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Bracketing sustainability: Carbon footprinting March Madness to rethink sustainable tourism approaches and measurements

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A R T I C L E I N F O

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A B S T R A C T

Amidst a backdrop of a global climate emergency, tourism continues to contribute to Earth's carbon footprint. In recognition of the negative environmental impacts of sport and event tourism, this study quantifies the carbon footprint of the 2019 National Collegiate Athletic Association Men's Basketball Tournament by considering the travel of fans and teams, food, waste, lodging, and stadium operations. The footprint is approximated at 210 million kilograms of carbon dioxide equivalents. Broken down, this equates to about 500 kg per participant. Travel is responsible for nearly 80 percent of that total which underscores the positive relationship between distance traveled and greenhouse gasses emitted in tourism. This paper presents a valuable linear model by which carbon footprints can be calculated with accessible data. This will, in turn, allow for the democratization of sustainability models for industries and organizations to introspectively quantify their environmental impact as an initial assessment for internal purposes or comparison to outside audits. This study's results demonstrate the need to make mega sport-tourism events like March Madness more sustainable. However, this can only be done by tourism managers closing the environmental value-action gap that too often manifests as inaction. By leveraging quantitative frameworks such as this study's methodology, sport and event managers can more easily use readily available data to evaluate their event's environmental impacts and thus begin to actionably mitigate their negative contributions to global climate change in more targeted ways.

1. Introduction

Our planet remains on the precipice of a climate change crisis. Anthropogenic contributions to the global warming phenomenon must be curbed to avoid irreversible damage (Steffen et al., 2018) by decreasing the emission of greenhouse gasses (GHGs) around the globe (Ripple et al., 2020). While the global political community (UN Human Rights Council, 2019) and United States (US) government (Wuebbles et al., 2017) are formally in agreement on the sources of and solutions to climate change, a rise of neoliberal populism globally has stymied progress on this front as a result of harmful national environmental policies (McCarthy, 2019). Despite decreased emissions, this reduction is not enough to provide relief from the larger system of global climate change. Governments worldwide still need to reduce emissions while balancing their economies across all business sectors, including sport and tourism (Le Quéré et al., 2020).

Scholars have long acknowledged the significant role tourism plays in contributing to global climate change, and tourism accounts for 8% of the global carbon budget (Lenzen et al., 2018). Sport and event tourism specifically proliferate this contribution (Collins et al., 2012; Pereira et al., 2017). Sports tourism must assess its impact and determine ways to minimize its impact to contribute positively to global sustainability efforts (McCullough et al., 2020a). Ecologically-minded sport and event managers, along with sport tourists and spectators, will need to expand industry practice boundaries with more concerted efforts to embody ecocentric management principles (Sartore-Baldwin and McCullough, 2018). One way sustainable tourism and event organizers can lead is to assess their environmental impact using quantitative modeling with internal and external data (Torres-Delgado and Saarinen, 2014).

This case study implements a carbon footprinting model for the 2019 National Collegiate Athletic Association's (NCAA) Division I Men's Basketball Tournament to demonstrate the application of Cooper's (2020) carbon footprint model to assess the event's footprint. The annual tournament is a prime example of sports tourism featuring 67 different basketball games across the US. We quantify the GHG emissions associated with tourism actors' participation (via travel, lodging,

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food, waste production, stadium operations) throughout the entire tournament. To do so, we employCooper's (2020) linear carbon footprinting model. However, our study builds upon Cooper's model in several key ways: specifically, our analysis embarks on using new literature-based data points to quantify emissions, evaluate emissions for both fans and participants, assess the carbon footprint of an entire multi-location tournament in the US, and utilize readily accessible external data (i.e., publicly available attendance figures, school and game locations, peer-reviewed emissions figures). The inputs used in our analysis are consistent with McCullough et al. (2020b) recommendations to expand the assessment of environmental impacts of sporting events to include production (i.e., stadium operations, waste production, food) and consumption (i.e., travel, lodging), or Scope 3 impacts, of sporting events focusing on the impacts generated per spectator.

Our study's results reinforce the consequential nature of sports tourism and highlight the need for more carbon footprinting in both sport and its disaggregated industries. Furthermore, Cooper's (2020) footprinting methodology presents a valuable linear model by which carbon footprinting can be conducted where organizations do not have access to highly precise input data. The model can be applied in organizations with varying access to and quality of data (e.g., data-rich vs. data-poor) that can estimate the organization's environmental impact. The US Environmental Protection Agency (2019) notes that organizations may have varying data quality when assessing their scopes of environmental impact. Over time, the EPA (2019) states that data quality will improve with more concerted efforts to determine the impact. While the results may hold a wide range of uncertainty, the use and expansion of this data-poor carbon footprinting model will allow for greater democratization of sustainability quantification for event planners of various scales of sporting events and in industries and organizations that seek to assess their environmental impacts and develop strategic plans to mitigate those impacts (Boulton et al., 1982).

2. Literature review

2.1. *Environmental footprinting*

Researchers use quantitative models to enhance sustainable tourism development (Torres-Delgado and Saarinen, 2014). One such popular model by which researchers and tourism managers assess tourism events' environmental impacts is footprinting. A footprinting model is a "quantitative measurement describing the appropriation of natural resources by humans" (Čuček et al., 2012 p. 10). The environmental footprint is popular for measuring the impact of tourism events (Collins et al., 2007; Collins and Cooper, 2017) by measuring the total land and sea area needed to support their function (Pandey et al., 2011). Alternatively, the carbon footprint model quantitatively approximates the total GHG emissions associated with an event or area over a defined period in terms of weight. Despite the name, the model does not exclusively measure carbon emissions but instead measures many GHGs and normalizes the results in carbon units (Pandey et al., 2011). This is a distinct benefit of implementing a carbon footprint (Wicker, 2018) and its ability to account for direct and indirect emissions associated with the target study event or area (Chester and Horvath, 2009; Collins and Cooper, 2017).

Therefore, the carbon footprint provides the tourism industry with a flexible and robust way to evaluate its progress in reducing its impact on the warming of the Earth and the degradation of air quality. Because of tourism's continued role in contributing to the global carbon budget (Lenzen et al., 2018), studies continue to evaluate the GHG contributions of tourism for both events (El Hanandeh, 2013; Filimonau et al., 2014) specific economic sectors (Debbage and Debbage, 2019) and places (Dwyer et al., 2010; Pandey et al., 2011). When used conductively and critically, environmental and carbon footprints can provide sport and event managers with highlights of both areas of current successes and failures where GHG emissions are concerned (Collins et al., 2012; Cooper, 2020; Pandey et al., 2011).

2.1.1. *Uncertainty of data*

It should be noted that environmental impact evaluations such as footprinting models, which utilize a life cycle analysis approach (Tukker, 2000), are only estimations because they lack a universally standardized methodology (Bergmann, 2013; Gallo et al., 2020). Environmental impact evaluations require the use of external data and, as a result, rely on assumptions, which introduces uncertainty of results (Tenney et al., 2006). Therefore, each footprinting model requires decisions to be made by the modeler that affects the scope of the results. However, the uncertainties of the data must be communicated in methodology, analysis, and discussion (Cardenas and Halman, 2016; Lees et al., 2016; Tenney et al., 2006). Capturing the full scope of GHG emissions from tourism is difficult because of the sector dynamics that include various point and nonpoint source emitters before, during, and after traveling (Gössling, 2013). As a result, uncertainty is prevalent in environmental impact evaluations across the sector. For example, geography is a significant factor necessary to consider in ascertaining the actual emissions of GHGs as "carbon footprints are likely to vary greatly between destinations" (Dwyer et al., 2010, p. 358).

The place-based and situational specificity of tourism-related emissions makes it challenging to translate emissions values to other tourism markets (Filimonau et al., 2014) and across multiple geographic scales (Sun and Higham, 2021). Regardless of the chosen market or scale, the choice of the footprint's input emissions values and exactly how they are calculated can yield different results (Padgett et al., 2008). Such differences in results can span a spectrum from estimations (i.e., less uncertainty) to the analysis of uncertainty (i.e., less precise data; He et al., 2018; Scrucca et al., 2020). However, even with the drawbacks of analyzing uncertainty, the quantification of emissions can help broadly identify important emissions sources. It can help direct management strategies to increase operational efficiencies and reduce those emissions (Pandey et al., 2011). This approach is especially welcome in new contexts considering disaggregated industries into aggregated products such as sport (Jóhannesson et al., 2020).

2.1.2. *Uncertainty of data and the sport sector*

Sport and event managers ought to be ecocentric leaders (Sartore-Baldwin and McCullough, 2018) by being more aware of the environmental impacts of sporting events to address the opportunities to improve environmental performance. Thus, decision-makers need to assess their events' environmental impact (McCullough et al., 2020b) and develop strategic plans to mitigate their environmental impact when possible. As the sport sector and specific organizations expand these industry practice boundaries to assess their environmental impact, information gatekeepers rely on external data despite the uncertainty surrounding such data sources (Boulton et al., 1982). That is, sport and event managers may rely on readily accessible data at first to conceptualize the breadth of the organization's environmental impact. This initial analysis can also be used for internal comparison purposes to evaluate against external audits and develop strategic planning. For example, an external contractor may conduct an environmental impact evaluation, and the sport organization can use this linear model as a comparison. Similarly, the model can be used internally to estimate environmental impacts to calculate carbon offset costs of the event.

However, it should be noted that the uncertainty of data and the results of the models in which they are used are commonplace in the sport sector. For example, sport and event managers regularly use data with a high degree of uncertainty to assess their event's economic impact – often resulting in (favorable) overstatements of economic impact (see Crompton, 1995). Nonetheless, sport and event managers conclude and communicate these results used by government officials and others in decision-making processes (Kellison and Kim, 2014). As a result, it is acceptable to draw upon the same data sources to assess sporting events' environmental impact to conceptualize an events' environmental impact (McCullough et al., 2020a).

2.1.3. Environmental footprinting in sports tourism

Footprinting models have been applied to sports tourism across global (Gallo et al., 2020), national (Pereira et al., 2017), regional (Cooper, 2020), and local (Gibson et al., 2012) scales. Researchers continue to publish on the carbon footprints associated with active sports tourism (Wicker, 2018), but more focus is typically directed towards large-scale sporting events (Collins et al., 2012). While various international case studies of tourism events are relatively common, there is a dearth of comprehensive carbon footprinting studies focused on sports tourism in North America, specifically intercollegiate athletic events.

