Abstract

Sporting mega-events generate substantial carbon footprint where return transportation of event participants and visitors between the source and host countries makes the largest contribution. To enhance environmental sustainability of sporting mega-events, it is paramount to select a host country with the lowest carbon footprint from international transportation without compromising the magnitude of major visitor flows. The Facility Location Problem (FLP) model represents an established tool employed in the business environment to determine the best location for the installation of facilities to provide for existing or envisaged consumer demand. The model has proven its feasibility in a number of economic sectors, but rarely been applied in tourism, and never with sustainability management and planning purposes. This study contributes to knowledge by demonstrating the applicability of the FLP model when planning for sporting mega-events. The model enables selection of a host country with better climate credentials by quantifying the magnitude of international transportation of the event participants alongside the associated carbon footprint. Application of the FLP model to the FIFA World Cups shows that, to facilitate the progress of these mega-events towards sustainability, a decision on a host country should be made after the team qualification round, rather than before, as it currently stands. The model can then identify prospective hosts with the lowest carbon footprint from international transportation.

Keywords: Facility Location Problem; Carbon Footprint; Mega-sporting event; FIFA World Cup; Transportation; Event participants

Highlights

- The Facility Location Problem (FLP) model is used to estimate the carbon footprint from transportation of the participating nations in the FIFA World Cup
- The Football Manager 2016 gaming platform is utilised to predict the participants in the future FIFA World Cups
- Analysis shows that selection of the FIFA World Cup hosts should be made after the participating nations are known
- Direction for future research are outlined

1. Introduction

The growing economic significance of international tourism is well recognised (WTTC, 2015) and so is its rising contribution to environmental problems. The increasing carbon intensity of tourism represents an issue of particular concern given it is responsible for at least 5% of the global greenhouse gas emissions (GHG) (WEF, 2009). The carbon impacts of tourism ought to be reduced, should the industry strive for sustainability in its operations.

According to the United Nations World Tourism Organization (UNWTO, 2014), tourism represents a combination of inter-related activities that can be grouped into three major categories or sectors: transportation, accommodation and activities/entertainment. Sporting events represent an integral element of the entertainment category (Getz, 2008) whose capability to attract substantial numbers of visitors, thus driving development of tourism, has been repeatedly recognised (Sales, 2015). Among sporting events, the men's Football World Cup (also known as the World Cup), administered by the Fédération Internationale de Football Association (FIFA), is the world's largest event in terms of media coverage (Capela, 2006) and the second largest sporting event globally in terms of attendance after the Summer Olympic Games (Herzenberg, 2010). The most recent World Cup 2014 held in Brazil had attracted circa 1.7 million international tourist arrivals which accounts for about 27% of the total number of overseas tourist receipts in the country in 2014 (Brasil, 2015). Effectively, the World Cup generated a 96% increase in the annual tourist numbers in Brazil compared to the baseline year of 2013 (Brasil, 2015). Likewise, the previous World Cup 2010 held in South Africa had brought about a 25% rise in international tourist arrivals (Terra, 2010). This demonstrates the significant magnitude of the global sporting mega-events market and underlines their important role in driving national and international tourism.

While sporting mega-events attract large audiences (Varrel & Kennedy, 2011), they also impose substantial negative impacts (Collins *et al.*, 2009). From the environment viewpoint, the latest World Cup in Brazil generated about 2.7 million tonnes of GHG emissions which is disproportionally high for a short-lived event (FIFA, 2014). For comparison, this is almost the amount of carbon footprint generated by the entire nation of Malta in 2014 (GCP, 2015). In terms of sectoral contribution, the GHG emissions of the World Cup 2014 in Brazil were produced by transportation (83.7%), sporting venues (9.65%), tourist accommodation (5.7%) and various destination-based tourist activities (0.95%) (FIFA, 2014). Within the largest contributing sector, i.e. transportation, most carbon footprint arose from international (60.5%), long-haul domestic (35.2%) and short-haul domestic / local travel (4.3%) (FIFA, 2014). This demonstrates that the transportation element of sporting mega-events represents a key carbon offender whose urgent mitigation is necessary.

Recently, tourist mobility has substantially increased because of improved public access to international flights and enhanced competition among airlines; this has generated enlarged tourist flows and, consequently, contributed to the growth in GHG emissions from tourism (McKinsey & Company, 2010). Given the important role played by sporting mega-events in tourism, it becomes paramount to select a host country based not only on the socio-economic benefits generated by a mega-event for the destination, but also on the environmental considerations, especially those attached to the climate implications of international transportation. This is to meet the postulates of the Davos and Djerba Declarations in which urgent mitigation of the GHG emissions from tourism to maintain sustainable growth of the industry has been called for (UNWTO 2007).

In terms of sustainability of sporting events, Getz (2005) underlines the importance of paying adequate attention to the environmental implications of their staging. In a similar vein, Cornelissen *et al.* (2010) suggest that sporting mega-events should be an object of careful environmental analysis undertaken from various perspectives and at different stages, starting with mega-event organisation/planning and extending beyond its closure, thus accounting for legacies. Despite the necessity to make holistic environmental assessments of sporting mega-events with a view to develop effective mitigation strategies, the environmental concerns have only recently entered the event planning and management agenda (IOC, 2009). For example, in the case of the World Cup, it was not until the 2006 World Cup in Germany that FIFA developed the environmental management vision through an initiative known as the Program Green Goal™ (FIFA, 2007). Despite the efforts made to-date, environmental considerations are not yet fully integrated into sporting mega-event planning and management (Gruneau & Horne, 2016). The most important shortfall is deemed to rest within the process of allocating a host country where decisions are largely driven by the political and economic, rather than environmental, considerations (Gruneau & Horne, 2016). This brings about growing public concern about the environmental implications of sporting mega-events' staging where a disproportionate share of international travel to/from a host country in the event's carbon footprint has attracted particular attention (Tóffano & Jesus, 2013).

