Planning and management of major sporting events: a survey

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Abstract: This paper provides a review of the literature on planning and managing mega sports events with a focus on the FIFA World Cup and the Olympics Games. Much of the literature has considered different sports or planning aspects in isolation, resulting in a large, yet scattered, body of works produced across different research communities. Our objective is to offer a cohesive discussion of this literature by examining salient topics related to operations and infrastructure planning. Of particular interest are studies related to attendance and visitor forecasting, transportation and logistics planning, infrastructure planning and sustainable development, operational planning and scheduling considerations in the context of mega sports events. We conclude this survey by a discussion of directions for future research in this field.

Keywords: event management; sport events; FIFA; Olympics; attendance; forecasting; transport; lodging; game scheduling; infrastructure planning.

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1 Introduction

The notion of sports and recreation dates back to ancient civilisations, be it Ancient Egypt, Mesopotamia, China, the Roman Empire, or Greece. Historical evidence supports the idea that, in such civilisations, various sports such as swimming, wrestling, rowing, and a variety of ball games have been invented and have become popular. Whether for the amusement of a ruler or for the entertainment of the masses, sporting events were held with regularity and offered an awaited opportunity to compete. In the 20th century, at a time of globalisation, many major sporting events that take place at global, regional, or national levels have matured and now receive an international coverage. This includes the Olympics and the FIFA World Cup at a global level, cricket competitions at a regional level, and the World Series or the Super Bowl at a national level. Attendance at each type of event is driven by the popularity and promotion of the sport in regions of the world – for example, cricket is popular in the Commonwealth nations, whereas baseball

is largely USA-centric. The popularity of a sport and the scale of the competition have dictated its evolution and the need to plan infrastructure development to accommodate large-scale operations and to meet the expectations of millions of fans.

The nature and scale of mega sports events have involved over the years numerous sporting organisations, official authorities, and business partners. From an academic point of view, such events have motivated research along multiple facets including sports marketing and branding strategies, infrastructure development, transportation and logistics planning, predictive analytics and forecasting models for particular sports, and operational planning and scheduling. A cursory examination of the literature reveals a wealth of works that are produced in isolation in different research communities. Unifying discussions of the scattered literature around the planning and management of mega sports events remain scarce. A relatively recent exception is found in the review of operations research studies in sports where Wright (2009) provides a partial classification of research in this fertile area. In particular, his survey focuses on the following themes:

1 optimising game tactics and strategies

2 fixture scheduling be it for real-life or theoretical studies and the scheduling of sports officials

3 forecasting studies that devise statistical predictive models for particular games

4 a variety of other OR works that do not belong to a specific theme, ranging from the Duckworth/Lewis method to compute a target score in Cricket game that gets interrupted by weather or other reasons, to the effect of changing the rules or playing conditions of a game.

There is, however, a persistent need for a survey that specifically covers the management and planning of mega sports events with the thematic anchors we have chosen in the present work, namely, attendance forecasting, transportation and logistics planning, sustainable infrastructure development and the economic impact of mega sports, and operational and scheduling considerations.

The remainder of this paper is organised as follows. Section 2 discusses attendance at mega sports events and studies pertaining to forecasting the number of fans and visitors. Section 3 reviews studies conducted to assess the transportation and logistics preparedness of a host country/city. Section 4 examines the impact of mega sports events on infrastructure planning and sustainable development in host nations. Section 5 reviews studies related to scheduling, security, and operational constraints for athletes. This review is concluded in Section 6 with a summary and directions for future research.

2 Attendance and visitor forecasting

Mega-events such as the Olympics and the FIFA World Cup are in general highly attended especially in the more recent years. Taking the World Cup as an example, the attendance statistics for the last six tournaments in the last 20 years is given in Table 1 in reverse chronological order.

This data is indicative of a high average attendance per game, calculated by taking the ratio between of the number of people who attended a game to the maximum capacity of the stadium at which that game was held and then averaging that number for all games

played in a specific event. Similar ratios are calculated for the minimum and maximum attendance percentage in each tournament (the actual attendance stats and stadia capacity were obtained from the FIFA website). For a prospective host city or nation, it is necessary to plan for the maximum attendance scenarios at the game level especially as the event progresses to its more advanced stages and attracts a larger audience. Planning at the macro-level, on the other hand, planners must consider the number of people entering the country and city before, during and after the event to account for infrastructure and system capacities. This is more complex to forecast especially that visitors are likely to attend multiple games and, hence, one cannot simply add attendance historical data to forecast inbound and domestic tourists.

Table 1 World Cup attendance for the last six tournaments

Host	*Year*	*Minimum attendance %*	*Avg. attendance % per game*	*Maximum attendance %*	*Total attendance*
Brazil	2014	90.81	96.73	100.00	3,355,135
South Africa	2010	61.77	87.92	100.00	3,148,756
Germany	2006	85.97	97.11	100.00	3,359,439
Japan/S. Korea	2002	46.76	83.75	98.61	2,705,197
France	1998	81.32	90.76	100.00	2,785,100
USA	1994	68.96	97.58	100.00	3,587,538

Researchers and economists have been interested in forecasting inbound tourist flow in general and the influx of tourists for mega-events in particular. This is an important research endeavour for its direct and indirect association with economic impact as well as its vital role in resource planning and infrastructure investment. Due to their infrequent occurrence, the influence of mega-events on inbound tourists is not straightforward to predict and has not been sufficiently studied. In 1998, the World Cup resulted in a significant increase in tourist arrivals to France in contrast to the 2002 World Cup in Japan and South Korea, which witnessed a decline in tourism (Lee and Taylor, 2005), possibly due to the extended effect of the US terror attacks of September 11, 2001 and the distant location of the host countries from the traditional football countries (Pillay et al., 2009). In contrast, the number of visitors to Germany in 2006 exceeded the expectations where about two million foreign tourists entered the country during the games month and about a total of three millions and half spectators attended the games (Pillay et al., 2009).

The general area of tourist demand forecasting is extensive with a number of original and review articles that have been published over the last three decades such as Martin and Witt (1989), Crouch (1994), Witt and Witt (1995), Li et al. (2005), Lim (1997a, 1997b, 1999), Song and Li (2008), and Chen et al. (2015). We, however, limit our attention in this paper to studies related to sports mega-events. Demand forecasting of inbound and domestic tourists is crucial: Underestimating demand on infrastructure systems such as transportation networks and lodging may lead to bottlenecks that will likely result in congestion and overcrowding, whereas over estimating the demand results in unused capacity and wasted resources that have a negative social and economic impact.