Dolf and Teehan (2015) focus on the LCA carbon footprinting of a Canadian intercollegiate athletics department. This work is beneficial, practical, and well-executed to serve as a foundation for further analysis because of how they analyze the tourism sectors of travel, accommodation, food, venue, and material waste to generate an aggregate carbon footprint for sporting events. Dolf and Teehan (2015) found that an entire intercollegiate athletic season at a Canadian university generated 8.3 million kg carbon-dioxide GHG equivalencies (CO_2eq). Yet, US athletic departments can exceed these totals in one season of football games (Dolf and Teehan, 2015). The past decade has seen an increase in carbon footprint assessments of college (American) football events (Cooper, 2020; Edwards et al., 2016; Triantafyllidis et al., 2018). Despite this focus on singular sporting events, little attention has been devoted to multicity sport tournaments (i.e., March Madness). This study seeks to fill this gap by quantifying the men's intercollegiate basketball tournament's carbon footprint at multiple sites across the US.

2.2. March Madness and uncertainty of large event data

The NCAA Division I Men's Basketball Tournament (i.e., March Madness), unlike other prominent American sporting events (e.g., Super Bowl, Daytona 500), is held over several weeks at geographically dispersed locations. Such a dynamic event takes on considerable challenges when conducting an environmental impact evaluation, especially surrounding the uncertainty of data used in the analysis. Specifically, Tenney, Kværner, and Gjerstad (2006) note that predictive environmental impact evaluation models differ from post-hoc assessments of environmental impacts. However, they challenge that such assessments should disclose such limitations in their data. To this end, it is important to address uncertainties in environmental impact evaluations, especially when communicating the results (Cardenas and Halman, 2016; Lees et al., 2016; Tenney et al., 2006; Ziyadi and Al-Qadi, 2019). This study addresses the uncertainty of our macro-level data and the metrics we use to analyze secondary sources. Furthermore, assessing the environmental impact of such an expansive sporting event (i.e., March Madness) differentiates our approach from prior work focused on centralized sporting events (Collins et al., 2007; Dolf and Teehan, 2015; Pereira et al., 2017) using organizational level data (i.e., microdata). Thus, we note the sources of such information and the process and procedures to gather and analyze our data and discuss the resulting assessment in the following section.

3. Methods

3.1. Model design

The current model (Fig. 3) was designed to approximate the GHG emissions of the 2019 NCAA Men's Basketball Tournament and contribute to the discussion of sustainable sports tourism by highlighting the challenges of carbon footprinting sports tourism events. To ascertain the environmental status of the tournament, attendance figures and teams playing per session provided the key inputs of the number of tourists and distances traveled. All data were entered into a PostgreSQL (PSQL) database table. All calculations were conducted in the database using Structured Query Language (SQL) and the PSQL spatial extension PostGIS for geoprocessing. PSQL database methodologies utilizing PostGIS are efficient for processing and storing large geospatial datasets, making them advantageous for quickly computing mathematical calculations dependent on spatial variables (Nguyen, 2009).[1]

The model for calculating the per-person carbon footprint (CFpp) follows as such:

$$CFpp = Df(s) * (F + S + W) + Tf(d) * 2 + cH * (Df(s) - 1)$$

Where D = number of days traveling which is a function (f) of success (s) in tournament setting, F = food-related emissions, S = stadium operations-related emissions, W = waste processing related missions, T = transportation emissions which are a function (f) of d = distance, and cH = hotel emissions depending on tourist's city.

The model for calculating aggregate level carbon footprints (CGfa) for a game, host destination, team, or an entire multi-game tournament follows as such:

$$CGfa = \sum CFt + \sum CFs$$

Which takes the sum ($\sum$) of the CFpp of associated team members (CFt) and spectators (CFs).

3.1.1. Model assumptions

To reiterate, we are proposing a linear model using publicly accessible macro-data instead of organizational or micro-data. Our model uses existing formulas from sport, tourism, and other LCA footprinting studies to leverage data from disaggregated industries that collectively produce sporting events. In short, we are conducting neither a statistical nor a geostatistical analysis. Instead, we position this model and its importance as being an industry-specific guideline that is easily accessible to apply to future academic research and practical applications, especially in the relatively understudied area of sport tourism that requires additional inquiry and approaches (McCullough et al., 2020b). Therefore, the results of our analysis depend strongly on both the assumptions we made when constructing the model and the fact that "the GHG emission factors" we employ are all "themselves subject to uncertainties [that] are difficult or impossible to quantify" (Berners-Lee et al., 2012 p. 188–189). We seek here to document and justify the model's embedded assumptions (Filimonau et al., 2011 p. 1928).

As a proxy for high-precision ticketing data, each session's announced paid attendance was divided evenly between the four schools competing in that session. In addition, the teams' location was used as an approximate origin point for all of its fans who attended the sessions due to the observed negative relationship between the number of fans and the distance to the program they supported (Dolf and Teehan, 2015). While both air and land-borne tourism travels are generally not undertaken from origin to destination in a direct, straight line (Debbage and Debbage, 2019), this model uses Euclidian distance to model "as the crow flies" travel patterns for efficiency.

3.1.1.1. Team assumptions. Pereira et al. (2017) show the need to include a team's travel as a part of a carbon footprinting analysis of sports tourism. The NCAA Sports Sponsorship and Participation Database show that the average number of team members for a Division I basketball team in 2019 was 15.7. Additionally, Pereira et al. (2017) and Dolf and Teehan (2015) demonstrate the necessity to include staff. NCAA regulations state each college basketball team may employ four total coaches. A rough sample of athletic websites of teams participating

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[1] The model was run in a PSQL database using the PostGIS extension. A full open-source online repository of the postgres and python code used to run the calculations as well as the initial team and host city locational datasets can be found at https://github.com/cooperjaXC/covid_marchmadness.

in the 2019 tournament revealed an average staff of twelve coaches, graduate assistants, and athletic trainers. Therefore, each session uses the approximate total number of people as members of each participating team as a sum of players and staff (n = 28) in the model. However, teams and fans did not always operate in the same way; the specifics are detailed below each emissions sector (Table 2).

The NCAA tournament comprises geographically dispersed multi-day mid-level events that vary in fans' and teams' length of stay, unlike other sports tourism events in one location. Each participating team in the NCAA Men's Tournament stays at a site for no more than two games. There is always a rest day between these games, meaning that when accounting for a day before to travel and a day after to return, no single trip is longer than five days. However, if a team loses in the first game of the trip, it would go home early and incur a three-day stay. Many athletic departments to reduce travel costs have travel policies to return to campus no more than 36 h after a loss. Yet, a tourist's (i.e., fan's) length of stay varies and depends on many factors (Borges et al., 2020).

3.1.1.2. Fan assumptions. The goal of the carbon footprinting model is to assess the GHG emissions from the total number of fans, not ticket holders. For example, a fan who traveled to see their team in the first session will stay to watch the second game if their team wins. To this end, the NCAA reports paid attendance per session. However, to ascertain the total number of fans per team per trip, we averaged the two calculated per-session attendance figures per team at a single location for more holistic averages. For example, to demonstrate this model, 16,512 fans attended a first-round session featuring two games involving four teams in Des Moines, Iowa. Louisville, one of the four teams competing in the session, was allotted in the model (16,512 total fans/4 teams =) 4,128 fans. Each of those fans was modeled to have traveled the 480 Euclidian miles from Louisville, Kentucky to Des Moines, Iowa. Louisville's team (n = 28) also traveled the same distance to and from Des Moines. They lost in the first round to Minnesota, so their trip spanned three days. Minnesota, however (4,128 fans + 28 team members), had five days since they won their first game and played in the second round. Fig. 3 models this scenario visually.

3.1.2. Model summary

Carbon footprinting models provide at best estimations of an event or location's contributions to the global carbon budget. It is recognized that this model provides an analysis of uncertainty of the emissions process using readily available data. This study's model highlights the dynamics of sustainability within sports tourism, specifically Scope 3 impacts of sport and entertainment events (McCullough et al., 2020b). The results contribute to the broader conversation on the nature and measurements of sustainable travel and industry in general and multicity sports events specifically. So, while the uncertainty of the overall results is noted, this methodology makes substantial inroads towards an innovative and more accessible approach to quantifying event emissions and sustainability that can be used by sport and event managers when assessing their environmental footprint with readily available data.

3.2. Descriptive statistics

The NCAA reported that 689,753 fans attended the 67 games of its men's basketball tournament in 2019. Twenty-one percent of the tournament's overall emissions came from the Final Four event in Minneapolis, where paid attendance for three games reached 144,885. Following the model, the total number of fans and team members who traveled to NCAA March Madness games in 2019 is estimated to have been 420,630. The median number of this inclusive attendance per team per trip was 4,040 fans and team members. The median distance from campus to the game for the tournament was 4,059 km (658 miles). An initial map of schools, host cities, and the routes between them can be found in Figs. 1 and 2.

3.3. Carbon footprint inputs

While high-level quantitative or qualitative tournament-specific data were unavailable as inputs to this model, existing literature provides a thorough review of tourism sectors contributing to the event's GHG emissions (Collins et al., 2012; Dolf and Teehan, 2015). Therefore, following Dolf and Teehan (2015) approximation of a carbon footprint for a singular collegiate athletic event and McCullough et al. (2020b) recommendation for a broader view of the environmental impact of sporting events, five input sources were evaluated: transport, lodging, food, waste, and stadium operations. The specific carbon footprint inputs are highlighted in Table 2 and are discussed further in the space below.

3.3.1. Transport

Tourism literature consistently demonstrates that the mode of transport people take to their destinations is the most significant contributor to the total carbon footprint of travel (Dwyer et al., 2010; Lenzen et al., 2018). This is true for sports events as well (see Dolf and Teehan, 2015). However, without specific data on tourists' travel patterns in question, it is difficult to ascertain which mode of transport basketball fans use to travel to NCAA tournament games. Dolf and Teehan (2015) note that transportation in terms of university-related activities exists for commuter transport but not for varsity sporting events. The transport mode of choice (i.e., plane, bus, or car) for tourists is a complex and multifaceted decision that depends on distance, price, and past experiences (Nerhagen, 2003).