This paper proposes to apply an established mathematical model to select a host country for sporting mega events. The advantage of the model is in that it accounts for the reduction in GHG emissions from international transportation, thus identifying a host with the lowest carbon footprint. While the model has proven its scientific rigour in various contexts, there is no evidence of its application in tourism. To demonstrate the applicability of the model, it is employed to analyse the carbon implications of the men's FIFA World Cups. It is believed that the proposed mathematical model could be adopted to support decision-making of event organisers in the allocation of host countries. The focus of the model is on the GHG emissions from international transportation only; the political and economic considerations have been excluded from analysis which is deemed to be a key limitation of this paper. Another limitation is in that this model only takes into consideration the carbon footprint from the participating teams (i.e. football players and accompanying official delegations). The GHG emissions from the event's attendees (i.e. spectators) are excluded from analysis due to data availability..

2. Tourism Events and GHG emissions

Events is a large and diverse sector of the tourism industry (McKercher & Prideaux 2014) consisting of a number of categories, such as sporting and recreational; business and trade; educational and scientific; political; cultural; arts and entertainment; and private events, to mention a few (Filimonau, 2016). The steady growth of events has determined the increasing magnitude of its impacts; in turn, this has accelerated research on the assessment of the environmental performance of events in tourism (Becken, 2013). Various impact assessment methodologies, such as Ecological Footprint analysis (Gössling *et al.*, 2002); Pollution Cost Assessment (Carić, 2010) and Life Cycle Assessment (Filimonau *et al.*, 2014) have been applied to estimate the environmental significant of tourism events. According to Schianetz *et al.* (2007), all these methodological approaches are feasible and yet they have different strengths and weaknesses, depending on the range of application (local or global), characteristics of tourist destinations, purpose and accuracy required in the evaluation. Table 1 outlines the key studies on environmental assessment of tourism events. It shows that while some sporting events have attracted research attention to-date, the scope and the scale of analysis has been limited and fragmented. Most importantly, no research has holistically addressed the topic of environmental performance attributed to football events, especially mega-events organised by FIFA.

(Insert Table 1)

The GHG emissions from transportation have been an issue of primary concern in literature on environmental assessment of tourism events (Collins *et al.* 2007, 2009, 2012). Table 2 reveals the carbon footprint associated with the last four World Cups (men's and women's) and demonstrates that transportation accounts for the largest proportion of the GHG emissions generated by the events assessed.

(Insert Table 2)

The disproportionally large carbon footprint of transportation has been an issue of particular concern not only for tourism events, but also for the entire tourism industry. For example, Peeters *et al*. (2007) show that the climate change impacts generate more than half of the environmental externalities of tourist transportation in Europe. Likewise, Filimonau *et al.* (2013; 2014), demonstrate how transportation choice can affect the carbon performance of various types of holidays. In a similar vein, Becken *et al.* (2003), Kuo & Chen (2009), Kuo *et al.* (2012) and El Hanandeh (2013) conclude that international transportation is a major source of GHG emissions for the most popular categories of tourist holidays. Van Goeverden *et al.* (2015) show that long-distance travel has recently intensified which will generate higher GHG emissions attributed to tourism as a result. Lastly, Pereira *et al*. (2017) demonstrate how the fuel choice in tourist transportation can affect the carbon performance of Brazilian tourism.

The large share of carbon footprint attributed to international transportation to tourism events emphasises the importance of making the “right” choice when deciding on an event host. The “right” choice should not only take into account the economic and societal advantages of event staging, but also its environmental footprint, such as the GHG emissions produced by event participants and its attendees. In this regard, the distance travelled to an event location is a key variable to consider. The carbon footprint will grow when a host country is located further from the participating countries and the countries supplying the majority of event attendees. Hosting decisions can therefore affect significantly the carbon performance of events and should be made with caution. For example, the decision of the International Handball Federation to host a sporting event in the Middle East, instead of traditional Europe, has brought about substantially larger event carbon footprint due to more international travel made by both event participants and tourists (IHF, 2015).

Given that the choice of a host country determines the carbon significance of a particular event reveals the important role played by event organisers, or those in charge of appointing event organisers, in affecting sustainability of events. This can be achieved by selecting a host which is best/centrally positioned to accommodate travel demand from all event participants and attendees, thus reducing the GHG emissions from international transportation (Collins *et al.* 2012). Choosing a remotely located country to host a mega sporting event, for instance, will generate excessive travel and, subsequently, increase the carbon footprint of the event.

Environmental considerations should be an integral part of the decision-making process on the selection of a host for mega sporting events (Collins *et al.* 2007, 2009, 2012). And yet, evidence shows that the main sports governmental bodies tend to primarily consider political and economic issues when appointing a host country while environmental concerns are residual (Coakley, 2009). Concurrently, mega sporting event hosting is prestigious (Ozinsky, 2011); as a result, a number of countries apply as prospective hosts and this expands the number of possible trip combinations. The carbon costs of each event hosting application should be thoroughly evaluated to make a selection which is truly sustainable (Ozinsky, 2011).

3. The Facilities Location Problem (FLP)

Mathematical modelling can aid in selecting the best host for mega sporting events from the environmental perspective. The model designed to solve the Facilities Location Problem (FLP) can be of primary use. Based on a set of candidate places, FLP can help to determine the locations that are best positioned to install the “facilities”, considering various criteria, such as the cost or the distance, in order to serve a set of the "client" or demand points in the best possible way (Farahani *et al.*, 2012). In this sense, the term "facilities" is diverse and may include, for example, schools, factories, distribution centers, ports and hospitals, to mention a few. Likewise, the term "clients" varies and comprises students or patients as well as entire neighbourhoods, cities or countries. FLP is of paramount importance for the economic development of regions as allocating facilities in the most cost-effective manner represents a strategic goal for many public and private organisations (Owen & Daskin, 1998; Ribeiro & Arroyo, 2008).

Due to its value, FLP has attracted significant research attention to-date; it has been substantially developed conceptually and explored through the application of different mathematical models (Ferri *et al.*, 2015). Lopez & Henderson (1989), Ballou (2006), and Bhatnagar *et al.* (2003) indicate that a number of factors may influence the decision to put facilities in a certain location and these can often be conflicting. In order to facilitate understanding of the different types of location problems alongside their solutions, Krarup & Pruzan (1990) divide FLP into a set of different categories. While a comprehensive review of FLP and its applications is beyond the scope of this paper, subsequent analysis outlines the most prominent examples of its empirical use.

