EXPLORING PHYSICAL ACTIVITY AND HARASSMENT IN URBAN CYCLING THROUGH A GEOLOCALISED APPROACH

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Dedico esta tesis doctoral

a mi familia.

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CERTIFICAMOS: Que la Sra. Laura Antón González ha trabajado bajo nuestra dirección en el Departamento de Educación Física y Deportiva de la Universitat de València, y ha obtenido y trabajado personalmente el material de su tesis doctoral titulada "*Exploring physical activity and harassment in urban cycling through a geolocalised approach*/Exploración de la actividad física y el acoso en el ciclismo urbano mediante un enfoque geolocalizado".

El mencionado estudio ha finalizado el día 17 de diciembre de 2024 con el máximo aprovechamiento, y los que subscriben han revisado la presente tesis doctoral y están conformes con su presentación para ser juzgada.

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ABBREVIATIONS

AIC: Akaike Information Criterion

AK: Author Keywords

BC: Black Carbon

BMI: Body Mass Index

BP: Bodily Pain

BSS: Bike Sharing System

EoT: Ease of Travel

ER: Emotional Role

GH: General Health

GHG: Greenhouse Gases

GPAQ: Global Physical Activity Questionnaire

ICT: Information and Communications Technology

ID: Unique Identifiers

LDA: Latent Dirichlet Allocation

LGTBI: Lesbian, Gay, Transgender, Bisexual, and Intersex people

MCS: Mental Summary Component

MET: Metabolic Task Equivalent

MH: Mental Health

MVPA: Moderate to Vigorous Physical Activity

PA: Physical Activity

PCS: Physical Summary Component

PF: Physical Function

PM: Particulate Matter

PR: Physical Role

SC: Smart Cities

SDG: Sustainable Development Goals

SF: Social Function

SF12v2: Short Form Health Survey 12 version 2

VT: Vitality

WHO: World Health Organization

ABSTRACT

Population density in urban areas is contributing to an unsustainable crisis in terms of environmental pollution, biodiversity loss, resource scarcity, traffic congestion and socio-economic inequalities (Y. Wu et al., 2018). Among the strategies proposed by the World Health Organisation to reduce the impact of motor vehicle use in urban environments, it is recommended to use active means of transport. Moreover, the use of these modes increases the population's physical activity levels and allows them to benefit from their advantages. Among the different active modes, cycling is proposed as a sustainable and viable alternative to motor vehicles, as it meets the requirements of sustainable and smart cities. However, despite it benefits associated, its use remains significantly lower compared to motor vehicles. Therefore, there is a need to generate scientific evidence that can be used by policy makers and urban planners to promote cycling in urban environments.

The main objective of this dissertation is to explore urban cycling use and some factors that influence it as a means of transport, specifically in a sample of residents in Madrid, Barcelona, Valencia and Seville. In particular, the aim is to examine built urban environment impact on urban cycling benefits, including perceived health and physical activity levels, and harassment risk during active trips.

To achieve these objectives, this dissertation is organised according to the structure detailed below. First, a research background section provides a general introduction that contextualises the theoretical framework, as well as establishes the objectives to be achieved. Subsequently, two studies focusing on the massive analysis of textual data using text mining techniques are presented. The first study exhaustively examines the scientific literature available in the Scopus database on cycling in urban environments, with the aim of providing a solid theoretical basis for the doctoral dissertation. Among the main results of this study is the growing interest in cycling among the scientific literature, especially in China and the United States. This growth reflects the need to transform urban environments into healthier spaces that prioritise active transport. In addition, the topics most researched by the scientific community include smart urban mobility, bike sharing systems, infrastructure and cycling behaviour. In the second study, to find out the population's perception and opinion on the urban cycling, this same data analysis technique was applied to X social network posts containing the keywords bicycle and city (or similar), or their associated emojis. One of the most relevant results was a generally positive public sentiment towards its use. In addition, among the most commented topics were safety and the importance of segregated lanes.

This is followed by two quantitative studies. The third study quantifies cycling as a mode of transport using socio-demographic, health and physical activity variables, as well as the amenities present in the built environment around the place of residence for cycling, public transport and car use. The results of this study show that factors such as age, physical activity levels and the presence of cycling infrastructure are crucial for increasing use. Another notable finding is that women showed a lower prevalence of cycling compared to men. These results reveal unequal patterns of use in the participating sample according to gender. Specifically, among the scientific literature, street harassment is one of the main barriers limiting women's cycling. Therefore, these results served as a pretext to establish the objective of the fourth study: to examine the experiences of harassment during active commuting from a geolocalised perspective.

Women participants in this study reported more incidents of harassment compared to men, especially during the winter months and at night. In addition, features of the built environment at risk of harassment were identified such as pedestrian areas, intersections, fountains, parks, areas near planters and outdoor areas for sporting activities. These results underline the importance of incorporating measures to improve cycling safety, paying particular attention to the needs of women.

After that, the final reflections of the dissertation are presented, outlining the conclusions derived from the four studies conducted and their policy implications. Finally, the bibliographical references used, and the relevant appendices are presented.

In summary, this dissertation provides valuable insights that can help policy makers and urban planners in urban space planning and redesign, specifically in the context of cycling as a means of transport. Moreover, it proposes a new methodological perspective in which human behaviour, in this case cycling, is analysed in an integrated approach along with the locations where these experiences of use occur. Thus, when designing and structuring urban spaces for cycling, it considers the people who use them, their characteristics and needs in these specific spaces, making them healthy, equitable and safe.

RESUMEN

La densidad de población de las zonas urbanas está contribuyendo a una crisis insostenible en términos de contaminación ambiental, pérdida de biodiversidad, escasez de recursos, congestión del tráfico y desigualdades socioeconómicas (Y. Wu et al., 2018). Entre las estrategias propuestas por la Organización Mundial de la Salud para reducir el impacto del uso de vehículos de motor en entornos urbanos, se encuentra la utilización de modos de transporte activos. Además, el uso de estos medios de transporte aumenta los niveles de actividad física de la población y les permite aprovecharse de sus beneficios. Entre los diferentes medios activos, la bicicleta se propone como una alternativa sostenible y viable al vehículo de motor, ya que responde a las necesidades de las ciudades sostenibles e inteligentes. Sin embargo, a pesar de los beneficios asociados al uso de estos modos de transporte, su utilización sigue siendo significativamente inferior en comparación con los vehículos a motor. Por lo tanto, es necesario generar evidencia científica que pueda ser utilizada por responsables políticos y urbanistas para promover el uso de la bicicleta en entornos urbanos.

El objetivo principal de esta tesis doctoral es realizar un análisis exploratorio sobre el uso de la bicicleta y algunos factores que influyen en ello como medio de transporte en las ciudades, concretamente en una muestra de población residente en las ciudades y áreas metropolitanas de Madrid, Barcelona, Valencia y Sevilla. En particular, se pretende examinar el impacto del entorno urbano construido sobre el uso de la bicicleta como medio de transporte, así como la salud percibida, los niveles de actividad física y el acoso durante desplazamientos activos.

Para alcanzar estos objetivos, la presente tesis doctoral se organiza según la estructura detallada a continuación. En primer lugar, se ofrece una introducción general que contextualiza el marco teórico, además de establecer los objetivos que se pretenden alcanzar. Posteriormente, se presentan dos estudios centrados en el análisis masivo de datos textuales mediante técnicas de minería de textos. El primer estudio examina exhaustivamente la literatura científica disponible en la base de datos Scopus sobre el uso de la bicicleta en entornos urbanos, con el objetivo de establecer una base conceptual sólida para la tesis doctoral. Entre los principales resultados de este estudio destaca el creciente interés por el uso de la bicicleta entre la literatura científica, especialmente en China y Estados Unidos. Este aumento refleja la necesidad de transformar los entornos urbanos en espacios más saludables que den prioridad al transporte activo. Además, los temas más investigados por la comunidad científica incluyen la movilidad urbana inteligente, los sistemas de uso compartido de bicicletas, las infraestructuras y el comportamiento de los ciclistas. En el segundo estudio, con el objetivo de conocer la percepción y opinión de la población sobre el uso de la bicicleta como medio de transporte, se aplicó esta misma técnica de análisis de datos a las publicaciones en la red social X que contenían las palabras clave bicicleta y ciudad (o similares), o sus iconos asociados. Entre sus resultados más relevantes destaca un sentimiento público generalmente positivo hacia su uso. Además, entre los temas más comentados encontramos la seguridad y la importancia de los carriles segregados.

A continuación, se exponen dos estudios cuantitativos. El tercer estudio cuantifica el uso de la bicicleta como medio de transporte utilizando variables sociodemográficas y de salud y actividad física, así como la infraestructura presente en el entorno construido alrededor del lugar de residencia para el uso de la bicicleta, el transporte público y el

coche. Los resultados de este estudio ponen de manifiesto que factores como la edad, los niveles de actividad física y la presencia de infraestructura ciclista son cruciales para aumentar el uso. Otro resultado a destacar es que las mujeres mostraron menor prevalencia de uso de la bicicleta en comparación con los hombres. Estos resultados revelan patrones desiguales de uso en la muestra participante en función del género. Concretamente, entre la literatura científica, el acoso callejero se encuentra entre las principales barreras que limitan el uso de la bicicleta a las mujeres. Por lo que, estos resultados sirvieron como pretexto para establecer el objetivo del cuarto estudio: examinar las experiencias de acoso sufridas durante desplazamientos activos desde una perspectiva geolocalizada. Las mujeres participantes en este estudio reportaron más incidentes de acoso en comparación con los hombres, especialmente durante los meses de invierno y por la noche. Además, se identificaron características del entorno construido con riesgo de acoso como zonas peatonales, intersecciones, fuentes, parques, zonas cercanas a jardineras y zonas al aire libre para actividades deportivas. Estos resultados subrayan la importancia de incorporar medidas para mejorar la seguridad el uso de la bicicleta, prestando especial atención a las necesidades de las mujeres.

Posteriormente, se presentan las reflexiones finales de la tesis, presentando las conclusiones derivadas de los cuatro estudios realizados y sus implicaciones políticas. Por último, se exponen las referencias bibliográficas utilizadas y los apéndices pertinentes.

En resumen, esta tesis doctoral ofrece información valiosa que puede ayudar a responsables políticos y urbanistas encargados de planificar y modificar los espacios urbanos, concretamente en el contexto del uso de la bicicleta como medio de transporte. Además, plantea una nueva perspectiva metodológica en la que se analiza el comportamiento humano, en este caso el uso de la bicicleta, de forma integrada junto a la ubicación donde se producen esas experiencias de uso. De forma que, a la hora de diseñar y estructurar los espacios urbanos destinados al uso de la bicicleta, se tienen en cuenta las personas que los transitan, sus características y necesidades en esos espacios concretos, favoreciendo que sean saludables, equitativos y seguros.

RESUMEN EXTENDIDO

Introducción

Las Naciones Unidas (2018) han pronosticado que para el año 2030, el 28% de la población mundial vivirá en ciudades de al menos un millón de habitantes mientras que para el año 2050, será el 75% de la población y para finales de siglo el 80% (Dizdaroglu & Yigitcanlar, 2014; Hardoy et al., 2013). Concretamente, estas zonas urbanas representan dos tercios del consumo mundial de energía y son responsables de hasta el 70% de las emisiones de gases de efecto invernadero (Bin et al., 2020). De hecho, ya existe un 80% de la población actual de las ciudades europeas que se ve afectada por la contaminación (Mourelatou & European Environment Agency, 2018). Estos problemas, asociados a una alta densidad de población, están llevando a las ciudades a una situación de crisis insostenible en términos de contaminación ambiental, pérdida de biodiversidad, escasez de recursos, congestión del tráfico o desigualdades socioeconómicas (Y. Wu et al., 2018). En este contexto, integrar la tecnología en la gestión de las ciudades está contemplándose como una posible solución (Bibri, 2018), hasta el punto de transformarlas en ciudades inteligentes, un modelo que resulta muy atractivo para los responsables políticos (Macke et al., 2018).

El concepto de ciudad inteligente está evolucionando rápidamente y está ganando adeptos alrededor del mundo (Camero & Alba, 2019). Se está relacionando con iniciativas ligadas a la sostenibilidad, la diversidad social y ecológica para que las ciudades del siglo XXI sean eficientes, tecnológicamente avanzadas, ecológicas y socialmente integradoras (Vanolo, 2014). Sin embargo, pese a que este concepto es ampliamente utilizado no existe un consenso en su delimitación conceptual (Angelidou, 2015; Hortz, 2016). La revisión de Camero y Alba (2019), identificó las definiciones más citadas en la literatura científica entre las que se encuentra la de Caragliu et al. (2011) que establecen que una ciudad es inteligente cuando las inversiones en capital humano y social y en infraestructuras de comunicación tradicionales y modernas impulsan un crecimiento económico sostenible y una alta calidad de vida, con una sabia gestión de los recursos naturales, a través de una gobernanza participativa. Concretamente, se distinguen 6 características en este modelo de ciudad (Manville et al., 2014): economía inteligente, entorno inteligente, gobernanza inteligente, vidas inteligentes, personas inteligentes y movilidad inteligente. En el estudio de Csukás y Szabó (2021) se encontraron nueve beneficios clave que la literatura científica destaca de este modelo de ciudad: prioriza la eficiencia, apuesta por la participación ciudadana, reduce el coste, favorece la creación e intercambio de conocimientos, facilita la escalabilidad y transferibilidad, fomenta la calidad de vida, prioriza la inclusión e igualdad, potencia la conectividad y reduce el impacto medioambiental.

Tal y como se ha señalado previamente, una de las áreas que aborda la ciudad inteligente es la movilidad, y entre sus principios se encuentra la promoción de medios de transporte sostenibles, innovadores y seguros. De hecho, uno de los mayores problemas de sostenibilidad de las ciudades actuales es el número de personas que realizan desplazamientos urbanos (Sarasma, 2021). La movilidad en la mayoría de las ciudades se caracteriza por la congestión del tráfico, la contaminación, la pérdida de tiempo, el ruido y una considerable ineficacia en términos de capacidad y consumo de espacio (Ceder, 2021). Además, los problemas de movilidad urbana surgen mientras los vehículos motorizados siguen siendo el principal medio de transporte urbano en muchos países e incluso el número de vehículos matriculados aumenta cada año (Israel Schwarzlose et al., 2014; Pucher et al., 2007). Tal es el impacto que el transporte urbano aporta alrededor del 40% de las emisiones de CO_2 y el 70% de otros contaminantes (Mourelatou & European Environment Agency, 2018). Al mismo tiempo, la congestión del tráfico en los entornos urbanos genera estrés en los y las conductoras, consume mucho tiempo y provoca contaminación acústica y reducción de las interacciones sociales (Delmelle et al., 2013; Ding et al., 2014; Pishue, 2021). Por lo tanto, es esencial identificar estrategias y ofrecer soluciones que promuevan la movilidad sostenible en los entornos urbanos (Conticelli et al., 2021), así como replantear estos espacios para aumentar y fomentar el uso del transporte no motorizado (Makarova et al., 2017).

