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THE CARBON FOOTPRINT OF MEGA SPORT EVENTS: A COMPARATIVE STUDY TO UNDERSTAND THE SUSTAINABILITY OF OLYMPIC GAMES

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ABSTRACT

Research Purpose: In line with Paris Agreement, International Olympic Committee (IOC) has committed to reduce direct and indirect carbon emissions by 30% by 2024 and 50% by 2030. Mitigating the impacts of climate change and recognizing the importance of sustainability, the environmental impacts of mega sporting events must be attended seriously. **Aim and Objective:** The study aims toward a systematic evaluation for existence of sustainability to evaluate the sustainability of the last four Summer Olympics from 2012-2024. The carbon budget is divided into travel, construction and operations which include catering, accommodation, and logistics, etc. The main objective of the study is to compare the carbon footprints produced during the games and the upcoming Paris Olympics, and also to understand the cost of hosting and steps taken toward reducing CO₂ emission. **Result:** The findings of the study indicates that London Olympics 2012 and Rio Olympics 2016 emitted 3.3 million and 3.6 million tonnes of CO₂, respectively whereas Tokyo Olympics 2021 emitted 2.73 million tonnes of CO₂ despite being deprived of spectators during the Covid-19 pandemic and the organizers of Paris Olympics estimated to cut down carbon emission to around 1.75 million tonnes. **Conclusion:** With varying degrees of success, organizers and promoters should attempt for measures to reduce negative impacts and enhance positive ones. Turning the games more sustainable we must re-size the event by minimizing venues, rotating the games among the same host cities, and by enforcing sustainability standards.

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INTRODUCTION

Since the first industrial revolution, the planet's median temperature has increased almost over 1.1 °C, estimated that global warming is growing currently per decade due to past and ongoing emissions (Khanna, M. et al. 2024). Human-caused climate change is a significant issue that over the course of the next century might cause extremely high levels of social, ecological, and economic upheaval (Khanna, M. et al. 2024b; Dolf, M., & Teehan, P., 2015; Change, N. I. P. O. C., 2023). Achieving a climate-neutral world by 2050 will require significant transformation across all economic value chains throughout the globe. In this context, it is important to recognize the various roles in this transformation towards climate neutrality (Khanna, M., Gusmerotti, N. M., & Frey, M., 2022). Sports events and sports facility produces waste connected to spectators and daily maintenance, polluting the environment (Thornewill, J. et al. 2022). For this reason, the UN has now included sport in its global climate action framework and aims for carbon neutrality for sport by 2050

(Pereira, R. P. T., Filimonau, V., & Ribeiro, G. M., 2019). International cooperation is required to reduce GHG emissions to fight against the global issue of climate change (Khanna, M., Gusmerotti, N. M., & Frey, M., 2022; King, A. D., & Karoly, D. J., 2017). The Olympic Games are a massive social and cultural event with the most intricate system and the broadest scope. With the growth of the Olympic Games, the environmental issues they cause have garnered more attention, and the sustainable growth of the Olympic Games has been prioritized. Huge sums of money must be spent on everything from the bid to the hosting of the Olympic Games. More than 30 hectares of forests were burned, tens of thousands of animals and plants lost their habitat, and many local biological species quickly vanished as a result of Albert, France, hosting the Winter Olympics in 1992. A total of 50 tonnes of CO₂ were released during the two weeks of the 2004 Athens Olympic Games, and after the event, there were around 500,000 tonnes of emissions, which had a significant negative influence on the national natural environment. Therefore, it is necessary to think about ways to minimize environmental impact while maximizing the economic and social benefits of the competition when hosting the Olympic Games.