Geoffrion & Chaves (1974) pioneered the implementation of FLP in the supply chain network design. In their seminal work, they sought to identify the most cost-effective location of the cargo distribution centers to meet the needs of all stakeholders. The study success prompted other authors to embrace FLP, develop it conceptually and test the feasibility of its use by applying FLP in a number of different contexts, such as Love *et al.* (1988), Stern *et al*. (1995), Pirkul & Jayaraman (1998), Dubke (2006), Jia *et al.* (2007), Ndiave & Alfares (2008), Goetschalckx (2011) and Camara *et al.* (2016).

The application of the FLP models in tourism in general, and in tourism events in particular, has been limited and a comprehensive literature review has identified only a handful of studies published in peer-reviewed sources on this topic (Table 3). No evidence of the FLP use in the context of sustainability management and carbon footprint analysis of mega-events has been found.

(Insert Table 3)

Given the yet limited application of FLP in tourism, and due to the significant potential it holds in terms of resolving various location challenges, the possibility of designing a tool which would employ FLP to aid in selecting the ‘best’ (from the environmental or carbon perspective) host for mega sporting events calls for in-depth investigation. The application of FLP to tourism events can raise awareness of event organisers about the environmental implications of their decisions. This paper develops a FLP-based carbon assessment tool and demonstrates its applicability to appraise the carbon significance of host decisions for the FIFA World Cups. This mega sporting event has been chosen as an example due to its large size and significant media coverage; however, a new proposed tool can be adopted and applied to any other sporting events. Educational, religious and business events can make use of the same tool with the purpose of carbon footprint assessment and its subsequent mitigation.

In the example of this FLP application, the "facility" enables selecting a host for a mega sporting event with the lowest carbon footprint while the "clients" are seen as the bid countries. A distinctive feature of this tool is in the assessment of the carbon impacts from international transportation rather than economic costs as set by traditional FLP. However, when travel distances are reduced, aside from the mitigation of GHG emissions, this may also lead to financial savings (for example, in fuel costs). Hence, although it is not a primary aim of this study, the environmental analysis conducted herewith may complement the economic analysis when properly adopted.

4. Mathematical Modelling for Selecting a Host for a FIFA World Cup

This study applies FLP to determine an "optimal" host for a FIFA World Cup, given a set of candidate countries. The "optimal" choice is the one which brings the maximum possible minimisation of GHG emissions generated as a result of round trip international transportation of football delegations (i.e. football players, coaching staff and country officials) to a host country. Given that this study aims to demonstrate the feasibility of FLP application in the mega sporting event context, its focus is on delegations only although the scope of analysis can be extended to tourists. Subsequent analysis planned as part of this research project will integrate tourist travel into the FLP tool developed.

The development of the mathematical model was underpinned by the following six premises; these were driven by the operational and staging mechanisms of the FIFA World Cups:

(1) As of July 2016, FIFA had 209 members (FIFA, 2016). In theory, all FIFA members can participate and host the World Cup. It is noteworthy that the number of members is higher than the number of internationally recognised countries, the United Nations Organization's members and the members of the International Olympic Committee. Among the FIFA members, there are some overseas territories (for example, the Faroe Islands); some countries that are not recognised by other nations (for instance, Palestine); some administrative regions (for example, Macau) and other countries that are recognised, but not associated, with FIFA, such as Monaco;

(2) Since the 1998 FIFA World Cup in France, the event has 32 participating countries. Aside from a host country which qualifies automatically, there are 31 other countries that are represented by the best teams qualified to the Cup from around the world. Qualification of these countries takes place in all six continental federations affiliated to FIFA (Table 4).

(3) Throughout its history, the World Cup host has only once been represented by two countries: South Korea and Japan in 2002. The next two World Cups whose hosts have already been selected will have only one host country: Russia in 2018 and Qatar in 2022. The possibility of having a shared future World Cup is therefore considered minimal;

(4) FIFA recommends that, in order to be considered as a host, a country should have between 8 and 12 stadiums with the capacity of at least 40,000 seats for regular and 80,000 seats for opening and final games (FIFA, 2011). This automatically excludes the "small" nations from hosting due to the inadequate sporting infrastructure or population size. Qatar, the host of the 2022 World Cup, will be the smallest country by population to ever host the event (Qatar, 2014);

(5) Currently, FIFA allocates 32 vacancies to its continental federations (Table 4) (FIFA, 2016a). The fractioned units are defined in qualifying games where the teams play a two-legged home-and-away series. The winner, decided on an aggregate score,

qualify for the FIFA World Cup. The only inter-confederation play-offs established by FIFA are AFC against CONMEBOL and OFC against CONCACAF. Oceania has a chance of qualifying by playing with the fifth-placed South American team; remembering that Australia joined the AFC in 2006, just to increase the classification possibilities (Reuters, 2015);

(Insert Table 4)

(6) Each of the 32 qualified delegations for a FIFA World Cup is made up by 45 people on average, which implies 1440 participants in total (CBF, 2013).

Based on the above premises, the FLP model has been developed. Here, S represents a set of all candidate countries to host a World Cup; P is a set of FIFA teams (countries) that can participate in a World Cup; G is a set of team groups; in this application, represented by the Continental Federations of FIFA; U_g is a set of teams under each group $g \in G$; Q represents the quantity of "conflict groups" that dispute any shared vacancies among themselves; and Tq are the subsets of P which represent the countries competing for shared vacancies, where $q \in \{1,2,\dots,Q\}$.

The model also considers the following parameters and variables:

- A_g – represents the number of vacancies reserved for each group $g \in G$ which must participate in a World Cup;
- V_q – represents the quantity of vacancies available to each conflict group $q \in \{1,2,\dots,Q\}$;
- C – represents the number of participating countries in a World Cup;
- d_{ps} – indicates the distance (in km) between a participant country $p \in P$ and a host country $s \in S$;
- td – represents the delegation size;
- E_{ps} – represents the amount of GHG emissions (in $kgCO_2e$) between a participating country $p \in P$ and a host country $s \in S$. Based on the emission factors (Factor) from Table 5, this parameter is calculated with the expression: $E_{ps} = d_{ps}\ (Factor\ .td)$;
- x_{ps} – a binary decision variable that receives 1 if a country $p \in P$ is allocated to a host country $s \in S$ and 0, otherwise; and
- y_s – a binary decision variable that receives 1 if a candidate country $s \in S$ is selected to be a host of a World Cup, and 0 otherwise.

