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"Evaluating the Impact of Urban Cycling Infrastructure on Public Health Outcomes: A Study of Accessibility, Safety, and Active Commuting Behaviour in Sustainable Transportation Systems."

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Abstract – *This research investigates the role of urban cycling infrastructure in improving public health by examining critical elements such as accessibility, safety, and active commuting behavior within sustainable transportation systems. As cities around the world prioritize environmental sustainability and public health, cycling has become a key component of active transportation. This study explores how the establishment of dedicated cycling lanes, bike-sharing initiatives, and integrated urban planning impact cycling participation and its related health outcomes. By employing a combination of quantitative surveys, spatial data analysis, and case studies of cities with well-developed cycling infrastructure, we evaluate changes in cycling frequency, improvements in air quality, increases in physical activity, and reductions in traffic-related injuries. The results indicate that effective cycling infrastructure significantly boosts cycling accessibility, enhances active commuting rates, and leads to better cardiovascular health, reduced exposure to air pollution, and fewer road traffic accidents. This research underscores the importance of policy interventions and planning strategies in fostering a cycling culture and offers recommendations for urban planners and policymakers to optimize the public health benefits of sustainable transportation systems.*

Keywords: Infrastructure, Public Health, Strength, Active Commuting Behaviour, etc.

1. INTRODUCTION

The assessment of urban cycling infrastructure and its influence on public health outcomes explores the ways in which the development and enhancement of urban cycling networks can affect elements of health. Three main topics are the focus of this study: safety, accessibility, and encouraging active commuting. In order to comprehend how modifications to cycling infrastructure might promote physical activity, lower the number of traffic-related injuries, and boost general community health, these components are examined within the larger framework of sustainable transportation systems

1.1 Accessibility:

This idea concerns the accessibility and usability of bicycle infrastructure, such as bike lanes, bike-sharing stations, and interconnected cycling routes. People's decisions to cycle are greatly influenced by the existence and thoughtful positioning of these facilities. Improving accessibility might encourage more individuals to choose cycling as their preferred form of transportation, which will ultimately increase the amount of cycling activity in urban areas, particularly in places with limited resources or crowded neighborhoods.

1.2 Active Commuting Behaviour:

This is the extent to which city dwellers choose to use bicycles for everyday transportation, like riding to work or school. Stress reduction, improved mental health, and increased cardiovascular fitness are just a few of the health advantages of active commuting, particularly when done by bicycle. Increasing the number of people who commute by bicycle can reduce air pollution, traffic accidents, and reliance on cars- All of which significantly contribute to improving urban public health Let me know if you'd like further changes or if you need something else .

2. LITERATURE REVIEW

Saelens et al. (2003)- It has been demonstrated that cycling participation is greatly impacted by the availability of bicycle infrastructure, such as bike lanes, bike-sharing stations, and linking routes. According to research by Saelens et al. (2003), accessible and well-designed bicycle infrastructure promotes active commuting. The authors of the study discovered that cycling rates were greater in communities with excellent bike accessibility, especially when those neighborhoods had direct access to important urban destinations like places of employment, educational institutions, and public transportation hubs. Pucher et al. (2010) provided additional support for these findings, pointing out that cities with more accessible and widely distributed bicycle infrastructure typically have higher levels of riding involvement, which helps both environmental and physical health.

Martin et al. (2016)- investigated how cycling rates in high-density or underserved metropolitan regions can be impacted by the distribution of bicycle infrastructure.

According to their findings, specific investments in cycling infrastructure in these locations might greatly boost riding rates, particularly among populations like low-income or minority communities who have historically faced obstacles to active transportation. This lends credence to the notion that expanding access to bike lanes can close disparities in transportation equity.

Heinen et al. (2010)- Safety is a crucial factor in evaluating the impact of cycling infrastructure on public. A robust body of literature has examined the connection between cycling safety and community well-being outcomes, particularly in reducing injuries and fatalities related to cycling. Buehler and Pucher (2012) explored the relationship between cycling infrastructure and cycling-related injuries in cities across the United States and Europe. They found that cities with protected bike lanes and well-designed cycling infrastructure had lower rates of cyclist injuries and fatalities compared to those with minimal infrastructure or poorly designed lanes.