3.3.1.1. Flight travel. Approximating the environmental impact for tourists requires the origin, the ultimate destination, and quantity. For this study, Filimonau et al. (2014) value of 0.15 kg CO_2eq per person per kilometer was used. This study importantly uses both CO_2eq that account for multiple GHGs emitted and a life-cycle analysis (LCA) that measures upstream and eventual downstream environmental emissions and impacts from the production and eventual destruction of materials involved in the transport. This is important because "'indirect' GHG emissions make a profound contribution to the total carbon footprint" (Filimonau et al., 2014). This European 0.15 kg CO_2eq/person/km value is very close to Pereira et al. (2017) UK-based LCA CO_2 eq (0.147)/p/km value for flights taken by English Premier League football teams. While LCAs are not a perfect GHG emissions measure (McCullough et al., 2020b), their ability to incorporate upstream emissions can allow for a more comprehensive total accounting of tourism emissions. Thus, to account for GHGs other than just carbon dioxide and use an LCA study to match our transportation model inputs (below), we used Filimonau et al. (2014) LCA CO_2eq value for air travel. While a GHG value from the same market (e.g., the US) would have been preferable, Graver et al. (2018) did not account for non-carbon or upstream LCA GHG emissions was not consistent with our other model inputs. Furthermore, the similar western air travel infrastructure and patterns of the US and Europe (Graham and Shaw, 2008; Khadaroo and Seetanah, 2007) will render Filimonau et al.'s (2014) CO_2eq value appropriate for this model.

3.3.1.2. Automobile travel. Fans and teams are assumed to use land-borne motorized transport modes to travel to and from basketball games who travel less than a 500 km threshold. Dolf and Teehan (2015) and Pereira et al. (2017) find that teams use coach buses to travel when they are not flying, and Cooper (2020) and Loewen and Wicker (2021) observe the prominence of automobile transportation for fans of intercollegiate athletics in the US and Bundesliga football in Germany, respectively. Dolf and Teehan (2015) values for both coach (0.058 kg CO_2eq per person per kilometer) and automobile (0.136 kg CO_2eq per person per kilometer) were used for this model because of its North

American market and use of LCA; reporting values in a life-cycle format is a responsible and holistic way to evaluate the carbon footprint of tourism and passenger transport (Chester and Horvath, 2009). Other studies have proposed various emissions values for coach or automobile (Filimonau et al., 2014; Pereira et al., 2017), but Dolf and Teehan (2015) use of LCA measured in CO_2eq in a North American market make their approximations useful for this study. Regardless of the mode of motorized transport chosen, it is expected that tourists' travel will significantly affect the sustainability of their event destination (Collins and Cooper, 2017).

3.3.2. *Lodging*

Lodging, or hotel stays, have associated GHG emissions that impact tourism's overall sustainability (Filimonau et al., 2011; Ricaurte and Jagarajan, 2019). For hotel stays in this model, Ricaurte and Jagarajan (2019) most recent hotel benchmarking index values were used to approximate the per-room emissions in each of the 14 host cities for the 2019 NCAA tournament. Each of these cities was represented in the dataset, and a summary of these values can be found in Table 1. To standardize this data at the per-person unit of analysis, Cooper's (2020) estimation of an average of two people per occupied hotel room in the US by dividing a hotel's occupied room GHG value by two was used. Each of Ricaurte and Jagarajan (2019) corresponding occupied room GHG values were halved and applied to this model for each NCAA tournament market.

3.3.3. *Waste*

Similarly, waste production contributes to the overall sustainability of an event. This is a challenging input to approximate emissions because GHG levels can vary widely based on the market where the waste processing occurs, the various ways in which waste is ultimately managed, and whether intentionally sustainable waste management practices are employed (Kaplan et al., 2009; Pereira et al., 2021). This study's model used Cooper (2020) value of 1.1 kg CO_2eq per person per day.

3.3.4. *Food*

The production, transportation, and food consumption are also difficult to footprint because these nuanced processes involve GHG emissions (Borsellino et al., 2020). However, it should not be overlooked as it can contribute significantly to the overall emissions for an event (El Hanandeh, 2013). Though the literature on this input, particularly in a tourism context, is sparser, Berners-Lee et al. (2012) provide a valuable LCA carbon footprint of an omnivorous British diet that approximates 7.4 kg CO_2eq per person per day. Virtanen et al. (2011) found a similar LCA value of 7.7 kg CO_2eq in the Finnish market. Because European and US food production and consumption patterns are similar (Borsellino et al., 2020; Gaugler et al., 2020), Berners-Lee et al.'s UK value is used as a proxy for otherwise lacking US data with the added benefit of accounting for the upstream production and transport of the food before it is consumed by tourists across the fourteen NCAA tournament destinations.

3.3.5. *Stadium operations*

Finally, the fourteen facilities that hosted the tournament have emissions associated with hosting three to six basketball games and daily operations. Dolf and Teehan (2015) approximated this value for five Canadian university basketball games, but the role of intercollegiate athletics in Canadian society is not as pronounced as it is in the US. Therefore, Hedayati et al. (2014) carbon footprinting of an Australian Rules football game is useful for this study. While the markets and sports differ, the attendance figures for the events are similar. More importantly, on a conceptual level, Hedayati et al. used an LCA model. This is important for modeling stadium emissions because it accounts for the static pollution from these facilities sitting empty most of the year. However, even when this is the case, a significant portion or even a majority of a facilities' total environmental impact can be incurred from simple "baseload operations" (Hedayati et al., 2014). Hedayati et al.'s approximation of 14.74 kg CO_2eq per person per game was used in this model to account for this.

3.4. *NCAA tournament carbon footprint model*

Considering these inputs and assumptions, the model formula for the 2019 NCAA Men's Basketball Tournament per-person Carbon Footprint follows as such:

$$CFpp = (Days\ at\ Site * (Food = 7.40 + Stadium\ Ops = 14.74 + Waste = 1.10)) + (Transport = [Air = 0.15,\ Car = 0.136,\ Bus = 0.058] * [km\ traveled]) * 2 + (Hotel = (see\ Table\ 1) * (Nights\ at\ Site))$$

The CF of one team at one game (CFtg) would be:

$$CFtg = (CFtm * 28) + \left(CFs * \left(\frac{Session\ Attendance}{4}\right)\right)$$

4. Results

Our model estimates that tourism activities from 2019 Men's March Madness resulted in a carbon footprint of just under 210 million kg CO_2eq. Divided by the total number of players, coaches, and fans, this equates to just under 500 kg CO_2eq per participant. The greatest contributor to the emissions total by sector was tourist and team travel which accounted for nearly 80% of the total carbon footprint (Table 3). Though hotel stays were the second most significant contributor (6.83%), it is only slightly above both food (6.37%) and stadium operations (5.90%), respectively. When analyzed by the host city (Table 4; Figs. 4 and 6), the results show the role of attendance and distance traveled on the total quantity of GHGs emitted. Minneapolis, the host city of the Final Four, had the most emissions by a wide margin. This final and most heavily attended round of the tournament accounts for about 18% of the tournament's total emissions despite only featuring three games. Although, unlike other tournament rounds, the Final Four is played in an American football-sized facility. The reported attendance for the 2019 championship game was 72,062. The sheer number of people who attend the last three games of the tournament ($n = 144{,}773$) render it the most emitting session in the tournament.

The quantity of games makes a difference too. The eight first- and second-round sites each host six games, while later rounds host only three. Table 4 shows that this translates to higher emissions totals for the longer, earlier rounds. The only city that hosted a later round and recorded similar emissions numbers was Anaheim, California. Anaheim hosted only three games and had much better hotel emissions rates than its peers due to the state of California's aggressive climate policies (Mazmanian et al., 2020). The teams who traveled there had to cover more miles on average than any other city (except San Jose, California). This West-Coast phenomenon becomes more pronounced when normalized to GHGs per capita (Figs. 5 and 7). Anaheim, San Jose, and Salt Lake City recorded the most GHGs per tourist. These three most-western cities hosted teams predominately from the central or eastern parts of the US (Figs. 1 and 2). This reinforces the extent to which transport is the most direct and greatest contributor to a tourism carbon footprint (Lenzen et al., 2018).

When broken down by team (Table 5), the results reinforce the importance that attendance and distance traveled contribute to the carbon footprint of sports event travel. The Final Four teams have the most significant footprint because they competed in more games than any other team in the tournament and the sheer quantity of people (i.e., players and coaches) who traveled to Minneapolis. The teams that did not have a large carbon footprint were located close to their game location, and the teams that lost their first game were eliminated from the tournament. Cincinnati, Vermont, and Gardner Webb all lost in the first round at a venue located under 200 miles away from their respective campus. Not only did their short appearances send both fans and players home early, the journey back to campus required ground, not air, transport based on the assumptions of the model. The role of distance is emphasized when normalizing GHG emissions per capita, as those teams with the highest values were those who had to travel across the country to play their games (Fig. 5). This included both east coast teams playing on the west coast and vice versa.

5. Discussion

Our analysis found an approximated total of about 210 million kg CO_2eq for the 2019 NCAA Men's March Madness basketball tournament. This dwarfs an entire Canadian intercollegiate athletic season (Dolf and Teehan, 2015: 0.96 million kg CO_2eq) or any single American college football game (Edwards et al., 2016: 2.4 million kg CO_2eq) or season (Cooper, 2020: 38 million kg CO_2eq). This difference is attributed to the number of sport tourists, players, and staff involved in these calculations. Because the model divided each session's attendance equally between its participating teams, we assume the estimates may be higher than actual emissions totals. Yet, we did not include the travel emissions of media broadcasters, television camera crews, officials, facility staff, and volunteers in this model. Despite the uncertainty of analysis by overestimating in one area (i.e., fan travel emissions) and excluding another (i.e., media, officials, facility staff, volunteer travel emissions), our result is consistent with other tourism studies that include air travel as a part of their models (Filimonau et al., 2014; Edwards et al., 2016; Pereira et al., 2017; Gallo et al., 2020).

Other comparative studies found a more significant proportion of tourism's overall carbon footprint came from hotel GHG emissions (Filimonau et al., 2014; Edwards et al., 2016; Pereira et al., 2017). However, our findings may differ because these prior studies used LCA. For example, Ricaurte and Jagarajan (2019) only measured nightly emissions for specific markets, limiting the scope of their emissions findings to just the visitors' stays. Our analysis takes a broader approach to capture the entire time the room was estimated to be paid by the sport tourist than the nightly emissions.

The uncertainty of data extrapolated across all annual sporting events should concern the global impact of mega sporting events. From a holistic sustainability perspective, such sporting events have an annual and sizable carbon footprint compounding year after year. In economic terms, the demand for spectators to attend such benchmark events encourages further expansion for increased revenues – perhaps without limits. This demand then becomes a structure for increased economic returns and increased environmental impacts. The detrimental impacts of an unfettered economic pursuit need to be tamed to support the urgent need to reduce carbon emissions. If sports managers continually exaggerate, claim, and publicize their events' local economic impacts (Crompton, 1995; Pereira et al., 2021), they should also acknowledge, account for, and take responsibility for the environmental damages they incur (Sartore-Baldwin et al., 2017). As such, the harmful effects of sporting events, and the sport sector as a whole, should be a part of the narrative for responsible consumption and production of sport (McCullough et al., 2020b). For this to occur, easier and more accessible environmental impact evaluations that utilize need to be available for internal sustainability analyses. Event organizers can use assessment tools like the linear model presented here to estimate their events' impact to develop actionable strategies to offset emissions.

