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PRIMARY RESEARCH

Paradigm shifts from social forestry to urban forestry: A synergy to mitigate urban heat Island in high-density developments

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Abstract
Urban heat islands are one of the biggest challenges for urban habitats. The two parallel worlds are growing together on this planet, one full of new opportunities for urbanization and another with shrinking green covers. High-density, high-rise development is a part of the first category of the world, i.e., a more urbanized one. It takes limited land resources to develop housing for more people by keeping more green covers intact than low-rise development. The dense developments are good for accessibility to different amenities and facilities. However, these developments pose challenges to sustainable development. However, the energy requirements are higher in high-rise-high-density settlements, and simultaneously, such developments challenge solar access to solar power. It eventually causes enormous growth in the environmental footprints of such urban habitats, resulting in higher surface temperature through the urban heat island effect. The study aims to explore the effectiveness of urban forestry in combating the increased surface temperature in highly dense cities. The study adopts a case study approach and investigates five different cases of cities where urban forestry was adopted as a mitigation measure to cut down urban heat island effects.

I. INTRODUCTION

The association of climate and urban area is two-way and cyclic: the climate drives the way urban spaces are used and the climatic performances of such spaces. In return, the metropolitan area influences the local environment [1]. The process of urbanization inspires our lives to grow in a more material and comfortable way. However, it induces many problems, too, such as pollution and global warming. The pollution and increase in surface temperature have adverse impacts at international levels, but their effects at the local levels are more quickly tangible; hence, their severity cannot be overlooked [2]. The urbanization process and its impact on climate goes on cyclically, and there might be a case when this process leads to a severe issue known as the Urban Heat Island (UHI) effect. As the urban spaces grow, the requirements of its residents also go higher, which results in higher energy demand and consumption, leading to higher greenhouse emissions and, thus, an increment in carbon footprint. The energy demand and consumption go upward due to increased lifestyle and use of comfort-giving materials/assets. It also surges due to increased transportation demands and even waste generation. For example, even an apple consumed by a person has a certain amount of carbon footprint, as illustrated in Figure 1. Ultimately, it causes an increase in surface temperature, thus creating urban heat island effects.

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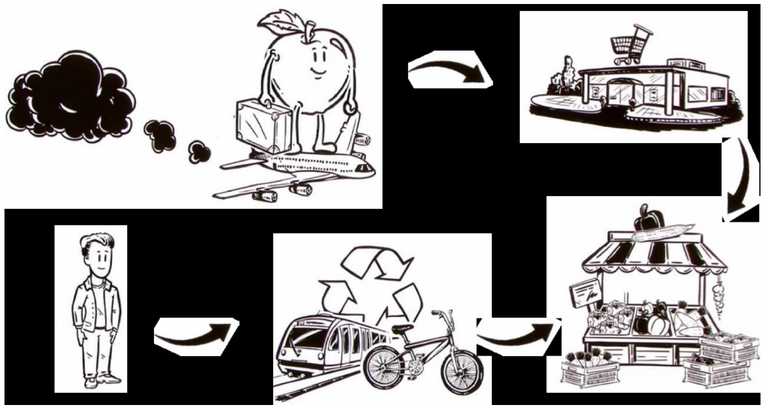

Fig. 1. An apple effect' illustrates carbon footprint generation due to increased consumerism (Source: Author's compilation of clip arts)

The urban heat island effect is a significant problem in high-density urban areas, especially in large and medium cities worldwide. As urban areas grow and expand, the increase in impervious surfaces and lack of vegetation can result in significantly higher surface temperatures than in surrounding rural areas. The urban heat island effect is when urban areas experience higher temperatures than rural areas due to human activities such as buildings, transportation, and energy production, as shown in Figure 2. This effect can adversely impact human health, the environment, and energy consumption [3, 1, 4, 5, 6].