Safety is also directly tied to mental and physical health outcomes. Heinen et al. (2010) found that cyclists who feel safer on the roads are more likely to engage in cycling as a regular form of transportation, leading to better overall health outcomes, including improved cardiovascular health and lower stress levels. This highlights the importance of not only increasing infrastructure but ensuring that it is designed with cyclist safety in mind.

Andersen et al. (2011)- also established that increased cycling participation leads to significant reductions in the risk of premature mortality. The study specifically found that cities with higher cycling rates experienced lower levels of all-cause mortality, especially in middle-aged populations. This reinforces the idea that urban cycling infrastructure not only encourages more cycling but has a direct impact on public health by fostering healthier commuting habits.

Garrard et al. (2006)- found that active commuting, including cycling, has significant mental health benefits, such as improved mood, reduced anxiety, and better overall well-being. This search align with the expanding body of evidence that emphasizes the role of cycling infrastructure in promoting positive mental well-being outcomes, especially in urban environments where residents frequently experience elevated levels of stress and pollution.

Hollingsworth et al. (2020)- Analyzed the effects of increased cycling infrastructure on air quality and traffic accidents. They concluded that more extensive cycling networks lead to reduced car use, which lowers emissions of harmful pollutants, thus improving air quality and reducing respiratory illnesses in urban populations. Additionally, by reducing car traffic, cycling infrastructure helps lower the occurrence of traffic-related injuries and fatalities, further enhancing overall community well-being outcomes.

Pucher et al. (2010)- Recommended a range of policy measures, including the creation of safe, segregated bike lanes, traffic calming measures, and incentives for employers to promote cycling to work. Additionally, Hidalgo and Graftieaux (2010) suggested that cities should invest in bike-sharing programs, particularly in areas with lower car ownership, to increase accessibility and encourage cycling among a wider range of residents.

The Future study in area should concentrate on the long-term effects of cycling infrastructure on well-being outcomes, particularly in low-income or marginalized communities. Additionally, studies examining the intersection of cycling infrastructure with other forms of sustainable transportation, such as public transit, will be crucial for understanding how cycling can be integrated into broader urban mobility strategies.

Hayauchi et al.- carried out A case study in Japan examined how topography impacts active travel and the introduction of a new public transport service in a hilly district of Yokohama. Their findings showed that the difficulty of uphill walking reduced the appeal of walking and cycling, although some locals were more accustomed to navigating the slopes. The study highlights the importance of developing strategies to account for topography in public transport planning. Utilizing travel behavior survey data from a suburban hillside area, the authors built a multinomial logit model to estimate utility-based accessibilities, incorporating the effect of topography on travel mode selection. Additionally, they evaluated the improvements brought about The results indicated that topography negatively affected walking and bus egress trips, while the model provided utility-based accessibility data for each area of the district, supporting the evaluation of accessibility improvements following the introduction of the new transportation service.

Kopal and Witkowsky's research explores the connection between the characteristics and functionality of the built environment and individual mobility patterns, focusing on identifying factors that encourage healthy mobility behaviors and enhance quality of life. They conducted a multidisciplinary survey (n = 500) in Essen, Germany, utilizing the "Triad" model, which combines aspects of urban planning, mobility planning, and health sciences. They advocate for more comprehensive approaches to mobility and urban planning to promote public well-being. particularly in light of the transportation sector's significant contribution to pollutant emissions. Their findings also suggest that a car-centric lifestyle leads to increased immobility. The study highlights a range of factors, from pollution levels to infrastructure that supports active modes of transport, which can either positively or negatively affect health. Through multiple regression analysis, they identified that factors like satisfaction with walking, access to public transit, and improved air quality are important contributors to healthier mobility choices.

