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Sport events and the environment: Assessing the carbon footprint of spectators' modal choices at professional football games in Austria

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ABSTRACT

As a response to the increasing threat to sport events from climate change and expectations around climate change mitigation, sport event managers increasingly engage in environmentally-related initiatives that aim to reduce GHG emissions. One of the major contributors to GHG emissions at large sport events is spectators' travel and, thus, their associated modal choices. Building on the Sport Logistics Framework (SLF) and using the case study of Rapid Vienna, the largest football club in Austria, this study investigates spectators' modal choice to systematically assess the total GHGs emitted by spectators at a professional football home game. Data was obtained from two sources: a) an extensive data set collected on Rapid Vienna season ticket holders, and b) three surveys at home games which, together, constituted 3317 valid responses. The calculation of the GHG emissions resulted in 99,548 kg GHG emissions per home game or 6.0 kg GHG emissions per spectator. It was also found that 42.4 per cent spectators arriving by car emit 71.6 per cent of GHG emissions, while in contrast, 52.8 per cent of spectators using public transport emit 27.1 per cent of GHG emissions. The results also indicate that the possession of an annual public transport ticket seems to determine travel behavior, i.e. the majority of spectators with an annual ticket are using it, while spectators without a ticket are using a car. As such, this paper not only provides an opportunity for academics and managers to benchmark the data in order to identify initiatives to reduce the impact of GHG emissions, but also allows for the systematic measuring of the environmental impact of fan and spectator travel.

1. Introduction

Climate change presents an environmental threat to the global community and is increasingly recognized by organizations and companies as a major business challenge (Breitbarth et al., 2023). Environmental concerns have been growing around the globe, captivating interest across all spheres of society, including politics (Aklin and Mildenberger, 2020), communities (Dietz et al., 2020) and business (Fiedler et al., 2021). In particular, researchers have examined the role of large events and gatherings as contributors to Greenhouse gas (GHG) emissions such as music festivals (Hazel and Mason, 2020), trade shows (Gallo et al., 2020) and religious tourism (El Hanandeh, 2013).

The consideration of sustainable and environmental impacts has also found its way into the sport industry and the subsequent planning, organization and execution processes of sport events such as in professional football (Breitbarth and Harris, 2008; Herold et al., 2023), the Olympic Games (Ross and Leopkey, 2017) and Formula One (F1) (Miller, 2016). An increasing number of major sporting bodies and sport event organizers integrate climate change-related initiatives in their operational practices (Cooper, 2020; Pereira et al., 2020). For example, the football club Newcastle United has recently installed a combined heat and power system, while Bristol City has implemented a new solar project at its stadium and increasingly considers environmental impacts as part of structured and strategic Corporate Social Responsibility (CSR) efforts (Breitbarth et al., 2019).

However, academic management literature that examines and scrutinizes sports' impact on the environment is still limited (Cooper, 2020; Wicker, 2019). Similarly, although sport organizations implement

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climate change-related initiatives, they often fall short of systematically measuring and reporting the environmental impact of their operations and events (Herold et al., 2022; Orr and Inoue, 2019). Here, the German professional Bundesliga football club VFL Wolfsburg remains an outlier with its externally conducted and certified GHG emission reporting (VfL Wolfsburg, 2020). Apart from this laudable exception, the lack of reporting by football clubs does not only undermine their climate change efforts, but also suggests that sport organizations have been missing out on significant opportunities to improve the environmental impact of their operations.

The largest share of GHG emissions at major sport events is caused by spectator travel (Musgrave et al., 2019). For example, the VfL Wolfsburg sustainability report shows that more than 60 per cent of all GHG emissions stem from spectator travel (VfL Wolfsburg, 2018). Importantly, these emissions are heavily impacted by the transport modes spectators choose to travel to the stadium (Dosumu et al., 2017; Hergesell, 2017). Spectators may come to the stadium walking, cycling, by car, bus or public transport and their preferred transport mode may depend on a variety of intrinsic and contextual factors. Lamentably, to date, there remains a lack of studies investigating the environmental impact of spectator mobility within an events context, in particular under consideration of the carbon footprint of the various spectators' modal choices (Dolf and Teehan, 2015; Orr and Inoue, 2019). In particular, existing literature lacks insights into what transport modes different groups of sport spectators choose to get to the sport event venue and how these different groups contribute to the overall quantity of GHGs emitted.

In response, this study investigates spectators' modal choices and the associated GHG impact. Using a case study of Rapid Vienna, Austria's largest football (soccer) club, the following two research questions were asked.

RQ1: What is the preferred transport mode of Rapid spectators at home games?

RQ2: What is the carbon footprint of Rapid spectators' modal choices?

To answer the research questions, this study takes a single case study approach to assess the relative and the total carbon footprint of spectators at a professional football home game based on the modal choices from spectators at Vienna Rapid home games. Data was obtained from two sources: a) an extensive data set collected on Rapid Vienna season ticket holders, and b) three surveys at home games, which, together, resulted in 3317 valid responses that were subsequently analyzed.