The present study is focused on London Olympic (2012), Rio de Janeiro Olympics (2016) and Tokyo Olympics (2020). According to international standards, a life-cycle assessment (LCA) can be used to determine a product's carbon footprint by concentrating on GHG emissions. The LCA approach is used to assess the effects of organizations, products, and services over the course of their whole life cycles, from the extraction of raw materials through manufacture, distribution, consumption, and end-of-life care. These many actions are referred to as "life cycle stages". A study examined three modes of the host city's 'Ecological Carrying Capacity' (ECC); light urban ecological burden mode, heavy urban ecological burden mode, and overload urban ecological burden mode. These modes are based on the comprehensive index of ECC, Environmental Kuznets Curve, and carbon footprint analysis of the Olympic Games host city competition cycle. The land surface temperature change map of Tokyo, Japan, from 1990-2015 is obtained based on the temperature sensor and GPS location, and the heat island effect of Tokyo is also determined. It is suggested that for the Olympic Games to be developed sustainably, the host city's ECC must be assessed throughout the entire cycle. Additionally, ecological priority must be established to prevent ecological burden overload (Bin Zhang and YuFeng Liu, 2022). Environmental risks make up four of the top five risks identified in the World Economic Forum's Global Risks Report 2024.

Table 1. Showing global risks by severity over 2-10 years

Sl. No.	Risk Category	Risk Severity Over 2-10 Years
1	Economic	1. Cost of living crisis 2. Large scale involuntary migration
2	Environmental	1. Failure to mitigate climate change 2. Failure of climate-change adaptation 3. Biodiversity loss and ecosystem collapse 4. Natural resource crisis 5. Large scale environmental damage incidents
3	Geopolitical	Geo-economic confrontation
4	Societal	Erosion of social cohesion and societal polarization
5	Technological	Wide spread cyber-crime and cyber-insecurity

At a time when public and private agencies recognize the importance of sustainable development, the environmental impacts of mega sporting events are commanding increasing attention. However, despite event sponsors often flagging the importance of environmental as well as socio-economic legacy components, the environmental impacts of events are difficult to assess quantitatively, being complex and often occurring over extended periods. The general assessment issue is particularly acute with regard to mega events such as the Olympic Games. Sports have increasingly become a part of global politics with their abilities of changing and affecting states. The sustainability strategies give an adequate example of the impact of the mega sport events on an international, national, and local level. In the study the three cases of last Summer Olympics i.e. 2012, 2016, 2020 and the 2024 Paris Olympics will be used to analyze the problem representation in their sustainability strategies. The Ecological Footprint initially pioneered in the early 1990's is an aggregated indicator of the global ecological impact of resource consumption, roughly analogous to GDP as a representation of the dimensions of the financial economy (Wackernagel & Rees, 1995). The footprint is measured using a standardized area unit equivalent to a world average productive hectare or 'global hectare' (gha) and is usually expressed in global hectares per capita (gha/capita).

Table 2. Showing contributors to the IOC Carbon-Footprint in 2022

Purpose	Carbon Emission (%)
Business Travel	72.3%
Freight	8.9%
Employee Commuting	5.2%
Accommodation	4.5%
Energy used in Buildings and Vehicles	4.2%
Food and Beverage	2.5
Uniforms	1.6%
Others	0.8%

Carbon-footprint is largely dominated by travel, and varies considerably year-on-year depending on locations of the host countries for the Olympic Games, Youth Olympic Games and other corporate events. The data presented below represents the best estimate of emissions based on current available data (GHG Protocol Methodology). CO₂ travel emissions directly linked to the Olympic Games Tokyo 2020, which were postponed to 2021, were excluded from the IOC's 2021 carbon footprint and added to the IOC's 2020 carbon footprint.

Table 1.3. Showing IOC's Annual Carbon-Footprint i.e. from 2016-2022

IOC Annual Carbon-Footprint	Tonnes of Carbon (CO ₂) Emission/Year
2016	34,840
2017	44,690
2018	53,925
2019	29,750
2020	14,445*
2021	7,355*
2022	17,175