The review by Zhu et al. provides a bibliometric analysis of spatial accessibility research from 1999 to 2022, showing a significant increase in publications during this time (20 in 1999; 1,090 in 2022). The authors anticipate continued growth in this field due to the expanding availability of data, as well as the development of new tools, methods, and technologies. They argue that enhancing spatial accessibility through efficient public transportation systems, improved walking infrastructure, and measures to reduce traffic congestion can improve access to destinations and decrease dependence on cars. Additionally, spatial accessibility is connected to creating more inclusive systems that ensure equitable access for everyone. The authors suggest that future research should explore new data sources and analytical techniques, while also examining the effects of emerging technologies like autonomous vehicles and e-commerce on spatial accessibility trends. They recommend conducting these analyses at various spatial scales.

Finally, Alquthani's research highlights the importance of improving pedestrian infrastructure from both macro and micro perspectives. While micro-level concerns regarding pedestrian infrastructure often receive attention, macro-level planning solutions tend to be overlooked. Alquthani advocates for involving stakeholders to enhance pedestrian access, especially for children traveling between home and school. Overall, the literature review underscores the increasing body of evidence supporting

the role of sustainable and active mobility through walking and public transport systems in urban settings. Despite the challenges, the review highlights the potential of these modes of transportation to contribute to environmental sustainability, public health, and the creation of more equitable and livable urban spaces. This review provides a comprehensive summary of existing research on sustainable and active mobility, drawing key insights from studies in urban transportation planning.

3. METHODOLOGY

3.1 Data Collection and Case Study Selection

This study explores the safety and usability perceptions of various cycle lane designs implemented or planned in Palermo, a city with a population exceeding 670,000, positioning it as one of the largest urban centers in southern Italy. The research concentrates on the present and future state of bicycle mobility in Palermo, especially considering recent initiatives such as the Plan of Active Mobility, launched in 2015. and has gained momentum since then. In 2020, an estimated 15,000 Palermitans were using bicycles and electric scooters daily. This number has since increased, likely due to a combination of factors such as the pandemic's effect on transportation habits and rising energy costs. As a result, the Palermo Bike Mobility Project has been developed to further expand the city's cycling infrastructure, with plans to extend the bike lane network by 80 kilometers using funds from the National Recovery and Resilience Plan (PNRR). The city’s urban center also attracts a significant number of tourists year-round, further contributing to the high volume of cyclists, both local and visiting.

The study starts with the premise that understanding the demographic diversity of bicycle users within Palermo's historic center is essential for shaping effective urban planning and transportation policies. To collect pertinent data, the research utilized a survey approach aimed at capturing a representative sample of the cycling community. A purposive sample of 50 participants was chosen to take part in the survey. which was conducted in December 2021. The data acquisition phase lasted for one month, during which participants were asked to complete a questionnaire that took approximately 8 minutes to finish.

The sample was designed to represent a broad demographic, with a focus on individuals ranging from 18 to 45 years old, categorized into two subgroups (18-35 and 36-45). This age bracket was chosen based on literature and previous studies, which indicate that cyclists in Italy, particularly in regions like Sicily, are predominantly in this age group (Pantelaki et al., 2023; Stamatiadis et al., 2019). The survey sought to gather insights into participants' cycling habits, including how often they use bicycles and the reasons behind their cycling choices, preferred routes, and any obstacles they encounter. Additionally, the survey sought feedback on existing cycling facilities, such as bike paths, parking options, and safety provisions, as well as suggestions for future improvements.

The 50 respondents were categorized into three groups:

- Group 1: 20 Palermo resident
- Group 2: 10 infrastructure specialists who are also reside of Palermo
- Group 3: 20 tourists or Italian commuters

The selection process used stratified random sampling to ensure a diverse representation of cyclists' perspectives. This approach was employed to gather a variety of opinions on different cycle lane designs, with a particular focus on assessing the perceived effectiveness of existing and planned infrastructure from the perspective of different demographic groups. The survey respondents were drawn from an association aimed at promoting the liveability of the city through greater adoption of public transport, bicycles, and other eco-friendly vehicles. This group, consisting of around 450 members, acted as a primary resource for recruiting participants who had a strong understanding of cycling infrastructure and its impact on urban mobility.