5.1. Limitations

Despite the strengths of our model to footprint a multicity multi-city event, there are limitations that researchers should consider when applying this model to other contexts. First, attendance for collegiate athletic events fluctuates based on multiple factors including the recent prominence or success of a fan's chosen team (Falls and Natke, 2014). Specifically, there is a significant negative relationship between a fan's location and the competition's location (Cooper, 2020). Considering this, and as outlined in our assumptions of the model (i.e., team and fans), the data presented does not account for fans coming from other geographical areas other than where the two competing schools are located.

Second, sports fandom is a complex socio-spatial process intertwined with economic and social factors that do not map perfectly to the central-place theory model (Cooper and Davis, 2019; McCullough and Kellison, 2016). Acknowledging this intricacy and the nature of our macro-data, subsequent results were limited—more precise (micro)data referable (Edwards et al., 2016; Cooper, 2020). Our analysis of uncertainty differs from prior research (Cooper, 2020) when survey data is inaccessible. Sport and event managers can use the proposed model using their internal (micro)data to improve their assessment of fan travel emissions.

Finally, there is inherently error introduced into the model when translating carbon emissions values across markets (Dwyer et al., 2010). There are not exact carbon emission values for the sport sector, in general, or sport events, specifically. This study introduces values from disaggregated industries to assess the dynamics of the environmental impact of sport events as suggested by McCullough et al. (2020b) and empirically tested on smaller scales (Cooper, 2020; Dolf and Teehan, 2015). The measures we used in this study were also not presented initially with uncertainty calculations and are thus absent from our analysis, but as noted before, all these measures “themselves subject to uncertainties [that] are difficult or impossible to quantify” (Berners-Lee et al., 2012 p. 188–189). We seek to provide transparency about the model’s embedded assumptions (Filimonau et al., 2011 p. 1928).

Even as the results of carbon footprinting models ingest input data in this way, these findings may not be specifically accurate in the final approximation of an area or event’s GHG emissions contributions. Thus, external communication of these figures should be done with extreme caution and qualified appropriately. Yet, while this model ultimately yields rough quantitative GHG emissions estimations, it is still beneficial and worthwhile to consider a conceptual model and initial method of sustainability analysis. Furthermore, traditional carbon footprints are calculated on the idea of absolute, bounded national spaces and do not adequately account for nuanced, relational, and global geographies of GHG emissions (Bergmann, 2013). Thus, while striving for precise and market-specific input data will enhance the results’ accuracy, peer-reviewed market-adjacent inputs like those leveraged here will still lead the analysis to illuminate a complete picture of an event’s emission especially considering areas often overlooked in environmental impact evaluations (McCullough et al., 2020b).

To assess the certainty of the results of input-based models, sophisticated error quantification measures such as sensitivity analyses and Monte Carlo simulations have successfully been utilized in carbon footprints (Cimini and Moresi, 2016; Röös et al., 2010). These measures could help understand the dynamics and variables of error within sustainability models that rely on secondary and extra-market input data. Therefore, future studies should strive to leverage highly precise input data (e.g., participant travel routes, means, and habits) and quantify the error through a sensitivity or uncertainty analysis when attempting to quantify an emissions footprint. This will give further insight into both the sustainability of the event and the confidence of the results. Specifically, governing bodies (e.g., United Nations, International Olympic Committee) and certifying agencies (e.g., Green Sports Alliance, Council for Responsible Sport, Global Reporting Initiative, International Standards Organization) should work closely with sport and event managers to develop sport-specific values to evaluate and compare emissions figures to the footprints of various sport events universally worldwide.

5.2. *Implications*

In terms of strategic development, the NCAA, like other sport organizations, should be proactive in advancing towards a more sustainable system (Cooper and Alderman, 2020). While sports organizations are engaged in environmental sustainability initiatives, there still is a deep environmental “value-action gap” (Blake, 1999) when operationalization occurs (Casper et al., 2012). For example, sport and event managers are generally unaware of the environmental impacts of their sporting operations (Casper et al., 2012). In addition, most collegiate athletic departments and the NCAA are often not proactive in assessing their environmental impacts (Pelcher et al., 2020) and lack the expertise to analyze complex data and develop strategic plans to address their environmental impacts (Casper et al., 2012). Our study makes this type of assessment more accessible. An event’s increased ability to conduct internal evaluations and use that information to address the event’s environmental impact thereby bridges the value-action gap. In the present time, as sport and event managers are becoming progressively more environmentally conscious (McCullough et al., 2016), it is increasingly vital that they have tools and methods to employ to respond to social pressure to take measurable action to enhance sustainability.

Specifically, managers can use existing and accessible data (e.g., ticket purchase information, hotel occupancy) to gain a general sense of their carbon footprint. Strategic planning generally starts with inexact data to develop a strategic approach (Boulton et al., 1982). This is also true for sport organizations as they begin their environmental efforts and address their environmental impacts (McCullough et al., 2016, 2020b). Sport and event managers should not focus solely on their GHG emissions from travel; assessing their GHG emissions ought to extend to all five categories that we examined here (travel, lodging, food, waste, stadium operations) and how the organization and structure of sports tourism events can aid or inhibit its sustainability efforts.

This expanded view notes that environmental impacts are missed through LCA assessments during the production and consumption of a sporting event (McCullough et al., 2020b). Thus, sport and event managers should actively assess their environmental footprints to address and mitigate these impacts when possible and offset the remaining and unavoidable GHG emissions. As sport managers begin to evaluate their environmental impacts, their processes and quality of data is likely to improve (McCullough et al., 2016).

Academics and sport and event managers can leverage this study’s approach to a preliminary assessment of the carbon footprinting of events. The benefit of this approach is that sport and event managers can use data on hand (i.e., ticket sales data) to calculate the carbon emissions from fan travel to an event, whether that be multicity and multi-stage tournaments or singular events. In one such application, this approach can be used by other watchdog organizations to evaluate claimed environmental impacts of sport events and organizations. For example, if a sport event or organization claims an environmental footprint, environmental groups and academics can check those claims against publicly available data analysis. For example, the Seattle Sounders have claimed to be the first carbon neutral team in North America, yet their claimed GHG emissions are not consistent with the proportions of GHG emissions from academic research (Collins et al., 2012; Dolf and Teehan, 2015).

Even while amalgamating data and emissions sources from different tourism markets results in greater uncertainty for this study’s model, its utilization can work to democratize a methodology of sustainability quantification to those sport and event managers who would otherwise be forced to outsource the analysis to “experts.” And, increasingly higher-quality input data will further help refine output GHG values for various scopes of the sport organization’s or event’s GHG emissions and even compare to similar entities. For example, signatories of the United Nations Sport for Climate Action Framework pledge to reduce their carbon emissions consistent with the Paris Climate Agreement. Eventually, these signatories will provide data to demonstrate the fulfillment of their commitment to emission reductions. However, common conceptualizations of what aspects are assessed and by which assumptions have not been determined. These aspects are necessary to determine, especially considering the accessibility these signatories have to data and the expertise to analyze their carbon emissions. This allows sport and event managers to make an initial assessment of their environmental impacts and then develop ways to mitigate their carbon footprint.

We highly recommend that sport practitioners seek to refine their data collection as they advance their efforts to calculate their carbon footprints. That is, sport practitioners should strive to ensure the strictness and accuracy of their data to the best of their capabilities and acknowledge the areas of their analysis that remain uncertain. This can and should be communicated internally. Carbon footprinting is an ongoing process continually being refined as sport organizations and events advance their capabilities to assess their environmental impact. This process of improving techniques over time is already noted among environmental regulatory agencies (EPA, 2019), management decision-making literature (Boulton et al., 1982), and within sport-specific research (McCullough et al., 2016, Trail and McCullough, 2021). As sport organizations, like any other organization, seek to advance their environmental efforts, there will be methodological and technological improvements to better assess their environmental footprint over time. These improvements will then help the organization make better internal decisions to advance their environmental efforts and address contributing factors to their carbon footprint and alleviate those impacts.

Specifically, in terms of the NCAA Tournament, the NCAA can develop policies to address environmental concerns. For example, travel emissions were the most significant contributor to the event's footprint, supporting prior research (Dolf and Teehan, 2015). To address this contribution, which would significantly influence the event's footprint, the NCAA can use internal data and data from corporate partners to assess its carbon footprint. This will help the event determine its total emissions across all three scopes and better understand the cost associate with offsetting various impacts. This data could be leveraged within corporate partnerships to offset specific aspects of the tournament (e.g., air travel, lodging, etc.). Additionally, this assessment can be used yearly to evaluate performance and continually refine processes to improve environmental performance. For example, the linear model could be applied to changes in the annual tournament (e.g., different host cities, participating schools, etc.) like between the 2019 Men's Tournament and the heavily modified 2021 Men's tournament limited to the state of Indiana with severe travel and attendance restrictions.

The NCAA can also favor and select host cities with more robust environmental policies and performance (e.g., high numbers of green hotel rooms, public transit systems). For example, the NCAA can develop bidding requirements for host cities to assess and mitigate the environmental impact of other aspects of the tournament (i.e., lodging, venue operations, food, waste). The IOC and FIFA require bidding countries and cities to highlight how their cities and venues promote strong environmental performance at the Olympics and World Cup. The NCAA can add requirements that bidding cities provide environmental credentials of the host venue and lodging options. This requirement can seek to minimize negative contributions from lodging and venue operations – the second and third largest impacts, respectively, of the NCAA tournament's carbon footprint.

5.3. Theoretical contributions

Readers and researchers of sport ecology should not view a lack of precise input data as a limitation. Instead, our study highlights the underpinning methodology as a positive contribution to the literature on carbon footprinting. After all, innovative approaches in geospatial techniques that tackle and answer questions with units of analysis that are data-poor are still scientifically grounded and are practically impactful in decision-making processes (Boulton et al., 1982). Approaches to carbon footprinting tourism have previously leveraged software-based carbon calculators (Filimonau et al., 2014), surveys of event participants (Wicker, 2018), and comprehensive geolocated spectator data (Cooper, 2020). However, the collection and utilization of such datasets and software can be time-intensive and costly. This renders previous footprinting methodologies less practical or scalable to the breadth and capacity of sports tourism personnel. This study pushes carbon-footprinting outside of a black box of methodological mystique and into the open for the democratization and accessibility for those sport and event managers who could benefit most.