Gratton et al. (2005) emphasised that although the number of pre-registered participants in sport events such as competitors and officials can be known with certainty, it is not easy to accurately predict attendance in general. The authors acknowledged a number of factors that can influence the number of people who actually attend, including event's venue(s), timing, the cost of attending, media reach (local, national and international), and the effectiveness of the ticketing campaigns. Despite its importance in sport event planning, forecasting inbound tourist remains a great challenge that can be manifested in the following questions:

1 How many people will travel to the host country or city for the event?

2 From which countries and regions will people travel and which modes of transportation will they use?

3 How will visitors' arrivals and departures be distributed over time (before, during, and after the event)?

4 How long is the duration of their stay?

5 What standard of lodging will visitors and tourists target?

6 In what type of activities (e.g., dining, site seeing, etc.) will visitors be interested?

7 What is the split percent between domestic tourists and international tourists?

2.1 Forecasting methods for mega-events

Demand forecasting methods can be broadly classified to two main categories, namely, *qualitative* and *quantitative* (Song and Li, 2008). Qualitative methods are typically used when historical data is insufficient or unrepresentative of future trends due, for example, to unprecedented events that will take place in the forecasted period. The most commonly used qualitative technique is the Delphi method which was introduced by Dalkey and Helmer (1963). In this method, input from experts and stakeholders is surveyed via questionnaires pertaining to data of interest. This method has been used by many to forecast the number of inbound and domestic tourists for the purpose of attending an event or being within its vicinity. Examples of such studies include Lee and Kim (1998), and Lee et al. (2008).

Quantitative forecasting methods can be classified as follows:

1 Time series analysis models: This is a widely used approach when historical data is available and bears relevance to planning future events. The most commonly used such models in tourism research employ exponential smoothing and autoregressive integrated moving average (ARIMA) techniques (Lee et al., 2008).

2 Causal or explanatory (regression) models: Such models are used when certain explanatory variables can be identified as potential contributors to change in output variables of interest. In forecasting tourism demand, explanatory factors such as income and location are examples of possible variables that are typically considered in studying the level of tourism demand.

3 Spatial (gravity) models: These models are special cases of regression models that are based on the Newton's gravity equation. This approach in essence forecasts the number of tourists travelling between a pair of countries as a function of several factors pertaining to both countries.

4 Artificial intelligence and machine learning methods such as neural networks.

5 Combination of the previous models: The objective of combining multiple forecasting methods is to enhance the forecast accuracy.

Getz (2008) reviewed the evolution of 'event tourism' and went back in history to 1885 when the International Association of Fairs and Expositions began with a half dozen fairs and to 1928 when the International Association for Exhibition Management was organised as the National Association of Exposition Managers to represent the interests of tradeshow and exposition managers. Academic programs in event management did not start until the 1990s. The author presented a conceptual framework of the core phenomenon and key themes in event tourism studies. With respect to the issue of tourist demand for events, the authors acknowledged that this is notoriously difficult to predict citing several studies like Pyo et al. (1988), Mules and McDonald (1994), Teigland (1996) and Spilling (1998).

Lee and Kim (1998) presented a forecasting model to predict international tourist demand for the 2002 World Cup in South Korea. They combined a time trend regression model and an autoregressive quantitative model with a Delphi qualitative model. The quantitative model was helpful in predicting tourist demand over the long-term (6 years) with high R-squared value and low mean absolute percentage error (MAPE) of 5% which is considered highly accurate. The qualitative Delphi method, on the other hand, was useful for the immediate short-term prediction especially for policy makers and the organising committee to determine the resource levels necessary for the forecasted demand of the event. Their Delphi study consisted of responses from 41 experts over two rounds of questionnaires.

Lee et al. (2005) studied whether empirical evidence supports that hosting a mega sport event stimulates international visitation and enhances the destination image. They focused in their study on the 2002 FIFA World Cup co-hosted by South Korea and Japan and surveyed tourists who visited South Korea at the time of the World Cup and assessed if their image of the country had changed during their visit. They analysed whether tourists who had explicitly travelled to South Korea for the event were different in their responses from those who were not World Cup related tourists. Their results demonstrate that hosting the World Cup was associated with a positive impact on tourist perceptions of South Korea, and emphasised that those who travelled for the World Cup were more satisfied with their experiences and had a greater willingness to recommend South Korea to others.

Wright (2007) explored the complexities of predicting the demand and, subsequently, the difficulty in planning the supply of elite sports event tourism at a local level. The paper focused on the challenges encountered by regional tourism organisations (RTOs) in the build-up towards the 2005 British and Irish Lions Tour of New Zealand. The approach taken was based on interviews conducted with the RTOs to analyse the planning challenges, the local impacts and the long-term implication of hosting elite sport events. The biggest challenge facing the RTOs was the difficulty of estimating the number of international supporters, how long they will stay, the standard of

accommodation they will target and the best manner in which to entertain them. Many regions decided the best way to overcome the uncertainty was to organise smaller second-tier events specifically targeting the local market. Without accurate predictions, many businesses decided to close and avoid the possible extra cost of staying open. During post-event evaluations, it turns out that businesses that 'took the gamble' and opened were 'subsequently rewarded with their busiest trading days ever'.

Martins et al. (2013) addressed the problem of forecasting the number of foreign tourists who would travel to Brazil in 2014 for the World Cup. The authors used a combination of forecasting models with some mathematical adjustments. They specifically combined ARIMA and artificial neural networks (ANN) techniques by the method of minimum variance in which less weight is assigned to methods that showed greater variability in their forecast errors. The analysis was based on the monthly number of foreign tourists who visited Brazil from 2003 to 2009. Furthermore, the analysis of this study was limited to the series of tourists in the World Cups held in 2002 and 2010. A growing number of foreign tourists is expected in the initial period of events like the World Cup. To account for the event, the authors evaluated the increase in the number of foreign tourists in countries located out of the Europe-North America axis where World Cups were held over the past 20 years including South Africa, in 2010, and Japan/South Korea, in 2002. They then observed the forecast error associated with the increase of tourists in the initial period of the tournaments for each location involved with the World Cup. The average error percentage was then attributed to the World Cup. Average percentage forecast errors for foreign tourists in 2002 and 2010 were 11.52%, which was used as a correcting factor for the World Cup event in 2014.