El transporte sostenible se define como aquel que emite menos gases de efecto invernadero y reduce el uso de recursos no renovables (especialmente el petróleo) (Deakin, 2002). Estos medios de transporte urbanos sostenibles tienen multitud de beneficios, como por ejemplo que garantizan la accesibilidad a todas las personas, reducen el impacto negativo del sistema de transporte sobre la salud, la seguridad y la protección de los ciudadanos. Además, reducen la contaminación atmosférica y las emisiones sonoras, las emisiones de gases de efecto invernadero y el consumo de energía (Behrends et al., 2008).

Entre las clasificaciones que existen de los medios de transporte urbanos, una de las más utilizadas recientemente es la de Christoforou et al. (2021). Esta clasificación atiende al tamaño del vehículo y a la capacidad de dichos medios y se divide en: micromovilidad, mesomovilidad y macromovilidad. La macromovilidad se refiere a los vehículos de gran capacidad, como vehículos de motor, autobuses, trenes o tranvías, que permiten recorrer largas distancias. Por otro lado, la mesomovilidad incluye los vehículos de motor de una o dos capacidades con posibilidad de recorrer distancias medias. La micromovilidad, según la International Transport Forum (2020, p. safe), se refiere a todo transporte personal que utiliza dispositivos y vehículos que pesan hasta 350 kg y no superan los 45 km/h. Este tipo de medios de transporte incluye el uso de vehículos de propulsión exclusivamente humana, como bicicletas, patines, monopatines y patinetes.

Entre los beneficios que ofrece la micromovilidad, McQueen et al. (2021) destacan que mejora la sostenibilidad medioambiental al reducir la dependencia del automóvil privado, reduce las diferencias sociales y económicas proporcionando un transporte fiable, barato y equitativo que conecta con el transporte público y otros modos de transporte. Pero, aunque todos reportan beneficios, concretamente caminar, usar la bicicleta y otras formas de micromovilidad activa que implican el uso de ruedas, aumentan la calidad de vida y las condiciones de salud al favorecer un estilo de vida activo (Brüchert et al., 2021) y, al mismo tiempo, aportan beneficios sociales, económicos y medioambientales (World Health Organization, 2018). Tanto es así, que los artículos científicos relacionados con transporte activo han aumentado exponencialmente desde el año 2000 (Cook et al., 2022).

La movilidad activa se define como aquellos desplazamientos en los que el esfuerzo físico mantenido del viajero contribuye directamente a su desplazamiento (Cook et al., 2022). De acuerdo con esta definición, se consideran transportes activos la carrera a pie, el caminar, el desplazamiento en bicicleta, el que se realiza en monopatín, los desplazamientos en silla de ruedas manual, y los desplazamientos nadando o mediante medios acuáticos como el piragüismo o el remo, entre otros. Tanto es el beneficio que reportan que ya existen nuevos modelos de ciudad, como la ciudad de los 15 minutos o el cronourbanismo, para los cuales la configuración urbana debe estar estructurada en función del tiempo que tardan los ciudadanos entre diversos destinos urbanos en transporte activo (Rojas-Rueda et al., 2024). Estos modelo de ciudad se traducen en distancias de desplazamiento más cortas favoreciendo los desplazamientos activos, lo que conlleva menores emisiones de CO_2 y de contaminación atmosférica y una mejor calidad del aire (Allam et al., 2022).

Según la Organización Mundial de la Salud (2022), el transporte activo ofrece múltiples beneficios para la salud y el medioambiente. En salud física, mejora la aptitud cardiorrespiratoria, reduce factores de riesgo de enfermedades y disminuye la mortalidad por cáncer y patologías cardiovasculares (Oja et al., 2011). También mejora la salud mental, reduciendo estrés (Avila-Palencia et al., 2017) y malestar psicológico (L. Ma et al., 2021). Además, su uso favorece el aumento de los niveles generales de actividad física (Stroope et al., 2022; Wanjau et al., 2023) y es por ello, que la Organización Mundial de la Salud recomienda utilizar estos medios para alcanzar los estándares mínimos de actividad física (World Health Organization, 2020d). Además, ofrece ventajas medioambientales como la reducción del uso de fuentes de energía y de la contaminación atmosférica y acústica (Martens, 2004). Incluso, favorece la reducción de formas predominantes de contaminación relacionada con el tráfico que pueden causar graves riesgos para la salud (Qiu et al., 2022).

Pese a todos los beneficios que reporta y la amplia literatura científica al respecto, su uso es todavía muy reducido en comparación con otros medios de transporte (European Environment Agency, 2019). Con el objetivo de revertir esta situación y aumentar los desplazamientos en bicicleta, la comunidad científica está analizando qué lleva a la gente a utilizar un medio u otro. La elección de este medio de transporte está condicionada por varios factores que interactúan entre sí. Entre estos factores se encuentra la configuración del entorno (Ewing & Cervero, 2010), las características socioeconómicas de las personas o sus factores psicológicos (Steg & Vlek, 2009; Van Acker et al., 2010), incluso experiencias pasadas (B. Gardner, 2009). El modelo desarrollado por de Vos (2024), llamado “Facilidad de desplazamiento”, integra todas estas variables y cómo interactúan entre sí. Este modelo considera la interacción de cuatro factores clave: motivación para viajar, aptitudes para viajar, opciones de viaje y calidad del viaje. Esta interacción modula el comportamiento de desplazamiento a través de la satisfacción del viaje, bienestar percibido y de la participación. Pero, además de la influencia de estos cuatro factores, también influyen los factores socioeconómicos y de salud, así como el entorno construido y los sistemas de transporte.

Entre los factores socioeconómicos, dependiendo del contexto, el uso de la bicicleta puede ser mayor entre las personas con ingresos altos (Bateman et al., 2021) o bajos (Guerra et al., 2020). Respecto a la edad, en el estudio de Laatikainen et al. (2019) se evidenció que los adultos mayores usan menos el transporte activo que las personas jóvenes. Además, factores sociales como el entorno familiar o las amistades influyen en el uso de la bicicleta (Willis et al., 2015), al igual que aspectos raciales (Lusk et al., 2017). También, altos índices de peatonalización en zonas urbanas favorece que las personas con discapacidad utilicen con mayor frecuencia el transporte activo, especialmente entre las personas que se desplazan en sillas de ruedas (Schreuer et al., 2019). En cuanto al género, las mujeres habitualmente usan menos la bicicleta en áreas urbanas (Böcker et al., 2020; Pans et al., 2023; Pellicer-Chenoll et al., 2021; Reilly et al., 2022). Ellas hacen frente a barreras específicas como la inseguridad, la falta de infraestructuras adecuadas y responsabilidades familiares de cuidado. Especialmente, el miedo al acoso y la violencia en espacios públicos es una limitación significativa (Mosquera et al., 2012). Respecto al entorno construido, la vegetación y los carriles bici incrementan el uso, mientras que las pendientes lo reducen (Ito et al., 2024). También es crucial para fomentar el uso de la bicicleta la proximidad a carriles bici (Mertens et al., 2016), sistemas de bicicletas compartidas con mucha disponibilidad de bicicletas y estaciones (Alvarez-Valdes et al., 2016) y aparcamientos seguros (Larsen, 2015).

Estos estudios mencionados previamente no abordan el uso de la bicicleta integrando datos geográficos con variables socioeconómicas, de salud o actividad física. De hecho, la relación entre el entorno construido, los sistemas de transporte y las variables sociodemográficas y de salud no forman parte del modelo "Facilidad de Desplazamiento" de De Vos (2024). Este modelo integra múltiples interacciones, pero no contempla una relación directa entre este tipo de variables. Sin embargo, analizar la interacción entre ellos puede ofrecer información valiosa para identificar medidas que fomenten desplazamientos activos sostenibles y que faciliten el acceso a oportunidades para las personas en los espacios que transitan.

Esta tesis doctoral aporta una nueva interpretación del comportamiento humano desde una perspectiva espacial. Anteriormente, no existían herramientas que permitieran recopilar y analizar datos geográficos de manera integrada con variables sociodemográficas, de salud o de comportamiento individual. Sin embargo, en la actualidad existen instrumentos que permiten integrar estas variables en un mismo análisis. Esto no solo favorece comprender mejor las interacciones entre el entorno físico y el comportamiento, sino que también proporciona una base sólida basada en evidencia científica para la toma de decisiones en políticas públicas, urbanismo y salud. La integración de estas variables ofrece nuevas posibilidades para el análisis de patrones espaciales y el impacto que tiene en la calidad de vida, la equidad social y la sostenibilidad.

Objetivos

El objetivo general de esta tesis es realizar un análisis exploratorio sobre el uso de la bicicleta y algunos factores que influyen en ello como medio de transporte en las ciudades. En particular, se pretende examinar el impacto del entorno urbano construido sobre los beneficios del uso de la bicicleta como medio de transporte, incluyendo la salud percibida y los niveles de AF, y sobre el riesgo de sufrir situaciones de acoso durante desplazamientos activos.

En definitiva, este trabajo busca identificar, a través de una nueva perspectiva metodológica que integra en un mismo análisis datos geográficos y variables sociodemográficas y de salud, información valiosa que pueda ayudar al fomento del uso de la bicicleta en entornos urbanos. De forma que, pueda servir a responsables políticos y urbanistas para mejorar el entorno construido y desarrollar planes efectivos que promuevan la bicicleta como medio de transporte. Al mismo tiempo, estos estudios se abordan desde una perspectiva interdisciplinar, lo que se refleja claramente en la diversidad de las referencias bibliográficas.

Estructura de la tesis

La elaboración de este trabajo cumple con lo establecido en la normativa de la Universitat de València (ACGUV 252/2024) para las tesis doctorales con mención internacional. Además, para su desarrollo ha contado con el apoyo de un contrato predoctoral de 3 años a tiempo completo (CPI-21-518) asociado al proyecto de investigación PROMETEO de la Conselleria de Innovación, Universidades, Ciencia y Sociedad Digital 'Transporte sostenible en Valencia: análisis socioambiental, urbanístico y sanitario del servicio Valenbisi' (GVAPROMETEO2021-026).

Cumpliendo con lo estipulado en la legislación (ACGUV 252/2024), la estructura de esta tesis es la siguiente:

- **Introducción**: Este apartado establece el marco general en el que se basa esta tesis doctoral. Esto permitirá contextualizar el tema de investigación abordado. Posteriormente, se establecen los objetivos generales que se pretenden alcanzar.
- **Revisión bibliográfica y percepción social**: Consta de dos estudios de revisión que aplican técnicas de minería de textos. El estudio 1 analiza lo publicado en la base de datos Scopus sobre el uso de la bicicleta en entornos urbanos, mientras que el estudio 2 examina publicaciones en la red social "X" (anteriormente Twitter) que incluyen palabras, hashtags y emojis relacionados con el ciclismo y la ciudad. Estos dos estudios permiten obtener una visión general de la percepción científica y social del ciclismo urbano.
- **Explorar el ciclismo urbano: actividad física y acoso**: Se compone de dos estudios relacionados con experiencias positivas y negativas asociadas al ciclismo en entornos urbanos. El estudio 3 analiza el uso de la bicicleta a partir de variables de salud y del entorno construido, como facilidades para el uso de la bicicleta, transporte público y el coche. El estudio 4 analiza situaciones de acoso durante desplazamientos activos y su relación con el entorno construido en el cual sucedieron los hechos.
- **Principales conclusiones, implicaciones políticas y perspectivas de futuro**: Contiene las conclusiones más relevantes de la tesis, destacando los resultados principales y mencionando las posibles implicaciones prácticas, así como futuras líneas de investigación derivadas de este trabajo.

Finalmente, se presentan las referencias bibliográficas utilizadas y los anexos pertinentes. Entre los estudios incluidos en esta disertación, uno de ellos ya ha sido publicado:

- Antón-González, L., Pans, M., Devís-Devís, J., & González, L.-M. (2023). Cycling in urban environments: Quantitative text análisis. *Journal of Transport & Health, 32*, 101651. https://doi.org/10.1016/j.jth.2023.101651

Estudios

El estudio 1 presenta un análisis masivo de textos científicos sobre el uso de la bicicleta en entornos urbanos. Concretamente, se han utilizado documentos de la base de datos Scopus para extraer información relevante sobre el tópico. Se analizaron los títulos, resúmenes y palabras clave de 7.743 documentos, identificando un total de 5.678 palabras, entre las que se destacan *system*, *model*, *traffic*, *public* y *travel* (excluyendo las palabras incluidas en la ecuación de búsqueda). Los términos más repetidos en combinaciones de dos y tres palabras fueron *physical activity* y *bike sharing system*, respectivamente. A partir del análisis de los 15 temas más relevantes identificados, se seleccionaron los más relevantes en los últimos años: movilidad urbana inteligente, estaciones de uso compartido de bicicletas, infraestructura ciclista, tráfico ciclista, la bicicleta como transporte urbano y el comportamiento de los ciclistas. Estos temas reflejan un interés significativo por los factores estructurales que influyen en el uso de la bicicleta en entornos urbanos. Sin embargo, se observa que los beneficios de salud asociados al uso de la bicicleta ocupan un lugar secundario en comparación con las preocupaciones estructurales.

Además de conocer las tendencias de investigación entre la comunidad científica, la opinión pública es un factor clave en la formulación de políticas que promuevan el uso de la bicicleta como medio de transporte. Tener en consideración la perspectiva social permite lograr una mayor efectividad. En este sentido, el estudio 2 tiene como objetivo analizar los temas y sentimientos hacia el uso de la bicicleta en entornos urbanos en la red social X (anteriormente Twitter) desde la implementación de los Objetivos de Desarrollo Sostenible. A través de la API de búsqueda de X se descargaron estas publicaciones; se eliminaron duplicados, réplicas y reenvíos. Entre los años 2016 y 2022, se publicaron más de 116.051 publicaciones sobre este tema. Además, entre todas las publicaciones se obtuvieron 9.641 palabras únicas, siendo *good* y *great* los términos más recurrentes (excluyendo las palabras incluidas en la ecuación de búsqueda y verbos o preposiciones). *bike lane*, *New York*, *#mobillity* y '🚌' fueron el bigrama, trigrama, hashtag y emoji más repetidos, respectivamente. El análisis de los temas resultó en 10 temas positivos y 10 negativos. El tema positivo más relevante fue beneficios del ciclismo como medio de transporte, y el tema negativo más relevante fue la coexistencia con vehículos motorizados. Este estudio ofrece una visión útil para guiar y apoyar políticas efectivas de promoción del uso de la bicicleta como medio de transporte entre la población y, en consecuencia, lograr los Objetivos de Desarrollo Sostenible.

Estos primeros estudios ofrecen una visión general sobre la percepción pública y científica sobre el uso de la bicicleta en entornos urbanos. El conocimiento sobre estas tendencias en la literatura y opiniones en redes sociales establece una base esencial para los dos estudios posteriores. En estos dos estudios cuantitativos, la muestra participante es población residente en las 4 ciudades más pobladas de España (Madrid, Barcelona, Valencia y Sevilla). Tras la aprobación del comité ético de la Universitat de València, las personas participantes cumplimentaron un cuestionario alojado en la plataforma Maptionnaire. Este software permite crear encuestas en línea con la posibilidad de recoger datos geográficos como rutas y/o localizaciones. Aunque la muestra participante es la misma, para cada estudio se aplicaron técnicas de preprocesado diferentes debido a las variables utilizadas en cada uno de ellos. Ambos estudios profundizan en los factores específicos del entorno construido, así como en las variables sociodemográficas y de salud que influyen en el uso de la bicicleta. También las experiencias negativas del acoso durante los desplazamientos activos.