Theoretical Background of the Study: In 1991, the International Olympic Committee (IOC) wanted to stress the importance of ES in sport events by adding "environmental protection" alongside "sport" and "culture" as a third pillar of Olympism (Paquette, J., Stevens, J., & Mallen, C., 2011). As a result, the Olympic-Charter was amended to state that "the Olympic Games are held in conditions which demonstrate a responsible concern for environmental issues and educates all those connected with the Olympic-Movement as to the importance of sustainable development" (IOC, I., 2019). This effort shaped the mission and goals of future Olympic Games, starting with the Winter Olympics organized in Lillehammer in 1994 (McCullough, B. P., & Kellison, T. B., 2017). Lillehammer incorporated the first comprehensive environmental programme and was therefore considered to be "green Games" (Müller, M., et al. 2021). Salt Lake City 2002, Athens 2004 and London 2012 were also deemed a success from an environmental perspective (Müller, M., et al. 2021). Unfortunately, the positive flow did not last because the Winter Games organized in Sochi 2014 and the Summer Games in Rio 2016 were considered a setback due to a lack of environmental prioritization (Del Fiacco, A. G., & Orr, M., 2019; Geeraert, A., & Gauthier, R., 2018). However, Tokyo Olympics 2020 was able to step up again by claiming to have been the first carbon-neutral games (Sustainability Post-Games Report; The Tokyo Olympic Committee of the Olympic & Paralympic Games, Tokyo, Japan, 2021). Despite the efforts to create green sport events, authors argue that MSE's continue to cause significant environmental pressure (Sotiriadou, P., & Hill, B., 2015). In general, it can be concluded that MSE's causes a high number of negative impacts like the degradation of natural areas, air pollution, excessive use of energy and water, waste generation, etc., despite protective agreements made during the bidding procedures for the events.

Review of Related Literature

Lomax, C. et al. (2024): Due to the interconnectivity between sport and the environment, sport is also being impacted by environmental changes, with some sport organizers resorting to artificial and wasteful practices, such as increased watering and fake snow to overcome these changes.

Manoli, A. E. et al. (2024c): Suggested that maintaining the social and natural environment to its current state is no longer viewed as sustainable. Arguments highlight the need for sport to improve its environment in order to be considered sustainable, due to sport's role as a social movement, or 'a key social platform', towards evoking wider change in environmental sustainability.

McCullough & Cunningham (2010): Explored the social and political pressures from the organizations' stakeholders, driving organizations' involvement in environmental sustainability programmes, and identified that sport organisations that were

environmentally sustainable were able to build stronger relationships with their stakeholders and had achieved a reputation for doing so.

McCullough et al. (2016): Argued that we have yet to be provided with a roadmap on how positive changes can occur for sport organisations, potentially further feeding into the lack of urgency demonstrated to fully engage in environmental sustainability and introduced the 'green waves' conceptual framework illustrating the evolution of environmental sustainability in sport.

Geeraert & Gauthier (2018): Olympic Games since 2012 have widely and at times excessively promoted their sustainability intentions and practices, leading critics to argue that their efforts are focused more on promoting a 'greener image' and less on being sustainable, giving ground to accusations of 'green washing'.

Müller et al. (2021): Olympic Games, due to their inadequate sustainability practices, argued that we are since 2012 experiencing an environmental regression in the Olympics, in which financial and success driven motivations are surpassing environmental concerns, even when directly linked with negative environmental impacts.

Scott et al. (2022): Argued that athletes have collectively the power to instigate and bring about change in sustainable practices, while contributing to a more holistic understanding of the phenomenon, and as such, we aim to offer a first glimpse to their, so far ignored, perspectives on environmental sustainability in sport and the Olympic Games.

Objectives of the Study

- To compare the budget estimate that was made in the Olympics between the four host nations: London Olympics (2012); Rio de Janeiro Olympics (2016); Tokyo Olympics (2020); and Paris Olympics (2024).
- To compare the Carbon-Footprints produced during the Olympic Games: 2012- 2020.
- To compare the steps that were taken to reduce Carbon-Footprints during the Olympics Games: 2012- 2024.

METHODOLOGY

Guided by the aim of this exploratory and descriptive research, small-scale research, quantitative data generated through secondary sources were used for this study. Focusing on the last three Olympic Games and Paris-2024 Games, the present study approached for analyzing and highlighting the potentiality and sustainability of Olympic Games where the whole world participates, and understanding the sustainability of these events towards mitigating the impact of climate change globally. Systematic, in-depth and thorough review has been done and the findings were discussed in the light of the objectives of the study. The sustainability of Olympic Games is a key area of doing research especially during the era of climate change where the whole world is facing issues related to it.

FINDINGS AND INTERPRETATION

London Olympics 2012: It worth \$15 billion, a figure far higher than the cost of staging the event. The London budget jumped significantly. Before the hikes were made official, it was already growing clear that a budget of more than \$12 billion seemed likely.