The sample aimed to capture a broad range of insights into the cycling experience in Palermo's historic center, allowing the researchers to understand the challenges and opportunities associated with the city’s growing cycling infrastructure. The focus on users aged 18-45 ensured that the study was aligned with demographic trends and the active involvement of younger residents and commuters in sustainable transportation. By incorporating feedback from residents, experts, and tourists, the study provides a holistic view of the current state of cycling in Palermo and identifies areas for potential improvement to create a more bike-friendly urban environment.

3.2 Complete Consistency Method (CCM) in Multi-Criteria Decision-Making for Urban Bicycle Infrastructure

In the context of evaluating urban cycling infrastructure, selecting the best geometric-functional design for bike lanes and related facilities is a complex problem that requires the consideration of multiple competing criteria. These criteria may include factors such as environmental sustainability, safety, accessibility, and comfort. The process of selecting the ideal cycling infrastructure design is a typical example of a multi-criteria decision-making (MCDM) challenge. As cities continue to develop their cycling infrastructure, urban planners and designers face the challenge of evaluating various design options that can fulfill different, sometimes conflicting, objectives.

3.3 The Complete Consistency Method (CCM). is a novel approach introduced in recent research to address these types of challenges in MCDM. The method, initially presented by *Pamučar et al. (2018)*, offers a structured, systematic way to evaluate and select the most appropriate design solution based on a set of defined criteria. FUCOM has gained attention in several fields, from transportation planning to environmental sustainability, as a tool for improving decision-making processes by minimizing subjectivity and increasing the reliability of the chosen solutions. Previous applications of FUCOM have been used in diverse studies (for example, Badi et al., 2019; Bozanic et al., 2020; Durmić, 2019; Everest et al., 2024), demonstrating its flexibility and adaptability.

Key Features and Benefits of FUCOM

One of the central advantages of FUCOM is its ability to simplify the process of determining criteria weights through pairwise comparisons. Traditional MCDM methods often require complex algorithms that involve numerous comparisons across all possible pairs of criteria. FUCOM, however, uses an efficient approach by limiting the number of comparisons to (n—1), where "n" represents the number of criteria. This reduction in comparisons not only saves time but also enhances the consistency of the results by reducing the possibility of error.

The FUCOM method is particularly beneficial for decision-makers who may not have access to highly sophisticated modeling tools or extensive data. It is a more accessible method, as it allows for the use of both decimal and integer values in the pairwise

comparison process. This flexibility ensures that decision-makers can apply FUCOM in real-world scenarios, where different data types and values are often encountered.

Furthermore, the FUCOM approach ensures that the criteria's weightings adhere to mathematical transitivity conditions, meaning that if criterion A is prioritized over criterion B, and criterion B is prioritized over criterion C, then criterion A must be prioritized over criterion C. This transitivity requirement is key to ensuring the consistency and reliability of the crating process, reducing the likelihood of contradictory or inconsistent conclusions.

3.4 Application of FUCOM in Cycling Infrastructure Planning

When applied to the selection of urban cycling infrastructure designs, FUCOM can help planners assess various proposed bike lane geometries and their suitability based on the predetermined criteria. For example, planners may consider factors such as:

- **3.4.1 Environmental Sustainability:** How well does the design reduce carbon emissions or improve air quality?
- **3.4.2 Safety:** Does the design minimize cyclist accidents or improve the safety of cyclists compared to existing infrastructure?
- **3.4.3 Comfort and Accessibility:** How easy and comfortable is it for cyclists to use the infrastructure, especially in different weather conditions or times of day?
- **3.4.4 Cost-Effectiveness:** What is the financial feasibility of implementing and maintaining the design?

Using FUCOM, each of these criteria would be compared in pairs to determine their relative importance. For example, planners might compare "safety" and "comfort," then "comfort" and "environmental sustainability," and so on, until all criteria are compared. The resulting weights would indicate which criteria are most critical to the decision-making process, helping planners prioritize aspects like safety or environmental impact based on the city's needs and goals.