Thus, the mathematical model is presented below:

$$Minimize \sum_{p \in P} \sum_{s \in S} E_{ps}\, x_{ps} \tag{1}$$

$Subject\ to$:

$$\sum_{p \in P} \sum_{s \in S} x_{ps} = C - 1 \qquad (2)$$

$$\sum_{s \in S} y_s = 1 \qquad (3)$$

$$\sum_{p \in P} x_{ps} = (C - 1)\, y_s \qquad \forall\, s \in S \qquad (4)$$

$$A_g - 0.5 \leq \sum_{p \in U_g} \sum_{s \in S} x_{ps} \leq A_g + 0.5 \qquad \forall\, g \in G \qquad (5)$$

$$\sum_{p \in T_q} \sum_{s \in S} x_{ps} = V_q \qquad \forall q \in \{1,2,\dots,Q\} \qquad (6)$$

$$x_{ps} = \{0,1\} \qquad \forall\, p \in P, s \in S \qquad (7)$$

$$y_s = \{0,1\} \qquad \forall\, s \in S \qquad (8)$$

The objective function (1) aims to minimise the amount of GHG emissions between the countries classified for a sporting event and the host country. Constraints (2) ensure that the number of selected countries should be equal to $C - 1$ as a host country automatically qualifies. Constraints (3) ensure that only a single host must be selected. Constraints (4) ensure that the countries will only be allocated to the host selected. Constraints (5) guarantee the minimum number of teams that must participate in a World Cup for each group $g \in G$. Constraints (6) guarantee that the quantity of shared vacancies between the conflict groups is respected. Constraints (7) and (8) are associated with the domain of the decision variables.

(Insert Table 5)

In this study, the model (1) – (8) was implemented in C/C++ programming language which was solved by CPLEX 12.6 software (IBM, 2015) on a computer equipped with AMD Phenom™ X4 (1.9 GHz), 4GB of RAM memory and Microsoft Windows 7™ operating system. Next section evaluates the FIFA World Cup scenarios through the application of the above model.

5. Analysis of Scenarios

The applicability of the FLP model is demonstrated through the evaluation of 11 scenarios. Due to space limit, the pictorial description of each scenario is provided in Supplementary materials. Initially, five scenarios were considered to apply and validate the model and compare the results with the FIFA World Cups already held: 1998 in France; 2002 in South Korea and Japan; 2006 in Germany; 2010 in South Africa; and 2014 in Brazil. Once the model had been tested and validated, the two further scenarios were created: Scenario 6 named "Ideal" and Scenario 7 based on the FIFA / Coca-Cola World Ranking (FIFA, 2016).

Scenario 6 sought to select the “best” host for a World Cup i.e. the one with the lowest carbon footprint by following the distribution of vacancies made available by FIFA. The size of a host country’s population was the only restriction considered in this scenario. Throughout the history of the World Cup, the smallest country by population to have ever received the event was Qatar with approximately two million residents; hence, only the countries with populations greater or equal to two million were considered feasible hosts (Mello, 2015). All FIFA members and affiliates were considered as being able to qualify and participate in the event.

Scenario 7 was based on the FIFA / Coca-Cola World Ranking for men's football teams. This ranking has been in place since 1993 and considers the best results demonstrated by each FIFA member/affiliate in the last twelve months. The ranking is updated monthly and considers all official football matches played by each team (FIFA, 2016). It was used in this scenario to assist the choice of teams that would be likely to play in future World Cups as of March 2016. The 31 best placed in the ranking teams, respecting the distribution of positions of FIFA (excluding a host country), and two more countries for each Continental Confederation were considered in this scenario. In both scenarios 6 and 7, only a single country can be chosen as a host as this trend can be observed in previous decisions made by FIFA.

Finally, four extra scenarios were built and evaluated. These were based on a popular video game series, the Football Manager 2016®, created by Sports Interactive in 1992 and distributed by Sega (2015). According to Crawford (2006), this digital gaming platform is one of the most successful football games at all times, particularly because of its "inter-textual" links between the real football and the video gaming industries. According to Bleaney (2014), this game helps the English Premier League clubs to scout and contract talented football players as the software holds a database of more than 80,000 players whose skills are regularly monitored and evaluated by professional football scouts. A distinctive feature of the game is its innovative and precise forecasting algorithm which enables very realistic simulations of future national championships and international tournaments, like a FIFA World Cup (Parking, 2015). The evidence of the Football Manager® use in various professional sports, including football, contexts is growing (Smith, 2016) which underlines its suitability for the use in this study with the aim to predict prospective participants in future World Cups. Therefore, the use of the Football Manager 2016® in the simulation of possible participants is essential as it is arguably more reliable than the FIFA / Coca-Cola World Ranking (FIFA, 2016).

Scenarios 8-11 employed the Football Manager 2016® to simulate the qualification rounds for the five previous World Cups (1998, 2002, 2006, 2010 and 2014) and the future World Cups 2018, 2022, 2026 and 2030. The game was run one hundred times for each of the cup to retrieve an average host candidate and check if the outcome of simulations was consistent with the real choice. For the World Cups whose hosts are already known, all game simulations generated the results that were very close to reality, with an acceptable error margin of 6% and the reliability rate of 90%. This proves the value of the game as a predictor of prospective participants for football mega events. For the 2018 and 2022 World Cups, the host countries already assigned by FIFA were used for analysis. For the 2026 and 2030 World Cups, the candidates who have expressed their interest to host the events were considered: USA, Australia/New Zealand, Canada, Colombia, Kazakhstan, Mexico, Morocco, Algeria, Argentina/Uruguay and Chile (Duffy, 2016; FIFA, 2010; Télam, 2014). The decision on the 2026 FIFA World Cup host will be made in May 2020 while the decision date for the 2030 World Cup host has not been set yet.