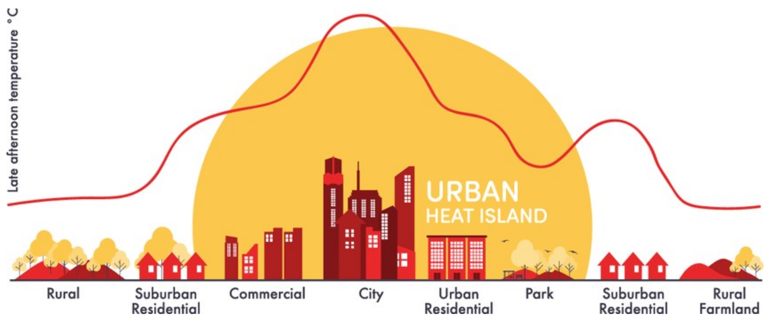

Fig. 2. Temperature variation causing Urban Heat Island (UHI) in different settlements (Source:https://shorturl.at/hoAF1)

Mitigating the urban heat island effect is thus an essential goal for urban planners and policymakers. Urban forestry has been identified as a potential solution to this problem. Urban forestry has emerged as a possible solution to mitigate the UHI effect. Multiple strategies (programs) to combat and reduce the urban heat islands are being practiced worldwide, such as 'wind paths' in Germany, 'heat-island reduction' initiatives in the USA, and 'river restoration' in Korea [7]. This study primarily focuses on the strategies and initiatives based on the forestation techniques being practiced worldwide. Therefore, this research article discusses the paradigm shift from social forestry to urban forestry and the potential for synergy between the two in mitigating the urban heat island effect.

The issue of global warming and the increasing surface temperature seems mammoth. However, it can be brought down by using small tools. The policy interventions stand sufficient in their place. However, they need to catch up regarding people's participation and community engagements, the simplest way to combat such a big issue. Therefore, studying and developing more participation-oriented solutions is theoretically and practically significant. Thus, the article discusses the challenges and opportunities associated with this shift in this article and highlights successful case studies worldwide. The paper refers to five case studies worldwide to elaborate on how urban forestry reduced the respective settlements' overall temperatures. However, before directly skipping to the case study part, the paper reviews the existing literature on urban forestry, its impact on the heat island effect, and the basic concepts associated with urban forestry.

II. LITERATURE BACKGROUND

Continuously increasing energy loads due to rapidly changing lifestyles sets an alarming situation for the climate. The increased use of electronic gadgets, rise in vehicle ownership, and incorporation of heavy-duty electrical appliances

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in our kitchen and domestic chores have drastically changed our lifestyles, resulting in increased demand and consecutive energy consumption. The more energy we use, the more greenhouse gas emission takes place. The current lifestyle significantly impacts individual carbon footprints, which is an invitation to various natural disasters (that are eventually artificial). The pollutants contributing to enlarging the carbon footprints consist of greenhouse gases and particulate matter emitted from line sources (transportation) and point sources (industries, residences). Drastic mechanized industrial revolutions occurred in the past few decades, resulting in changed lifestyles. As a result, the line sources, as well as the point sources, have emerged tremendously (as illustrated in Figure 3), whereas the mitigation measures still lack behind [8, 9, 10, 11].

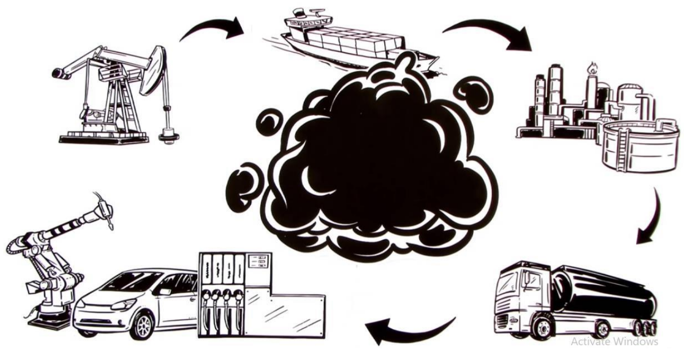

Fig. 3. Different urban and regional activities with increasing energy demands, resulting in more significant carbon footprints. (Source: Author's compilation of clip arts)

The convergence of social forestry with urban forestry solves this challenge by generating a synergy between high-density developments and urban forest canopies. The scientific evidence posts the consensus on the multiple benefits of urban forestry. The advantages include combating the urban heat islands and the psychosocial restoration and quality of life of urban habitats through ecosystem services [12]. The new forestry paradigms cover the multiple techniques under its umbrella: roof-top farming to shelter belts within housing communities [13]. The study aims to express the benefits of urban forestry, mainly its role in mitigating urban heat islands in high-rise, high-density settlements. The comparative case studies confirm that urban forestry can combat urban heat islands in high-density developments.