Some researchers used what is known as the spatial (gravity) models to predict the number of tourists travelling between pairs of countries and to identify which predictors are more significant than others. The basic concept is based on Newton's universal gravitation, in which the gravitational force between two objects is directly promotional to their masses and inversely proportional to the squared distance between them. The idea was adapted for trade and tourism and was developed in the '60s and '70s using the same formula of $F_{ij} = gm_1m_2 / d_{ij}^2$ where F_{ij} represents in this case the trade flow between two countries i and j; m_i and m_j are their economic sizes; d_{ij} is the distance between them; and g is a constant. This relation means that trade flows between two countries are proportional to the scale of their economies and inversely affected by the distance between them (Keum, 2010). Since then, the model has gone through several iterations of development by several researchers to predict the amount of trade, and then the number of international tourists as a form of trade commodity, and to also identify the significant predictors.

Keum (2010) applied the gravity model to understand whether countries develop more active international tourism and trade transactions with adjacent countries or with larger economies, and whether the tourism flows are more related to countries with similar income. The paper specifically applied the model to South Korea and its 28 major trading partners worldwide from 1990 to 2002. The author concluded that economic size and distance are significant predictors in determining the number of inbound tourists where tourism flows would take place more where the income or economic size of the origin and destination countries is larger and the distance between the two partners is closer. No mega-events were explicitly considered in this paper.

In their paper, Fourie and Santana-Gallego (2011) researched the question of whether mega-events significantly influence inbound tourist flows, and if so, whether the event type matters or not. Furthermore, they tested the legacy effect of mega-events and whether the effect of the events lasts for subsequent years. They also tested whether more tourists will arrive from game participating countries compared to non-participating countries. The authors extended previously published gravity models to answer those questions. Their model predicted the number of tourists from an origin country to a destination as a function of bilateral trade-in-goods, GDPs per capita, populations, distance, relative cost of living between both countries, whether a pair of countries has common language, common border, common currency or has had a colonial relationship. They also included variables that capture mega-events effects as well as the fixed effects of origin, destination and year. Their regression results based on the 1995 to 2006 data from the United Nations World Tourism Organization (UNWTO) implied that hosting a mega-sport event would increase tourist arrivals by 8.1%. They found several factors to be significantly important including trade, GPD, distance, relative price level, sharing a common language, a common land border, a common currency and colonial ties. Six mega-events were tested and the results indicated that hosting the Summer Olympics, FIFA World Cup, Cricket World Cup, or Lions Tour had a positive impact on inbound tourists while hosting the Winter Olympic or Rugby World Cup had a negative impact, which means 'tourist displacement' may take place in such events. To test for the impact of mega-events on tourism legacies, they coded three years before and three years after the event to find out that there are significant gains during the same year that the event is held and in the years leading up to the event. Finally, they also found out that more tourists will originate from countries participating in the games.

3 Transportation and logistics

Transportation networks, logistics planning, and traffic management are critical elements that contribute to the success of a large-scale event such as Olympic Games, Asian Games, and World Cups among others. In fact, Zyryanov (2012) considered transport systems as the most important among 35 basic functional areas during a mega-event since almost all other functional areas depend on it. Transport systems should ensure the smooth flow of thousands (possibly, millions in the Olympic Games) of visitors, fans, workers, volunteers, and official representatives through host cities. It is particularly important to manage traffic in a fashion that controls and curtails congestion as much as possible. International sport federations such as FIFA require an efficient, reliable, punctual, and safe transport system in host countries.

Mega-events provide the opportunity for host countries to develop their transport infrastructure, enhance their logistic systems and improve their public transport system. As a result, mega-events can participate in the sustainable development and the economic growth of host cities and countries. In this section, we provide an overview of studies concerned with transport planning, traffic management and logistical issues for sport large-scale events. First, we investigate the impact of mega-events on the transport infrastructure for a variety of events. Then, we explore the different approaches used in the transport planning and traffic management (e.g., simulation or information technology-based approaches).

3.1 Transport infrastructure development

Governments argue for hosting mega-events that various investments in the countries' transport infrastructure such as roads, bridges, rail networks, airport development, taxi recapitalisation, and road improvements serve as a catalyst for socio-economic development for years after the event.

Before hosting the World Cup in 2010, South Africa's existing transport infrastructure was relatively poor and of limited capacity. Schoeman (2009) studied the impact of hosting the event on the transport infrastructure development in South Africa as mandated by FIFA requirements. The paper described the legislative and policy framework developed by the government for transport planning and infrastructure development. The policies are mainly described in the national transport policy and the 'Moving South Africa' project documents, which incorporate the vision for the transport system in South Africa in 2020. The paper emphasised the role of big sport events hosted by the country such as the Rugby World Cup in 1995, the Cricket World Cup in 2003, and the FIFA World Cup in 2010 on the sustainable development of transport infrastructure and subsequently on the country's economic growth.

Xiaoming et al. (2008) described the new transport and urban infrastructure investments to host the 2008 Olympic Games held in Beijing. Beijing expedited the construction of new facilities to manage the high travel demand during the event. It also invested in the construction of rail transit, road networks by building new roads and highways principally around the venues. The transport planning during this large-scale event was centred on the subway system. Therefore, Beijing invested in building new subway lines. The number of lines increased to 8 with 42 km of additional lines. The operational lines were extended to reach 190.64 km throughout the city (Jiang, 2008). New connection hubs between the different lines enhanced the subway system performance. The Olympic Games provided an opportunity for the host city to have a strong and efficient transport infrastructure. The author further stated that the construction efforts conducted during 8 years before the event were equivalent to those conducted through 32 years.

Similarly, Lee et al. (2003) examined the transport infrastructure development in the city of Seoul for the 2002 FIFA World Cup in Korea and Japan. The subway system also played an important role in the traffic management and transportation policies adopted for the event. The infrastructure development was centred on building new subway lines and new roads (13.4 km) around the host stadium in Seoul in order to increase the capacity. Sher et al. (2007) proposed building park-and-ride facilities to encourage the public transport utilisation in the city of Johannesburg during the South Africa 2010 World Cup event. Such facilities are public transport stations where people can safely park their personal cars and use public transports such as buses or the metro system. Using simulation, the paper concluded that ensuring a smooth traffic during the event required building nine park-and-ride facilities throughout Johannesburg. Likewise, Frantzeskakis and Frantzeskakis (2006) analysed the transportation planning for the 2008 Olympic Games in Athens for which new infrastructure was built to enhance the transport system performance and traffic capacity. Hence, Athens proposal for the event included several projects such as a new international airport, metro station improvements, and a new freeway connecting the airport with the city centre totalling 700 million euros in cost.