One way to evaluate sustainable progress over time is through environmental and carbon footprinting. More precise data (i.e., lessening the effects of the uncertainty of data) will allow sport and event managers to assess how much carbon is emitted with activities associated with their events. Market-specific measures are critical in conducting accurate footprinting research (Dwyer et al., 2010). This March Madness footprinting model would, for instance, benefit from more precise US-based emissions data for transportation, food, waste management, and sports stadium operations. However, the lack of readily available data leaves sport and event managers with a degree of uncertainty. And, as sport organizations take a more concerted effort to assess their environmental impacts by using more precise input data, the uncertainty of their results will decrease. It is time industry and the academy took the challenging work of these approximations seriously by using existing data, generating new data sources, and refining their processes for environmental impact evaluations. Then, those assessments and resulting climate targets will be fulfilled through sound science and quantitative methodologies (Torres-Delgado and Saarinen, 2014).

6. Conclusion

Amidst a global climate crisis backdrop, sports tourism continues to contribute to Earth's carbon footprint. In 2019, the NCAA Men's Basketball Tournament added millions of GHG gasses to this phenomenon through participants' and fans' travel and related tourism activities. The results reinforce the literature's long-held notion that the total quantity of tourists and how they travel to the destination is the most significant factor in contributing to an event's carbon footprint. The NCAA Tournament's uniquely geographically decentralized format presents distinct challenges for sustainable emissions management in the future. Sport and event managers should close the value-action gap and make meaningful progress towards assessing their GHG emissions and developing strategies to reduce their emissions where possible.

To this end, despite inherently flawed and unstandardized due to the uncertainty of input data, environmental impact assessments like carbon footprinting stand as tools for the academy and industry to evaluate its environmental impact and develop strategic plans to address their impacts. This paper presents an accessible linear model by which researchers in both industry and the academy can bring carbon footprinting to scale in data-poor sporting events and organizations. More research should be done to evaluate and mitigate the emissions of GHGs in the US sports and tourism industries. As tourism researchers and managers work towards more clearly identifying applicable metrics to assess the environmental impact of sporting events, they can begin to accept the results with less uncertainty and mitigate their negative contributions to global climate change in more targeted ways. First, however, employing innovative and readily useable quantitative models to understand emission sources and patterns is an important starting point.

CRediT authorship contribution statement

J.A. Cooper: Conceptualization, Methodology, Software, Formal analysis, Data curation, Writing – original draft, Visualization. **Brian P. McCullough:** Conceptualization, Validation, Writing – review & editing.

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.

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Appendix

Table 1
GHG Emissions from US Hotel Markets (Ricaurte and Jagarajan, 2019)

City	State	GHGs per Occupied Room per Night	GHGs per Person per Night
Tulsa	OK	30.2	15.10
Kansas City	MO	27.3	13.65
Des Moines	IA	25.9	12.95
Minneapolis	MN	24.7	12.35
Louisville	KY	23.9	11.95
Columbus	OH	23.9	11.95
Washington	DC	19.8	9.90
Salt Lake City	UT	19.5	9.75
Dayton	OH	19.1	9.55
Jacksonville	FL	18.9	9.45
Columbia	SC	14.2	7.10
Hartford	CT	12.0	6.00
Anaheim	CA	10.6	5.30
San Jose	CA	8.8	4.40

Table 2
Use of Source-Based GHG Emissions in the Current Study

Source	Emissions Sector	kg CO2eq pp	Notes
Filimonau et al. (2014)	Travel (Air)	0.15	per km
Dolf and Teehan (2015)	Travel (Automobile)	0.136	per km
	Travel (Coach Bus)	0.058	per km
Berners-Lee et al. (2012)	Food	7.40	per day
Cooper (2020)	Waste	1.10	per day
Hedayati et al. (2014)	Stadium Operations	14.74	per session
Ricaurte and Jagarajan (2019)	Lodging	Variable	see Table 1

Table 3
2019 NCAA Basketball Tournament GHG Emissions by Tourism Sector

	Food	Lodging	Waste	Stadium Operations	Travel	Tournament Total	GHGs per Person
Sum	13,363,549	14,342,131	1,986,474	12,382,278	167,814,764	209,889,196	499
Percent of Total	6.37%	6.83%	0.95%	5.90%	79.95%		

Table 4
2019 NCAA Basketball Tournament GHG Emissions by Host City

City	State	Rounds	Food		Lodging		Waste		Stadium Operations		Travel		Total Site GHGs	GHGs per Person	Site's Percent of Total Tournament Footprint
			Sum	Pct of Site Footprint	Sum	Pct of Site Footprint	Sum	Pct of Site Footprint	Sum	Pct of Site Footprint	Sum	Pct of Site Footprint			
Minneapolis	MN	Final 4 & Nat. Champ.	2,684,017	7.0%	3,580,043	9.4%	398,976	1.0%	3,199,450	8.4%	28,245,996	74.1%	**38,108,481**	***526.1***	18.2%
Salt Lake City	UT	1st & 2nd Rounds	1,011,055	4.1%	1,004,465	4.1%	150,292	0.6%	759,272	3.1%	21,732,741	88.1%	**24,657,824**	***721.9***	11.7%
San Jose	CA	1st & 2nd Rounds	878,380	3.8%	391,934	1.7%	130,570	0.6%	656,490	2.8%	21,189,939	91.2%	**23,247,314**	***783.4***	11.1%
Columbus	OH	1st & 2nd Rounds	1,164,146	6.9%	1,410,411	8.3%	173,049	1.0%	869,852	5.1%	13,273,978	78.6%	**16,891,435**	***429.5***	8.0%
Hartford	CT	1st & 2nd Rounds	884,722	6.1%	538,800	3.7%	131,513	0.9%	661,826	4.6%	12,227,938	84.7%	**14,444,799**	***483.3***	6.9%
Des Moines	IA	1st & 2nd Rounds	984,585	7.1%	1,294,430	9.3%	146,357	1.1%	736,676	5.3%	10,735,135	77.2%	**13,897,183**	***417.8***	6.6%
Anaheim	CA	Sweet 16 & Elite 8	587,834	4.6%	334,854	2.6%	87,381	0.7%	691,645	5.4%	11,060,220	86.7%	**12,761,934**	***809.4***	6.1%
Jacksonville	FL	1st & 2nd Rounds	793,043	7.2%	765,639	7.0%	117,885	1.1%	597,117	5.4%	8,708,087	79.3%	**10,981,772**	***409.9***	5.2%
Tulsa	OK	1st & 2nd Rounds	743,648	7.0%	1,139,657	10.8%	110,542	1.0%	556,243	5.3%	8,028,427	75.9%	**10,578,519**	***421.1***	5.0%
Columbia	SC	1st & 2nd Rounds	950,663	9.5%	685,917	6.8%	141,315	1.4%	712,001	7.1%	7,560,401	75.2%	**10,050,297**	***312.9***	4.8%
Louisville	KY	Sweet 16 & Elite 8	763,584	8.0%	994,766	10.4%	113,506	1.2%	933,057	9.8%	6,744,150	70.6%	**9,549,062**	***459.5***	4.5%
Dayton	OH	First 4	529,137	5.6%	455,249	4.8%	78,656	0.8%	351,328	3.7%	7,978,974	84.9%	**9,393,342**	***394.1***	4.5%
Kansas City	MO	Sweet 16 & Elite 8	643,437	7.8%	948,047	11.5%	95,646	1.2%	765,846	9.3%	5,787,030	70.2%	**8,240,007**	***475.3***	3.9%
Washington	DC	Sweet 16 & Elite 8	745,298	10.5%	797,920	11.3%	110,788	1.6%	891,475	12.6%	4,541,746	64.1%	**7,087,228**	***352.2***	3.4%