Trees have more to do with social work than we think. Social forestry, which involves planting trees in rural areas for fuelwood, timber, and other purposes, has been the dominant paradigm in forestry for several decades. However, the urban environment presents unique challenges that require a shift in forestry practices. Urban forestry involves the planting, management, and care of trees in urban areas to enhance the ecological, economic, and social benefits of trees in the built environment. This paradigm shift from social forestry to urban forestry represents a significant change in how we approach forestry in the context of urbanization [14].

Urban forestry significantly differs from traditional forestry as its goal is not to entirely transform the received wood into a genuine commodity but to care for trees planted in cityscapes. However, being situated in an urban context with a high population density offers an opportunity for diversified participation and efficient use of resources through tree management - not only logs but also leaves, branches, or fruits. Urban forestry benefits tremendously due to the emergence of new technology, investment, and information. Under the umbrella of urban forests, the ability to choose and grow trees in cities is enhanced, and the capacity to quantify the benefits amassed by their existence is expanded [15].

Ecological economics elaborated on the capacities of urban forestry to contribute to urban resilience during vulnerable and uncertain times. Often, there is a mismatch between environmental and cultural diversities due to patterns of urbanization. The two tend to be opposite directions, yet many global cities emerge as natural ecosystems with prosperous biodiversity [16]. On the other hand, some studies recorded the importance of public-partner-community partnerships to make urban forestry projects successful, reminding of the cruciality of social relationships in physical urban environments [17]. In Geo-sociology, similar acts are used as a lens to analyze the peri-urban fabrics. [18], recommended "positioning humans and more-than humans as collective subjects, as opposed to a more traditional resource management-oriented relationship." There

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are different types of urban forests, like linear forests, street trees, gardens and private greenspaces, parks and public greenspaces, trees along waterways, woodlands, and roadways, establishing urban forestry as a sustainable practice in a true sense. It becomes more sustainable as the concept is implemented in high-density settlements.

A. High-Density Developments and Heat Island Effect

There are several reasons why high-density developments are needed in cities, as established by different authors [19, 20, 21, 22].

1) *Population growth* : As cities continue to grow, there is an increasing need for housing to accommodate the growing population. High-density developments allow more people to live in smaller areas, which can help meet the housing demand.

2) *Efficient use of land* : High-density developments can make more efficient use of land, as they require less space per person than low-density developments. It can help to preserve open space and reduce urban sprawl.

3) *Access to amenities* : High-density developments are often located in urban areas, providing residents access to many amenities, such as public transportation, shops, and restaurants. It can help to reduce the need for car use, which can, in turn, reduce traffic congestion and carbon emissions.

4) *Economic benefits* : High-density developments can provide economic advantages, such as increased property values and tax revenue for local governments. They can also support local businesses by providing a more extensive customer base.

5) *Social benefits* : High-density developments can promote social interaction and community cohesion by bringing more people together in a smaller area. They can also provide a diverse mix of residents, which can help to create a vibrant and inclusive community.

However, it is essential to note that high-density developments must be designed and managed carefully to ensure they are sustainable, liveable, and healthy environments for residents. Factors such as access to green space, public transportation, and services such as schools and healthcare must be considered in the planning and design process. High-density developments can exacerbate Urban Heat Islands (UHIs) due to several factors [23].

6) *Reduced green space* : High-density developments often result in less open space and vegetation, which can increase the heat absorbed by concrete and asphalt surfaces.

7) *Increased impervious surfaces* : High-density developments can also result in raised impervious surfaces, such as roads, buildings, and parking lots, which absorb and reradiate heat.

8) *Increased energy use* : High-density developments typically have more buildings and people, resulting in increased energy consumption for cooling and ventilation, which can further contribute to the urban heat island effect.

9) *Reduced air circulation* : High-density developments may also reduce air circulation, leading to higher temperatures and a greater concentration of pollutants.