3.2 Transport planning and traffic management

Beyond infrastructure development, several studies considered traffic management and the transportation planning for large-scale sport events. Most of the related literature analyses transportation and traffic management issues simultaneously due to the strong relationship between them. In fact, the development of an efficient traffic management policy during a big event needs a coordination of the transport system for visitors and their lodging plan (Soojin et al., 2003). Many studies used simulation tools for traffic management. Sher et al. (2007) considered the traffic management and transportation planning in the city of Johannesburg, South Africa for the 2010 World Cup. It was estimated that the transport system in Johannesburg should ensure the mobility of 95,000 spectators to the soccer city stadium during a game day as well as 100,000 non-ticket holders around the city. Thus, the main challenge was to manage the traffic especially in peak periods such as the afternoon. To alleviate this problem, the use of public transport was encouraged. However, the Johannesburg city was characterised by an underutilised and underdeveloped public transport with several problems in the rail and road network before the event. The paper described the design of a high level model for which the spatial data collection was performed by the geographic information system software ArGis. The *EMME*2 simulator was then used for traffic simulation with only several origin and destination regions. With this, the key research question addressed in this paper was simplified and focused on determining the optimum number of park-and-ride facilities in order to ensure a smooth traffic flow with the least amount of congestion. In order to successfully apply the proposed traffic management policy, the paper emphasised the importance of a big advertising campaign to urge people to park-and-ride during the event.

Frantzeskakis and Frantzeskakis (2006) also used traffic simulation for the 2008 Olympic Games in the congested metropolitan area of Athens in which car congestion and parking problems were growing rapidly. Athens was expected to develop a transportation plan that can manage the traffic for 11,099 athletes participating in 301 events through 35 athletic venues with 3,581,080 ticket holders, 21,000 accredited representatives of media, 11,000 employees and 45,000 volunteers. The transportation plan was successfully employed without any major traffic problems during the event. Several important aspects were systematically used with this plan: First, EMME2 simulation software was used for traffic movements taking into consideration the new infrastructures and peak periods during the games. Second, movement demand estimates of spectators, members of Olympics Committees, workforce, sponsors and VIPs were also a crucial aspect of planning the transport model. Third, the simulation of the Olympic family movements (e.g., officials, media representatives, spectators, etc.) in the city and around the Olympic venues was effectuated via SATURN software. The authors considered different simulated scenarios under different conditions during the games. The utilisation of the public transport was encouraged and the city in some cases enforced some measures to urge people not to drive their private cars. This included special express bus lines, new fixed rail system, extensions of metro lines, parking control zones around venues, zones of controlled entrance and traffic, and periodic prohibition of private cars based on odd-even license plate numbers.

Other host cities used intelligent systems and technology to control the traffic congestion during large-scale events. For example, Willenbrock et al. (2007) investigated the traffic management system in Hanover (Germany), which successfully organised

several large-scale events such as Expo 2000 and the World Cup in 2006. The public transport, traffic management and parking guidance strategies in the city were highly appreciated by both officials and visitors. The paper points out the role of the unification of all transport decision-makers in one centralised traffic management centre. The authors also emphasise the importance of public-private partnership through a traffic management project based on GPS/GSM base floating car data technology capable of efficiently collecting mobile data about the traffic conditions in addition to classical fixed detectors. This approach has less impact on the environment through saving 40% of fuel consumption and considerably reducing CO_2 emission.

Guangzhou city of China hosted the 2010 Asian Games; the largest Asian sport event with more than 100 thousands people involved. As it was expected to experience congestion and transportation problems during the games due to the lack of available spaces for new infrastructures, the city adopted an intelligent transportation system (Xiong et al., 2010). The successful implementation of the intelligent system was based on several measures such as smart parking facilities and bus transit rapid lines, enhancing the quality and the capacity of bus services and taxi systems, GPS-based information system and an intelligent traffic management system called parallel traffic management system (PtMs). PtMs uses artificial transportation systems for modelling, computational experiments for traffic analysis, and parallel execution for traffic management.

Travel demand forecasting is an important input to planning a transport system especially for large-scale events. Several papers analysed the travel demand for sports events such as the Olympics and World Cups. Dosunmu (2012) investigated the transportation system of London's 2012 Olympic Games in which quick, reliable and smooth movement of a great number of spectators, Olympic family members, athletes, accredited media and officials were necessary. The author described the different models and tools required to develop a successful Olympic transport plan. This work is concentrated on the different aspects of travel demand forecasting methods and models with data derived from previous Olympic events, a wide range of surveys carried out in the UK and other sources such as hotel accommodation databases, Olympic tickets ballots, and information about ticket holders. Many factors can affect the forecasting process such as the trips that would be made by game family and spectators, ticketing strategies, political and economic climates among others. The public transport demand forecasting is crucial to develop a successful transport plan. The adopted strategy before the game was encouraging spectators and workforce to use the public transport, walking, and cycling. The estimation of number of spectators moving around the venues was carried out through a two stage modelling strategy: producing origin-destination matrices of workforce and spectators trips, followed by identifying route and service choices. The estimation process used the tickets data to generate a ticket choice model (TCM), the distribution model to predict different trip origins during the game and the Mode Choice Model (MCM) to illustrate the transport mode used. In addition, other models were used in the travel forecasting process such as venue movement model (VMM). The operational transport modelling around the venues was performed using VISSIM software. The game family demand was forecasted via a gravity model using several key variables such as capacity at each venue, type and time of event, popularity of events, number of trips per day, and venue type (competition vs. non-competition). The paper concludes by emphasising that the forecasting and transport planning tools should efficiently react toward daily changes of information, conditions and assumptions.

Yan et al. (2009) also explored the travel demand during the 2008 Beijing Olympic Games taking into consideration the combined daily travel demand of residents as well as of visitors. The authors divided the travel demand into two models: Base model and game model. In the first model, they used the ordinary travel demand of Beijing residents, while in the second they considered the travel demand during the game time. The base model includes three sub models: activity model, destination choice model and mode choice model. The activity model is useful for calculating trip generation according to the population travel behaviour and the activity chain data. The trips distribution can be identified through the destination choice model while the mode choice model views the transport mode shared by the population. With respect to the Olympic game model, the authors presented the spectators forecasting process and they implemented their model using the activity-chain-based analysis methodology to describe the spectators' distribution. They noticed that the road traffic volumes decreased and the public transport share increased. The main contribution of this paper is an activity chain-based analysis of the travel demand characteristics during a successful mega sport event such as Beijing 2008 Olympic Games.