Table 5
2019 NCAA Basketball Tournament GHG Emissions by Team

Team	Trips Made	Food		Lodging		Waste		Stadium Operations		Travel		Total Team GHGs	GHGs per Person	Percent of Total Tournament Footprint
		Sum	Pct of Team Footprint	Sum	Pct of Team Footprint	Sum	Pct of Team Footprint	Sum	Pct of Team Footprint	Sum	Pct of Team Footprint			
Auburn	3	990,727	6.0%	1,300,695	7.9%	147,270	0.9%	1,118,795	6.8%	13,005,579	78.5%	**16,563,066**	**618.8**	16.3%
Texas Tech	3	934,609	6.9%	1,169,343	8.6%	138,928	1.0%	1,066,395	7.8%	10,303,661	75.7%	**13,612,935**	**540.2**	13.4%
Virginia	3	1,009,343	7.7%	1,257,887	9.6%	150,038	1.1%	1,151,773	8.8%	9,480,657	72.7%	**13,049,697**	**478.0**	12.9%
Michigan State	3	1,012,055	10.3%	1,311,373	13.4%	150,441	1.5%	1,146,201	11.7%	6,182,590	63.1%	**9,802,660**	**358.7**	9.7%
Oregon	2	338,489	4.9%	317,881	4.6%	50,316	0.7%	349,305	5.1%	5,845,140	84.7%	**6,901,131**	**754.6**	6.8%
Florida State	2	285,753	4.5%	173,844	2.7%	42,477	0.7%	283,391	4.4%	5,615,457	87.7%	**6,400,922**	**830.9**	6.3%
Michigan	2	300,634	5.3%	299,532	5.3%	44,689	0.8%	295,408	5.2%	4,730,307	83.4%	**5,670,570**	**699.1**	5.6%
Washington	1	181,407	3.4%	234,578	4.4%	26,966	0.5%	144,673	2.7%	4,767,296	89.0%	**5,354,921**	**1091.2**	5.3%
Virginia Tech	2	313,094	6.0%	260,473	5.0%	46,541	0.9%	325,083	6.2%	4,288,100	81.9%	**5,233,292**	**614.8**	5.2%
Fairleigh Dickinson	2	159,923	3.1%	139,284	2.7%	23,772	0.5%	106,183	2.1%	4,729,028	91.7%	**5,158,190**	**716.0**	5.1%
Saint Mary's	1	82,179	1.7%	44,421	0.9%	12,216	0.3%	54,564	1.1%	4,661,621	96.0%	**4,855,000**	**1311.5**	4.8%
Northeastern	1	92,618	2.1%	81,354	1.8%	13,768	0.3%	61,495	1.4%	4,225,237	94.4%	**4,474,472**	**1072.5**	4.4%
LSU	2	308,859	7.1%	326,320	7.5%	45,912	1.1%	321,594	7.4%	3,343,894	76.9%	**4,346,578**	**517.9**	4.3%
Liberty	1	126,977	3.0%	61,270	1.4%	18,875	0.4%	102,627	2.4%	3,917,390	92.7%	**4,227,139**	**1214.3**	4.2%
Arizona State	2	135,437	3.3%	151,112	3.7%	20,132	0.5%	89,925	2.2%	3,690,133	90.3%	**4,086,739**	**669.9**	4.0%
Syracuse	1	93,900	2.3%	82,480	2.1%	13,958	0.3%	62,347	1.6%	3,750,088	93.7%	**4,002,773**	**946.3**	3.9%
North Dakota State	2	156,899	4.0%	114,984	2.9%	23,323	0.6%	104,175	2.6%	3,547,556	89.9%	**3,946,936**	**558.5**	3.9%
Gonzaga	2	307,311	7.9%	253,624	6.5%	45,681	1.2%	301,647	7.8%	2,977,900	76.6%	**3,886,163**	**468.5**	3.8%
North Carolina	2	342,059	8.8%	471,208	12.1%	50,847	1.3%	335,722	8.6%	2,684,530	69.1%	**3,884,366**	**420.3**	3.8%
Utah State	1	108,436	2.8%	116,740	3.0%	16,119	0.4%	71,998	1.9%	3,555,044	91.9%	**3,868,335**	**792.0**	3.8%
Wisconsin	1	92,618	2.5%	36,714	1.0%	13,768	0.4%	61,495	1.6%	3,527,361	94.5%	**3,731,956**	**894.5**	3.7%
Mississippi State	1	71,795	2.3%	28,459	0.9%	10,672	0.3%	47,669	1.5%	2,931,643	94.9%	**3,090,238**	**955.5**	3.0%
Kentucky	2	289,725	9.4%	369,547	12.0%	43,067	1.4%	294,940	9.5%	2,091,987	67.7%	**3,089,267**	**394.5**	3.0%
Houston	2	277,389	9.0%	427,441	13.9%	41,234	1.3%	284,180	9.3%	2,038,980	66.4%	**3,069,223**	**409.6**	3.0%
Nevada	1	91,420	3.0%	106,656	3.5%	13,589	0.5%	60,699	2.0%	2,743,831	91.0%	**3,016,195**	**732.4**	3.0%
Kansas State	1	92,618	3.1%	36,714	1.2%	13,768	0.5%	61,495	2.1%	2,774,254	93.1%	**2,978,848**	**714.0**	2.9%
Saint Louis	1	71,795	2.5%	28,459	1.0%	10,672	0.4%	47,669	1.7%	2,687,994	94.4%	**2,846,589**	**880.2**	2.8%
Purdue	2	329,311	11.8%	338,876	12.2%	48,952	1.8%	344,043	12.4%	1,721,967	61.9%	**2,783,148**	**311.3**	2.7%
Baylor	1	160,145	6.0%	169,762	6.4%	23,805	0.9%	128,323	4.8%	2,184,901	81.9%	**2,666,937**	**612.7**	2.6%
Florida	1	153,883	5.9%	215,967	8.3%	22,875	0.9%	122,909	4.7%	2,088,377	80.2%	**2,604,012**	**624.6**	2.6%
Montana	1	91,420	3.8%	106,656	4.4%	13,589	0.6%	60,699	2.5%	2,128,786	88.7%	**2,401,150**	**583.1**	2.4%
Kansas	1	158,863	6.8%	168,636	7.2%	23,615	1.0%	127,472	5.4%	1,861,914	79.6%	**2,340,499**	**541.3**	2.3%
Tennessee	2	373,289	16.1%	484,220	20.8%	55,489	2.4%	378,317	16.3%	1,032,196	44.4%	**2,323,511**	**229.4**	2.3%
Oklahoma	1	147,029	6.7%	113,504	5.1%	21,856	1.0%	117,821	5.3%	1,809,886	81.9%	**2,210,095**	**553.0**	2.2%
Murray State	1	139,002	6.9%	90,279	4.5%	20,662	1.0%	110,893	5.5%	1,653,217	82.1%	**2,014,052**	**535.4**	2.0%
Buffalo	1	116,232	5.9%	190,124	9.6%	17,278	0.9%	92,796	4.7%	1,565,434	79.0%	**1,981,863**	**629.6**	2.0%
Abilene Christian	1	75,519	3.8%	64,293	3.3%	11,226	0.6%	50,142	2.5%	1,766,836	89.8%	**1,968,016**	**578.5**	1.9%
Duke	2	338,012	18.1%	316,108	16.9%	50,245	2.7%	344,057	18.4%	822,752	44.0%	**1,871,175**	**205.0**	1.8%
Iowa	1	182,601	10.8%	235,863	13.9%	27,143	1.6%	145,465	8.6%	1,104,121	65.1%	**1,695,193**	**343.5**	1.7%
Marquette	1	82,973	5.2%	44,850	2.8%	12,334	0.8%	55,091	3.4%	1,415,273	87.9%	**1,610,520**	**430.9**	1.6%
Ohio State	1	116,737	7.4%	190,811	12.2%	17,353	1.1%	93,131	5.9%	1,150,341	73.3%	**1,568,373**	**496.5**	1.5%
Seton Hall	1	75,519	4.8%	64,293	4.1%	11,226	0.7%	50,142	3.2%	1,362,406	87.1%	**1,563,585**	**459.6**	1.5%
New Mexico State	1	92,618	5.9%	81,354	5.2%	13,768	0.9%	61,495	3.9%	1,310,939	84.0%	**1,560,174**	**374.0**	1.5%
Yale	1	69,603	4.5%	59,256	3.8%	10,346	0.7%	46,214	3.0%	1,363,951	88.0%	**1,549,370**	**494.2**	1.5%
Prairie View A&M	1	66,023	4.3%	56,803	3.7%	9814	0.6%	43,837	2.9%	1,354,159	88.5%	**1,530,637**	**514.7**	1.5%
Belmont	2	135,625	9.1%	116,060	7.8%	20,161	1.4%	90,050	6.1%	1,126,513	75.7%	**1,488,409**	**243.6**	1.5%

(*continued on next page*)

Table 5 (*continued*)

Team	Trips Made	Food		Lodging		Waste		Stadium Operations		Travel		Total Team GHGs	GHGs per Person	Percent of Total Tournament Footprint
		Sum	Pct of Team Footprint	Sum	Pct of Team Footprint	Sum	Pct of Team Footprint	Sum	Pct of Team Footprint	Sum	Pct of Team Footprint			
Iona	1	108,436	7.4%	116,740	7.9%	16,119	1.1%	71,998	4.9%	1,155,433	78.7%	**1,468,725**	**300.7**	1.4%
Maryland	1	122,742	8.6%	127,117	8.9%	18,245	1.3%	99,138	6.9%	1,061,736	74.3%	**1,428,977**	**424.9**	1.4%
Colgate	1	109,629	8.1%	118,024	8.7%	16,296	1.2%	72,790	5.4%	1,036,750	76.6%	**1,353,489**	**274.1**	1.3%
Georgia State	1	69,680	5.6%	94,790	7.6%	10,358	0.8%	46,265	3.7%	1,028,638	82.3%	**1,249,731**	**398.2**	1.2%
Louisville	1	92,263	7.5%	107,640	8.7%	13,715	1.1%	61,259	5.0%	959,516	77.7%	**1,234,394**	**297.0**	1.2%
Northern Kentucky	1	69,175	5.7%	94,103	7.7%	10,283	0.8%	45,930	3.8%	996,785	82.0%	**1,216,276**	**390.3**	1.2%
UCF	1	151,480	13.2%	116,351	10.1%	22,517	2.0%	120,776	10.5%	735,890	64.2%	**1,147,015**	**280.0**	1.1%
Ole Miss	1	86,186	7.7%	55,128	4.9%	12,811	1.1%	57,224	5.1%	913,954	81.2%	**1,125,304**	**289.9**	1.1%
UC Irvine	1	147,800	14.7%	69,524	6.9%	21,970	2.2%	116,453	11.6%	652,011	64.7%	**1,007,759**	**255.1**	1.0%
St. John's	1	66,261	6.8%	57,009	5.8%	9850	1.0%	43,995	4.5%	797,514	81.8%	**974,629**	**326.5**	1.0%
Minnesota	1	154,727	16.3%	216,951	22.9%	23,000	2.4%	123,470	13.0%	428,610	45.3%	**946,757**	**226.1**	0.9%
Wofford	1	128,658	14.0%	132,154	14.3%	19,125	2.1%	103,066	11.2%	538,755	58.4%	**921,758**	**263.7**	0.9%
Old Dominion	1	82,179	9.3%	44,421	5.0%	12,216	1.4%	54,564	6.1%	694,862	78.2%	**888,241**	**240.0**	0.9%
Temple	1	66,023	7.6%	56,803	6.6%	9814	1.1%	43,837	5.1%	690,266	79.6%	**866,743**	**291.4**	0.9%
Iowa State	1	69,680	8.1%	94,790	11.0%	10,358	1.2%	46,265	5.4%	642,899	74.4%	**863,993**	**275.3**	0.9%
VCU	1	90,637	10.7%	57,975	6.8%	13,473	1.6%	60,180	7.1%	624,484	73.8%	**846,749**	**207.4**	0.8%
NC Central	1	66,261	9.0%	57,009	7.7%	9850	1.3%	43,995	6.0%	561,632	76.0%	**738,747**	**247.5**	0.7%
Bradley	1	92,263	13.8%	107,640	16.1%	13,715	2.0%	61,259	9.1%	394,720	58.9%	**669,598**	**161.1**	0.7%
Villanova	1	138,208	21.0%	89,850	13.6%	20,544	3.1%	110,366	16.8%	299,860	45.5%	**658,828**	**176.0**	0.6%
Cincinnati	1	109,629	20.7%	118,024	22.3%	16,296	3.1%	72,790	13.7%	213,371	40.3%	**530,110**	**107.3**	0.5%
Vermont	1	82,973	16.5%	44,850	8.9%	12,334	2.5%	55,091	10.9%	308,008	61.2%	**503,255**	**134.7**	0.5%
Gardner-Webb	1	86,186	23.3%	55,128	14.9%	12,811	3.5%	57,224	15.5%	157,848	42.8%	**369,198**	**95.1**	0.4 %