3.5 Reducing Subjectivity in Decision-Making

One of the key benefits of FUCOM in the context of urban planning and cycling infrastructure is its ability to reduce subjectivity. Decision-makers often face challenges when it comes to ranking criteria based on personal preferences, biases, or incomplete

data. FUCOM helps standardize the weighting method by providing a more organized approach to evaluating criteria, reducing personal bias in the decision-making process. This leads to more objective, consistent results that are aligned with the goals of urban sustainability and public health.

Additionally, FUCOM offers a clear and straightforward algorithm for determining the weights of the criteria, making it easy for planners and urban designers to apply in practical settings. This is particularly useful in urban environments, where quick decisions are often needed, and planning teams may not have the luxury of conducting exhaustive research on every possible criterion.

4. GRAPH AND CHART

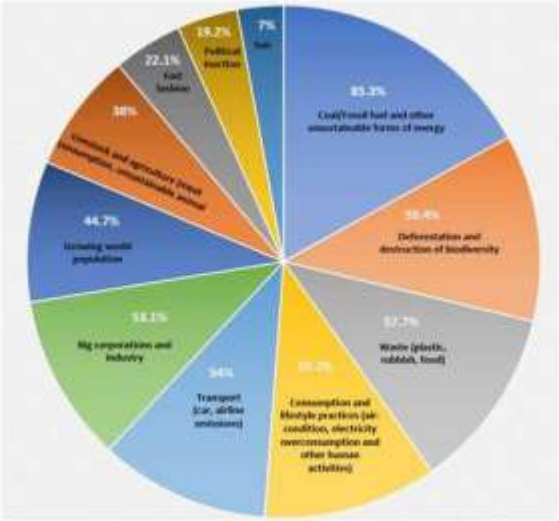

Fig.4.1 Cycling Infrastructure on Public Health

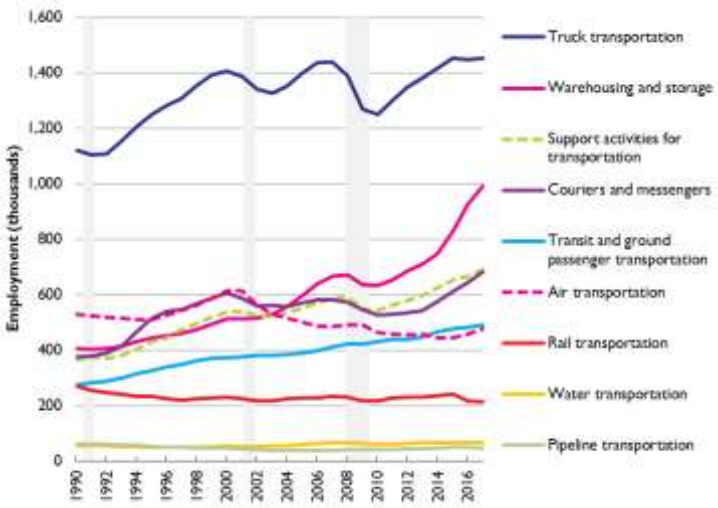

Fig.4.2 graph b/w years and development

CONCLUSIONS

Pedestrian and cycling safety is often overlooked in U.S. cities, making these forms of transport dangerous. However, countries like the Netherlands and Germany have much lower injury and fatality rates, proving that with the right measures, walking and cycling can be safe. American cities can adopt similar strategies, as the technology and methods already exist, based on decades of European success.

Safety improvements would reduce deaths and injuries, and public campaigns should highlight these personal impacts to encourage more people to walk and bike regularly, promoting exercise, mobility, and independence. Countries with higher rates of walking and cycling, such as the Netherlands and Denmark, also have lower obesity and health issues, demonstrating the benefits of active transport.

Walking and cycling can also ease traffic, reduce pollution, and conserve energy. These benefits are why European countries support strategies that promote walking and cycling safer and more convenient. In the U.S., various groups, including health experts and urban planners, should work together to advocate for better infrastructure.

Public health professionals play a crucial role in motivating people to adopt walking and cycling as daily habits for better health. However improving infrastructure will require support from policymakers at all levels of government to fund and implement necessary change.

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