Public transport is a vital key to a successful traffic management of a large-scale event. Jiang (2008) analysed the Beijing subway transport system used in the 2008 Olympic Games. In spite of the added pressure on traffic, Beijing's transport subway system was robust to manage this flow where 68.13 million passengers were transported without much disturbance to traffic. The paper described the passengers flow spatial and temporal characteristics in operating lines during the event. The flow was analysed during the weekdays and holidays in the city centre and Olympic venues as well as during peak days such as opening and closing ceremonies. The author concluded that the geographical distribution of venues and subway stations affect the flow during the event. Also, preparing emergency plans, limiting the passengers' entrance to the stations, and avoiding the ticket checkout procedures when passenger leave the stations are important measures.

Ceder and Perera (2014) investigated the public transit connectivity optimisation issue during large-scale events. Two cases of studies were considered: London and Auckland city hosting the 2012 Olympic Games and Rugby World Cup, respectively. The paper proposed the use of maximum flow algorithm to detect weak segments and bottleneck locations in a public transit network in order to improve its connectivity and find solutions for the identified congested locations. Since London and Auckland transport systems are mainly based on public transit, the paper compared the proposed framework when applied to the public transit network in both cities. The network analysis can also make the transport preparatory activities more efficient (e.g., deciding on new infrastructures to be build, deciding capacities, making a transport policy). A weak public transit network can be improved by increasing the capacity of the detected bottleneck (e.g., vehicle sizes, seating capacity, and stations capacities), changing routes, and urging passengers to modify their routes and travel times. One should notice that based on this study there is a clear lack of available data, which affects the quality of the public transit network model. In other words, the logistics operation planning for large-scale sport events issue has received little attention.

Minis et al. (2006a) investigated the design of logistic operations during the Athens 2004 Olympic Games. The paper describes a methodology to design the logistical organisations based on previous events experiences such as those in Sydney and Atlanta

Olympic Games with Olympic and host country specific characteristics such as the transient nature, size, demand diversity and uncertainty. The paper proposes to apply logistic management process approaches such as just in time (JIT) and direct-to-site. The paper also establishes some recommendations taking into consideration the logistics operation of previous games with country and location characteristics apriori. For that purpose, data about the host country should be collected and the planning process should start as early as possible. Some approaches such as the outsourcing of logistics operation can be applied if necessary.

4 Infrastructure planning and sustainable development

Infrastructure development constitutes an important motivation for cities and countries to bid on hosting mega-events. The preparedness for major sporting events is usually accompanied by major public expenditures and private investments. Such investments aim at building or modernising important infrastructures that are necessary to ensure a successful event and to convey a positive image of the host country or city. Such infrastructure include sporting facilities such as stadia, training grounds, athletic compounds, and infrastructures related to water and energy systems, air and ground transport networks, and IT and communication systems. However, the economic viability of such events, the return on investment, and the magnitude of their tangible benefits to a host country remain questionable. Many authors argue that short-term economic impacts may be limited, but long-term improvements in urban development may constitute a worthwhile objective. The debate will continue, however, on the need to alternatively invest in other important infrastructures (e.g., healthcare and educational systems), and virulent social opposition to holding such events frequently manifests itself, as in the case of the Brazil 2014 FIFA World Cup. Infrastructure planning constitutes a promising field of research that has received limited attention. In the remainder of this section, we discuss the literature related to urban planning, economic benefits, and sustainable development in the context of mega sports events.

4.1 Infrastructure legacy and urban development

Throughout the literature, many investigated the impact of major sporting events on urban infrastructure development of host regions. Host countries typically spend significant amounts of funds on building and renovating sport and service infrastructure. For example, and according to FIFA's website, the overall cost of the preparation program for the 2018 World Cup in Russia will total to about $20.9 billion, and according to many reports and news outlets, Qatar has committed up to $200 billion in preparation for the 2022 World Cup.

Preuss (2007) studied the legacy that mega-events leave in general. Due to the complexity of defining such a term and the subjective perspectives that host cities have on the topic, this paper is an attempt to quantify such a concept. Legacies are divided into commonly recognised or direct legacies such as sport infrastructure, indirect legacies such as enhanced international reputation, and negative legacies such as high costs. The paper describes different approaches to measuring legacy of a mega-event such as top-down approach and bottom-up approach. The paper also makes a distinction between short-term economic impacts and the lasting legacy of mega-events.

Hosting the Olympic Games or the World Cup, which are considered the biggest sport events around the world, is an opportunity to build or renovate sport facilities and boost the urban development of the host regions in order to change the city's image and status as well as to attract investments. In this regard, Chalkley and Essex (1999) studied the impact of the different Olympic Games competitions starting from 1896 on urban development and infrastructure. When Germany hosted the 1932 games, it built a new stadium with a capacity of 100,000 seats, a swimming pool and other sport facilities. In addition to sport facilities, the legacy also included a new large assembly for large demonstrations, open-air theatre and a large administration building for the house of German sport. The Olympic Games held in Melbourne in 1956 also left great sport infrastructure legacy including a cricket ground, and Olympic park complex with various sport venues such as soccer, hockey, athletics and so forth. Rome city which organised the 1960 games used the event to improve its urban infrastructure such as sport facilities, a new water supply system, a new airport, and an improved public transport infrastructure. Tokyo 1964 games spent around US $2.7 billion for a significant improvement to the host city infrastructure such as renovating existing sport facilities, constructing new roads and highway network and improving the supply water system and public health facilities. Many more similar examples were presented by the authors to include Montreal 1970, Munich 1972, Moscow 1980, Los Angeles 1984, Seoul 1988, Barcelona 1992 and Atlanta 1996.

The influence of the Olympic Games as a mega-event on urban development of the host regions was modest relative to the more recent years. The tipping point had been marked by the Barcelona games in 1992, when the event became a catalyst in boosting urban development in host regions (Qu and Spaans, 2009). Barcelona was among the most successful host city models to bring major changes to the city's sport infrastructure (e.g., 15 new venues, and redevelopment of the main stadium in the city) with strong cultural and tourism infrastructure legacy. Since then, Barcelona became a world-class destination to attract conference organisers with over 68,148 participants to conferences (Preuss, 2007).