El objetivo principal del estudio 3 fue cuantificar el uso de la bicicleta en entornos urbanos considerando la presencia de infraestructuras para bicicletas, automóviles y transporte público en los alrededores de las residencias, así como analizar las características sociodemográficas y calcular la salud percibida y niveles de actividad física. Finalmente, tras el preprocesado, un total de 957 personas formaron parte del estudio. Tras el procesamiento de datos para el análisis estadístico inferencial, se aplicó una prueba de Chi-cuadrado para determinar si existían diferencias significativas entre el uso de la bicicleta como medio de transporte y las variables sociodemográficas, y luego se utilizó un árbol de decisión para cuantificar la probabilidad de usar la bicicleta como medio de transporte urbano. Los resultados mostraron que el género y el nivel socioeconómico presentaron diferencias significativas en el uso de la bicicleta en la ciudad. Además, el árbol de decisión generó 18 perfiles de personas, de los cuales tres nodos concentraron el mayor número de encuestados/as, todos estos nodos agrupaban personas que no utilizan la bicicleta como medio de transporte urbano. En orden descendente, el primer nodo agrupó a mujeres de niveles de actividad física bajos o moderados (38% de la muestra), el segundo personas muy activas mayores de 41 años (14% de la muestra), y el tercero personas muy activas menores de 41 años, con bajos ingresos, pocas facilidades en el entorno de residencia para bicicleta y trabajos de nivel de actividad física medio (11% de la muestra). Por el contrario, entre los nodos que agrupan personas que sí utilizan la bicicleta, destacan hombres con niveles de actividad física bajos o moderado y con niveles bajos de salud física percibida. De este estudio, se concluye que, para fomentar el uso de la bicicleta en entornos urbanos, no se deben considerar las infraestructuras para diferentes medios de transporte de forma aislada, y se deben integrar las características de las personas que habitan en estos entornos, con especial atención a la perspectiva de género.

Puesto que, entre los resultados más relevantes de este estudio, se encontraba que las mujeres han representado gran parte de la población que no utiliza la bicicleta como medio de transporte, estas conclusiones originaron el propósito del siguiente estudio. Entre las barreras reportadas por la literatura científica para este colectivo se encuentra el miedo a sufrir acoso en espacios públicos. Por ello, con el objetivo de arrojar información sobre esta problemática, el propósito del estudio 4 fue describir las situaciones de acoso sufridas en desplazamientos activos, así como predecir el riesgo de sufrirlo teniendo en cuenta las características del entorno.

Este estudio tuvo como objetivo caracterizar los espacios en los que las personas participantes en el estudio experimentaron acoso durante desplazamientos activos, como caminar o desplazarse en bicicleta, patines o silla de ruedas. También se propuso predecir el riesgo de acoso en estos desplazamientos, en función de las características del entorno construido. Finalmente, tras el preprocesado, una muestra de 1.788 personas (38.1% hombres, 61.5% mujeres y 0.4% otros) fueron incluidas en los análisis. En el cuestionario indicaron si habían experimentado acoso durante desplazamientos activos, geolocalizando los incidentes e indicando el día, la hora, el tipo de acoso y cómo se estaban desplazando. De forma similar a como se realizó en el estudio posterior, para cada ubicación de acoso, se descargaron las etiquetas descriptivas de estos espacios desde *OpenStreetMap*, y se realizó un análisis de las situaciones de acoso en función de las características del entorno construido. Un total de 208 personas informaron haber experimentado acoso, 138 de las cuales eran mujeres. La mayoría de estos incidentes ocurrieron durante el invierno y de noche. El acoso verbal fue la forma más prevalente de acoso experimentada por mujeres (60.5%), mientras que los hombres reportaron mayor prevalencia de acoso visual y verbal (31.1% para ambos). Caminar fue el modo de transporte activo más común (mujeres: 84.1%; hombres: 68.9%). En el análisis predictivo, la presencia de áreas peatonales, cruces, fuentes, parques, áreas cercanas a jardineras y espacios al aire libre destinados a la práctica deportiva se identificaron como predictores significativos del riesgo de acoso.

Conclusiones generales, implicaciones políticas y futuras líneas de investigación

Los resultados presentados en este trabajo aportan información valiosa para urbanistas y responsables políticos en relación con el uso de la bicicleta en la ciudad. Aunque en cada estudio se han presentado los resultados relevantes, es necesario destacar algunas conclusiones generales que derivan de la presente tesis doctoral.

Por un lado, los estudios 1 y 2 ofrecen una visión general del tópico del ciclismo urbano, uno desde la perspectiva de la comunidad científica y otro desde la perspectiva de la población. Como principales conclusiones, se observa un aumento exponencial de la investigación sobre el uso de la bicicleta en entornos urbanos. Esto puede ser debido a la necesidad de convertir los espacios urbanos en entornos saludables que prioricen los medios de transporte activos frente a los vehículos de motor. Junto a esta preocupación de la comunidad científica, el análisis de los posts publicados en la red social X sobre ciclismo y ciudad ha reflejado un sentimiento general positivo hacia el ciclismo urbano. Además, destaca la preocupación sobre la seguridad y las infraestructuras, especialmente sobre los carriles segregados. Este análisis ofrece a los responsables políticos la oportunidad de ajustar las intervenciones en función de las preocupaciones de los usuarios.

Por otro lado, tanto el estudio 3 como el 4, basados en la misma muestra, destacaron no sólo los elementos del entorno construido para fomentar el uso de la bicicleta, sino también los retos específicos a los que se enfrentan determinados grupos, especialmente las mujeres, en relación con la seguridad. En cuanto al estudio 3, las características del entorno construido mostraron un impacto en el uso de la bicicleta como medio de transporte. Para empezar, la disponibilidad de instalaciones ciclistas cerca del lugar de residencia puede ser un factor determinante en la elección del uso de la bicicleta. Además, las variables sociodemográficas y de salud, como el sexo, la edad y los niveles de AF fueron cruciales para cuantificar el uso de la bicicleta. Además, las mujeres han mostrado un menor uso de la bicicleta urbana y un nivel de AF bajo o moderado durante el tiempo de ocio en comparación con los hombres, lo que ilustra que las mujeres se enfrentan a barreras adicionales en el uso del transporte activo y el acceso a la AF. En relación con el estudio 4, se han identificado características específicas de los espacios urbanos que aumentan el riesgo de acoso, como los cruces de calles o las zonas recreativas. Además, las mujeres se han visto especialmente afectadas, limitando sus opciones para elegir el transporte activo. Esto sugiere que, para promover el transporte activo, tanto las infraestructuras como las características personales deben abordarse conjuntamente en las políticas urbanas. Asimismo, este estudio destaca la importancia de diseñar espacios que no sólo faciliten el uso de la bicicleta, sino que también minimicen el riesgo de acoso. Por lo tanto, es esencial que las políticas de transporte activo incluyan una perspectiva de género que no sólo mejore las infraestructuras, sino que también aborde las cuestiones de seguridad e igualdad de oportunidades.

Por último, la metodología aplicada en los estudios 3 y 4 ha puesto de manifiesto la importancia de las características del espacio urbano y el impacto en el comportamiento humano, concretamente en el uso de la bicicleta. Este es un aspecto novedoso que responde a la necesidad de desarrollar planes de promoción adaptados a espacios concretos, teniendo en cuenta la población que los utiliza. En definitiva, ambos estudios sugieren que las políticas de promoción del transporte activo, en particular de la bicicleta, deben considerar de forma integrada las infraestructuras, la accesibilidad, la seguridad en el entorno urbano y las características de la población. Asimismo, se deberían tener en cuenta tanto las necesidades la población como los riesgos percibidos en el entorno, especialmente en las zonas en las que las personas denuncian experiencias de acoso. Esto permitirá crear entornos más inclusivos y seguros que promueven el transporte activo como una opción viable, segura, saludable y atractiva para toda la población.

Los resultados de este trabajo tienen importantes implicaciones para los responsables políticos y los planificadores urbanos que deseen promover el transporte activo. En primer lugar, ha quedado constancia de que la relación entre el entorno urbano construido y las características de la población es crucial para el uso de la bicicleta y el ciclismo urbano. En segundo lugar, las experiencias de acoso durante los desplazamientos activos, tal y como constata la literatura científica, tienen un impacto directo en la elección de estos medios de transporte. Por lo tanto, minimizar en la medida de lo posible las malas experiencias, como el acoso, es esencial para promover eficazmente el transporte activo, especialmente entre las mujeres. En este sentido, el diseño del entorno construido debe estar configurado para reducir estos riesgos. De forma que se creen espacios que ofrezcan seguridad y confianza a los y las ciudadanas, promoviendo un mayor interés por estos medios de transporte.

Finalmente, tal y como se ha mencionado previamente, esta tesis forma parte del proyecto 'Transporte sostenible en Valencia: Análisis socioambiental, urbano y de salud del servicio Valenbisi' (PROMETEO 2021-026). El objetivo general de este proyecto era analizar los datos de los desplazamientos de las personas que utilizan el servicio Valenbisi (Valencia, España). Además, estos datos se analizarían junto con otros datos urbanos, sanitarios y socioambientales de la ciudad y su población, y desde una perspectiva de género. Este proyecto ha dado lugar a algunos trabajos que no se incluyen en esta tesis doctoral que han sido elaborados utilizando la base de datos Valenbisi y enriquecidos con otras bases de datos. Sin embargo, a pesar de ello, haber participado en el equipo de autores me ha ayudado a adquirir conocimientos y habilidades que se han aplicado en los estudios incluidos en la tesis. En este sentido, aunque este proyecto finaliza en diciembre de 2024, todavía hay estudios en preparación, que serán objeto de próximas publicaciones y el inicio de futuras investigaciones.

Aparte de los estudios futuros que puedan derivar del proyecto, una de las futuras líneas de investigación derivadas de esta tesis será el análisis de los patrones de movilidad activa en entornos urbanos de personas con discapacidad. Esta línea es fruto de mi participación en el proyecto "Muévete con Lesión Medular" durante la elaboración de este trabajo. Al participar en el análisis de las barreras para la práctica de actividad física de personas con lesión medular, comprobamos que algunas de las dificultades se encontraban en el desplazamiento a los espacios urbanos de práctica de actividad física. Por ello, para obtener datos en este sentido, se incluyeron variables relacionadas con la discapacidad y el transporte activo en el proceso de diseño del cuestionario a cumplimentar por la muestra participante en los estudios de tesis. Así, esta posible línea de investigación se centraría en desarrollar un estudio sobre la movilidad urbana y el transporte activo de las personas con discapacidad, yendo más allá de la accesibilidad, en la que se centra la literatura actual. El objetivo sería cuantificar y caracterizar los desplazamientos diarios, estimar el gasto energético asociado y analizar los factores sociales, personales y ambientales que influyen en la movilidad. También se podría comparar el gasto energético entre quienes utilizan el transporte activo y quienes no, teniendo en cuenta variables como el género o el nivel socioeconómico. En definitiva, los resultados de esta futura investigación podrían mejorar la movilidad, accesibilidad y autonomía de las personas con discapacidad, con efectos positivos sobre su salud y por la reducción del aislamiento social. También se espera que contribuya al desarrollo de políticas inclusivas y al diseño de entornos urbanos más accesibles, promoviendo así una sociedad más justa y equitativa para todos.

Otra posible línea de investigación futura podría centrarse en el análisis de los patrones de movilidad activa urbana desde una perspectiva de género. Como muestran los datos de esta tesis y la literatura científica, las mujeres son menos propensas a utilizar la bicicleta como medio de transporte y también son más propensas que los hombres a tener experiencias negativas durante los desplazamientos activos. Entonces, es imperativo favorecer que los espacios públicos sean seguros y equitativos. Esta posible investigación futura se centraría en caracterizar los espacios urbanos utilizados para los desplazamientos activos identificando las barreras experimentadas por las mujeres. Identificar y analizar estas barreras específicas permitiría diseñar espacios públicos más seguros y equitativos en los que las mujeres puedan utilizar el transporte activo con mayor seguridad y frecuencia. Esta investigación no sólo aportaría un enfoque más inclusivo al estudio de la movilidad urbana, sino que también contribuiría a crear entornos más accesibles, seguros y cómodos para todas las personas, fomentando el uso equitativo de los espacios públicos y promoviendo la igualdad de género en las políticas de planificación urbana.

En conclusión, esta tesis resulta ser el comienzo de un viaje activo hacia la igualdad y la accesibilidad urbana.

INTRODUCTION

Research background

During the last decades, most of the world's population has settled in cities and urbanisation continues to increase. United Nations (2018) projected that by 2030, 60% of global population will live in metropolitan areas and 28% in cities of at least 1 million inhabitants. Cities are responsible for two-thirds of the world's energy consumed and for up to 70% of greenhouse gas emissions (Bin et al., 2020). In fact, a recent study indicated that up to 88% of the people who live in European cities is affected by pollution (Mourelatou & European Environment Agency, 2018). These problems, associated with high population density, are leading cities into an unsustainable crisis situation in terms of environmental pollution, biodiversity loss, resource scarcity, traffic congestion and socio-economic inequalities (Y. Wu et al., 2018). In this context, integrating technology into city management is being seen as a possible solution (Bibri, 2018), to the point of transforming them into Smart Cities (SC), a model that is very attractive to policy makers (Macke et al., 2018).

The concept of SC is evolving rapidly and is gaining adherents around the world (Camero & Alba, 2019). In fact, today, this city model is seen as a manifesto, a vision or a promise to be the ideal sustainable city form of the 21st century, an efficient, technologically advanced, environmentally friendly and socially inclusive city (Vanolo, 2014). However, although it is widely used, there is no consensus on its conceptual delimitation (Angelidou, 2015; Hortz, 2016). It is a term that brings together different areas such as urban planning, economy, and sustainable environment, technology, energy, mobility, and health, among others (Trindade et al., 2017). Specifically, there are two main approaches to the SC model, the Information and Communications Technology (ICT) oriented approach, and the people oriented approach (Bibri & Krogstie, 2017). In order to explore the concept of SC in more depth, the literature review by Camero and Alba (2019), identified the most commonly cited definitions in the scientific literature, including Harrison et al. (2010) which defines it as cities that connect physical infrastructure, ICT infrastructure, social infrastructure and business infrastructure to leverage the city's collective intelligence. Also noteworthy is the definition by Caragliu et al. (2011) who establish that a city is smart when investments in human and social capital and in traditional and modern ICT infrastructures drive sustainable economic growth and a high quality of life, with wise management of natural resources, through participatory governance. Specifically, 6 characteristics can be distinguished in this city model (Manville et al., 2014):

- **Smart economy**: it involves local and global interconnectedness and international integration with physical and virtual flows of goods, services and knowledge.
- **Smart environment**: this includes smart energy systems such as renewable energy, ICT-based energy networks, pollution control and green buildings. It also includes resource efficiency, reuse and substitution.
- **Smart governance**: requires coordinated governance within and between cities, integrating services and interactions between public, private and civil organisations to ensure the efficient functioning of the city through ICT.
- **Smart lives**: aims to promote healthy and safe living in a culturally vibrant city, with diverse cultural facilities, and incorporating good quality housing and accommodation.