To mitigate the effects of high-density developments on UHIs, strategies such as green roofs, cool roofs, and permeable pavements can be implemented to reduce heat absorption and improve air circulation. Additionally, increasing the amount of green space and trees can help to lower temperatures and provide shade. Finally, reducing energy use through sustainable building design and using renewable energy sources can help reduce the heat emitted by buildings.

B. Urban Forestry and Its Impact on Heat Island Effect

The opportunities presented by urban forestry include enhanced biodiversity, improved air quality, reduced storm water runoff, and energy conservation. Trees also provide social benefits such as aesthetic value, improved mental health, and community building. However, urban forestry also presents several challenges, including limited space for tree planting, competition for resources, and the need for specialized maintenance practices. For example, community-led tree-planting initiatives can involve residents caring for and managing urban trees, creating a sense of ownership and community pride. These initiatives can also provide additional benefits such as employment opportunities and income generation [24].

Urban forestry has several benefits in combating UHI effects. First, trees and vegetation can provide shade and reduce the direct sunlight that reaches the ground. It can lower surface temperatures and reduce the heat absorbed by buildings and other structures. Trees and vegetation can also help to cool the surrounding air through a process called evapotranspiration, which is the release of water vapor from plants into the atmosphere. In addition to reducing UHI effects, urban forestry has several other benefits for cities and metropolitan areas. For example, trees and vegetation can improve air quality by absorbing pollutants and releasing oxygen. They can also help reduce stormwater runoff by absorbing and filtering rainwater, reducing the risk of flooding and improving water quality. Furthermore, urban forestry can provide various social and economic benefits, such as creating green spaces for recreation and relaxation, increasing property values, and attracting businesses and tourism.

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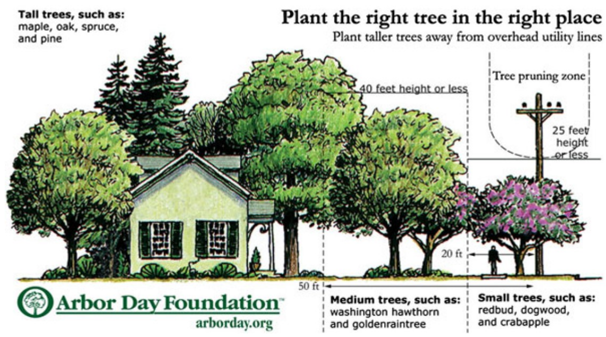

Fig. 4. Different urban and regional activities, resulting in more significant carbon footprints

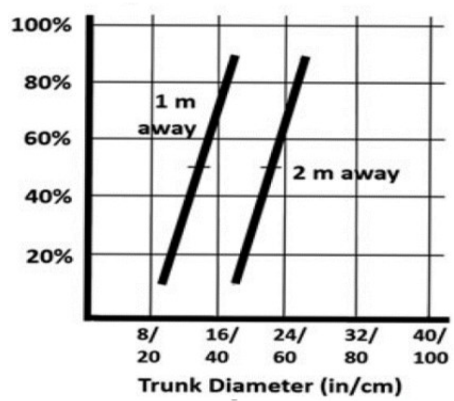

Fig. 5. Infrastructure damage probability by trunk diameter

To effectively combat UHI effects through urban forestry, it is essential to implement strategic planning and management practices. It includes selecting suitable tree species and planting locations based on local climate and environmental conditions and ensuring proper maintenance and care for trees and vegetation, as shown in Figures 4, 5, and 6.

It is also essential to engage and educate community members on the benefits of urban forestry and involve them in the planning and implementation process. Urban forestry is critical in combating UHI effects and promoting more sustainable and liveable urban environments.

Through strategic planning and management practices, cities and metropolitan areas can leverage the benefits of trees and vegetation to reduce surface and air temperatures, improve air and water quality, and provide various social and economic benefits for their communities. Trees and vegetation provide shade, lower surface temperatures, and enhance evaporative cooling, all of which can help to mitigate the urban heat island effect in the following aspects.

1) Shade : Trees provide shade, which can reduce the amount of direct sunlight that reaches the ground, reducing the amount of heat absorbed by surfaces such as roads, buildings, and sidewalks. The effect of the right tree at the right place is demonstrated in Figure 6.