In an effort to emphasise the changing role of mega-events on urban development and infrastructure, Essex and Chalkley (1998) classified the Olympic Games into three categories: First, games that failed to boost the urban development and to provide a significant infrastructure by relying on existing sport facilities and infrastructure in order to minimise the total expenditure. Second, games that provided new sport facilities to the host cities with some development effort; however, these host cities failed to stage a very successful mega-event due to the lack of the necessary urban infrastructure such as transport infrastructure. Third is the category of games with successful host cities experiences (e.g., Rome 1960, Tokyo 1964 and Barcelona 1992) where the infrastructure development went well beyond sport facilities provision to include new road systems, public transport initiatives, urban renewal programs, tourist and cultural facilities among others.

The FIFA World Cup is also a mega-event that requires large investments in sport facilities and infrastructure. For example, Germany in 2006 invested in sport infrastructure by building and renovating 12 stadia in different host cities nearly 1.6 billion euros for construction and additional, and about 1.6 billion euros for the related infrastructure in the cities (Feddersen et al., 2009). Russia and Qatar are investing

significantly higher amounts for the 2018 and 2022 tournaments respectively, as was mentioned earlier.

4.2 Economic impact

The short and long-term economic benefits for hosting mega-events have recently been debated by many receiving much attention in the literature. Cities that bid on hosting sport events argue that the economic benefits would outweigh the costs especially on the long run. Many, however, counter argue that hosting such events is extremely costly and it is unrealistic to assume that deep economic investment will be ever recouped. There seems to be a consensus, nonetheless, that there are long-term benefits for host cities in terms of infrastructure legacy that can translate to economic benefits in the years following the events.

Szymanski (2002) discussed the accuracy and reliability of economic impact forecasts of hosting mega-events such as FIFA's World Cups. The author makes the argument that most forecasts are overly optimistic about the economic impact of mega-events. For example, the Dentsu institute in Japan forecasted that the 2002 World Cup hosted by Korea and Japan would generate around $11 billion for the Japanese economy and a long-term boost of $26 billion. This is equivalent to 0.6% increase in GDP, a considerable increase given that the Japanese economic growth had averaged only 1.1% per year over the decade prior the games. Similarly, the Korea Development Institute (KDI) produced even more optimistic economic forecast impact of $8.2 billion representing an increase of 2.2% in GDP, which is very significant compared to an average 5.6% over the previous decade. The paper introduced the concept of multiplier economic effect to predict economic effects from initial injections considering the direct and indirect trickle down effects caused by economic stimuli. For the 2002 World Cup, the author considered the consumption demand of foreign visitors in calculating economic impact using the multiplier resulting a much lower GDP increase of 0.2% and 1.2% for Japan and Korea, respectively. The paper also tested statistically if the 20 largest economies that hosted at least one mega-event over the last 30 years had more growth but found no evidence to support that.

Owen (2005) investigated the economic impact of the Olympic Games on the host cities' economic growth. The paper analysed Atlanta's 1996 Summer Olympic Games, Salt Lake's 2002 winter Olympic Games and Sydney's 2000 summer games. The paper refutes, via thorough analysis, any evidence for positive impacts from hosting these events. Furthermore, the author predicted the same non-significant economic effects for Beijing's 2008 Olympic Games from revenue, tourism, and legacy effects perspectives.

Maennig and Du Plessis (2007) did an ex post study of the costs and benefits of the 2006 World Cup in Germany and carried out a comparative analysis with the case of South Africa 2010 world cup. In Germany's case, the investment created infrastructure for which there is a demand, and the projects are economically sustainable. In South Africa, the situation is less justified as private financing is hardly available due to the weaker financial position of the local soccer clubs. However, the paper also argues that the 'feel-good' and public image effects of sports events should be included in cost-benefit studies of large sporting events as they can be very significant but difficult to estimate ex ante.

Allmers and Maennig (2009) also studied the economic impact of hosting the FIFA World Cup on host countries. Specifically, the paper attempts to predict the economic benefits for South Africa in 2010 in comparison to developed host countries such as Germany in 2006 and France in 1998 with the caveat that South Africa is a poor developing country with poor infrastructure. Before the competition, the economic benefits were estimated by $2.5 billion, 159,000 annual jobs, $845.8 million of governmental taxes and 480,000 tourist visitors. The economic benefits were analysed for France and Germany in terms of overnight stays, national income and retail sales. Using regression analysis, there was no significant enhancement of the overnight stays in France and Germany during the World Cup period, nor did the national income increase greatly. These results agree with previous studies that the World Cup has no noticeable effect on the tourism sector but may have a significant impact in terms of infrastructure and urban legacy. This paper too pointed out that other unmeasurable effects such as 'feel good effect', self-marketing and image building should be considered more than the economic benefits.

In the same way, Bohlmann and Van Heerden (2008) also examined the economic impact of hosting the 2010 World Cup on South Africa. The paper established a computable general equilibrium (CGE) comparative economic model to measure the economic impact of the event by simulating several scenarios representing the estimated effects of infrastructure construction, transport and new hotels on the overall economy. From a short-term perspective, the impacts were insignificant and unidentifiable. Nevertheless, the authors emphasised that a successful event can be considered as a catalyst that brings foreign investments and increased domestic activity. Organising a mega-event requires massive planning, correct investment decisions, and legacy planning to avoid financial waste and failures. The authors recommended that host countries should invest in infrastructure such as building and upgrading stadia as a key factor to the success of the event.

Li et al. (2013) assessed the economic impact of the Beijing Olympics via CGE modelling under imperfect competitive markets. Their CGE used actual economic data to estimate how an economy might react to changes in policy, technology and other external factors. The proposed approach follows three steps in estimating economic effects of an event: first is to estimate the money injected in the host economy (i.e., the injected money is the increased tourism expenditure). Second is to build the CGE model and third is to shock the model with the new estimated money. The findings suggest that hosting the Olympics brings economic benefits but the scale of the impact is not significant compared to the total size of the economy (the larger the economy, the less the impact). The welfare impacts of the Beijing Olympics under imperfect competition are shown to be higher than when perfect competition is assumed.

Du Plessis and Maennig (2011) focused on the short-term impact of the 2010 World Cup in South Africa. They estimated the number of international visitors by studying airplanes landings and hotel occupancy daily and monthly rates in the three major cities. Their forecast was much less than estimates that were publicly available, which means that the tourism economic impact on the short-term would be less optimistic. Among the reasons for this lower forecast are the international recession, crowding-out of normal tourists, and high flight and lodging prices. The authors also pointed out the importance of the 'feel-good' effect and its long-term effect on attracting visitors.