- **Smart people**: people who have access to e-skills, to work in ICT-enabled environments, to education and training, to human resources and skills management, all within an inclusive society that enhances creativity and fosters innovation.
- **Smart mobility**: refers to integrated transport and logistics systems supported by ICT, prioritising sustainable, safe, interconnected and non-motorised options. Smart mobility provides real-time information to the public to save time, improve travel efficiency, reduce costs and CO2 emissions, and help transport managers improve services and provide information.

However, despite the proven benefits of applying this model, it is necessary to clarify that there are authors who take a critical view of it. As it can come to be understood as an imaginary model that promotes the interests of business elites and diverts attention from urgent urban problems such as urbanisation (Grossi & Pianezzi, 2017). In contrast, Csukás and Szabó (2021) identified nine key benefits from the scientific literature: it prioritises efficiency, supports citizen participation, reduces costs, favours knowledge creation and sharing, facilitates transferability, promotes quality of life, prioritises inclusion and equality, enhances connectivity and reduces environmental impact.

As we have seen, one of the areas that SC addresses is mobility, one of the principles being the promotion of sustainable, innovative and safe means of transport. In fact, one of the biggest sustainability issues in cities today is the number of people making urban trips (Sarasma, 2021). Mobility in most cities is characterised by traffic congestion, pollution, wasted time, noise and considerable inefficiency in terms of capacity and space consumption (Ceder, 2021). Problems of urban mobility are emerging while motorised vehicles remain the main means of urban transport across developing countries, and the number of registered vehicles is increasing every year (Israel Schwarzlose et al., 2014; Pucher et al., 2007). Urban transportation contributes around 40% of CO_2 emissions and 70% of other pollutants (Mourelatou & European Environment Agency, 2018). Indeed, the high level of pollution in urban spaces has become a major health problem worldwide. For instance, it is estimated that almost 10.2 million premature deaths are attributed to the burning of fossil fuels in cities (Chew et al., 2017). Moreover, traffic congestion in urban environments generates stress in drivers, is time consuming, and causes noise pollution and reduction in social interactions (Delmelle et al., 2013; Ding et al., 2014; Pishue, 2021). Exposure to high levels of noise pollution, sounds at levels that are harmful to health, can cause hearing loss, fatigue, loss of balance, enhance asthma symptoms, nausea, headaches, and even mental disorders (Berglund et al., 1999; Eze et al., 2018; Glazener et al., 2021). Another negative effect of motor vehicle use is traffic accidents, which are a leading cause of death worldwide, despite a recent steady decline (World Health Organization, 2021b). It is therefore essential to identify strategies and offer solutions that promote sustainable mobility in urban environments (Conticelli et al., 2021), as well as rethinking urban space to increase and encourage the use of non-motorised transport (Makarova et al., 2017). In fact, in the Sustainable Development Goals (SDG), specifically Goal 11 'Sustainable cities and communities' is to provide access to safe, affordable, accessible and sustainable transport systems (United Nations, 2015)

One of the most commonly used classifications of urban transport modes in recent times is associated with the three levels of mobility proposed by Christoforou et al. (2021).

According to the weight of the vehicle and the capacity of these means: micromobility, mesomobility and macromobility (Figure 1).

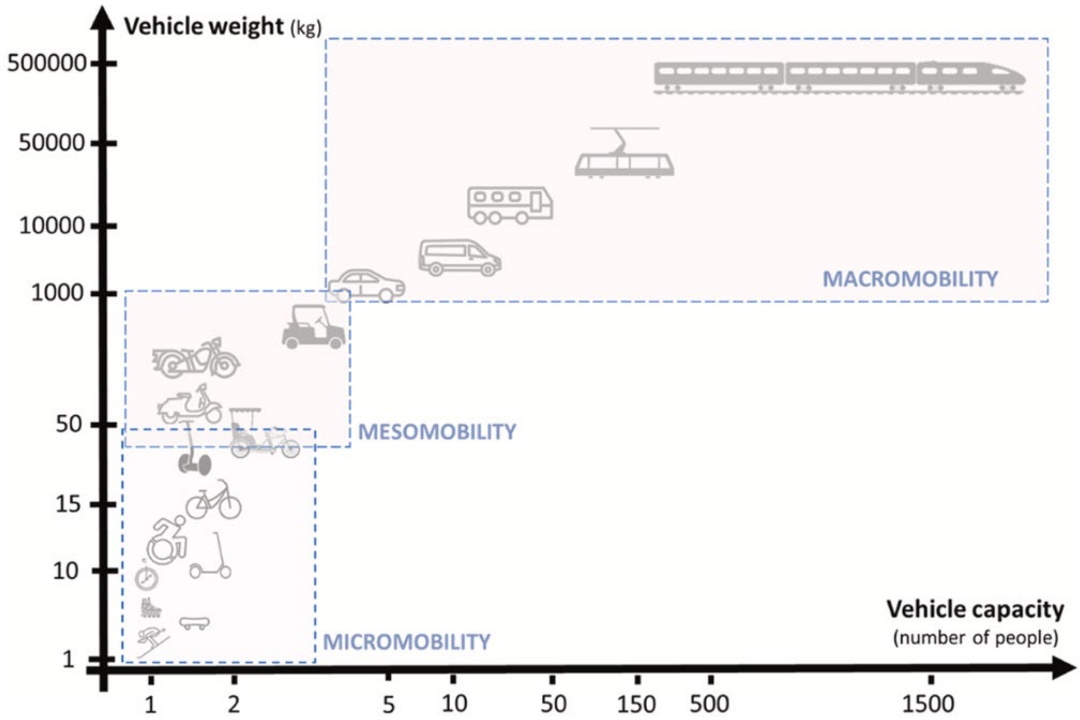


Figure 1. Urban modes of transport classification

Source: Christoforou et al. (2021)

Macromobility refers to high-capacity vehicles such as motor vehicles, buses, trains or trams that allow long-distance travel. On the other hand, mesomobility includes single or dual-capacity motor vehicles with the possibility to travel medium distances. Micromobility is particularly related to this work and, according to the International Transport Forum (2020), refers to all personal transport using devices and vehicles weighing up to 350 kg and whose speed does not exceed 45 km/h. Micromobility includes the use of purely human-powered vehicles such as bicycles, wheel chair, scooters, skateboards and scooters. On the other hand, Christoforou et al. (2021) defines it as modes of transport that allow hybrid use and behave as a pedestrian or a vehicle as appropriate (e.g. to cross a street or to board a bus). These can range from the lightest scooters to the heaviest two-wheeled personal scooters. They can be motorised or non-motorised, shared or privately owned. Moreover, they can have an approximate weight threshold of about 40 kg. Among the benefits offered by micromobility, McQueen et al. (2021) highlight that they improve environmental sustainability by reducing dependence on the private car, they reduce social and economic disparities in mobility by providing reliable, cheap and equitable transport that connects to public transport and other modes of transport. In addition, they also point out that the human experience is improved by offering new, fun and joyful ways of commuting, while reducing barriers to non-car travel. But while all have benefits, in particular walking or wheeling (cycling or skating) and other forms of active micromobility increase quality of life and health conditions by promoting an active lifestyle (Brüchert et al., 2021) and, at the same time, produce social, economic and environmental benefits (World Health Organization, 2018).

Active mobility is defined as trips where the sustained physical effort of the commuter contributes directly to their movement (Cook et al., 2022). According to this definition, active transport includes walking, running, cycling, skateboarding, manual wheelchair travel, swimming and water transport such as canoeing and rowing, among others (see Figure 2).

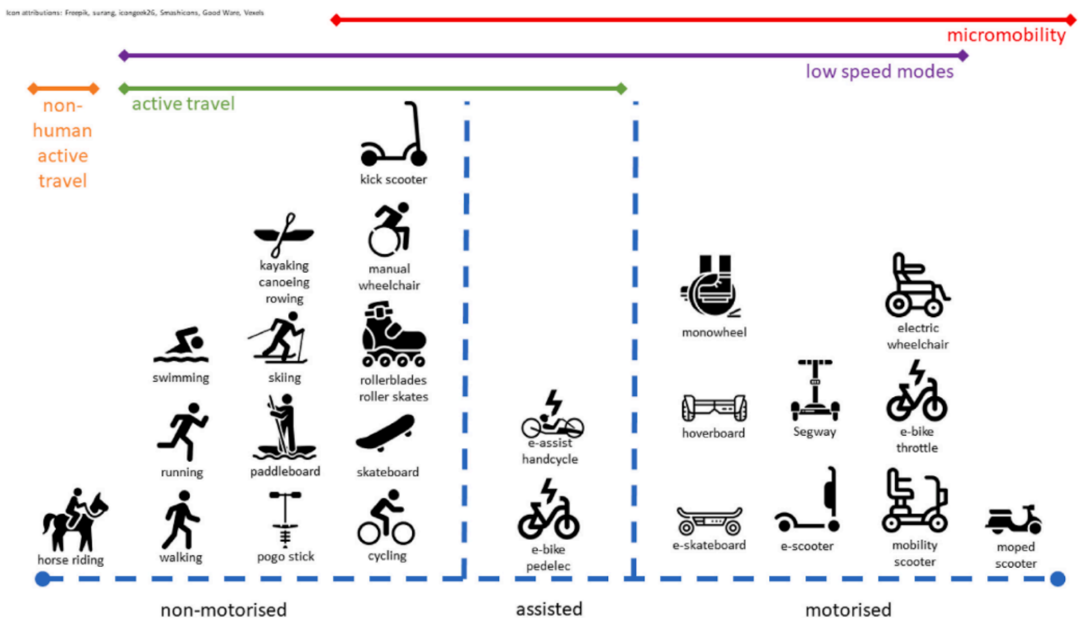


Figure 2. Active means of transport classification

Source: Cook et al. (2022)

According to the World Health Organisation (WHO) (2022), the use of active modes of transport offers health, environmental and urban mobility benefits. Moreover, regardless of the geographical context, the health benefits of PA are particularly relevant and outweigh the detrimental effects of traffic incidents and exposure to air pollution (Mueller et al., 2015). A summary of the benefits of this type of mobility can be found in figure 3. The WHO states these benefits specifically for walking and cycling, however, most of them can be extrapolated to the rest.

The benefits of cycling as urban transport can be analysed from various perspectives. From the health perspective, cycling improves cardiorespiratory fitness, reduces disease risk factors, significantly decreases mortality risk from cancer, cardiovascular disease, and obesity (Oja et al., 2011), reduces BMI values (Bassett et al., 2008; Useche et al., 2024) and sedentary behaviour (Bista et al., 2020). Furthermore, people who walk or cycle are generally more active or likely to enhance their PA levels (Stroope et al., 2022). Since active transport raises overall PA levels (Wanjau et al., 2023), the WHO recommends walking or cycling to achieve minimum activity standards (World Health Organization, 2020b). Moreover, cycling offers notable mental health and well-being benefits, such as reduced stress (Avila-Palencia et al., 2017), enhanced quality of life (De Geus et al., 2008), decreased psychological distress, and improved life satisfaction (L. Ma et al., 2021). Apart from that, urban cycling offers environmental benefits such as the reduction of the use of energy sources and air and noise pollution (Martens, 2004). It also reduces predominant forms of traffic-related pollution, which can cause serious health risks for cyclists (Qiu et al., 2022).

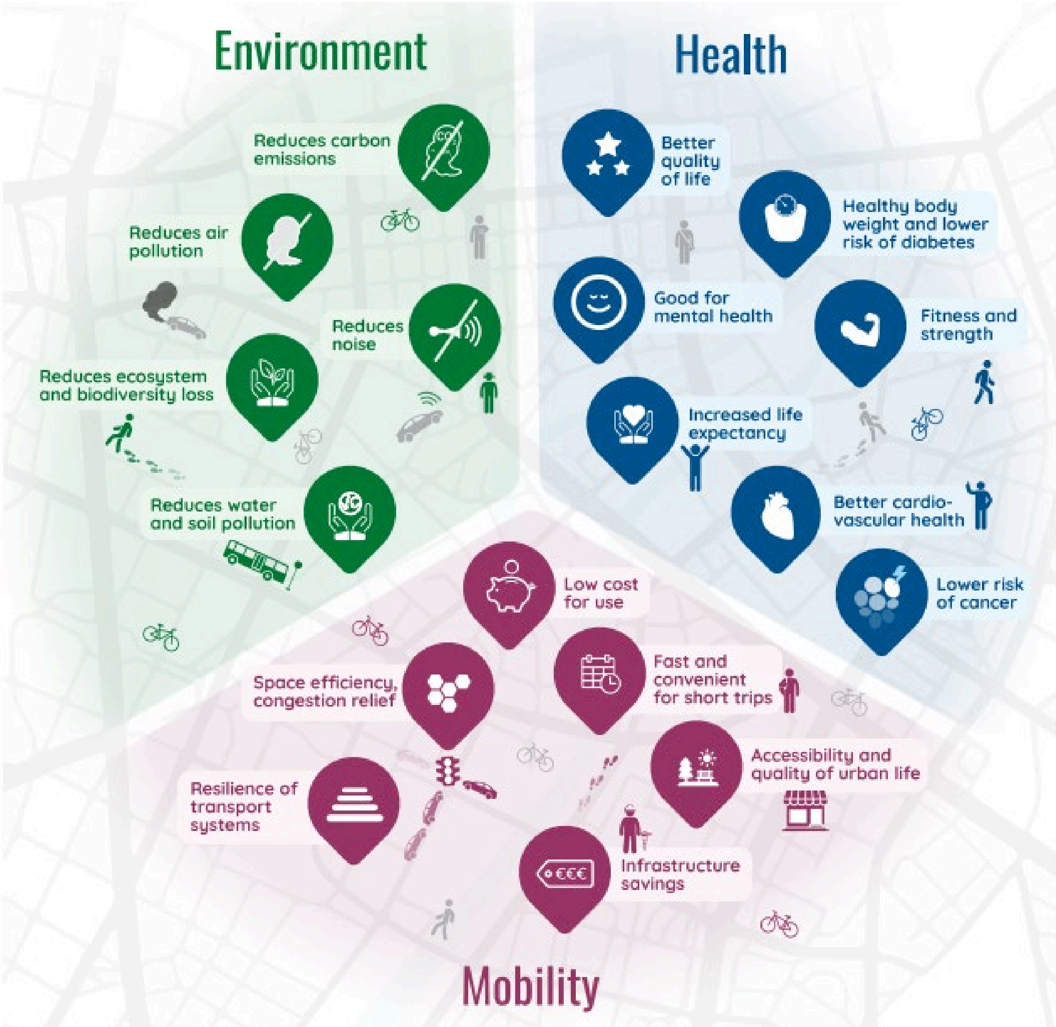


Figure 3. Summary of benefits of using active transport in urban environments
Source: World Health Organization (2022)

They are so beneficial that there are already new city models, such as the 15-minute city or chronourbanism, for which the urban configuration must be structured according to the time it takes citizens to travel between different urban destinations by active transport (Rojas-Rueda et al., 2024). Specifically, 15-minute cities are about residents being able to access services essential to living within a 15-minute walk or wheeling from their homes (Moreno et al., 2021). This city model results in shorter travel distances favouring active travel, which leads to lower CO_2 and air pollution emissions and better air quality (Allam et al., 2022). Among the different active modes of transport, cycling is the most sustainable and feasible means of transport (Pucher & Buehler, 2017).