The contribution of this article is threefold. First, this study investigates spectators' modal choices and their related GHG emissions at home games, thereby highlighting the relative impact of different spectator travel groups. As such, this study not only provides insights into the variances in emissions between the different transport modes, but it also discusses the rationale and characteristics associated with the variances. Second, the actual GHG emissions of spectator travel are calculated, thereby providing a chance for sport academics and managers to benchmark the data in order to identify opportunities to reduce the impact of GHG emissions in sport events. As only few professional sport organizations measure their indirect emissions, quantifying the GHG emissions is a critical step towards building a database for comparison and decision-making. And third, the study represents a first approach towards systematically measuring the environmental impact of spectator modal choices, thereby providing a template for GHG reporting of spectator travel in football clubs. By using the established 'fans and spectators' pillar of the Sport Logistics Framework (SLF) as the contextual frame to assess the GHG emitted by spectator travel to Rapid home games, a theoretical foundation is presented that can be adopted for any sport events.

2. Linking carbon footprints and sport events

2.1. Environmental sustainability and sport events

The risk of climate change has put sustainability high on the agenda of businesses and policy makers, urging them to engage in environmental initiatives and to minimize or eliminate the negative effects of GHG emissions (Breitbarth and Herold, 2018). Studies show that the median temperature of the planet has increased by over 1.1° Celsius since the preindustrial era, resulting in melting ice caps, rising water levels and more frequent storms (Dantas and Pausas, 2022). While this temperature increase affects almost all life on the planet, it has also implications for sport-related activities and events. Sport can both be affected by the effects of climate change as well be a contributor to GHG emissions. For example, the Winter Olympics are under threat as the climate suitability is increasingly questioned due to the potential lack of snow (Ito et al., 2022). However, sport events are also contributing to climate change emitting GHGs, in large part due to the spectators' travel to and from these sport events (Wicker, 2019).

Sport organizations are aware of the environmental impacts of their events and not only show increasingly responsibility for their GHG emissions, but also engage in several sustainability initiatives to address stakeholder concerns (McCullough et al., 2023). Research also suggests that sport events as a highly visible platform present an opportunity to initiate broader societal change and raise awareness for more climate action (Schulenkorf, 2012). As a consequence, international sport governing bodies such as the International Olympic Committee (IOC) and the FIFA have made pledges ranging from low-carbon commitments to 'climate positive' Olympic Games in 2032 (Tham, 2023). For events, most sport organizations have also adopted the management and reporting guidelines of the International Standards Organization's document, ISO 20121:2012 Event Sustainability Management Systems – Requirements with Guidance for Use (2012) and the Global Reporting Initiative's Sustainability Reporting Guidelines & Event Organizers Sector Supplement (GRI, 2012).

It can be observed that sport managers aim to incorporate a wider concept of sustainability for their sport events such as waste management (Bianchini and Rossi, 2021), water management (Daddi et al., 2022) or renewable energy (Lyu, 2024). However, this study focuses on one of the most pressing societal concerns, the generation of GHG emissions by sport events, in particular the carbon footprint from the modal choices of spectators.

2.2. Measuring GHG emissions in and for sport events

Sport events often generate significant GHG emissions which have an impact on the environment and climate change, both locally and globally (Dolf and Teehan, 2015). But while it has become standard in most organizations to report on emissions from Scope 1 (direct emissions, e.g. steaming from operating own car fleet) and Scope 2 (indirect emissions, e.g. emissions caused through consumption of acquired energy), the assessment of Scope 3 is considered difficult and often complicated (Dingle and Mallen, 2020; McCullough et al., 2019). Critically, the majority of GHG emissions at sport events stem from Scope 3 sources, i.e. from spectators' travel to games, which means that sport organizations have been missing out on significant opportunities to determine and improve the environmental impact of their operations.

While several assessments for reduction measures exist (Collins and Roberts, 2017; Mallen et al., 2010), specific frameworks for the evaluation of GHG emissions for spectators at events are limited. One prominent tool providing framing and guidance to investigate sport event-related activities and matchday operations is the Sport Logistics Framework (SLF) by Herold et al. (2020) (Fig. 1).

