interpreted as a location attractiveness for the participants. It was found that participants are less willing to travel outside their continent due to the conference. The model serves for demonstrative purposes, for further and more detailed analysis, it can be refined using new variables (attractivity, interactions, etc.) and adding data from other conferences. The linear model Eq(8) was used to generate input data for the optimization problem.

5. Results and discussion

All stated models and equations were used to calculate the optimal location for the conference venue. The optimal location based on external cost per participant is the Czech Republic (with capital city Prague) with an objective function value of 242 € / cap. An illustrative transportation map is depicted in Figure 2. The map shows the number of participants and total external cost from each continent. These values would be saved in the case of remote presentation where no travelling is needed.

Figure 2: Results of the optimal conference venue location (EC=external cost, PC=number of participants)

The external costs were calculated for locations of past five PRES conferences, see Table 3 for comparison.

Table 3: Comparison of outputs for the past five PRES conference locations

Country	Estimated number of participants	External cost [€ / p]	Total external cost [€]
China	738	354	260,857
Czech Republic	586	242	141,776
Greece	406	262	106,243
Malaysia	760	425	322,875
Italy	384	283	108,583

They were organised in Greece in Crete and Rhodes (2019, 2013), the Czech Republic in Prague (2018, 2016, 2014, 2012), China in Tianjin (2017) and Malaysia in Kuching (2015). The calculation is based on the assigned international airport. The table includes countries, the expected number of participants and calculated external costs (based on the estimated number of participants and emission produced). External costs were calculated in total and also per participant for comparison with the result of the optimisation model (both values are rounded) corresponding with the Czech Republic. If this location is banned, the subsequent optimum location with minimal cost would be Estonia (Romania afterwards). These countries do not have many international long-haul flights and most delegates would fly via Germany, UK, or Paris in reality. When total external costs are assumed in the objective function instead of normalised by the number of participants, the suggested location would be Ukraine with expected 380 participants and external cost equal to 96,686 €. Such a value is caused by the low number of participants expected. The limitation of the regression model is that it underestimates the number of participants from organising countries. A more accurate regression model would lead to different results. The suggestion is to model local and foreign participants separately China could be suggested instead as an optimal location thanks to the high number of locals. Specifying the different modes of transport and the entire transport chain would also increase the credibility of the presented approach. Another model could be developed for participants from the organising country to estimate the total attendance more accurately. Worth discussion is also the choice of flight, which depends on the participant. This is often decided on the basis of the price of air tickets and may lead to a transfer flight preference causing higher impact. The final decision should also consider the maximisation of participants' interactions which are also influenced by the diversity of countries. Such a measure could be done by estimating the number of universities connected to the conference.

6. Conclusion

The presented approach suggested holding the PRES conference in the Czech Republic, which offers the lowest environmental footprints in transporting. The estimated external cost is 242 € / cap. However, the result is limited to air transportation and other assumptions as discussed. A sequential computation can propose an order for the conference venues for several years. The subsequent conferences would be in Estonia and Romania, with 243 € and 253 € / cap. The conference venue is also dependent on contacts of organisers with the local academic community (these could account up to 50 % of attendance) where the list of candidate locations can be restricted. The methods proposed can be used for a general event, while new factors would be included. The model can also be formulated as multi-objective to take into account other essential criteria that play a role in organising a conference. Essential factors to be considered for future study are social factors, attractiveness, price and safety. The multi-criteria in decision-making may incorporate ranking approach. The scope can also be extended by quantifying other environmental impacts such as the average carbon footprint of PRES attendance.

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