Despite all the benefits and the extensive scientific literature, its use is still very low compared to other modes of transport (European Environment Agency, 2019). To reverse this situation and increase cycling, the scientific community is analysing which leads people to use one means or another. The choice of this means of transport to travel in urban environments is conditioned by several interacting factors. Among these factors we can find the configuration of the environment (Ewing & Cervero, 2010), the socio-economic characteristics of individuals or their psychological factors (Steg & Vlek, 2009;

Van Acker et al., 2010), even past experiences (B. Gardner, 2009). The model developed by de Vos (2024), "Ease of travel" (EoT) (Figure 4), integrates all these variables and how they interact with each other into a single model. This model indicates EoT by considering the interaction of 4 key factors: Motivation to travel, travel skills, travel choices and travel quality.

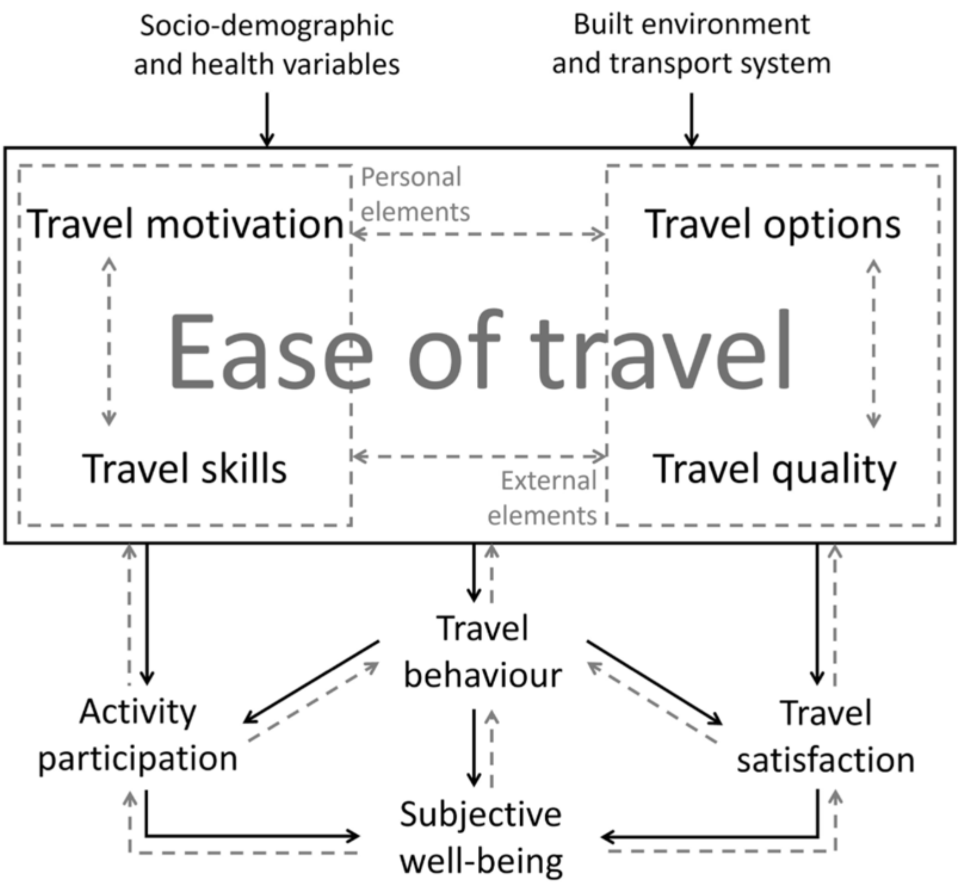


Figure 4. Ease of Travel and related constructs

Source: De Vos (2024)

As De Vos explains in terms of "travel motivation", motives can be varied, such as satisfying basic needs (e.g. shopping, working), psychological (e.g. socialising) or personal fulfilment (e.g. studying for a university degree). Moreover, it can be extrinsic, or internal (Ryan & Deci, 2000). In relation to transport, extrinsic motivation may be related to travel to work or shopping, while intrinsic motivation may be related to enjoyment of the environment or speed without any destination (Hook et al., 2022). Regarding "travel skills", they can be physical, mental or organisational (De Vos, 2024). Physical skills refer to the ability to cycle or walk long distances. Mental skills encompass the capacity to identify obstacles or anticipate movements. Organisational skills consist of the ability to determine the optimal route or combination of transport to reach a destination. In terms of "travel options", De Vos (2024) asserts that they encompass access to the ability to utilise a range of transportation modes, including motor vehicles, public transport, and infrastructure for walking or cycling. Finally, "travel quality" refers to the benefits that each mode of transport offers to the user. For example, the quality of walking or wheeling may be influenced by the quality of infrastructure or safety. In contrast, motor vehicles may be influenced by higher travel speeds or roads with little traffic. It is the interaction of these factors that modulates travel behaviour through travel satisfaction, perceived well-being and activity participation. But, in addition to the mutual influence of these 4 factors, they are also affected by socio-economic and health characteristics, as well as by the built environment and the transport system.

Among the socio-economic factors, it has been shown that economic resources are a determining factor in the use of bicycles. In this sense, the scientific literature has shown that depending on the cultural context, bicycle use may be higher among high-income (Bateman et al., 2021) or low-income individuals (Guerra et al., 2020). In terms of age, there are studies that analyse usage trends according to different generations. For example, the study by Laatikainen et al. (2019), showed that older people generally make very little use of active transport to commute. Also, social factors, such as family, friends and work colleagues, clearly influence the decision to cycle (Willis et al., 2015). Even different trends according to race (Lusk et al., 2017). Moreover, increasing walkability rates has been shown to encourage people with disabilities to use active means of transport, especially those who are dependent on wheelchairs (Schreuer et al., 2019). Another relevant variable in this regard is gender, where in most cases it is women who make less use of bikes in urban environments(Böcker et al., 2020; Pans et al., 2023; Pellicer-Chenoll et al., 2021; Reilly et al., 2022). Globally, women face specific barriers that limit their access to cycling, from perceptions of insecurity to lack of adapted infrastructure to care responsibilities that affect their daily mobility. For example, fear of harassment or violence in public space is a barrier, as women are more likely to experience verbal or physical harassment while walking or cycling, which further limits their willingness to use this mode of transport in their daily lives (Mosquera et al., 2012). Health-related factors also impact cycling behaviour, as people are more likely to cycle in areas with lower pollution levels and where cycling is perceived as a safe physical activity. In fact, individuals who utilize walking or cycling as their primary mode of transportation are more likely to meet physical activity guidelines (Marquet et al., 2017). As we have seen before, cycling has been shown to contribute positively to physical and mental well-being, which, in turn, promotes higher levels of cycling as people seek to maintain or improve their health.

In terms of the built environment, it has been observed that the presence of vegetation and cycle paths significantly encourages cycling, while hillsides have a negative influence on cycling (Ito et al., 2024). In addition, population and employment density tend to be positively related to cycling while the presence of bus lines negatively affects it (Zhou et al., 2024). Regarding the transportation system, the availability and quality of transportation alternatives, such as well-integrated Bike Sharing Systems (BSS) and dedicated bike lanes, play a crucial role in supporting cycling as a mode of transport (Caggiani & Camporeale, 2021). Areas with limited or unsafe cycling infrastructure often see reduced bicycle use, underscoring the importance of safe and accessible cycling facilities (Pucher et al., 2010). The scientific literature has demonstrated that the use of bicycles for trip purposes is associated with the proximity to cycle lanes (Mertens et al., 2016), the presence of a high-capacity bike-sharing system (Alvarez-Valdes et al., 2016) and the availability of sufficient secure parking (Larsen, 2015).

These aforementioned studies do not address cycling by integrating geographical data with socio-economic, health or PA variables. In fact, the relationship between these variables is not part of De Vos (2024) “Ease of Travel” model. This model integrates multiple interactions but does not contemplate a direct relationship between these types of variables. However, analysing their interaction can provide valuable information to identify measures that promote sustainable active travel and facilitate access to opportunities for people in the spaces they travel through.

This dissertation provides a new perspective on the interpretation of human behaviour from a spatial perspective. Previously, there were no tools that allowed the collection and analysis of geographical data in an integrated way with socio-demographic, health or individual behavioural variables. Nowadays, however, there are tools that allow the integration of these variables into a consistent analysis. This not only helps to better understand the interactions between the physical environment and behaviour, but also provides a solid evidence-based basis for decision-making in public policy, urban planning and health. The integration of these variables offers new possibilities for the analysis of spatial patterns and their impact on quality of life, social equity and sustainability.

General aim

The overall purpose of this dissertation is to carry out an exploratory analysis of cycling and some of the factors influencing cycling as a mode of transport in cities. In particular, it aims to examine the impact of the built urban environment on the benefits of cycling as a mode of transport, including perceived health and PA levels, and on the risk of harassment during active trips.

This work tries to identify, through a new methodological perspective that integrates geographical data together with socio-demographic and health variables valuable information that can help to promote cycling in urban environments. This can be used by policy makers and urban planners to improve the built environment and develop effective plans to promote cycling as a means of transport. At the same time, these studies are approached from an interdisciplinary perspective, which is clearly reflected in the diversity of the bibliographical references.

Thesis structure

This doctoral thesis with International Mention has been prepared in accordance with the regulations of the Universitat de València (ACGUV 252/2024). For its development it has been supported by a 3-year full-time pre-doctoral contract (CPI-21-518) associated with the PROMETEO research project of the Regional Ministry of Innovation, Universities, Science and Digital Society 'Sustainable transport in Valencia: social-environmental, urban and health analysis of the Valenbisi service' (GVAPROMETEO2021-026).

As stipulated in the legislation, the structure of the thesis is as follows:

- **Introduction**: This part consists of establishing the general framework on which this thesis is based. This will allow to contextualise the research topic addressed. Subsequently, the general objectives to be achieved are established.
- **Literature review and social perception**: It consists of two studies that apply text mining techniques. The first one consists of analysing what the scientific community has published in the Scopus database related to cycling in urban environments. Then, the second study consists of analysing the posts published in the social network 'X' that contained words, hastags and emojis related to cycling

and the city. This chapter gives us an overview of the scientific and social perception of cycling in the city.

- **Exploring urban cycling: physical activity and harassment**: It is composed of two studies related to positive and negative experiences because of cycling in urban environments. The first study quantifies urban cycling using health and built environment variables such as cycling facilities, public transport and motor vehicles. The second study consists of analysing situations of harassment during active travel and their relationship to the built environment.
- **Main conclusions, policy implications and future perspectives**: It contains the most relevant conclusions derived from the thesis, highlighting the most relevant results. It also mentions the possible policy implications and future research that may derive from this work.

Finally, the references used and the annexes are exposed. Among the studies included in this dissertation, one of the studies has been already published:

- Antón-González, L., Pans, M., Devís-Devís, J., & González, L.-M. (2023). Cycling in urban environments: Quantitative text analysis. *Journal of Transport & Health, 32*, 101651. https://doi.org/10.1016/j.jth.2023.101651

LITERATURE REVIEW AND SOCIAL PERCEPTION

Study 1. Cycling in urban environments: Quantitative text analysis

1.1. Introduction

Due to the growing interest in converting cities into sustainable environments, the scientific literature related to cycling in urban environments has increased in the last decade. Different works approach this topic from different points of view, but most studies tend to focus on a particular aspect, such as a review of bicycle sharing service planning issues (Shui & Szeto, 2020), systematic literature reviews based on bibliometric analyses (Benita, 2021; Zhou et al., 2022) or a review of cycling prevalence and trip characteristics from 17 countries worldwide (Goel et al., 2022).

However, there is still a need for an analysis of cycling in urban environments that covers a wider range of years and takes a more comprehensive and global approach of different areas of study, as opposed to the specialized and particular focus of systematic reviews. In order to respond to this problem, techniques for massive text analysis, such as text mining, facilitate the extraction of implicit knowledge from textual data (Feldman & Sanger, 2007). This type of analysis, which has been developed to manage a large volume of information, allows to draw conclusions and determine the direction of cycling studies in urban environments. This text analysis provides an easy communication of this focus of study in a visual and understandable manner, without losing its validity and rigor. Because textual data are obtained via the Internet as a source in a uniform format, it can be easily accessible and processed accurately (Taeho, 2019).

The application of text analysis techniques in studies addressing urban sustainability offers two distinct advantages. Firstly, as these methods assist in identifying trends across large document sets, they are particularly beneficial in interdisciplinary areas of study, such as urban cycling. As transport is a multidisciplinary area (Corazza, 2024), this allows for the integration of information from a variety of fields, including transport, public health, ecology, and urban planning, providing a comprehensive perspective that facilitates the analysis of sustainability from multiple angles. Secondly, applying text mining to urban issues allows us to discover new areas of research which are not always apparent in traditional reviews. This is crucial in a field that is constantly evolving and highly influenced by changes in public policies, technological innovations and the needs of local communities. Ultimately, the use of these techniques can be beneficial in uncovering patterns and insights (Fang, 2022), enabling a deeper understanding of the dynamics and trends in the field (Oh et al., 2023). This is essential to guide future research and effective policies for sustainable city planning.

In this context, the purpose of this study is to determine which topics have been researched in documents included in the Scopus database in relation to cycling in urban environments. Furthermore, it aims to find the existing relationships between the topics obtained and the most relevant ones. Based on an exhaustive analysis of the existing literature, the aim is to identify the predominant areas of research and possible gaps in knowledge, which will allow us to establish a solid theoretical basis for this work and also guide future lines of study in the field of urban cycling. The purpose comprises three complementary specific objectives: (a) to examine how the terms “bicycle”, “urban”, and their derivatives appear in the titles, abstracts, and author keywords (AK) of the quantitatively analysed documents; (b) to qualitatively analyse the relevant topics extracted after the quantitative analysis; and (c) to identify the dynamics of these topics over the last 20 years.

The results of this study will be advantageous to contextualise the present doctoral thesis, establishing a theoretical framework on which to discuss its results. Moreover, it is also useful for professionals in the field, as we will provide keywords and topics that facilitate the search for related literature. Additionally, our methodology allows for automatic selection of the most significant publications on each subject, which simplifies the process of navigating through the extensive body of scientific literature in the field.

1.2. Materials and methods

1.2.1. General procedure

We initially conducted a structured search in the Scopus database with the intention of collecting all documents (no restrictions were applied in the search strategy) that have been published about cycling in urban environments. For each document, we obtained the title, abstract, keywords, and the date of publication. This corpus of documents was pre-processed and then analysed.

The analysis was composed of three major blocks. The first one quantified the most common words and their combinations, descriptive n-grams. The second block extracted from the documents the main topics addressed in the documents over the years, Latent Dirichlet Allocation (LDA) and dynamic topics, and a third block in which the documents were classified by topics and analysed separately. Figure 5 shows the general procedure used for this analysis. Each of the steps is detailed in the following sections.