Conceptually, the SLF provides a tool for measuring GHG emissions according to four distinct yet interrelated sport pillars, namely venue logistics, fan and spectator logistics, athletes' logistics, and equipment

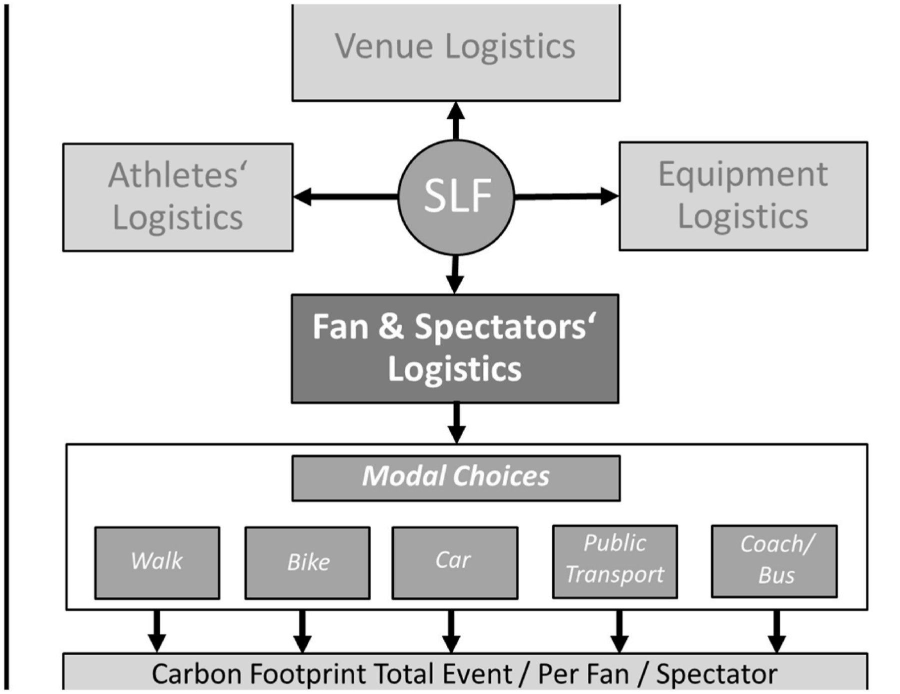

Fig. 1. The Sport Logistics Framework and Carbon Footprint (adapted from Herold et al. (2020, p. 361).

logistics (Breitbarth and Herold, 2021). While the pillar representing venue logistics focuses on the activities in the stadium and related GHG emissions (including, for example, facilities, electricity, security, and hospitality operations) (Minis et al., 2006b; Robinson et al., 2010), the pillar representing athletes' logistics includes activities such as travel by the athletes, the coaching and management entourage (Bovy, 2009; Minis et al., 2006a). Equipment logistics refers to the classic task of logistics services like freight forwarding and the transport of the required goods, but also the organization of warehouses and the associated distribution, which may represent a significant portion of total GHG emissions (Chakrabarty and Premkumar, 2023).

Of particular interest for the purpose of this study, however, is the pillar of fans' and spectators' logistics (including, for example, transportation systems) as it can be regarded as a key component for and in sport event management (Bovy, 2009; Herold et al., 2021; Kassens-Noor, 2019). While venue logistics management focuses on the logistics activities inside the venue, spectator logistics management focuses on the logistics activities outside the venue (Kassens-Noor, 2010; Mulley and Moutou, 2015). In the context of large events, these outside logistics activities comprise mainly the transportation of spectators to the venue including the infrastructure of and behind transport arrangements (e.g. the planning of transport demand and supply as well as parking space) (Bovy, 2006; Herold et al., 2022). As such, sport event managers often influence modal choices for spectators, as they work towards providing smooth and convenient travel to the event.

Studies show that spectators' travel to games is by far the largest GHG emitter (Collins et al., 2012; Loewen and Wicker, 2021). However, the literature lacks insights into spectators' modal choices and its GHG emissions implications. Here, the spectators' logistics pillar of the SLF represents a robust focal point for empirical investigations into the GHG emissions associated with spectators' travel to and from home games.

2.3. Carbon footprint of sport spectators' modal choices

Carbon footprint assessments present an ideal approach towards measuring the GHG impacts of sport events (Breitbarth et al., 2011; Florek et al., 2008). The construct of carbon footprint represents "the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product" (Wiedmann and Minx (2008, p. 4). The advantage of using carbon footprint as a measure is its ability and relevance to assess people, events, but also organizations and nations. The carbon footprint represents GHG emissions in grams, kilograms, or tons of carbon-dioxide equivalent emissions (named CO2e), i.e. it converts the potential climate change impact of other greenhouse gas emissions (e.g. nitrous oxide, methane and other fluorides) into carbon dioxide equivalents (Wicker, 2019).

In sport management – and in particular for sport event management – carbon footprints are frequently used by scholars to assess the overall environmental impact of sport events (Wicker, 2018; Wilby et al., 2023). For example, scholars have used carbon footprint calculations to asses match days at Bundesliga games (Loewen and Wicker, 2021), mega bicycle races (Collins et al., 2012), winter sporting activities (Wicker, 2019), rugby matches (Collins and Roberts, 2017) and college football (Cooper, 2020). These events and distance-based carbon footprints are often constructed by aggregating multiple emissions contributors such as transportation, temporary accommodation, and event-specific activities. Existing literature has also used models to assess the different modal choices or transport types and their GHG implications. Here, scholars not only found that transport of spectators is the highest contributor to GHG emissions, but that air travel is the most harmful transportation mode (El Hanandeh, 2013; Gössling and Dolnicar, 2023). Meanwhile, cars and car usage – in particular for long-distance travel – is also associated with significant GHG emissions (Filimonau et al., 2014; Kummer et al., 2021). More broadly, research has shown that all motorized modes of transport on the ground – when spectators travel long distances – contribute heavily to total GHG emitted and have a considerable impact on the environment (Breitbarth et al., 2023; Collins et al., 2009).