To calculate the carbon footprint from international transportation, the capital of each participating/host country was considered as a base point. Consequently, the capital-to-capital flying distances were calculated and assigned the GHG emission factors (Table 5). The selection of capitals as a geographical center of the country is considered a limitation of this study as, to-date, no single capital has ever hosted all FIFA World Cup games. However, capitals often host the gateway airports for mega sporting event participants. In-country transportation is subsequently represented by ground modes whose carbon impact is substantially lower compared to air travel (Filimonau *et al.*, 2014). In total, 21,840 possible combinations of each of the 209 possible locations were collected. To precisely measure the geographical distance travelled, Geographic Information Systems (GIS) were employed. The TransCAD software (Caliper, 2014) was used to obtain the latitudes and longitudes of each capital. This enabled accurate calculation of GHG emissions (parameter E_{ps}).

6. Results and Discussion

Tables 6 and 7 present the outcome of simulations for Scenarios 1-7. The analysis shows that, in general, the current distribution criteria applied to the World Cup vacancies by FIFA appear to be beneficial from the climate change perspective. Indeed, the allocation of approximately 40% of all vacancies to UEFA members (which translates into 13-15 vacancies) contributes to the reduction of GHG emissions if a member of this continental federation is also assigned as a host (Figure 1). Hence, the first three positions of all scenarios are always occupied by European countries. On the other hand, when the only allowed country from OFC (Oceania) takes place in the World Cup (which is normally Australia), the GHG emissions become disproportionally high due to the longer distances travelled. Same holds true for the participants representing AFC (Asia) with an exception of those countries from the Middle East that sit closer to Europe.

(Insert Figure 1)

Quite logically, all scenarios demonstrate that the largest carbon footprint is attributed to the participating teams from Oceania. Given the current distribution of the FIFA vacancies, the decision to assign Australia instead of Germany as a 2006 World Cup host would have brought about a three-fold increase in the event's GHG emissions (i.e. 6.058 tCO_2e versus 2.172 tCO_2e); in contrast, if Switzerland had been chosen, there would have been a small drop in GHG emissions (2.096 tCO_2). This country would have therefore been the "best" host from the climate change perspective.

(Insert Table 6)
(Insert Table 7)

Same statement applies to the African nations. In all scenarios analysed, southern countries of the continent have much higher carbon footprints than the hypothetical World Cup hosts located in central countries of the continent, such as Cameroon, Ivory Coast, Ghana, Nigeria and Togo. Interestingly, the proximity of some North African countries to Europe would have made it feasible from the climate standpoint to organise a World Cup in Algeria in 2014, Tunisia in 2002, or in Morocco in 1998. If these countries hosted the World Cups, the carbon footprints of the events would have been smaller than hosting these in such European countries as Norway, Portugal and England, for example.

In Americas, the World Cups hosted by the members of North America's CONCACAF would have had smaller carbon footprint compared to the hosts from South America's CONMEBOL. The only exception is the countries located close to the equator, such as Colombia, Ecuador and Venezuela. The relative geographical proximity of these countries to Europe and some Asian countries determines smaller amounts of GHG emissions attributed to the World Cups hosted in these locations.

Among the first five scenarios considered, only the 1998 World Cup in France had the "best" host from the climate perspective. The worst scenario from the carbon viewpoint is the 2002 FIFA World Cup in South Korea and Japan. If this event had been hosted by France, the GHG emissions would have been reduced by 53%. The distances travelled highlight this difference well: the 2002 World Cup hosted in France would have had 293.930 kilometres travelled by the delegations of all participating countries which is less than half of the 661.084 kilometres travelled by the delegations to reach Korea and Japan. This shows that if, through the application of the FLP model, the host country had been chosen after the definition of the event's participants, the FIFA World Cups could have been more carbon-efficient.

Scenario 6 ("ideal") requires some explanation. 11 of the 32 countries selected by the model (Table 6) have never qualified for a FIFA World Cup throughout its history which is due to their low rankings: Andorra (201^{st}) Antigua and Barbuda (90^{th}), Bermuda (164^{th}), Jordan (82^{nd}), Lebanon (145^{th}), Libya (107^{th}), Liechtenstein (163^{rd}), Luxembourg (142^{nd}), Palestine (117^{th}), Syria (123^{rd}) and Venezuela (75^{th}). The "best" host from the climate perspective for Scenario 6 would have been France (1.350 tCO_2e and 188.522 km travelled) due to its relative proximity to the qualified countries in Americas and Africa. Given that the model sought to identify the 'ideal' participating and host countries from the carbon standpoint, it did not select those that would traditionally qualify for the World Cup, such as Argentina, Germany, South Korea, Italy, Japan and Mexico. This scenario is therefore least real.

Scenario 7 recommends Belgium as the "best" host from the climate change perspective. The 31 candidates from all International Federations were selected as well as the two consecutives of each Continental Federations, based on the FIFA /Coca-Cola World Ranking (FIFA, 2016). In total, 44 countries were analysed and only those that are presented in Table 6 were considered. The countries considered and not qualified by continental federations were: Australia (AFC); Ghana and Tunisia (CAF); Costa Rica and Mexico (CONCACAF); Argentina, Chile and Uruguay (CONMEBOL); Cook Islands, New Zealand and American Samoa (OFC); and Turkey (UEFA). Due to a large number of European countries, the FLP model proposed a country from this continent as the ‘best’ host (Figure 1). The carbon footprint of this World Cup equates to 1.832 tCO_2e with the total delegation distance travelled of 262.962 km. The results of Scenario 7 are more realistic than Scenario 6 due to its reliance on the official FIFA /Coca-Cola World Ranking. The absence of Mexico and Argentina, the countries that traditionally qualify for the World Cup, is worth noting.

While being most climate-benign, Scenario 6 is far from reality as it involves countries that are unlikely to become participants of future World Cups. This demonstrates that the mathematical model developed in this study should integrate a number of additional criteria as proximity on its own cannot be considered the only viable parameter despite the carbon savings it brings. The FIFA /Coca-Cola World Ranking (FIFA, 2016) can be useful for future simulations and yet they can only demonstrate the existing performance of prospective participants while being incapable to make future predictions. To overcome the restrictions of applying the FIFA /Coca-Cola World Ranking, the predictive capabilities of the Football Manager 2016® were used to identify the future hosts for the 2018, 2022, 2026 and 2030 FIFA World Cups. Table 8 present the outcome of simulations (Scenarios 8-11). Due to space constraints, the countries participating in each of the future World Cups are listed in Supplementary materials.