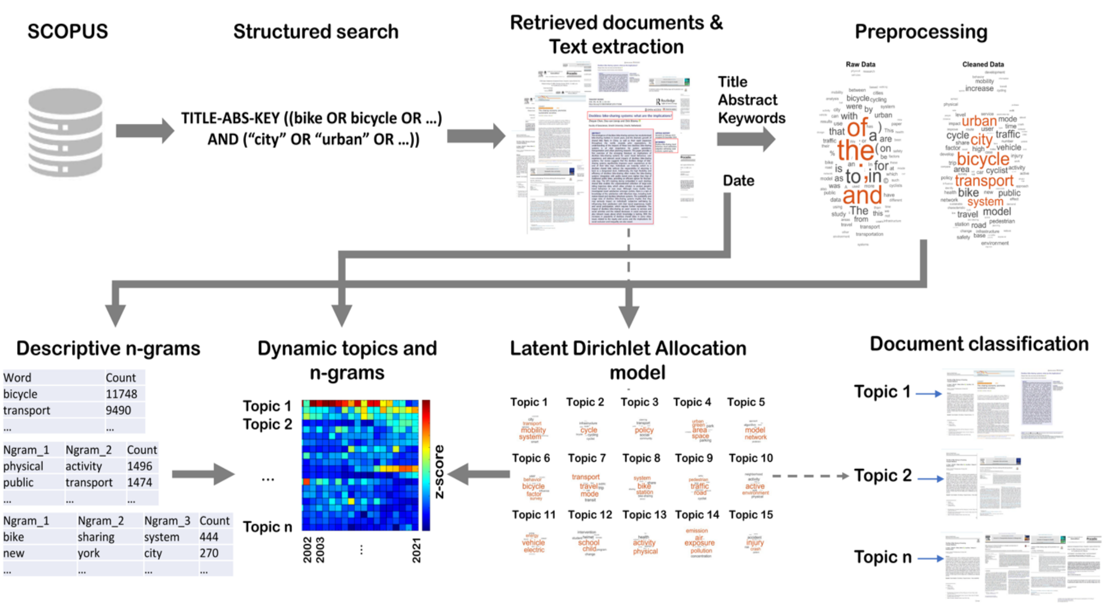


Figure 5. General procedure overview

1.2.2. Data retrieval and preprocessing

This study was based on the analysis of a global mass of documents (9,421 documents) with the purpose of extracting relevant information about cycling in urban environments. For this purpose, different quantitative methods (e.g. LDA model) of text-mining-based analysis were applied, allowing for an objective view of the topic addressed.

Our intention was to find the greatest variety of documents on cycling in urban environments that represented all possible areas of knowledge (e.g. health, sport, urban studies, transport...). For this reason, a generalist database such as Scopus was selected. It is also an easy database to use, provides easy access to cited papers, is open to the Internet, and has web pages and links to journal publisher websites as advantages over other main databases. (Burnham, 2006). Furthermore, the number of publications found in Scopus was higher than in the other databases because it covers specialised journals in different fields. Furthermore, the title, abstract, and AK have been chosen for analysis because text mining allows for analysis of a large number of documents. The title provides clear, easy and understandable information about the content of the presented work (Langford & Pearce, 2019), and AK express concisely the main ideas of the analysed documents (Jones & Jackson, 1970). Finally, abstracts were analysed as they provide the most important highlights of the publication (Alspach, 2017).

The search equation used in Scopus included two keywords “bike” and “urban” in the title, abstract, and AK, to limit the documents to those that were related. To cover as many related words as possible, all possible synonyms and derivatives of both words, such as “cycling” or “city”, respectively, were included. The complete equation is shown in Table 1. No date restrictions were applied in the search. A total of 9 486 documents were downloaded in blocks of 2 000 documents in plain text with the following fields selected: i) citation information, ii) bibliographical information, iii) abstract & keywords, and iv) other information. The files were extracted and stored in a CSV file for further analysis. The first step in the preprocessing was to eliminate all duplicate documents using the digital object identifier (ID) and title fields. This process results, after removing duplicates and those with non-keywords or abstracts, in 7 743 documents for analysis. The text analysis of the documents was conducted by MATLAB (R2021b, MathWorks Inc., Natick, MA, USA), following the standard recommendations used in similar studies (Pans et al., 2021).

Table 1. Search equation Scopus

TITLE-ABS-KEY ((({bicycle} OR {bicycled} OR {bicycling} OR {bike} OR {e-bike} OR {e-bikes} OR {bikes} OR {biking} OR {bikers} OR {cyclist} OR {cycleways} OR {cycleway} OR {cycle ways} OR {cycle way} OR {cyclists} OR {bicyclist} OR {bicycler} OR {bicyclers} OR {bicyclists} OR {cycle path} OR {cycle paths} OR {pedicab} OR {pedicabs} OR {pedelec} OR {pedelecs} OR {s-pedelec} OR {s- pedelecs} OR {tricycles} OR {tricycle} OR {tricyclist} OR {tricyclists} OR {trike} OR {trikes} OR {trishaw} OR {trishaws} OR {unicycle} OR {unicycles} OR {unicyclist} OR {unicyclists} OR {autocycle} OR {autocycles} OR {autocyclist} OR {autocyclists} OR {rickshaw} OR {rickshaws})) AND (({city} OR {cities} OR {citywide} OR {city centre} OR {city centres} OR {cities centre} OR {megacity} OR {megacities} OR {urban} OR {urbanism} OR {urbanized} OR {urbanize} OR {urbanization} OR {urbanite} OR {town} OR {hometown} OR {hometowns} OR {towns} OR {small-town} OR {small-towns} OR {downtown} OR {downtowns} OR {metropolitan} OR {megalopolis} OR {metropolis} OR {aerotropolis} OR {village} OR {villages} OR {hicksville} OR {capital} OR {borough} OR {boroughs} OR {conurbation} OR {conurbations} OR {dorp} OR {dorps} OR {hamlet} OR {hamlets} OR {hill station} OR {hill stations})))

The documents were reduced to tokens (tokenisation), and the following actions were performed in order:

i. punctuation marks and special characters were removed;
ii. words were converted to lowercase;
iii. words that could add noise to the text and did not add content to the documents were eliminated (e.g. “a”, “and”, and “to”): the list of stopwords in the MATLAB text analytics toolbox was used;
iv. the copyright and name of the publisher included in the abstracts were removed as they do not provide information on the content of the documents;
v. words were normalised through a lemmatisation process by which a morphological analysis of the words was performed to reduce them to their headwords using a predefined dictionary; to improve the process, part-of-speech details were added indicating whether the words were nouns, verbs, adjectives, etc.;
vi. words with character length less than 2 or greater than 30 and those with document corpus frequency of less than 10 were also eliminated.

With the resulting tokens, a bag of words (unigrams), a bag of bigrams, and a bag of trigrams were formed. The original documents (raw data) and the associated fields were also stored for later qualitative analysis.

1.2.3. Descriptive analysis of documents and word dynamics over the years

Descriptive analysis was used to establish which words were the most used in the retrieved documents. For this purpose, the bags of words (unigram, bigram, and trigram) saved after preprocessing and generated from the titles, abstracts, and keywords of the retrieved documents were used.

Additionally, to see the increases and decreases in the influence of the words over time, a count of the main bigrams over the last 20 years was made. Bigrams were used because they show better performance for automatic keyphrase extraction compared to unigrams or trigrams (F. Liu et al., 2008). The main intention of this analysis was to establish the changes in the influence of the words each year, so it was necessary to account for the varying number of documents in different years. To avoid the overestimation of years with more documents, the data were normalised using *z*-scores. The z-score allows for the analysis of the probability of a score occurring within a normal distribution and enables the comparison of two scores from different normal distributions (Al-Faiz et al., 2019).

1.2.4. Identification of the main topics and their dynamics

To determine the topics collected from our corpus (i.e. collection of titles, abstracts, and AK), a LDA model was applied (Blei et al., 2003). This model assumes the existence of a fixed number of latent topics that appear across multiple texts (i.e. the downloaded documents). Each document is characterised by a topic mixture, and each topic is characterised by a discrete probability distribution over words; that is, the probability that a precise word is present in a text document depends on the presence of a latent topic (Büschken & Allenby, 2016).

In this study, the LDA model had a double function: 1) to extract the main topics from the corpus and 2) to serve as a method for selecting documents related to certain topics of interest.

For the analysis, we used the "filtlda.m" function, implemented in MATLAB text analytics toolbox (version 1.4). We used the previously preprocessed bag of words (unigram). The first step was to ensure good cohesion in the resulting topics by establishing the number of required topics. To ensure the goodness of fit of the LDA model, perplexity, which indicates how well the model describes a set of documents, was calculated previously. A lower perplexity suggests a better fit.

Adjustments were made for 10, 15, 20, 25, 30, 35, and 40 topics. With our data, the number of topics that yielded the lowest perplexity value was 15. Once the number of topics was established, an LDA model based on the Gibbs sampling algorithm was implemented (Griffiths & Steyvers, 2004). Of the 15 topics obtained after adjusting the model, those with the highest probabilities of their 10 most representative words were selected. In addition, to analyse the changes in topics over the course of the study time, the topics were represented using heatmaps. All frequency values were normalised using *z*-scores.

1.2.5. Document classification

As previously mentioned, the LDA model not only extracts the main topics but also allows for the unsupervised classification of documents that are more closely related to each other. If we consider that in the LDA model each document is a mixture of topics and we choose those documents that have a higher amount of a topic, we can select and classify the most representative documents of each theme. In general, for a document to be classified under a topic, it had to achieve at least a probability equal to or greater than 0.6 of belonging to that topic.

In this way, a reduced number of documents that were the most representative of the topic were selected for each one. These publications were used to carry out the discussion of the different topics found. For the analysis of these documents, a similar procedure was followed as in a systematic review. First, the research group members read these publications, and then the qualitative aspects of interest in each of the selected works were highlighted. Finally, the most important aspects of each topic were shared to build the discussion of this article.

1.3. Results

1.3.1. General data of the documents published

After preprocessing, 7 743 documents published in Scopus were analysed. The exponential growth in the number of publications shows the importance that cycling in urban environments has acquired among the scientific community. The first document related to the analysed topics was published in 1920, and from 2008, the number of documents in Scopus has increased exponentially (Figure 6). Although the overall number of documents produced in 2022 related to cycling in urban settings increased (reaching approximately 1 100), only papers published up to the last day of the formal search were used.

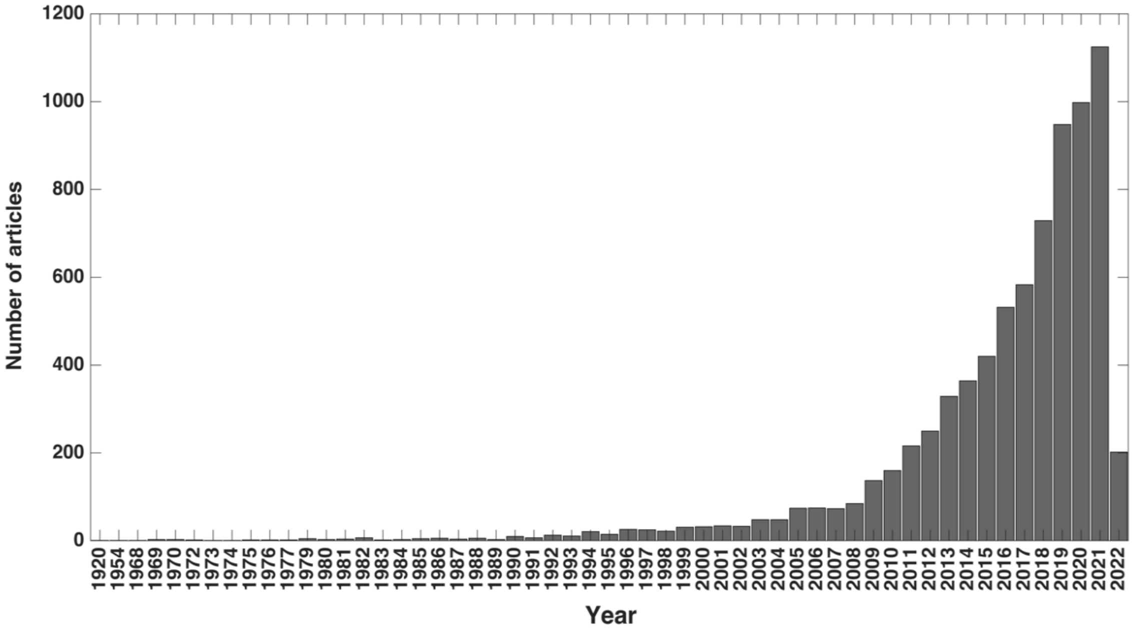


Figure 6. Number of documents published related to cycling in the urban environment until 1 March 2022

The analysis of the authors' countries of origin yielded United States with 24% of the retrieved documents, followed by China with 14%. Authors from Canada, United Kingdom, Germany, Australia, Italy, India, Netherlands and Spain follow in order from the highest to lowest proportion (Figure 7).

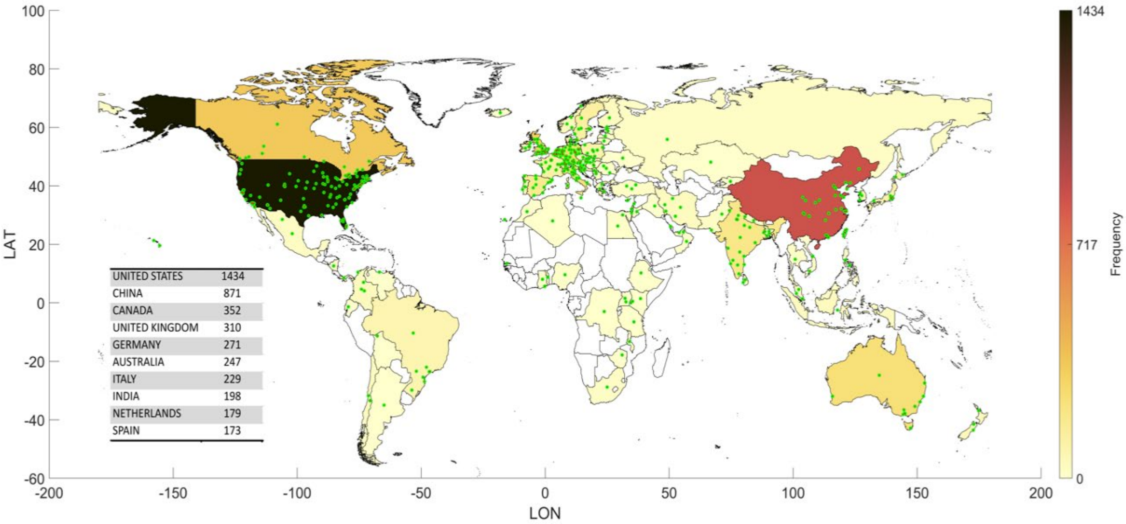


Figure 7. Main countries' document production and research center locations

Note: We have used the authors' provided correspondence addresses. The colour of each country corresponds to the total number of papers published, while the dots indicate the location of the corresponding authors workplace. In cases where it was not possible to geolocate an address, we used the central latitude and longitude coordinates of the country listed in the address.

1.3.2. Description of the words published in the documents and their dynamics

A total of 5 678 (unique) words appeared in all analysed documents. The most repeated words were “bicycle”, “transport”, “city”, and “urban”, but some of them were part of the search keywords used. However, one of the aims of the present study was to determine the main terms found next to the most repeated ones. Table 2 shows the 20 most repeated unigrams, bigrams, and trigrams in our work. The most frequent unigrams, excluding those used in the search equation, were “transport”, “system”, “model”, “traffic”, “public”, and “travel”. Among the bigrams, “physical activity” was the most repeated, and “bike sharing system” was the most prominent trigram.