4.3 Infrastructure planning and sustainability development

Mega-events effectively contribute to urban and infrastructure development of host cities. However, since large-scale infrastructure projects take long time to develop with a significant amount of time and funds, it is necessary to have in place a sustainable urban development plan for the host cities. Qu and Spaans (2009) explored the case of Barcelona's 1992 Olympic Games and defined the concepts of mega-event strategy and the strategic spatial planning. The strategy outlines how a mega-event can be used as an engine of urban development and how host cities should effectively plan infrastructure projects in accordance with the social, economic and environmental objectives for the long-term. To explain, the strategic spatial planning should be used as a tool to re-imagine and promote the host cities and manage the strategic infrastructure investments over several years in a sustainable and effective ways. Due to the competitiveness with other European countries and the crisis that faced Barcelona in 1980, strategic projects were planned not only to have a successful event, but to also revitalise the city and achieve detailed socio-economic and spatial environmental objectives. The evaluation of the event shows a positive outcome and boosted economy through various urban projects such as an enlarged airport, new roads and highways, renovated stadia and so forth. Through this sustainable new planning approach, Barcelona was successfully transformed into a dynamic and developed metropolitan area by the mid-1990s.

Financial planning is also an important component of the overall mega-event infrastructure planning due to the substantial amount of funds necessary. Büttner et al. (2007) analysed Germany's 2006 World Cup the relationship between the investment funds in stadia compared to those invested in other infrastructure related to the event. The aim was to propose some rules that can help future host cities planners predict the required volume of investments for sport infrastructure. The paper analysed the different host cities using investment data for sport venues and the related infrastructure. The analysis showed that the related infrastructure can be much more costly than the stadia. Using cluster analysis, the paper classified the stadia into new-built stadia and reconstructed (extended) stadia to test the effect of the different groups. The discriminance analysis was used to identify correlations between the World Cup stadia and different variables such as volume of sport venues investment cost, volume of the World Cup's related infrastructure and number of inhabitants. In conclusion, when planning for a future mega-even, planners should pay much attention to the event's related infrastructure costs just as much if not more to the investment in stadia.

5 Scheduling and operational aspects

In this section, we review research related to scheduling and operations management aspects in planning sports events. It should be noticed, however, that game scheduling in particular has been the subject of intensive research in the literature from both theoretical and applied points of view. The reader is referred to several rich survey papers such as Kendall et al. (2010) which references over 160 papers and Rasmussen and Trick (2008) which reviews the related works over the last 30 years. These papers investigate most of techniques and approaches used to model and solve the game scheduling problems. Most papers deal with round robin tournaments such as football, baseball, basketball, cricket

and hockey leagues or tennis tournaments in order to minimise objectives such as the breaks between games and the travel distances. Less research has been published on game scheduling for elimination tournaments and competitions such as World Cups. In this section, we aim to review the literature that covers other operations management issues in planning mega sport events and sport competitions including athlete transportation, team performances, referee scheduling and security.

5.1 Operational issues for athletes

Ensuring the fairness of a game is a critical aspect of different sports and is a contentious issue for the sport's stakeholders including managers, fans, officials and in particular athletes. Referee assignment in many cases creates conflicts between the participants before, during and after a game. Due to its importance, the referee assignment problem (RAP) seems to be a crucial and difficult problem for which operations research techniques can be very helpful. However, few papers have been dedicated to this issue throughout the sport management literature.

The basic version of RAP can be described as assigning referees to time slots associated with games scheduled over a given time interval with the objective of minimising the absolute value of the difference between the target and the actual number of games assigned to each referee for all referees. Several constraints must be respected in a solution to this problem including having the required level of skill and experience, referee availability and uniqueness for a game, travel time and distance between host cities, referee nationalities, the possible number of games a referee can officiate among other constraints that may be tournament-specific. Most of proposed models divide these constraints into hard constraints that must be satisfied and soft constraints that should be satisfied as much as possible. Duarte et al. (2007) solved the basic problem optimally via integer programming for limited sizes and used heuristics with larger instances. Duarte and Ribeiro (2008) considered the bi-objective referee assignment problem (biRAP) in which the objective was to minimise both the deviations between the actual assignment and the target assignment and the idle times between consecutive games assigned to the same referee for all referees. The models are solved by meta-heuristics based on greedy algorithm and local search heuristics. Yavuz et al. (2008) explored the RAP for the Turkish football premiere league during the 2005 to 2006 season and proposed an optimisation model, a constructive heuristic and a local search algorithm for the problem. Based on an extensive computational study, the proposed methods produced high quality solutions to the problem.

In tennis games, an umpire is the chief referee in a tennis game. The umpire crew scheduling for professional tennis tournaments was considered by Farmer et al. (2007) who investigated the US Open tournament. Due to the limitations of the existing umpire scheduling process which produced local solutions that sometimes turned out to be infeasible, the authors developed an integer programming model for the problem to minimise the weighted deviation of the assigned skill ratings from target skill rating for each position. A two-phase algorithm was developed based on a constructive heuristic followed by a simulated annealing to find near-optimal solutions. The algorithm performed very well when tested on various real case tennis tournaments such as the 2003 and 2004 US Open, 2003 RCA Championship.

The umpire scheduling and travel minimisation problem for baseball tournaments such as the Major League Baseball (MLB) of the USA was also investigated by Trick et al. (2012). The paper uses exact solution approaches (e.g., integer programming and constraint programming formulations) as well as a combined heuristic that starts with a greedy heuristic to generate an initial solution and then a simulated annealing to enhance the quality of the solution. The proposed methods were tested with instances obtained from real cases of the 2006, 2008 to 2010 seasons. The obtained schedules are more balanced with high quality in terms of travelled distances and number of officiated games for each crew.

Lamghari and Ferland (2007) considered the judges assignment issue for another type of large-scale event such as the John Molson International competition. This is an annual event organised by Concordia University of Montreal which is considered the largest of its class attracting around 30 teams of business students from international universities around the world. Due to the complexity of the problem, the paper proposes a three-stage metaheuristic based on a tabu search approach. An initial solution is randomly generated (or using HLA-HOA heuristics), then tabu search is executed at each stage in order to reach an optimal or near-optimal solution by extensively exploring the search space.