Rio de Janeiro Olympics 2016: It was \$13.1 billion, paid for with a mix of public and private money. The massive costs and dubious benefits associated with hosting the Olympic Games have led to criticisms about the process for selecting a host city. Many have called for reforms to the process, including reducing the cost of bidding and encourage cities to develop more sustainable development strategies.

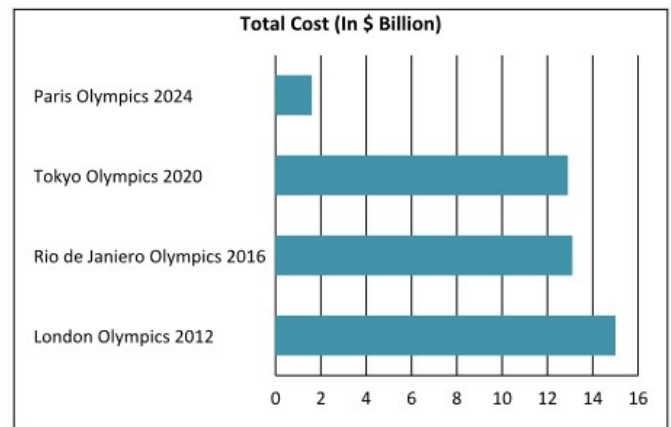


Figure 6.1. Showing the budget estimated for Olympics from 2012- 2024

Tokyo Olympics 2020: It cost \$12.9 billion, 20% more than initial calculation. The cost of hosting the Tokyo 2020 Olympic and Paralympics Games exceeded by 20% than what was calculated by the organizing committee. The audit board has also claimed that the organizing committee did not include spending on factors like anti-doping measures, athlete training and renovation of the Olympic Stadium etc.

Paris Olympics 2024: Venues were already in place and the investment budget includes; an Olympic village (estimated cost of € 1.5 billion), the Aquatics Centre (€175 million), and a new arena for badminton and gymnastics (€138 million). The overall budgeted cost is well below that of the three previous games.

The Carbon-Footprints during the Summer Olympics from 2012-2024:

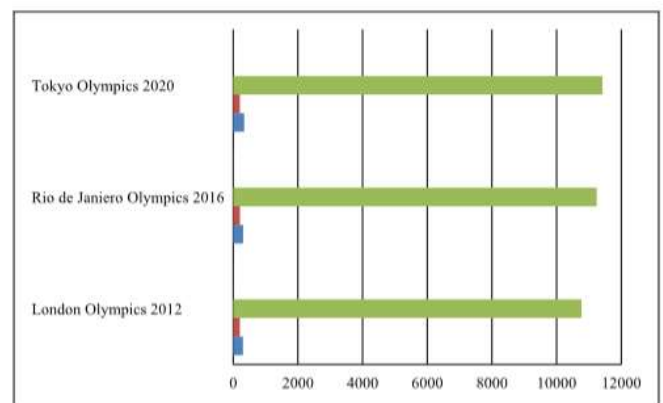


Figure 6.2. Showing Carbon-Footprint and Event Size.

Steps taken towards reducing Carbon-Footprints during 2012-2024:

London Olympics (2012): One of London 2012's most visible achievements was the creation of the Olympic Park on once-contaminated industrial land, which became the largest new urban parkland in Europe for 150 years. London 2012 was also the first Olympic Games to measure its carbon footprint over the entire project term and was the first Games to commit to- and achieve- a 'zero waste' to landfill target through the strategic 'Zero Waste Games Vision'. In total, Games organizers saved the equivalent of 400,000 tonnes of carbon dioxide thanks to their sustainable practices, while 100% of Games operations waste was diverted from landfill, with 62% of that waste being reused, recycled or composted. Additionally, 99% of the waste from installing and decommissioning the Games venues was reused or recycled.

Rio de Janeiro Olympics (2016): Rio de Janeiro had seven sustainability successes.

- Carbon mitigation.
- Off-site renewable and on-site energy efficiency.
- Low-carbon transport and logistics.
- Green buildings and venues.
- LED lighting.
- Sustainable food and drink schemes.
- Resource-efficient medals.