3. Methodology

This paper adopts a qualitative single, holistic case study design to gauge the analytical reach and practical power of assessing transport modal choices of spectators and its GHG emission implications (Denzin and Lincoln, 2013; Yin, 2014). The value of case studies is well established in management research, especially in providing insights into complex, new and real-world phenomena (Eisenhardt, 1989; Mintzberg, 1979). A case study method has the capacity to build new knowledge by utilizing both past and ongoing data from "real-life" situations that may not be captured using alternative research designs and approaches (Stake, 1995). Single case studies are particularly appropriate for exploratory research when existing literature on a phenomenon is limited (Eisenhardt and Graebner, 2007; Hsieh and Shannon, 2005).

3.1. Case: rapid Vienna

Rapid Vienna (original full name: Sportklub Rapid Wien) is a professional football team in the Austrian Bundesliga, based in Vienna, Austria. Football is the most popular sport in Austria (Statista, 2024), and Rapid Vienna, founded in 1899, is the largest and most successful football club in Austria, having won the most Austrian championship titles (32) and having frequently qualified for UEFA football competitions. The home games take place at the Allianz Stadium in Huetteldorf, located in Vienna's 14th district Penzing. The stadium has a capacity of 28,345 seats, with an average attendance of 16,265 spectators per home game (Rapid Wien, 2023). Rapid Vienna presents a welcome opportunity to examine the modal choices and its GHG emission implications at a home game matchday for the following two reasons: a) its size and status within the Austrian football league resulting in the largest fan base in professional Austrian football and b) the stadium's location in the city providing easy access via a large variety of transport modes.

3.2. Data collection of modal choices at Rapid Vienna and its associated GHG impact

Data was collected via two distribution channels, a) Rapid Vienna obtained data online as part of its annual club survey with season ticket holders in early 2019 with 19 per cent of ticket holders responding, and b) the researchers collected data in-person during three home games in September and October 2019 resulting in a sample of 4.5 per cent of the average spectatorship of a Rapid home game. The questionnaire design was informed by a) existing validated surveys from England (CBTransport, 2013) and Scotland (Repucom, 2013), and b) feedback from Rapid Vienna. With a focus on spectators' modal choices and their locations, participants were asked which transport mode(s) is/are usually chosen to come to games with options restricted to walk, bike, car (alone), car (shared/how many co-riders), public transport, coach or any combination of the listed options. Public transport options include the metro, bus, tram and inter-city trains, while a coach is a chartered bus for the trip to the football game. Moreover, questions related to possible explanatory variables were included, namely respondents' place of residence/origin and zip code, age, gender, fan affiliation and whether they own an annual public transport ticket and/or a car. Together, this approach resulted in 3317 useable responses. It should be noted that, for the purpose of this study, all spectators, i.e. both Rapid fans and fans of the respective competitor teams were surveyed. Please find an overview of the data collection and data analysis process in Fig. 2.

3.3. Data analysis

The data analysis consisted of three steps: First, to determine respondents' distance travelled, each zip code and Google Maps was used to calculate the distance in kilometers (km). More specifically, we used the road kilometers from Google Maps to calculate the shortest distance from the centroid of the respondent's zip code to the stadium. Second, based on the carbon footprints per modal choice per km (see Table 1), the respondents' carbon footprint per modal choice was calculated. The GHG emissions per modal choice per km was adopted from a leading German carbon mobility advisory Forliance (2022), which was also adopted for the sustainability report from the Bundesliga club VfL