Athletes transport planning is a key to the success of large sport events. The complexity of athlete transportation problems stems from characteristics that differentiate them from other transportation problems such as common starting and terminal points, large distances between athlete villages and venues, dependence on bus route and schedules (characterised by daily variations), dependence on traffic conditions and strict delivery times. Minis et al. (2006b) focused on athlete transportation planning during the Athens 2004 Olympic Games. The paper divides the overall problem into several sub-problems: service level and resource planning, management structure, route planning and scheduling and rostering problem. The transportation planning of around 15,000 athletes is a great challenge for planners. The transportation system should ensure their movements to competitions and training venues in time. This paper analyses the service level and resource planning first in order to estimate the necessary resources including buses and headways early before the competition. For the first issue, the development of service specification in which the paper defined the key inputs of the resources estimation model is a crucial step. A key input is the distribution of athlete arrivals to venue for each route and each day for both individuals and teams. Other inputs are specified such as total round trips, travel times, load/unload time, security check times and so on.

Wu et al. (2009) studied a new type of athletes transportation planning called the lane reservation problem in time-constrained transportation in which athletes must be delivered within a narrow time window to geographically distributed venues during a large-scale event (2010 Asian games held in Guangzhou). The complexity of the problem is due to several factors including the heavy traffic and the large distances between athlete villages and the different venues (more than 40 km in some cases). The paper presents a network model and a mathematical formulation for the problem under consideration. Since the problem depends on the traffic conditions, a cost (objective) function is determined to reserve the lanes with as little impact on the normal traffic as possible while satisfying the time constraint. The paper also proposed an effective heuristic that reached near-optimal solutions efficiently.

The performance analysis of teams and athletes participating in sports events and tournaments is another field of investigation. Peña and Touchette (2012) investigated

performance analysis of teams participating in the 2010 FIFA World Cup held in South Africa. The authors applied network theory to provide a visual snapshot of teams strategy, determined the players performance, measured their intervention and contribution in a game and detected weak spots and problems between team members within a team. In the process, the paper proposed measures such as the closeness (i.e., how easy to reach a player in a team), betweenness (i.e., the impact of a player on the whole team if he is removed) and page rank (i.e., the popularity of a player defined by the probability of getting the ball from his teammates after a certain amount of time). The paper also analyses the interaction within a team (how clustered or fragmented) through the network cliques. These proposed measures were computed for the different teams of the 2010 World Cup such as Spain, Holland, Germany and Brazil. The obtained results confirmed the players' and teams' performances reported by media and experts during the competition.

5.2 Security issues

The security during mega sports events is an ongoing issue for host cities, and in today's geopolitical atmosphere, it is more important than any previous time. A strict city control, a smooth evacuation of fans from stadia and efficient interventions should be taken into consideration when establishing security policies and strategies. Operation research optimisation and modelling techniques are becoming more and more useful in this field. Evers (2012) investigated the unmanned aerial vehicles patrol-planning problem (referred as UAV PPP) and their use in strengthening security for sporting events. UAVs are remotely connected aircrafts without a human pilot which can be used during sport events to collect useful information such as videos, footage and pictures of the locations where possible conflicts can occur throughout the host city. The goal of the research is to find a short UAV tour to efficiently scan the different locations and also fly to the locations in which unexpected conflicts arise. The paper develops a mathematical formulation of the problem with a General Fractional Program whose objective is the summation of several quotient terms composed of linear functions. The first term of the objective finds a tour such that the total time required to carry out observation over all locations is minimised while the second term is a ratio that represents the weighted location reaching time averaged over all possible moments during the entire tour to find an optimal path between the different locations. When the proposed method was applied to an artificial case of study, the model identified UAV tours with a reasonable time and a good response time.

Pedestrian evacuation including stadium evacuation has been studied in the literature using various approaches. Simulation-based approaches are probably the most realistic to use with such problems due to the complexity of the evacuation process especially when human behaviour is factored into it. Zhang et al. (2014) studied spectator evacuation in a stadium using agent-based modelling (ABM) in which the authors introduced a decision making framework at the individual (agent) level that is affected by the distance of agents from exits and the density of the surrounding agents. The authors also considered spectators' gender and age distribution, existence of obstacles and the positions of exits. Simulation results showed that the simulation can reproduce realistic stadium evacuation, and therefore, it might be useful to assess public buildings design.

Klupfel and Meyer-Konig (2005) described a cellular automata simulation for the evacuation of a seven level stadium case study. Although human behaviour and

interaction was not modelled, the authors reported that the results were realistic to a knowledgeable staff.

Li et al. (2010) proposed a multi-objective evacuation route assignment model in which three objectives were considered: minimise the total evacuation time, minimise the total travel distance of all the evacuees and minimise the congestion during the evacuation process. Genetic algorithms was used with this multi-objective optimisation problem and Wuhan Sport Center in Wuhan city of China was used as the experiment scenario. The results showed that it can provide some system optimal evacuation plans. Zong et al. (2010) addressed the same problem and stadium but applied ant colony optimisation to it.

Ai-chun et al. (2014) combined both cellular automata and ABM for stadium evacuation. Simulation results showed that cell agent combines the advantages of ABM and cellular automata and when compared to traditional cell cellular automata, it is more close evacuation situation of the realistic major sports stadium, and it shortens the evacuation time and improves the safety.

Helbing and Johansson (2010) presented a comprehensive discussion on pedestrian, crowds and evacuation dynamics in general and included various models and methods for such problems.

6 Summary and conclusions

This paper surveyed a large body of works related to planning mega-sports events, spanning a spectrum of topics usually studied within different research communities. The survey provides an up-to-date discussion of studies related to forecasting foreign fan attendance, transportation planning, infrastructure development, and operational constraints related to athletes, security, and advertising campaigns.

In so far, studies related to the FIFA World Cup have considered host nations that involve multiple, large host cities, each having its independent transportation and lodging network. New challenges will present themselves when, for example, a more compact nation such as Qatar hosts the event in 2022. Although Qatar is proposing seven host cities, they are near proximity to one another and seven out of the 12 proposed stadiums are in the capital, Doha, and its adjacent city of Al-Rayyan. We recommend capacity analytics studies for lodging and transportation planning for such instances, where fans will be simultaneously using hotels and modes of transportation that are concentrated in a single geographic area, in and around the capital. Such planning studies will necessarily require a stochastic examination of attendance scenarios with visibility to the role affluence of fans from neighbouring countries.

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