(Insert Table 8)

For the World Cup 2018, four bids were short-listed and Russia was chosen as a host (FIFA, 2010). The analysis shows that it was the ‘worst’ host decision from the climate perspective as the amount of GHG emissions generated from international travel to Russia exceeds the carbon footprint of other candidates (Table 8, Scenario 8). Another factor that contributes to the high carbon intensity of Russia as a host is its size. This is due to the games taking place in various locations across the country which implies extra GHG emissions due to intra-country travel of delegations.

In contrast, the choice of Qatar for hosting the 2022 World Cup appears correct in climate terms (Scenario 9). Despite the on-going criticism of this selection where, next to political and socio-cultural issues, carbon concerns were raised due to the necessity to cool sports venues in the arid climate (The Guardian, 2015), Qatar represents the second most carbon-benign host among the five candidate countries, after USA. Importantly, and similar to Russia, USA are large in size which suggests further GHG emissions attributed to intra-country travel. This, again, underlines the ‘correctness’ of the Qatar choice from the carbon perspective.

To-date, the 2026 World Cup (Scenario 10) has attracted expressions of interest to host the event from Canada, Mexico, Colombia, Morocco, USA, England, Kazakhstan and New Zealand with Australia (joint bid) (Duffy, 2016; FIFA, 2010; Télam, 2014). The FLP model suggests that, among the willing hosts, England represents the "best" choice in terms of carbon footprint closely followed by Morocco (Table 8). This indicates that when the formal bids are submitted, the selection should be made in favour of these two countries while the choice of Australia and New Zealand as a prospective host should be avoided. Such decision will make the 2026 World Cup more carbon-efficient.

Lastly, the possibility to host the 2030 World Cup (Scenario 11) has so far attracted interest from the following parties: Algeria, Chile, Colombia, England, USA, and two joint bids from Uruguay & Argentina and New Zealand & Australia. Table 8 demonstrates that, again, England has the lowest carbon footprint among the candidate countries and therefore represents the most "climate-benign" host for this event. Algeria ranks second which suggests it can be the most feasible host given that it is a FIFA's policy to never assign the same hosts to two consecutive events. This excludes England if it becomes chosen for the 2026 World Cup, as per above. Again, a joint bid from Australia and New Zealand should be discounted due to the climate considerations.

7. Conclusions

Sustainability of mega sporting events represents an issue of growing concern for tourism and environmental policy-makers, event managers, academics and the general public. The carbon implications of international travel of event participants and attendees attract particular attention due to the disproportionate contribution it makes to global climatic changes. To make mega sporting events more sustainable from the environmental perspective, these should be accurately assessed with a view to develop effective mitigation.

One of the most effective ways to reduce the climate significance of mega sporting events rests within the selection of their hosts. Indeed, remote host location implies larger travel distances for event participants and attendees which, in turn, builds carbon footprint. While the decision-making process on the mega sporting event host allocation is complex and involves consideration of various political and socio-economic issues, it is argued that the environmental concerns should be more closely integrated into this process. This will enhance the environmental sustainability of mega sporting events.

The question of how to allocate the "best" host from the climate perspective is therefore important and yet there are no tools which would assist policy-makers and event managers in making the "right" decision. This study developed a mathematical model to aid in hosting decisions based on the carbon footprint considerations. The model capitalises upon the potential of the Facilities Location Problem (FLP) which is an established concept in the field of economics and logistics studies but has never been employed in tourism. This study demonstrated a new avenue for its application, i.e. to assess the GHG emissions from mega sporting events with their subsequent reduction.

The FIFA World Cup was used to demonstrate the analytical capabilities of the FLP model. Eleven scenarios were evaluated; among these five scenarios looked into the events that already took place and six scenarios considered future World Cups. The modelling results showed the best hosts for these mega sporting events based on the climate considerations. Importantly, the proposed method can be adapted and applied to other tourism events, to assess their carbon significance.

The model suggested that, given the current distribution of the FIFA vacancies for the World Cup's participants, hosting future mega sporting events in Europe, North Africa and/or North America represents the "best" decision from the carbon footprint perspective. Assigning a host from Australia and Oceania would bring about substantial GHG emissions. Same holds true for the prospective hosts from South America. While this is an important finding, the key limitation of this analysis is in that, in reality, the decisions on hosting mega sporting events are traditionally based on a range of political and socio-economic considerations while the environmental issues have been residual. This paper argues that this status quo ought to be changed.

The study can be developed further. As it was primarily aimed at testing the analytical capability of the FLP model and its applicability in tourism, the focus was on the sports delegations of participating countries in the World Football Cups. Future research should be extended towards tourists, accounting for spectators of the mega sporting events, to reveal the "true" magnitude of the carbon footprint attributed to international travel associated with event attendance. It is deemed that such holistic analysis, with the inclusion of the event spectators, could provide a number of new insights into the choice rationale of a World Cup host, due to the carbon assessment of tourist flows. Predicting tourist flows is however more laborious than forecasting participants in the World Cups as, unlike in the case of the Football Manager software employed in this study, no models exist to anticipate tourist figures for mega sporting events. Future work is required in this direction. The different types of tourism events can also be looked into. Music and entertainment events that have been growing in popularity recently (such as the music festivals and concerts) represent an interesting avenue for future application of the developed model. This is because such events are not always fixed to one location but can move around. The model can also be applied in the context of business / Meetings, Incentives, Conferences and Exhibitions (MICE) tourism to identify the most carbon-efficient host location based on the knowledge of prospective event attendees.

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Table 1: Assessment of environmental impacts of tourism events: an overview of key studies.

Study	Object of analysis	Type of tourism event
IOC (2004, 2006)	Olympic Games	Sporting and recreational
Ecomass Programme (2005)	2005 World Championships in Athletics	
Hunter & Shaw (2006)	Apply the ecological footprint for ecotourism tourism scenarios	
Collins *et al.* (2007)	The 2003/04 England Cup	
Collins *et al.* (2009)	The FA Cup and 2004 Wales Rally GB	
Mallen *et al*. (2010)	International multi-sport event.	
Collins *et al.* (2012)	The British stage of the 2007 Tour de France	
FIFA (2014)	2014 FIFA World Cup Brazil	
Sales (2015)	World Surfing Championship, Peniche Stage, Portugal	
Dolf *&* Teehan (2015)	Sports events at the British Columbia University	
Collins & Cooper (2016)	Hay Festival of Literature and Arts (Wales, GB)	
El Hanandeh (2013)	The Hajj festival	Religious

Table 2: The carbon significance of transportation in mega-sporting events.