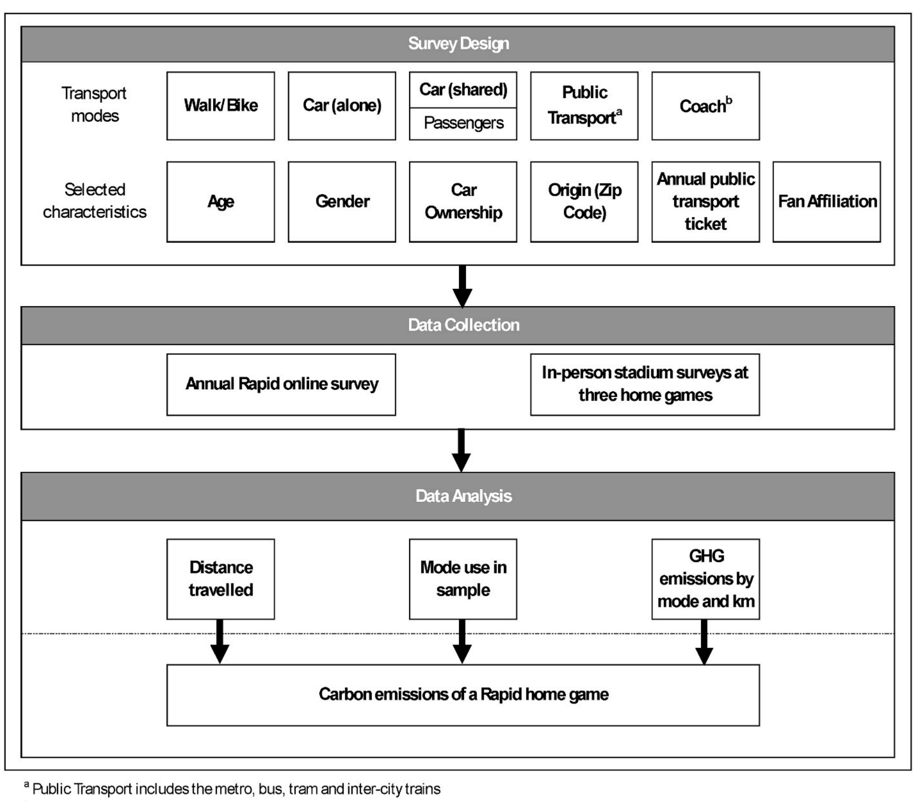

Fig. 2. Data collection and data analysis process.

Table 1
Transport modes and GHG emissions per km.

Transport Mode	Number Persons	GHG emission intensity (CO_2e kg/km*)
Walk/Bike	1	0
Car (alone)	1	0.325
Car (shared)	2.6	0.325
Public Transport	1	0.1722
Coach/Bus	1	0.094

*Includes both the travel to and from the stadium.

Wolfsburg and the associated assessment of GHG emissions by the VfL Wolfsburg's spectator travel. Third, based on the sample a) the distribution of transport mode use across all respondents was calculated, b) the overall GHG emissions by transport mode was assessed, and c) the overall GHG emissions of the entire home game audience was calculated by extrapolating our results to the average audience of Rapid home games, assuming congruence between sample and population mode share.

4. Results

4.1. Spectator origin and transport modal share

The results show that the majority of the spectators arrived by public transport with 52.8 per cent. This is followed by spectators arriving by car, which is mainly driven by the category 'Car (shared)' with 32.5 per cent plus 10.0 per cent who used the car alone (see Table 2). To assess vehicle occupancy, the average of category 'Car (shared)' with $n = 849$ was calculated and the mean occupancy was found to be 2.6 people per car, which is similar to – and comparable with – the finding of 2.6 persons from Collins and Cooper (2017) as well as the 2.7 persons per car from Cooper (2020). Taken together, over 40 per cent of spectators arrived at the Rapid stadium by car. Finally, 3.7 per cent of spectators arrived by bike or were walking, while only 0.9 per cent of spectators took a dedicated coach.

The results also reveal that the mean distance spectators travel to the stadium ranges from 6 to 78 km. In particular, and in mean terms, spectators who decided to walk or cycle to the stadium travelled 5 km, while spectators using public transport travelled 15 km to see the games. Spectators who chose to use the car travelled from further away with 20 km (alone) or 28 km (shared), respectively. The longest distance to the stadium can be attributed to the spectators using a dedicated coach.

The data also indicates a gradually declining spectator participation with growing distance (distance decay), with 31 per cent of spectators travelling from within 10 km, 26 per cent within 20 km, 22 per cent within 50 km and only 13 per cent within 100 km. The remaining 8 per cent arrived from locations that were more than 100 km away from the stadium.

When comparing the three components modal choice, distance and the share of spectators, the data provided also meaningful insights. As Fig. 3 shows (the x-axis is showing the one way trip distance), and not surprisingly, almost all of the 3.7 per cent of spectators that walked or cycled to the stadium did so within less than 10 km. The analysis also revealed that 80 per cent of spectators travelling less than 10 km use public transport or walk/cycle. That number changes only slightly within a 20 km radius, with 70 per cent of spectators arriving by public transport. Overall, the analysis also shows that the further away spectators live, the greater the likelihood of using a car, i.e. car usage increases with a greater distance to the stadium (distance decay).

The analysis also showed that most of the spectators arriving by 'Car (shared)' and by public transport are between 25 and 34 years old, with 9.1 per cent and 13.5 per cent respectively (see Table 3). This is followed by the age group of 35–44, where 7.7 per cent arrive by shared car and 12.3 per cent arrive by public transport. While these age groups were also the biggest groups in the sample, those aged 25–34 years old were significantly less likely ($p < 0.01$) to have arrived alone by car with only 6.9 per cent of respondents in that age group doing so compared to 10 per cent of respondents across all age groups.