Related to the dynamics over the years of the 20 most repeated bigrams using the normalised values (z-scores), the bigrams “public transport” ($\bar{z} = 2.60$) and “bike sharing” ($\bar{z} = 1.27$) are the most prominent over the last 3 years. On the contrary, “physical activity” shows a decrease in average within the first 10 years ($\bar{z}$=3.23) and the last 3 years ($\bar{z}$=0.7).

Table 2. Top 20 n-grams found in published papers

Unigram	Count	Bigram	Count	Trigram	Count
bicycle	11 748	physical activity	1 496	bike sharing system	444
transport	9 490	public transport	1 474	New York City	270
city	9 300	urban area	1 046	vulnerable road user	193
urban	8 438	bike sharing	867	public bicycle system	160
system	6 741	build environment	855	informal limit trade	160
bike	6 702	transport system	784	bicycle sharing system	135
model	6 022	transport mode	749	public transport system	133
cycle	5 725	public bicycle	722	city around world	126
traffic	5 621	air pollution	693	geographic information system	124
public	4 710	road user	622	travel mode choice	112
travel	4 618	sharing system	616	urban transport system	111
cyclist	4 527	bike-sharing system	613	National Academy Science	106
area	4 516	motor vehicle	609	logistic regression model	102
vehicle	4 327	mode transport	601	declaration compete interest	102
road	4 194	urban transport	588	American society civil	101
mode	4 098	active transport	585	society civil engineer	101
increase	3 983	pedestrian cyclist	544	road traffic accident	100
high	3 538	mode choice	532	road traffic injury	99
user	3 506	travel mode	496	science business medium	94
factor	3 263	bike share	466	increase physical activity	90

Note: Proper nouns are capitalised to respect spelling rules.

1.3.3. Main topics found in the LDA model and their dynamics over the years

The words found were classified into 15 clusters through an LDA model, ordered from highest to lowest probability of appearance in the entire corpus of documents. To label the topics, an extensive reading of the publications was carried out to identify commonalities and find an umbrella title for each topic. Figure 8 shows the 15 topics whose main word is most likely to appear when talking about the topic they represent; each topic is composed of a group of words that have an associated probability of appearing together in different documents. The analysis system provides a ranking of the words most related to the topic, and a ranking of the documents with the highest probability of belonging to the topic in question is also possible.

Figure 8. Representative words of the topics found in the LDA model

Note: Ordered from left to right and from top to bottom in order of relevance using their normalised values (z-scores). A larger size represents a higher probability of appearing in the documents associated with each topic and a smaller size represents a lower probability of appearing in the documents associated with each topic.

Figure 9 shows the dynamics of these topics over the past 20 years using their normalised values (*z*-scores). A substantial increase in the number of publications was observed in "bike sharing station" and "smart urban mobility" topics, and a moderate one in the "model" and "cycling as a means of urban transport" topics. Moreover, a constant number of publications was observed on "bicycle infrastructure" and "bicycle behaviour" topics, and a decrease on "school", "active infrastructure", and "active transportation" topics.

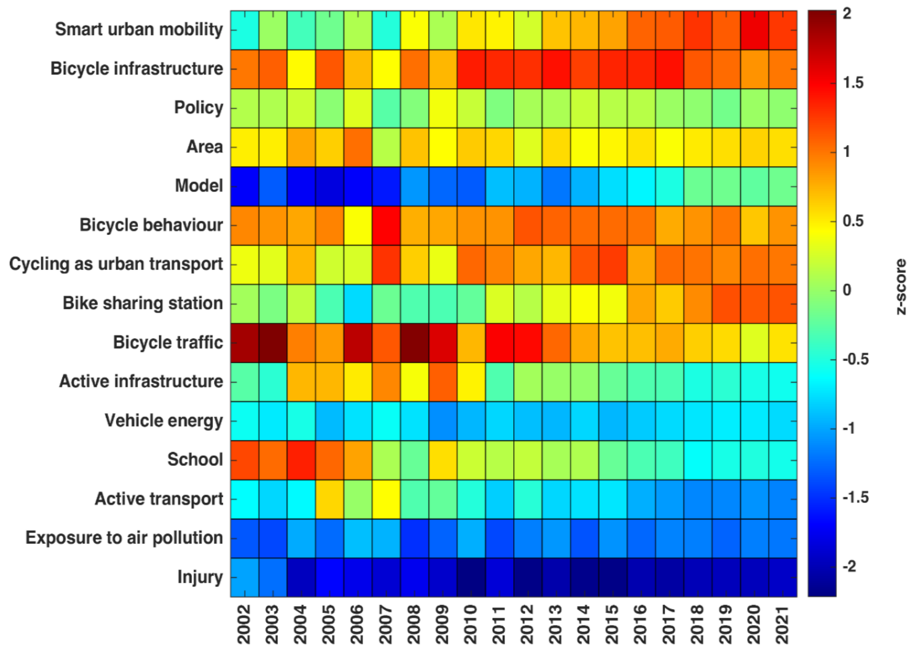


Figure 9. Dynamics of the 15 topics most repeated words during the last 20 years

1.4. Discussion

1.4.1. Principal findings from general data

The results show that from 2008 to 2021, the number of documents on cycling in urban environments has increased exponentially, probably due to the unhealthy and negative environmental effects of motorised traffic in the worldwide climate crisis (Khreis et al., 2016). Providing evidence of benefits of bicycles as a means of transportation is expected to encourage their use and reduce the use of motor vehicles in cities with high levels of pollution (Buckley et al., 2014). In the case of the United States, private cars are used 50% of the time for short distances in most of its metropolitan areas (INRIX, 2019), and in Chinese cities such as Beijing the ratio of people travelling by private car increased by 9.4% from 2000 to 2012 (The Guardian, 2010). Moreover, authors from China and the United States have published the most documents, and these countries continue to show high levels of urban pollution and motorised traffic (Greene & Plotkin, 2011; Yang et al., 2021). Therefore, the reason researchers in these countries publish studies on cycling in the urban environment from a critical point of view may be the concern for the sustainability of cities and not only that they are large countries with a large number of researchers. However, countries such as the Netherlands are in ninth place in terms of the number of documents published but have the highest cycling population (Goel et al., 2022).

The most relevant unigrams found in the present study, excluding those in the search equation, are “transport”, “system”, “model”, and “traffic”. This may be due to the interest among the scientific community to optimise the means of transport with different systems and models that are able to reduce its negative effects on health and the environment (Alessio et al., 2021). The most frequently mentioned bigrams are “physical activity”, “public transport”, and “urban area”. The first bigram has lost relevance in recent years in favour of the other two bigrams. The modes of transport and the configuration of the urban environment are of a greater research concern compared to the physical activity benefits of urban cycling. Particularly, in the last years “public transport” and bigrams related to sharing systems show a strong emergence, probably because of the great opportunities for mitigating the climate change they provide (J.-W. Hu & Creutzig, 2022). Although systems such as ride sharing (Chan & Shaheen, 2012), electric car sharing (Firnkorn & Müller, 2015), and bike sharing (H. Li et al., 2021) offer multiple environmental benefits, it is the last one which also offers health benefits (Clockston & Rojas-Rueda, 2021), which explains the great research support for encouraging city cycling policies (Handy et al., 2014). In fact, “bike sharing system” was the trigram with the highest *z*-score in the present study, probably due to its increase in popularity in recent years and its consequent multiple benefits (Y. Chen et al., 2022; DeMaio, 2009). This system is seen as the most sustainable and active alternative in urban environments, which allows its combination with public transport, which was also found to be a relevant bigram in this study. The relationship between these two *n*-grams was the object of multiple studies focused on the public transport stops and bicycle parking connection to increase the potential number of users of bike sharing system and public transport (Heinen & Buehler, 2019).

1.4.2. Most relevant topics

The discussion is focused on the most relevant topics found, which were those with an above average *z*-score (Figure 9): “smart urban mobility”, “bike sharing stations”, “bicycle infrastructure”, “bicycling behaviour”, “cycling as urban transport” and “bicycle traffic”. The scientific community has lost interest in other topics such as “injury”, “school”, or “active transport” in recent years, and these are not discussed in this study. To carry out this analysis, the most relevant documents (i.e. those with a probability equal to or greater than 0.6) associated with the topic have been used.

One of the highest *z*-scores was obtained by the “smart urban mobility” topic, which integrates intelligent technological systems in urban mobility to achieve social and economic needs of citizens in the urban areas (Cifaldi & Serban, 2018). This means that mobility systems use the Internet of Things to achieve efficiency, integration, sustainability, and quality of life for people living in cities (De La Iglesia et al., 2019). For instance, the intelligent transportation systems are created and implemented in cities to reduce traffic congestion and improve fuel efficiency; this consequently decreases pollution and enhances accessibility and safety (Šurdonja et al., 2020). The technological advances are also integrated with the BSS, called “Internet of Bikes”, to collect and analyse bike sharing data to further improvement of the system (Zguira et al., 2018). These intelligent transportation systems, such as Smart Social Bike or Bike-Sharing, allow for analysis of the strengths and weaknesses of these cycling systems to optimise their functionality for urban planning or for reducing theft and vandalism (Carpanen et al., 2016).

“Bike sharing stations”, which refers to the group of studies focused on stations as hubs that need to optimise their operations, was also a topic with a high *z*-score. The unequal distribution of bicycles at different stations is one of the biggest challenges in BSSs; therefore, tools are being designed to predict the bicycle flow at different stations to ensure that there is always service (P. Chen et al., 2017). This topic also encompasses station location optimisation models, which are being designed according to the interests of both users and station investors (F. Wang et al., 2020; Y.-J. Wang et al., 2022). The user’s perspective on the sharing stations has been adopted in studying their spatial efficiency, such as the characteristics of bicycle stations and accessibility between bicycle stations and other urban facilities (Zhang & Huang, 2012). Stations at peak hours have also been studied in relation to bicycle users’ behaviours and their changes according to the number of available bicycles and the introduction of an incentive (Gimon, 2018). Certain problems linked to stations were overcome by the emergence of dockless BSSs, especially when there are reduced number of locks/stations due to restrictions of the city space and municipal budget. In fact, trips by dockless BSS show the highest travel satisfaction (Z. Chen et al., 2022). Moreover, these systems offer a reduced membership fee, sometimes zero, compared with the traditional dock-based system, and allow the user to freely use the dockless system within the designated service areas (Qian et al., 2020).

Another relevant topic in the present work refers to the “bicycle infrastructure” and its influence on the use of bicycles by commuters. In fact, the improvement and extension of protected cycling infrastructure is considered a key issue in the increase of cycling over the coming years (Buehler & Pucher, 2021). However, the effects of land use mix, the availability of cycle paths to non-residential destinations, and the slope of the terrain on cycling behaviour remained weak (Y. Yang et al., 2019). There are systems that analyse the quality and safety of the cycling infrastructure to optimise them and consequently persuade commuters to use them. Among the different systems, we can mention the “Quality Assessment Index of Cycling Infrastructures” (Batista & Lima, 2020) characterised by a compendium of categories with their corresponding indicators that allow rating the quality of the infrastructure. In the system proposed by Kirner Providelo and Penha Sanches (2011), the infrastructure was analysed from the user's perspective through surveys that contemplate different dimensions including visibility, pavement conditions, and lane width. The results of these analyses support planning actions, public policies, and management of cycling in urban environments and contributes to increasing the use of these infrastructures. Furthermore, public policies and private initiatives targeted to combine transport infrastructures in the cities make the use of BSSs and cycling in general especially attractive for the population (Ashraf et al., 2022). Safety in the use of cycling infrastructures is also a key issue for researchers in this topic to ensure that cycling is a secure means of transport. The development of tools to assess the safety of urban cycling infrastructure is important from users' perspective. For instance, the eye-tracking technology shows images from Google Street View that reveal hazards related to cyclists in urban environments (Brazil et al., 2017).

As a result of the growth in bicycle usage, new types of infrastructure have been introduced to accommodate the increasing proportion of "bicycle traffic", or the flow of bicycles, another relevant topic identified by the present study. We found specific structures for cycling traffic shared with motor vehicles, such as bicycle boxes. Bicycle boxes are advanced stopping areas for cyclists at intersections to facilitate turns with the goal of increasing cyclist safety at intersections (*Urban Bikeway Design Guide*, 2012). Because of shared structures and traffic, many studies analysed issues of safety and cyclist injuries linked to risky bicycle passing on urban arterial routes. In fact, unsafe passing has been used to assess the need for a specific type of cycling facility (e.g. on-street bike lanes) on a given road beyond other habitual criteria used such as speed or traffic volume (Mehta et al., 2019). Among the severe bicycle accidents requiring hospitalisation, 26% are caused by collisions with motor vehicles (Berk et al., 2022). Moreover, another factor influencing cyclists' health is riding close to high-traffic routes. In fact, cyclists' exposure to pollution could be more than three times higher when riding on a busy route compared to riding on a route without traffic (Mitsakou et al., 2021). Finally, bicycle traffic and cycling infrastructures are determinant factors that influence people to use bicycles in urban areas and central targets of global road safety for achieving the commitment of SDG 11, Target 11.2 (Useche et al., 2019; World Health Organization, 2020a). To reach this commitment, cycling must be promoted and prioritised as an accessible means of transport to become the only mode of mobility in urban areas for many people or to be combined with other sustainable modes of transport.

The aspect of promoting has also been reflected in the present text-mining study since "cycling as urban transport" emerged as another research topic with an above average *z*-score. Although multimodal trips using cycling and metro have received much promotional attention, this combination of transport modes is still less used than combinations of other modes. In fact, in cities such as Nanjing (China), this may be due to the fact that citizens do not perceive the overnight bicycle parking in metro stations as sufficiently safe and, moreover, bicycles are not allowed on the metro (J. Wu et al., 2018). Meanwhile, it has been observed that in lockdown situations, bike sharing systems are more resilient than the metro (H. Wang & Noland, 2021). Nonetheless, cycling is recognised as an excellent mode of transport to combine with other modes because bicycles are flexible, convenient, and fast and offer good accessibility, low cost, economical operation, and low carbon emissions (Lang et al., 2019). However, despite being an active and environmentally friendly alternative for short and medium distances, cycling represents a low percentage of journeys compared with other modes of transport in different cities (European Environment Agency, 2019). In fact, the further away from the city one lives, the lower the use of bike sharing as a means of transport (Xin et al., 2019). However, the results in the different cities showed that the most acceptable distances for cycling were around 4 kilometres, but it is not chosen as the main mode of transport even by users who are active travellers and have the highest levels of travel satisfaction (De Vos et al., 2016). In a hypothetical scenario of cities without private cars, it has been estimated that 55% of the total urban population would choose walking or cycling as urban transport (Reul et al., 2021), which would allow cities to meet their climate responsibilities and establish sustainable and environmentally friendly transport systems.