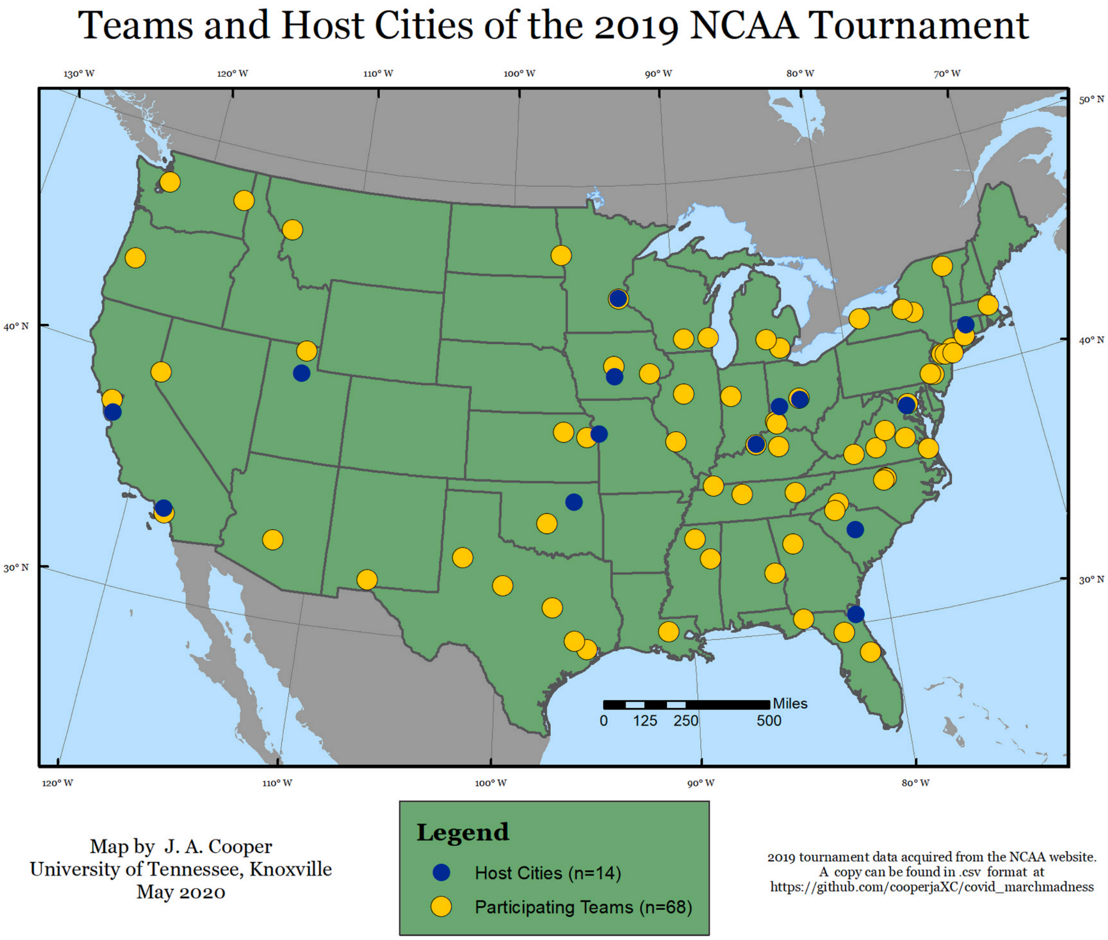
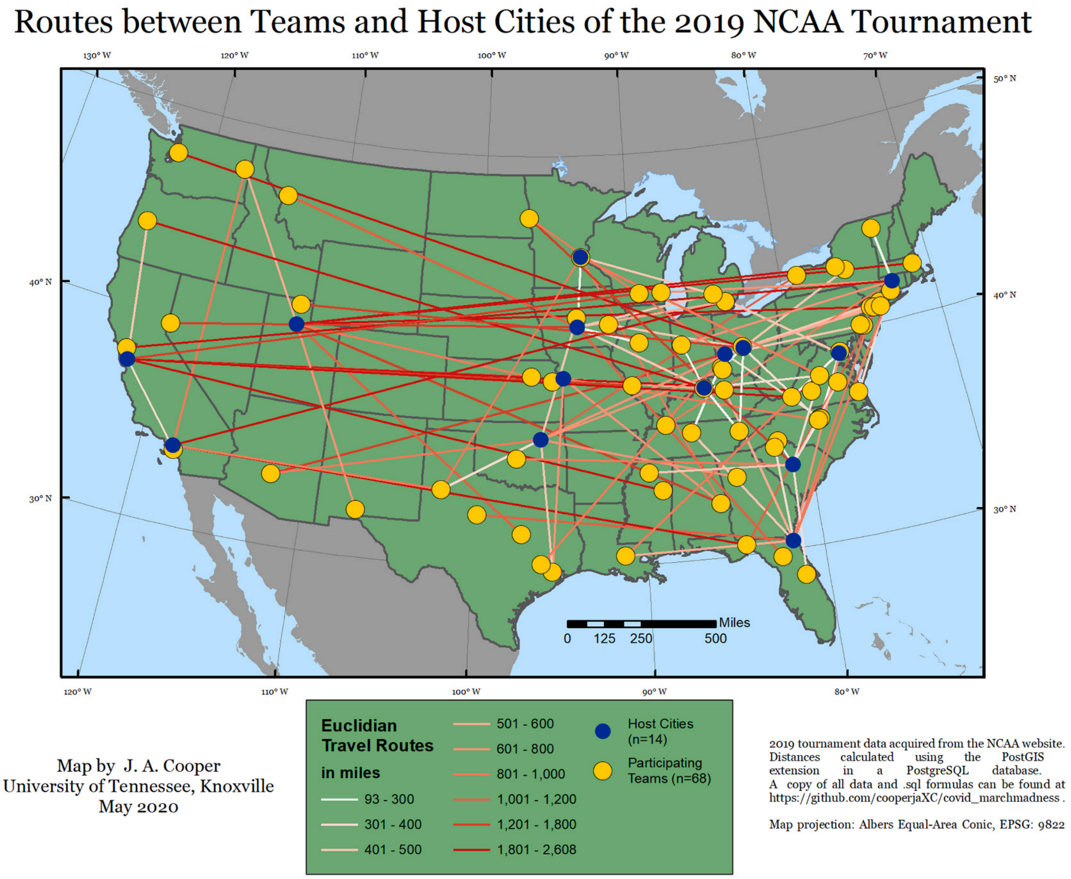


Fig. 1. Locations of the 68 Teams & 14 Host Cities of the 2019 NCAA Tournament.



2019 tournament data acquired from the NCAA website. Distances calculated using the PostGIS extension in a PostgreSQL database. A copy of all data and .sql formulas can be found at https://github.com/cooperjaXC/covid_marchmadness .

Map projection: Albers Equal-Area Conic, EPSG: 9822

Fig. 2. Euclidian travel routes from the 68 Teams to their 2019 NCAA Tournament Host Cities by Distance.

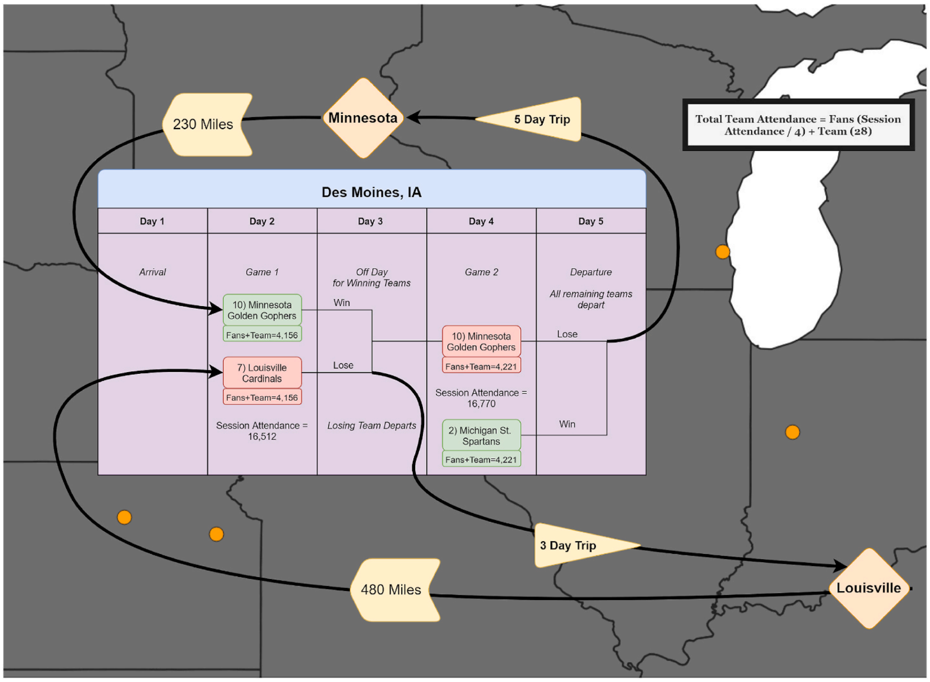


Fig. 3. Example of Model's Travel Time Calculations using 7) Louisville vs. 10) Minnesota

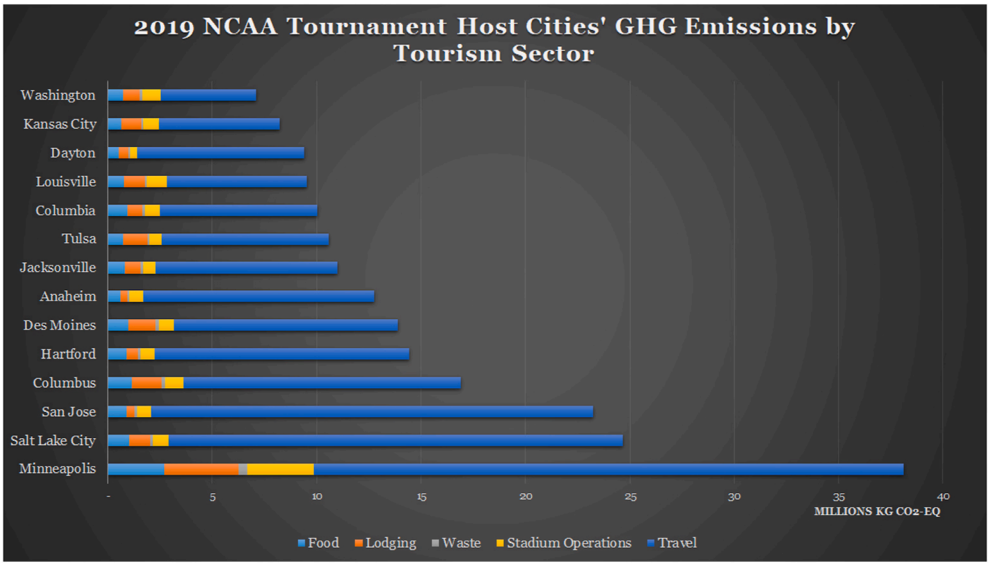


Fig. 4. 2019 NCAA Tournament Host Cities' GHG Emissions by Tourism Sector .