Moreover, while only significant at $p < 0.05$, difference between men and women could be noted, with more women (37.3 per cent) arriving by 'Car (shared)' compared to only 31.4 per cent of men.

It was also found that spectators owning an annual ticket for public transport for Vienna were more likely ($p < 0.001$) to use public transport, while those without the annual pass were more likely to arrive by car either alone or with others (see Table 4). Specifically, the analysis shows that 76 per cent of spectators with an annual ticket used public transport, while only 39 per cent of spectators without an annual pass arrived by public transport. Similarly, those spectators who own a car were more likely to use it ($p < 0.001$); specifically, 63 per cent of car owners arrived by car either alone or with others while only 31 per cent of those not owning a car arrived by car, almost exclusively travelling with others (shared car).

4.2. GHG emissions at the Rapid Vienna home game matchday

The analysis of the modal choices and its associated distances allowed the calculation of GHG emissions output not only for the entire population, but also examined the respective output and distribution share per modal choice (see Table 5).

The results of the sample were extrapolated to the average stadium audience of Rapid home games, which had 16,265 spectators on average in 2018. This resulted in a total GHG output of 99,548 kg of CO_2e emissions, which translates into a carbon footprint of 6.0 kg CO_2e emissions per spectator. The results show that arriving by car is the biggest GHG contributor with 42.4 per cent of the spectators ('Car alone' plus 'Car shared') causing 71.6 per cent of total GHG emissions related to spectator travel. In contrast, 52.8 per cent of spectators arriving by public transport accounts for 27.1 per cent of all GHG emissions.

5. Discussion

Against a background of growing expectations around climate change mitigation, sport event managers are increasingly engaging in environmental-related initiatives that aim to reduce GHG emissions, including the adjustment of spectators' travel behaviour. In response to a general lack of insights into how different groups of sport spectators choose their transport to the stadium – and how these different groups contribute to the overall quantity of GHGs emitted – the present study has revealed a number of critical insights into modal choices and the associated environmental impact of stadium attendees.

When comparing the carbon footprint per person at a Rapid Vienna home game, the number seems to be lower compared to other football events. For example, while the carbon footprint per spectator at Rapid games was calculated at 6.0 kg CO_2e, Collins and Flynn (2008) found that the carbon footprint per spectator at the FA Cup final in England was 7.6 kg CO_2e. However, it should be noted that the calculation of Collins and Flynn (2008) included indirect emissions to some extent, which were excluded in the present study. Moreover, while Rapid home games are visited mostly by spectators in near proximity (almost 80 per cent of spectators travel from within a 50 km distance), the FA Cup final

Table 2
Transport modal share and distances.

Transport Mode	Mode Share	Mean Distance	GHG emission intensity (CO_2e kg/km)
Walk/Bike	3.7%	5 km	0
Car (alone)	10.0%	20 km	0.325
Car (shared)	32.4%	28 km	0.125
Public Transport	52.8%	15 km	0.1722
Coach	0.9%	78 km	0.094

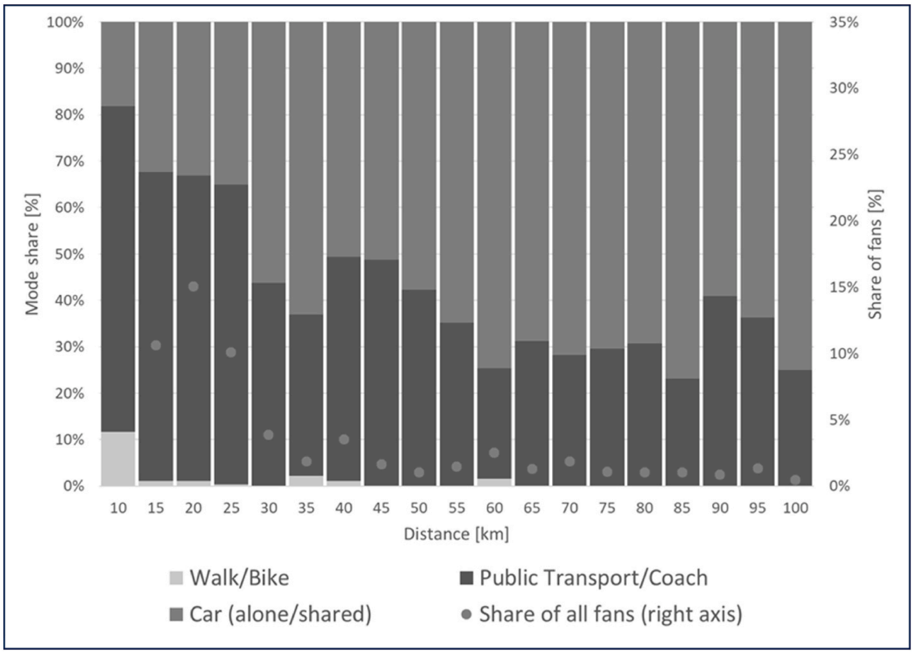

Fig. 3. Modal choice of spectators at Rapid Vienna.