Mega-sporting event assessed	Transportation GHG emissions (total / %)		Event GHG emissions (total / %)		Source
2006 FIFA Men's World Cup Germany	2,100,000 tCO_2e	77.2%	2,719,594 tCO_2e	100%	Focus (2006); Hochfeld *et al.* (2006)
2010 FIFA Men's World Cup South Africa	2,381,127 tCO_2e	86.4%	2,753,250 tCO_2e	100%	Econ-Poyry (2009)
2011 FIFA Women's World Cup Germany	33,600 tCO_2e	84%	40,000 tCO_2e	100%	OC (2011)
2014 FIFA Men's World Cup Brazil	2,279,784 tCO_2e	83.7%	2,723,756 tCO_2e	100%	FIFA (2014)

Table 3: FLP model and its modifications as applied to tourism events: an overview of existing studies

Source	**Technique employed**	**Object of analysis**	**Type of tourism events studied**
Newsome & Eating (2000)	Only theory	Growth of the North American Football League and search of localities in cities for the installation of the necessary infrastructure	Sports
Florida & Jackson (2010)	Economic Method Location Quotient	Location of musicians and institutions according to the size of North American cities between 1970 and 2004	Music
Torrent-Fontbona *et al.* (2013)	Immobile Location-Allocation (ILA)	The types of sports event a bartender must provide to their customers to watch	Sports
Deichmann (2014)	Gravitational Model	To assess the choice of countries for performances of the U2 music band within its more than 33-year long career	Music

Table 4: Continental Federations of FIFA, the number of members and vacancies to qualify for the World Cup.

Continental Federations of FIFA	Members	Vacancies
Asian Football Confederation (AFC)	46	4.5
Confederation of African Football (CAF)	54	5
Confederation of North, Central American and Caribbean Association Football (CONCACAF)	35	3.5
South American Football Confederation (CONMEBOL)	10	4.5
Oceania Football Confederation (OFC)	11	0.5
Union of European Football Associations (UEFA)	53	13
Host Country	-	1
Total:	**209**	**32**

Table 5: GHG emission factors for various flight distances. Source: Van Goeverden *et al.* (2015).

Emission factor (kg/person km)	**Distance**
0.297 kg CO_2e	< 1.000 km
0.200 kg CO_2e	1.000 - 3.000 km
0.147 kg CO_2e	> 3.000 km

Table 6: Carbon footprint by country for Scenarios 1-7, in ascending order. The hosts are marked in grey.

Position	Scenario 1 1998	Scenario 2 2002	Scenario 3 2006	Scenario 4 2010	Scenario 5 2014	Scenario 6 Ideal	Scenario 7 Ranking
01º	**France**	France	Switzerland	Switzerland	Spain	**France**	**Belgium**
02º	Belgium	Belgium	France	France	France	Belgium	England
03º	Croatia	Spain	Italy	Italy	Belgium	Luxembourg	Switzerland
04º	Netherlands	England	Croatia	Algeria	Algeria	England	Netherlands
05º	Italy	Italy	Netherlands	Spain	Switzerland	Netherlands	Spain
06º	England	Croatia	Czech Republic	Slovenia	Portugal	Andorra	Wales
07º	Austria	Slovenia	England	England	England	Switzerland	Croatia
08º	Germany	Germany	Spain	Netherlands	Netherlands	Wales	Italy
09º	Spain	Ireland	Tunisia	Slovakia	Italy	Spain	Algeria
10º	Tunisia	Tunisia	**Germany**	Portugal	Croatia	Liechtenstein	Austria
11º	Yugoslavia	Denmark	Serbia & Montenegro	Serbia	Germany	Croatia	Germany
12º	Denmark	Portugal	Portugal	Germany	Bosnia and Herzegovina	Angelia	Bosnia and Herzegovina
13º	Scotland	Poland	Poland	Denmark	Greece	Austria	Hungary
14º	Bulgaria	Sweden	Sweden	Greece	Ivory Coast	Tunisia	Portugal
15º	Morocco	Turkey	Ukraine	Nigeria	Nigeria	Slovakia	Romania
16º	Norway	Russia	Ivory Coast	Ivory Coast	Ghana	Denmark	Senegal
17º	Romania	Senegal	Togo	Ghana	Russia	Morocco	Cape Verde
18º	Nigeria	Nigeria	Ghana	Cameroon	Cameroon	Libya	Egypt
19º	Cameroon	Cameroon	Iran	USA	USA	Egypt	Ivory Coast
20º	Iran	Saudi Arabia	Saudi Arabia	Brazil	Iran	Syria	Iran
21º	Saudi Arabia	USA	Angola	**South Africa**	Colombia	Lebanon	Saudi Arabia
22º	USA	Brazil	USA	Honduras	**Brazil**	Jordan	USA
23º	Jamaica	Costa Rica	Trinidad & Tobago	Paraguay	Costa Rica	Palestine	United Arab Emirates
24º	Brazil	South Africa	Brazil	Mexico	Honduras	Iraq	Trinidad & Tobago
25º	Colombia	Ecuador	Costa Rica	Uruguay	Ecuador	Bermuda	Jamaica
26º	South Africa	Mexico	Ecuador	Argentina	Mexico	Canada	Colombia
27º	Mexico	Paraguay	Mexico	Chile	Uruguay	USA	Panama
28º	Paraguay	China	Paraguay	North Korea	Argentina	Antigua & Barbuda	Brazil
29º	Argentina	Uruguay	Argentina	South Korea	Chile	Venezuela	Ecuador
30º	South Korea	Argentina	South Korea	Japan	South Korea	Colombia	Peru
31º	Chile	**South Korea**	Japan	Australia	Japan	Brazil	South Korea
32º	Japan	**Japan**	Australia	New Zealand	Australia	Ecuador	Japan

Table 7: Carbon footprint by country for Scenarios 1-7, in ascending order.