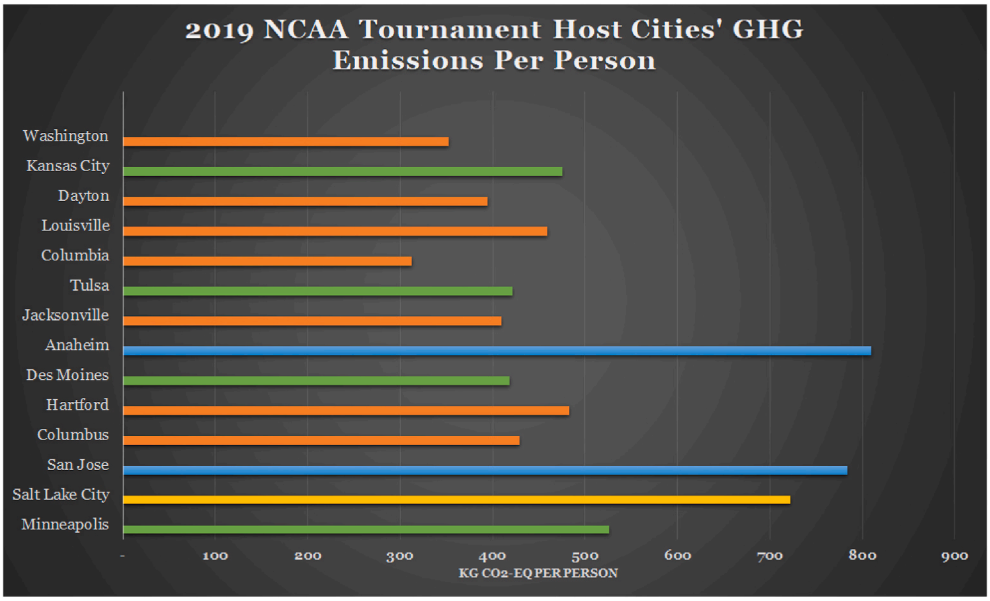
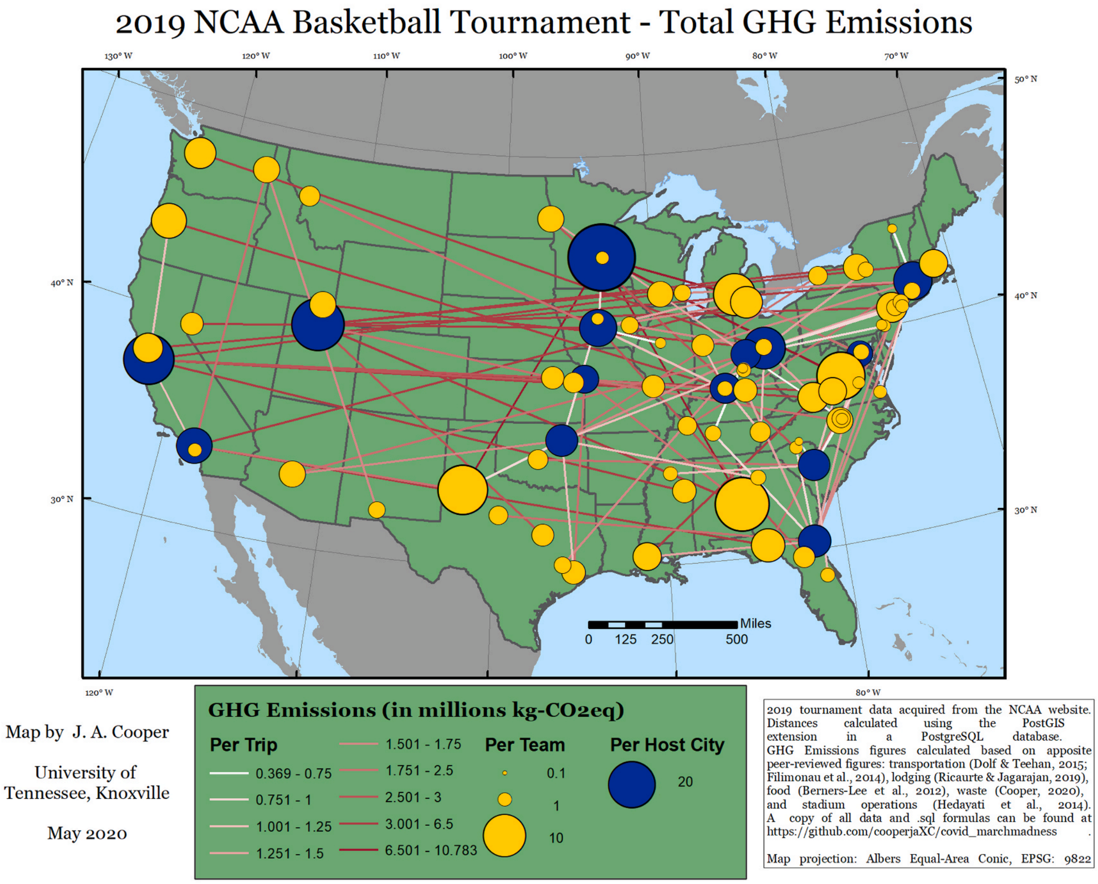


Fig. 5. 2019 NCAA Tournament Host Cities' GHG Emissions per Person.



Map by J. A. Cooper

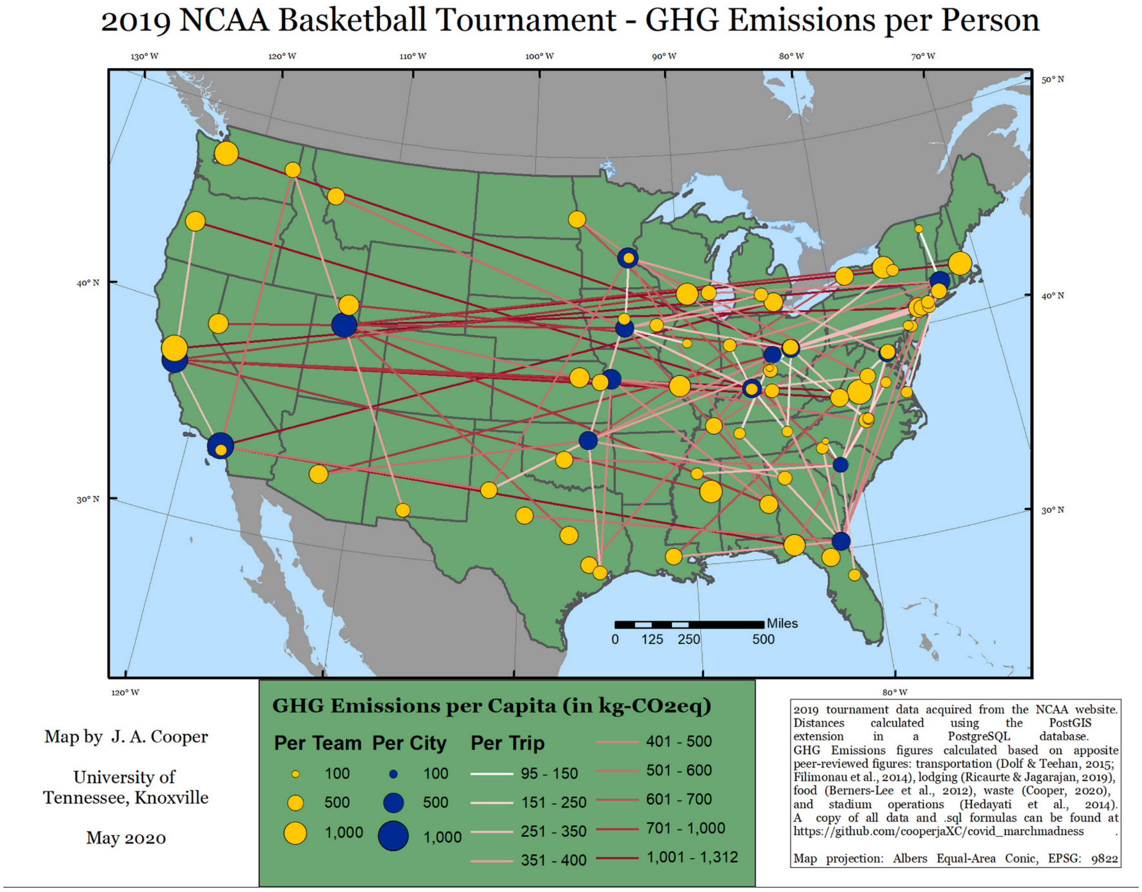
University of Tennessee, Knoxville

May 2020

2019 tournament data acquired from the NCAA website. Distances calculated using the PostGIS extension in a PostgreSQL database. GHG Emissions figures calculated based on apposite peer-reviewed figures: transportation (Dolf & Teehan, 2015; Filimonau et al., 2014), lodging (Ricaurte & Jagarajan, 2019), food (Berners-Lee et al., 2012), waste (Cooper, 2020), and stadium operations (Hedayati et al., 2014). A copy of all data and .sql formulas can be found at https://github.com/cooperjaXC/covid_marchmadness .

Map projection: Albers Equal-Area Conic, EPSG: 9822

Fig. 6. Total Greenhouse Gas Emissions from the 2019 NCAA Tournament by Teams, Host City, and Travel Route.



Map by J. A. Cooper

University of Tennessee, Knoxville

May 2020

2019 tournament data acquired from the NCAA website. Distances calculated using the PostGIS extension in a PostgreSQL database. GHG Emissions figures calculated based on apposite peer-reviewed figures: transportation (Dolf & Teehan, 2015; Filimonau et al., 2014), lodging (Ricaurte & Jagarajan, 2019), food (Berners-Lee et al., 2012), waste (Cooper, 2020), and stadium operations (Hedayati et al., 2014). A copy of all data and .sql formulas can be found at https://github.com/cooperjaXC/covid_marchmadness .

Map projection: Albers Equal-Area Conic, EPSG: 9822

Fig. 7. Per-Capita Greenhouse Gas Emissions from the 2019 NCAA Tournament by Teams, Host City, and Travel Route.

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