Tokyo Olympics (2020): In addition to a reduction in Olympics-related personnel, the organization of the Tokyo 2020 Olympic Games also demonstrated a commitment to sustainability by re-using or recycling 99 per cent of non-consumable items procured for the Games, utilizing hydrogen to fuel the Olympic torch and making the 5,000 medals awarded to athletes from precious metals extracted from discarded electronic devices. “The Tokyo 2020 Olympic Games have demonstrated that major international sports events can significantly reduce their carbon footprint, if organizers are willing to make some changes”, according to a new study by Japan’s Chukyo University. Due to the pandemic, the number of inbound event-related personnel who attended the Tokyo 2020 Olympics was significantly reduced, from 141,000 to 41,000 attendees. The Tokyo 2020 Games were planned and delivered in alignment with main sustainability themes: Climate Change, Resource Management, Natural Environment and Biodiversity, and Human Rights.

Paris Olympics (2024): Paris 2024, with the first Olympic Games fully aligned with Olympic Agenda-2020; promises to deliver spectacular Games that are more responsible, more sustainable and more inclusive. The organizers have laid out a cutting-edge plan to halve the Games-related carbon footprint compared to previous Games, with innovative solutions for energy, food, venues, transport and digital services. Paris 2024 is working to do more with:

- **Anticipating and avoiding impact:** Paris 2024 committed to reducing the Games carbon footprint by half compared to previous editions. Targeting a 50% reduction in carbon emissions compared to the average of London 2012 and Rio 2016. This means that Paris 2024 will offer the first Olympic Games aligned with the Paris Agreement on Climate Change, adopted in 2015.
- **Reducing, renting and reusing:** Paris 2024’s circular economy strategy is based on three key principles: organising the Games with fewer resources, making better use of these resources and ensuring the second life of resources after the Games. A total of 95% of the Paris 2024 competition venues will be pre-existing or temporary. Out of two million pieces of sports equipment, three-quarters will be rented or provided by sports federations. More than three-quarters of the electronic equipment such as screens, computers and printers are also rented.
- **Regeneration:** In line with the IOC’s Olympic Agenda 2020, the French authorities aim to leverage the Paris 2024 Games to achieve long-term improvements in the living conditions of the local community. Conceived as an eco-neighbourhood, the Olympic Village will be transformed after the Games into a new residential and business district, providing workplaces for 6,000 people and apartments for an additional 6,000. The Games are also serving as an accelerator to clean the River Seine, with significant investment allocated for pollution remediation, with the aim of enabling all Parisians to enjoy the river from 2025 onwards.
- **Sustainability on the plate:** During the Olympic and Paralympic Games, 13 million meals will be delivered in a more responsible manner. Some 120 organisations including farmers, producers, caterers and nutritionists, as well as 200 athletes, were involved in the creation of the Paris 2024 Food vision. The organizers are pledging to deliver meals with half the carbon emissions of an average French meal. Worldwide Olympic Partner Coca-Cola will install 700 water and soda

fountains across all Paris 2024 sites, and install free drinking water points.

- **Low-Carbon Transportation:** The Paris 2024 organizers have structured 400 km of new bike lanes; more than 80% of the Olympic venues are situated within 10 km of the Olympic Village. Public transport operators plan to expand the bus, metro and train services in the Paris region by 15% compared to regular summer traffic. The vehicle fleet catering to athletes and the accredited participants is set to include electric, hybrid and hydrogen-powered vehicles provided by worldwide Olympic partner Toyota. In an effort to further reduce impact, the fleet used will be optimised, with about 40% fewer vehicles compared to previous Games.

A methodology defined in advance and fully integrated into the overall strategy and operations (ARROM): Paris Olympics-2024 is applying the already well known ARO approach; avoid, reduce, then offset, and further has introduced two additional stages i.e. to forecast emissions and to mobilize action.