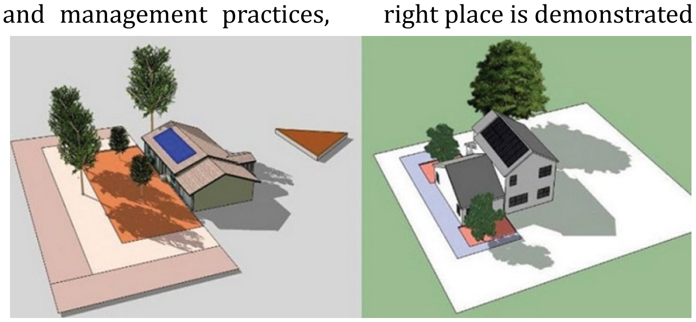

Fig. 6. Effect of canopies on building shading, if planted appropriately (Source: https://shorturl.at/txOST)

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2) Evapotranspiration : Trees also engage in evapotranspiration, which releases water vapor into the atmosphere through their leaves. This process cools the air around the tree and can help to reduce ambient temperatures.

3) Heat absorption : Vegetation absorbs less heat than pavement, buildings, and other surfaces, reducing the heat re-radiated into the atmosphere.

4) Carbon sequestration : Urban forestry can help mitigate the urban heat island effect and provide other environmental benefits, such as carbon sequestration, which can help alleviate the impacts of climate change.

In addition to these benefits, urban forestry can improve air quality, reduce stormwater runoff, and provide habitat for wildlife. To maximize the advantages of urban forestry, choosing appropriate tree species, maintaining trees properly, and incorporating trees into urban design plans are essential.

III. RESEARCH GAP AND METHODOLOGICAL OUTLINE

There are ample techniques and strategies studied for efficient tree plantation as a part of various forestry exercises. However, a direct connection to people's participation is found undertoned in the existing literature. As understood while referring to the current body of literature, the significant research gap persists as follows [25, 1, 26, 27]:

- General public awareness about the correct tree plantation techniques
- Mass impacts can be created by masses utilizing urban forest programs; however, such initiatives are limited to only megacities.
- Micro-level initiatives are limited to the elaborated contribution of urban local bodies.

In line with the literature review and the gap identified, the current study aims to comprehend the public campaigns about urban forestry assignments organized by the local governments at micro levels and their impact on the urban heat island of the local area. Therefore, five case studies, New York, Singapore, Barcelona, Tokyo, and Mumbai, have been undertaken. A typical literature-based study approach was adopted for the same.

IV. CASE STUDIES

Several successful case studies demonstrate the potential for synergy between social and urban forestry in mitigating the urban heat island effect.

A. Case Study 1: New York City, USA

In New York City, Million Trees NYC is a public-private partnership that aims to plant one million trees by 2017. This initiative involves community engagement and provides environmental and social benefits to residents, including enhanced air quality, storm water management, and energy conservation. New York City has one of the world's most extensive urban forestry programs. The City has implemented a tree-planting program, Million Trees NYC, which aims to plant one million new trees by 2025. The program has already produced over 700,000 trees in the City, significantly increasing tree canopy cover. The increase in tree canopy cover has been shown to reduce surface temperatures by up to 10^0F in some areas, mitigating the UHI effect. The program has also helped to improve air quality, reduce storm water runoff, and provide numerous social and economic benefits.

B. Case Study 2: Singapore

In Singapore, the National Parks Board implemented the City in a Garden initiative, which involves planting one million trees and enhancing biodiversity in the city-state. This initiative includes community-led tree-planting programs and encourages the use of green roofs and walls to improve energy efficiency. Singapore is a small island city-state with a population of over 5 million people. The city-state has implemented a comprehensive urban forestry program to increase green cover to 50% by 2030. The Community in Bloom Initiative program includes the planting of more than 200,000 trees annually, along with the construction of numerous green roofs and walls. The increase in green cover has been shown to reduce surface temperatures by up to 6^0C, mitigating the UHI effect. The program has also helped to improve air quality, reduce stormwater runoff, and provide numerous social and economic benefits.