	Scenario 1 1998	**Scenario 2 2002**	**Scenario 3 2006**	**Scenario 4 2010**	**Scenario 5 2014**	**Scenario 6 Ideal**	**Scenario 7 Ranking**
Host Country	France (1º)	South Korea and Japan (31º and 32º)	Germany (10º)	South Africa (21º)	Brazil (22º)	France	Belgium
Carbon Footprint	1.918 tCO_2e	4.388 tCO_2e*	2.172 tCO_2e	3.666 tCO_2e	3.332 tCO_2e	1.35 tCO_2e	1.832 tCO_2e
Total Distance	273.656 km	661.084 km*	310.474 km	554.214 km	500.584 km	188.522 km	262.962 km
Best Host Country	France	France	Switzerland	Switzerland	Spain	France	Belgium
Carbon Footprint	1.918 tCO_2e	2.060 tCO_2e	2.096 tCO_2e	2.482 tCO_2e	2.286 tCO_2e	1.35 tCO_2e	1.832 tCO_2e
Total Distance	273.656 km	293.930 km	300.880 km	360.646 km	332.174 km	188.522 km	262.962 km
Worst Host Country	Japan	Japan	Australia	New Zealand	Australia	Ecuador	Japan
Carbon Footprint	4.494 tCO_2e	4.482 tCO_2e	6.058 tCO_2e	6.060 tCO_2e	6.010 tCO_2e	3.592 tCO_2e	4.448 tCO_2e
Total Distance	678.822 km	675.486km	916.014 km	914.650 km	908.538 km	538.374 km	671.790 km
Carbon Footprint Saved*²	2.576 tCO_2e	94 tCO_2e	3.886 tCO_2e	2.394 tCO_2e	2.678 tCO_2e	2.242 tCO_2e	2.616 tCO_2e
Total Distance Saved*³	405.166 km	14.402 km	605.540 km	360.436 km	407.954 km	349.852 km	408.828 km

* Average of the carbon footprint distances between South Korea and Japan.

*[2] Carbon Footprint avoided as a result of selecting the actual host as opposed to the 'worst' offender in terms of climate credentials.

*[3] Total Distance avoided as a result of selecting the actual host as opposed to the 'worst' offender in terms of climate credentials.

Table 8: Carbon footprint and total distances travelled for future FIFA World Cups hosts based on the Football Manager's simulations and the FLP model (Scenarios 8-11).

Bids that have been submitted or that will be submitted	**Scenario 8 2018**		**Scenario 9 2022**		**Scenario 10 2026**		**Scenario 11 2030**	
	km	tCO_2e	km	tCO_2e	km	tCO_2e	km	tCO_2e
Belgium/Netherlands	313.973	2.180	-	-'	-	-	-	-
England*(2026/2030)	314.605	2.199	-	-	330.519	2.291	305.796	2.149
Russia	377.626	2.617	-	-	-	-	-	-
Spain/Portugal	315.647	2.202	-	-	-	-	-	-
Australia	-	-	914.647	6.050	-	-	-	-
Japan	-	-	682.855	4.522	-	-	-	-
Qatar	-	-	460.492	3.052	-	-	-	-
South Korea	-	-	659.781	4.370	-	-	-	-
USA*(2026/2030)	-	-	454.878	3.019	463.822	3.078	460.497	3.046
Australia/New Zealand*	-	-	-	-	913.871	6.056	910.285	6.033
Canada*	-	-	-	-	452.272	3.001	-	-
Colombia*	-	-	-	-	518.694	3.437	541.064	3.585
Kazakhstan*	-	-	-	-	462.577	3.082	-	-
Mexico*	-	-	-	-	567.687	3.764	-	-
Morocco*	-	-	-	-	339.329	2.382	-	-
Algeria*	-	-	-	-	-	-	306.024	2.168
Argentina/Uruguay*	-	-	-	-	-	-	624.525	4.151
Chile*	-	-	-	-	-	-	648.587	4.302

* Countries that have expressed interest in bidding for the 2026 and 2030 FIFA World Cups (Duffy, 2016; FIFA, 2010; Télam, 2014).

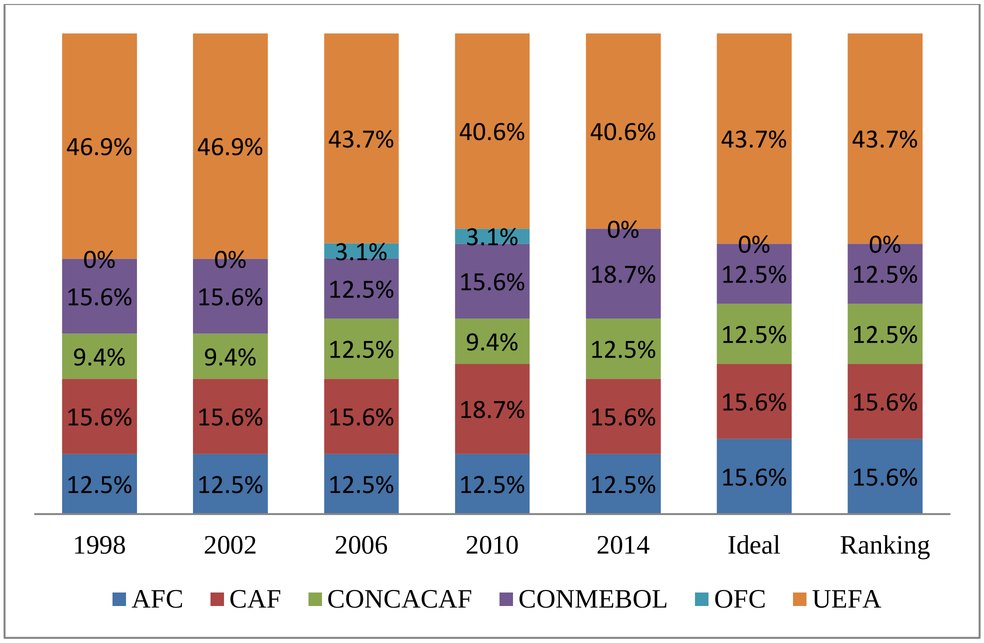

Figure 1: Distribution of FIFA vacancies over the years.