Table 3
Modal choice by age.

Transport Mode	Age							
	<18	18–24	25–34	35–44	45–54	55–64	>65	Total
Walk/Bike	0.1%	0.3%	1.0%	0.7%	0.9%	0.6%	0.3%	**3.7%**
Car (alone)	0.2%	1.1%	1.8%	2.7%	2.6%	1.2%	0.5%	**10.0%**
Car (shared)	0.8%	3.3%	9.1%	7.7%	6.1%	4.2%	1.2%	**32.4%**
Public Transport	1.3%	5.1%	13.5%	12.3%	11.5%	6.8%	2.4%	**52.8%**
Coach	0.0%	0.0%	0.3%	0.2%	0.2%	0.1%	0.1%	**0.9%**
Total	**2.3%**	**9.7%**	**25.7%**	**23.6%**	**21.3%**	**12.9%**	**4.5%**	**100.0%**

Table 4
Car usage vs public transport.

Transport Mode	Do you own an annual public transport ticket?		Do you own a car?	
	Yes	No	Yes	No
Public Transport	76.0%	38.8%	31.1%	64.7%
Car	4.2%	13.6%	5.2%	0.5%
Car (Shared)	15.1%	43.0%	58.1%	30.4%

has likely attracted spectators from the entire United Kingdom, plus international spectators. This suggests that the average travel distances for the FA Cup final are by far greater and thus more GHG intensive. Meanwhile, the carbon footprint for football games generally seems to be rather low when compared to other sport events. For instance, the 2004 Wales Rally resulted in 20.2 kg CO2e per person (Jones, 2008), the World Orienteering Championships led to 25.4 kg CO2e per person (Scrucca et al., 2016), and different Tour de France races in the UK resulted in 50.5 kg CO2e per person (Collins et al., 2012). While research into specific types of sports will reveal more robust comparative results in the future, one likely reason for these differences lies in football's international approach, attracting spectators worldwide, and a higher popularity of these professional sport events.

The present study also provided insights into the distribution of public transport and car usage. Whilst a similar focus has been applied to football studies in the past, the results from Rapid Vienna provide a more nuanced picture. For instance, an English study found that 43 per cent of spectators arrive by car to professional football games (CBTransport, 2013), while a study conducted in Scotland found that 64 per cent of spectators travel by car to home games (Repucom, 2013). Similar to the English study, 42.4 per cent of Rapid spectators arrive by car. This relatively high car usage is somewhat surprising given the publicly

Table 5
GHG emissions per modal choice.

Transport Mode	GHG emissions (CO2e-Output (kg))	GHG emissions (CO2e-Distribution)	GHG emissions (CO2e-per capita (kg))	Mode Share
Walk/Bike	0	0.0%	0	3.7%
Car (alone)	12,634	12.7%	12.8	10.0%
Car (shared)	58,630	58.9%	7.0	32.4%
Public Transport	26,934	27.1%	4.6	52.8%
Coach	1349	1.4%	4.1	0.9%
Total	**99,548**	**100%**	**6.0**	**100%**

acclaimed, efficient and very affordable public transport system in Vienna (Breitbarth et al., 2021; Haslauer et al., 2015). While 55.0 per cent of all Rapid spectators come directly from within the city of Vienna, 52.8 per cent of all Rapid spectators arrive by public transport. Although this is relatively high compared to the previously mentioned UK and Scottish studies that highlighted that 40 per cent of spectators arrive by public transport (CBTransport, 2013; Repucom, 2013), the high share of car users and its major contribution to GHG emissions remains a challenge.

Moreover, it seems that the possession of an annual ticket significantly influences travel behavior, i.e. transport choice. The analysis revealed an association between, on the one hand, annual ticket owners and the use of public transport, and on the other hand, between car owners and car usage to drive to the stadium. While this is an interesting insight given the increasing popularity of combined event and public transport tickets, it remains unclear whether the positive association between an annual ticket and public transport use for event travel is due to cost savings, experience/knowledge of and a positive attitude towards public transport, or a combination of these and other related factors.

From a broader perspective, the trade-off between cost, time and experience of spectators travelling to home games might also be an area of future investigation. Here, existing research suggests that spectators tend to either choose a shorter travel time over higher financial cost, or opt for a longer travel time with lower price tag (Fezzi et al., 2014; Li et al., 2020). However, given that a significant portion of spectators travel together in a shared car, the travel experience to the stadium may in fact contribute to the overall sport event experience (Fairley, 2009). In other words, this added dimension may well play a critical role in the decision-making process and influence people's choice for their preferred travel mode.