- **Anticipate:** The previous Summer Games emitted an average of 3.5 million tonnes of CO₂. Paris 2024 considered this as its starting point and has developed a pioneering tool to gauge its carbon footprint.
- **Avoid:** By using 95% existing or temporary infrastructure, and by only building facilities that can be used after the Games are over in the areas involved, Paris 2024 is organising an event with more moderation, which helps reduce its impact not only on the climate but also on the environment.
- **Reduce:** Paris 2024 has accurately identified sources of emissions and proposed solutions for every activity: low-carbon structures, renewable energy, sustainable catering, etc. Paris 2024 has set the target of halving the carbon footprint of the Games compared to the average of previous Summer Games.
- **Offset:** Paris 2024 has taken into account the broadest category of emissions as Scope-3 which also covers the indirect impact of the Games, such as travel by spectators. All emissions that cannot be avoided will be offset by projects designed to bring both environmental and social benefits on all five continents.
- **Mobilise:** Paris 2024 hopes to harness the potential of sport as an effective driver of the environmental transition and thereby Paris 2024 has launched its own “Climate Coach”, an app designed to help its employees recognise and reduce their personal and professional carbon footprint. Paris 2024 is also encouraging its partners and suppliers to apply sustainability and limit their climate impact for 100% of Games purchases, as part of its ‘Responsible Procurement Strategy’.

Environmental strategies of the largest sport events encompass aspects such as resource management, infrastructure, energy usage, and climate neutrality. However, these strategies lack binding and quantitative, measurable standards, resulting in increasing environmental impacts of previous editions of major sport events. Frequently applied methods to measure those impacts include environmental input-output analysis, ecological footprint analysis, and carbon footprint analysis. Empirical results show that spectators’ and athletes’ travel activities, accommodations, and event operations contribute significantly to the events’ carbon emissions. Consistent quantitative assessments of environmental impacts and increased efforts to mitigate carbon emissions are necessary to accomplish the widely applied goal of carbon neutrality (Wicker, P., & Thormann, T. F., 2024).

Suggestions

Klower *et al.* (2020) suggested three possible next steps:

- Local/regional officials should be given priority to cut down on travel time, even though international federation officials are essential for the successful organization of a sporting event.

- In terms of media personnel, organizing bodies for Olympic events should make use of remote media by providing options for online press conferences and live virtual reality broadcasting. To enable distant attendance, the Olympic family and marketing partners should be given access to the same virtual media possibilities.
- Organising committees may think about imposing a carbon price on all event-related workers, which might be graded according to trip distance and air travel class (Ito, E., Higham, J., & Cheer, J., 2022).

Yet incisive reforms are required to up the game in Olympic sustainability. These reforms need to aim both at reducing resource input and at improving the governance of the Olympic Games to produce sustainable outcomes. The following three actions are feasible in the short run and would result in major improvements in sustainability:

- Greatly downsizing the event will lead to a gain on almost all sustainability indicators by reducing resource requirements. It will diminish the carbon emissions by visitors and bring down the ecological and material footprint by reducing the size and cost of the new infrastructure required. This measure also makes cost overruns and displacement of people less likely. Reducing in-person presence of spectators can be compensated by providing immersive sports content in digital form.
- Rotate the Olympics among the same cities. This way, all required infrastructure will already be in place, and the Olympic Games could be hosted with minimal social and ecological disruption and at minimal cost.
- Improve sustainability governance. This means creating or mandating an independent body to develop monitor and enforce credible sustainability standards. This action will improve the current situation, where each Olympic host city sets its own sustainability goals and remains unaccountable when not achieving them.

The journey towards a more sustainable future begins with understanding the impact of our actions and making conscious choices to reduce our carbon footprint. As we look forward to the Paris 2024 Olympics, World Cups, World Championships, International Titles, and more beyond, let us embrace sustainability principles and work together to create a healthier, more sustainable world for future generations. We must focus on 'Green Games' initiatives; waste reduction, energy efficiency, and water conservation. Initiatives included energy-efficient buildings, solar power use, and extensive recycling programs, minimizing the environmental footprint and raising public awareness about sustainable living. Together, we can make a difference.

CONCLUSION

Quantifying the environmental impacts of major sporting events will become increasingly important as sustainable development commitments become the mainstream. The Olympics movement appears to be leading the way in this respect but other organizations with global sporting reach are also working to make events more sustainable. Sustainability of mega sporting events represents an issue of growing concern for tourism and environmental policy-makers, event managers, academics and the general public. The carbon implications of international travel of event participants and attendees attract particular attention due to the disproportionate contribution it makes to global climatic changes. To make mega sporting events more sustainable from the environmental perspective, these should be accurately assessed with a view to develop effective mitigation. To enhance environmental sustainability of sporting mega-events, it is paramount to select a host country with the lowest carbon footprint from international transportation without compromising the magnitude of major visitor flows.

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