C. Case Study 3: Barcelona, Spain

Barcelona is a Mediterranean city that experiences high temperatures and intense heat waves during summer. The City has implemented a comprehensive urban forestry program to increase the number of trees and green spaces in the City. The program has included creating new parks and green spaces, planting over 20,000 trees, and developing green corridors along major transportation routes. The program has been shown to reduce surface temperatures by up to 2.5^0C, mitigating the UHI effect. The program has also helped to improve air quality, reduce noise pollution, and provide numerous social and economic benefits. Due to the urban forestry campaign, Barcelona and its administrative area were named the 'European Forest City 2022' by the European Forest Institute (EFI). It was an attempt to recognize the efforts made by local urban management to

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promote green infrastructure through the Barcelona Nature Plan, which aimed at increasing greening and favoring biodiversity by 2030. A large part of this infrastructure corresponded to Urban Forests, which range from planted roundabouts to small forests in urban parks and extensive forests in natural protected areas like the Collserola natural park (with 8000 hectares of Mediterranean forests close to the City).

D. Case Study 4: Tokyo, Japan

Several scholars have widely addressed the historical presence of Japan's forestry practices. From the role of forests as 'commons managed collectively by rural communities, the formation of the timber industry during the Edo period to provide construction material cities, the exponential growth of this industry during the postwar decades, and the resultant environmental transformations. Tokyo, one of the largest cities in the world, with a population of over 13 million, implemented a comprehensive urban forestry program to increase overall green cover and mitigate the urban heat island effect. The program included the planting of more than two million trees annually, along with the development of different green roofs and walls. The increase in green cover reduces surface temperatures by up to 3^0C, curtailing the Urban heat island effect. The program also turned to help improve air quality, reduce stormwater runoff, and provide social and economic benefits.

E. Case Study 5: Mumbai, India

As per government estimates, India's total forest and tree cover now stands at 80.73 million hectares—roughly 24.5% of its geographical area. That is far from the target of 33%, which India has committed to raising by 2030. Maharashtra, for example, has lost a whopping 1,610 sq km of forests in the past 30 years. With five trees per human against the prescribed ratio of 7 trees per human, there is an increasing need to build back the forest cover in Indian cities.

The Miyawaki method was adopted. Forests grown under the Miyawaki method grow 10 times faster, are 100 times more biodiverse, and have 30 times more green surface area with no maintenance required after 2 years. The Miyawaki method of afforestation involves planting several different types of trees close together in a small space. The technique works well in cities and places with less available land for the plantation of forests. A dense plantation retains more groundwater and recharges the groundwater table. It attracts more birds and insects, produces native fruits, and improves air quality. Miyawaki forests require a minimum plantation of 2000 saplings.

In Mumbai, India, the Urban Afforestation Project involves planting trees on roadsides, medians, and open spaces. The project also involves community participation in the care and maintenance of urban trees, leading to increased biodiversity and improved air quality.

V. CONCLUSION

As explained through case studies, urban forestry's direct effects on reducing urban heat island effects are evident. Urban forestry has emerged as a better alternative to social forestry and a potential solution to mitigate the UHI effect in cities worldwide. The case studies presented in this paper highlight the effectiveness of urban forestry in reducing surface temperatures, improving air quality, reducing stormwater runoff, and providing numerous social and economic benefits. These case studies demonstrate the importance of implementing comprehensive urban forestry programs to mitigate the UHI effect and improve the overall liveability of cities.

As urban areas grow and expand, cities must prioritize implementing urban forestry programs to curtail urban heat island effects and create more sustainable and liveable cities. A few of the policy interventions on urban forestry to combat the urban heat island effects could be as follows:

- Public awareness programs for the ordinary people to improve results through efficient urban forestry.
- Tax incentives to the part icipants of urban tree plantation programs.
- Incentives for implementing roof-top plantation.
- Organise forestry events at regular frequencies by local urban bodies.

Urban forestry presents opportunities for enhancing biodiversity, improving air quality, reducing stormwater runoff, and energy conservation. However, urban forestry also presents several challenges, including limited space for tree planting, competition for resources, and the need for specialized maintenance practices. These challenges can be addressed in further studies in this domain.

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