6. Conclusion and implications

This study set out to analyze the preferred modal choice of spectators at Rapid Vienna, and the associated GHG impact of spectators' modal choices. Such assessments are not only critical to improve the environmental impact of sport events and its implications for spectators and society, but also to provide a better understanding of how sport organizations can contribute to low(er) GHG emissions and the setting of priorities when designing transport mode options at home games. For this study, Rapid Vienna provided an extensive dataset from season ticket holders which was complemented with additional data collected at three home games, resulting in 3317 useable observations/responses. It was found that each home game, on average, generates a total GHG output of 99,548 kg of CO2e, which translates into a carbon footprint of 6.0 kg CO2e per spectator. Whilst it was encouraging to see that from a modal choice perspective shared car rides clearly outweighed single car use, the relatively low percentage of public transport uptake in Vienna – a city with one of the most acclaimed public transport systems in the world – remained a concerning surprise.

These results have a number of critical implications for sport event managers, policy makers and sport management scholars. For sport event managers, the potential of maximizing the use of public transport – which has considerably lower GHG emissions than the car – has not been fully realized. Here, sport clubs' strategy and marketing departments will have to improve their efforts in getting more people off the road and into trains. Overall, sport managers are also encouraged to engage more strategically with public authorities – and especially decision-makers in the transport ministry and associated departments – to optimize the service levels at home games. Stronger collaboration with city planners and transport authorities presents a critical step towards targeted campaigns that may involve attractive travel incentives, ticket bundling or bonus programs. Finally, such innovations will also lead to new potential research avenues that investigate the relationship between public transport uptake and sport events across a variety of strategic management, marketing and finance domains.

Relatedly, for policy makers, this study shows that the fragmentation of public transport systems and other contextual factors might be perceived by spectators as barriers to public transport use. More specifically, as 45 per cent of spectators in this study were coming to home games from outside of Vienna's city borders, better alignment and greater event-specific public transport capacities before and after games may also help to shift modal choices. This may open up an interesting research avenue to further examine these relationships to better understand and identify ways of encouraging increased public transport use among car owners. Finally, for sport management academics, this study provides a foundation for further scholarly engagement with – and evaluations of – modal choices use as well as critical investigations into its choice determinants of spectators for both home and away games. Despite their significance for individual and managerial decision-making, as well as policymaking, there remains a lamentable dearth of detailed studies on spectators' modal choices. For example, examining why the share of public transport users is lower than the share of spectators from Vienna provides an exciting opportunity for further research.

The authors acknowledge that this study's results and their implications must be viewed in the light of existing research limitations. Although the findings provide insights into spectators' modal choices and the implications on GHG emissions, the interpretation of data, in particular in a single case study, is inherently subjective. For example, the assumption of congruence between sample and population mode share may not be representative for all games as the distribution of fan and season ticket holder attendance may differ thus suggesting the need for further research into differences in spectator group attendance by type of game. And although this study can be regarded as one further step to better understand the rationale behind modal choices for events, future research can and should target specific transport modes and how spectators can be encouraged to choose more environmentally friendly transport. Moreover, the measurement approach applied is rather static in nature and relies on established models of CO2e output per km and transport mode, thereby neglecting potentially new measurement models (such as Life-Cycle-Assessment (LCA)) for the different mode choices or new technologies (such as the impact of electric cars). In particular, as data was collected in 2019, the share of electric cars in Austria was marginal and studies in the future will be able to determine more specifically the value and impact of electric cars as part of the sustainable transport puzzle. Next, this study relied on data from a leading German carbon mobility advisory, Forliance. The organisation also provided the output data for the sustainability report from the Bundesliga club VfL Wolfsburg and the associated GHG calculation of the fan travel. While this provides a validated approach that has already been used and thus can also be utilized for comparison, the authors acknowledge that the CO2e per km numbers may be different in other countries or regions dependent on its carbon intensity or electricity mix. Taking this into account, there is a critical need for additional research – both qualitative and quantitative and across geographical and sporting boundaries – to establish a better (global) understanding of environmental concerns and associated mitigation strategies that will make a noticeable difference in society.

Despite the sport event industry's constant growth in its local and global footprint, topics such as sustainability, environmental responsibility and carbon footprint management are only beginning to emerge on managers' operational and strategic horizons. However, with growing public concern and an increasing critique of sport event gigantism, these topics are more important than ever. They deserve to be tackled by managers, policy makers and customers in unison and hopefully the insights from this study will spark new interest, critical ideas, robust discussions and innovative projects on how to fill a largely open sport event canvas.

CRediT authorship contribution statement

David M. Herold: Writing – review & editing, Writing – original draft, Validation, Supervision, Data curation, Conceptualization. **Tim Breitbarth:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Conceptualization. **Anja Hergesell:** Writing – review & editing, Validation, Formal analysis, Data curation, Conceptualization. **Nico Schulenkorf:** Writing – review & editing, Validation, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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