A group of studies focused on "bicycling behaviour", a topic that refers to people's cycling patterns according to different demographic variables. For instance, gender differences have been found in the use of bicycles in different areas of the city, with the density and centrality of the travel network differing for men and women and the peripheral zone being less used by women for nighttime trips (Pellicer-Chenoll et al., 2021). Even differences in the use of active transport among women have been found in later reviews. For instance, women with high socio-economic status, high education level, high leisure time and access to safe and convenient infrastructure tend to cycle more compared to women with low incomes status that tend to walk more (Yuan et al., 2023). However, an increase in the number of women cyclists from different age ranges is widely observed in a recent international study (Goel et al., 2022). This may be due to the fact that if women feel safe, they are more likely to cycle to destinations such as the post office, schools, stores, or restaurants (Emond et al., 2009). Thus, the promotion of safe environments by politicians to the population, both male and female, will allow for the use of bicycles as urban transport and for achieving the commitment of Sustainable Development Goal 5, Target C (European Union Agency for Fundamental Rights, 2015). In terms of behavioural differences between age groups, some studies indicate that people older than 55 years prefer cycling for short commuting, whereas the rest of the population prefers other means of transport, even if the distances are less than 2 kilometres (L. Yang & Wang, 2018). However, among the young population, university students are more likely to use bicycle as urban transport (Du & Cheng, 2018). This is probably because college students have a high capacity to accept new things, high degree of education, and limit on daily expenses, and they tend to have a strong sense of safety and protection of the environment (S. Ma et al., 2019). Another relevant socio-demographic variable is the degree of education: the frequency of bicycle use is lower in the groups with lower levels of education (Fu & Farber, 2017). This could be due to the fact that the population with higher educational levels is more concerned about environmental care and the importance of bicycling as a means to improve health (National Academies of Sciences, 2014).

1.4.3. Limitations and future research

This analysis of the literature has some limitations that should be considered. Our analysis focused on the titles, abstracts, and keywords of many documents. Although these parts of the publications contain information of interest, it would be interesting to perform a full-text analysis in future work. Our working group does not currently have sufficient technology to undertake this task; moreover, we do not have access to all the published papers. We believe that a work of this magnitude should be undertaken by several research groups together, sharing resources (i.e. a computer cluster).

Furthermore, it should be noted that this study was intended to provide a global view of the subject to be investigated, based on text-mining techniques; therefore, the discussion is very general. The large number of topics found in this work should be analysed separately by experts in each of the subjects. Although there are already systematic reviews (Götschi et al., 2015) that have addressed some of the topics that we highlighted in our results, it is desirable that other researchers analyse those areas that have been investigated. Other methodologies (Zhou et al., 2022) already explored in the scientific literature may help the reader in the interpretation of the main findings found in our research.

It is necessary to emphasise that this work has focused on the most repeated and usual words that appear in published works. This is standard when working with large masses of text. However, it is not always the most repeated or popular terms that are the most important for science. Occasionally, papers appear that use neologisms, or words from other areas of knowledge, which can be of great importance for the area. These papers that use fewer common words do not appear in our study, but they may be no less important. Future studies should explore words with low frequencies, to identify disruptive or new ideas that are contributing non-trivial knowledge to the research topic of the present study.

Finally, it is essential to draw readers' attention to the importance of not inferring conclusions solely from the visualization of the figures in this study, as this must be accompanied by a reading of the associated documents.

1.5. Conclusions

In this study, it has been presented a text analysis using text-mining methodology to discover the most relevant themes of research on cycling in urban environments. As far as it is known, this is the first analysis on this issue that takes a comprehensive and global approach of different areas of study, as opposed to the specialized and particular focus of systematic reviews.

A general conclusion points out an exponential increase in the number of scientific documents on this topic since 2008, with most publications written by authors from China and the United States. The most relevant unigrams found were, excluding those in the search equation, “transport”, “system”, “model”, and “traffic”. Furthermore, it is observed that the bigrams related to urban cycling that have become most important in recent years are “public transport” and “sharing system”. Moreover, the most representative trigram was the BSS, which has gained prominence due to its environmental and health benefits.

We also found 15 relevant topics related to cycling in urban environments using the LDA model and we have analysed those that have shown the most relevance at present, using the most representative documents of each topic. The topics analysed have been “smart urban mobility”, “bike sharing station”, “bicycle infrastructure”, “bicycle traffic”, “cycling as a means of transport”, and “bicycle behaviour”. These topics show the concern among the scientific community about the structural factors of cycling in urban environments with the aim of promoting cycling by offering facilities to users. However, the health benefits of cycling as a means of urban transport were found to be secondary.

The results of this study provide a solid basis for the development of this thesis, which also will benefit academics, publishers and practitioners in the field of urban active transport, particularly cycling, by identifying current relevant issues. The application of the text mining technique allows policy makers in this field to process information in an accessible and simple way and to discover new knowledge. This can replace manual information processing and increase the effectiveness and efficiency of procedures. In addition, text mining applications can improve the rationality of policy makers during decision-making and the organisation's overall ability to process information. Therefore, this study can support policies that encourage people to use active urban transport as the main variables that are currently being studied that influence its use. Moreover, this work can guide the focus of future research and theoretical frameworks.

However, to obtain a comprehensive overview of the issue, it is essential to know the opinion of the population to ensure that promotion plans are effective. In this sense, the following chapter analyses the Trends in the debate on the social network X on cycling in urban environments.

Study 2. Trends in the discussion of cycling in urban environments: An X-based study

2.1. Introduction

Due to the growing concern about transforming cities into sustainable environments, as we can see in the study 1, the scientific community has recently focused on cycling infrastructure, especially bike-sharing stations, cycling behaviour and traffic, and how technology is integrated into urban cycling mobility.

However, despite the efforts of the scientific community and despite being an active and environmentally friendly option for short and medium distances, cycling represents a low percentage of journeys in comparison to other means of transport in different cities (European Environment Agency, 2019). To enhance the use of cycling, it would be beneficial to implement feedback systems that can identify areas for improvement in active transportation. In this sense, knowledge gained through social media can be utilised to discover and expose users' preferences in a way that is useful for decision-making in urban planning (López-Ornelas & Morales Zaragoza, 2015). The enormous amount of available information does not allow conclusions to be drawn on this issue, making it impossible to deduce the meaning of bicycle users' opinions in the city. However, advanced text analysis methods like text mining enable the extraction of implicit information from textual data (Feldman & Sanger, 2007). Text mining also enhances political influence of the citizens, thus expanding their democratic opinions, because text mining techniques allow policymakers to process masses of messages in the policy space or on social media (Ngai & Lee, 2016). These techniques have been widely used in this field of knowledge (Das et al., 2015, 2019; Rahim Taleqani et al., 2019; Serna et al., 2017).

For this purpose, X (formerly Twitter) was selected as a source of data because it provides free and accessible information (Y.-J. Li et al., 2019). This is the most popular microblogging social media platform on which people express their daily activities and concerns (Chaturvedi et al., 2020). Additionally, the sentiment analysis of X allows us to classify the polarity of sentiments into negative, neutral, and positive (L. Wang et al., 2020). Analysing the polarities of X users' sentiments has enabled the development of strategies for political elections (Paul et al., 2017). Companies also use X-sentiment analysis as an effective way to understand people's sentiments towards their products and brands (Bravo-Marquez et al., 2016). Moreover, emojis have been included in the analysis as part of the study because of their communicative functions, such as expressing emotions (Jaeger & Ares, 2017), strengthening expression and adjusting tone (T. Hu et al., 2017). Additionally, to complete the analysis, hashtags were used as the objects of the study. A 'hashtag' is a word or a phrase without spaces prefixed with the hash symbol # inserted anywhere in the body of posts (Otsuka et al., 2014). These hashtags allow posts to be framed according to what they mean, allowing users to indicate the specific meaning of what they are posting about (Bonilla & Rosa, 2015).

Owing to X's potential for mining, a study was conducted to analyse X users' feelings about cycling between 2009 and 2016 to extract patterns to promote cycling (Das et al., 2019). The results of this study showed that cycling in a city is associated with weather and seasonal patterns. Furthermore, in terms of the polarity of feelings, the general feeling about cycling has been positive in recent years. However, negative feelings were associated with bad weather, crime, and other problems. Nevertheless, since 2016, there have been substantial changes in policies promoting urban cycling, which may have changed people's sentiments towards cycling. On 25 September 2015 the United Nations General Assembly approved the 2030 Agenda for Sustainable Development (*Social Development for Sustainable Development | Division for Inclusive Social Development (DISD)*, 2015). It contains a set of 17 SDGs addressing major global challenges, such as climate change and sustainable cities. As mentioned before in previous sections of this work, Goal 11 (sustainable cities and communities) was developed to transform cities and human settlements into inclusive, safe, resilient, and sustainable environments. Therefore, the use of sustainable and environment-friendly means of transport plays a key role in achieving this goal. In response, governments have taken measures to promote cycling among the population to mitigate the impact of motor vehicles and complement it with other transport policies, turning cities into healthy and sustainable environments.

To establish a solid foundation alongside the scientific review study (study 1) and to contextualise the subsequent research in this thesis, it is essential to understand people's perceptions and opinions about cycling in urban environments following the implementation of the SDGs. Therefore, this study aims to explore what is being discussed regarding urban cycling in X from 2016 to 2022. To this end, the most-used words related to bicycles and their use in the city, as well as the most-used hashtags and emojis, were analysed. Additionally, the sentiments inherent in the words posted by users during the study period were considered. Finally, it has been identified the most common topics of interest during these years. To analyse what was posted, specific tools are needed to obtain the data (e.g. application programming interfaces [APIs]), and in this case, text mining was used.

2.2. Material and methods

2.2.1. Data retrieval and pre-processing

The general procedure is similar to the one specified in study 1 section 1.2. but with some variations since the text data to be processed come from a different database. To build the database, a MATLAB script (R2019b, MathWorks Inc., Natick, MA, USA) was used to perform queries using the X-search API. The search focused on retrieving posts in English containing the term 'bicycle' and 'city', along with their variations (e.g. 'bike' and 'urban'), combined with the emoji of the urban bicycle or urban cyclists (e.g. 🚲 and 🚴) (see Table 3), from 2016 to 2022. Combining emojis and keywords in the search equation will allow us to further adjust the search to our purpose and avoid noise in the analysis.

Conversations associated with the original posts in which users expressed their thoughts about the original post were also retrieved. Published posts were discarded from the search because we focused only on the opinions of the original posts.

Table 3. Search equation X

(bicycle OR bike OR e-bike OR boda boda OR chopper bike OR cyclo-cross OR derny bike OR dirt bike OR fixie OR fixed bike OR surrey bike OR tandem OR tagalong bike OR cargo bike OR keirin bike OR pushbike OR recumbent bike OR cycleway OR cycle way OR cycle path OR pedicab OR pedelec OR s-pedelec OR tricycle OR trike OR trishaw OR unicycle OR bicycled OR bicycling OR biking OR biker OR cyclist OR bicyclist OR bicycler OR tricyclist OR unicyclist OR cyclotourist OR gutter bunny OR velocinoobs OR velookers OR whip OR velocipede OR boneshaker OR penny farthing OR moped) (city OR cities OR citywide OR megacity OR megacities OR urban OR urbanism OR urbanize OR urbanization OR urbanite OR town OR hometown OR downtown OR metropolitan OR megalopolis OR metropolis OR aerotropolis OR village OR hicksville OR capital OR borough OR conurbation OR dorp OR hamlet OR hill station OR dumbtour OR asphalt jungle OR burg OR cosmopolis OR megacity OR municipality OR exurb OR suburb OR suburbia) (lang:en)(-is:retweet)

The data for each post were stored in JSON format to extract the fields of our analysis. The files contain information on the retrieved post and its creator, encompassing more than 150 attributes, of which we used only 11. About 179 691 posts were retrieved before removing duplicates, replicas, and reposts. The collection of documents (retrieved posts) is referred to as a corpus. For data pre-processing, all duplicate posts were removed using the unique post identifier field. Standard recommendations used in similar studies (Jianqiang & Xiaolin, 2017) were followed to prepare post-texts for further analysis. The documents are then reduced to tokens (tokenisation), and the following actions are performed in a manner similar to that described in the study 1 (study 1 section 1.2.2.), with some differences:

i. All hyperlinks (‘http://url’), hashtags (‘# hashtag’), emojis, and username links (‘@username’) that appeared in the posts were removed;
ii. Punctuation marks and special characters were removed;
iii. Words were converted to lowercase;
iv. Words that could add noise to the text and that did not add content to the posts (e.g., ‘a’, ‘and’, and ‘to’) were removed, using the stopword list that MATLAB's text analytics toolbox (version 1.4) has by default;
v. The words were standardised through a lemmatisation process, in which a morphological analysis was carried out to reduce them to their roots. In this process, a predefined dictionary is used. To improve this process, part-of-speech details were added to indicate whether the word was a noun, verb, or adjective.
vi. Words with fewer than two or over 20 characters and whose frequency in the corpus of documents was less than two, were also deleted.

From the resulting tokens, one bag of words (unigrams: one token) and two bags of grams (bigrams: two tokens in a row; trigrams: three tokens in a row) were formed.

Original documents (raw data) and associated fields were stored for further analysis. The remaining fields containing text (e.g. username, entity mention, and location) were not pre-processed. Although duplicates were located through their ID, several posts were published with slight variations from others. Therefore, after the documents were cleaned, posts with slight variations from the original text were removed.

The post IDs used in the analysis were retrieved from the Data S1_id. To comply with X's terms of use, we only published the collected post-IDs for non-commercial use in this research. Users who want to reuse their IDs may retrieve the original data using existing software on the market (e.g. Hydrator). Given that the retrieved data are public and several users may be unaware of their relevance or further use, we followed ethical recommendations (Williams et al., 2017).

2.2.2. Descriptive analysis and dynamics across the years of posts

Descriptive analysis was used to establish the most frequent n-grams in the posts. An n-gram is a sub-sequence of n elements in each word sequence. For this purpose, the bags of words (including unigrams, bigrams, and trigrams) that were saved after preprocessing and generated from the posts were employed. The country of origin was identified to determine the locations of X users. To accomplish this, the country of origin was identified for each user by examining the location field in their profile. Ultimately, 10 564 locations were identified.

To comprehend the dynamics across the years included in the study period, a figure was elaborated to establish the growth and decline in the frequency of posts related to urban cycling.

2.2.3. Emojis

Emojis, defined as a standardised set of small pictorial glyphs representing everything, from smiley faces to international flags, have witnessed an exponential increase in use on social media (Eisner et al., 2016). Therefore, including them in the analysis is essential to get closer to the communicative reality in social networks. To perform sentiment analysis of the posts, they were first extracted from the text of the posts and then stored separately. Subsequently, all of them were counted, and the most repeated ones were graphically represented (using the Symbola.ttf font for Unicode symbols). In addition, the most common meanings were retrieved using the Full Emoji List (*📙Emojipedia — 😃 Home of Emoji Meanings 💁👌🎍😍*, s. f.). Emoticons were not included in the analyses to facilitate text pre-processing (i.e. removal of punctuation marks and special characters).

2.2.4. Sentiment analysis

Sentiment analysis is a technique that analyses the sentiments in written language (B. Liu, 2012). This method assigns a combination of words in a text, such as positive, neutral, or negative words, to a sentiment. Therefore, we obtained a score for the frequencies of positive and negative terms. First, a polarity score was calculated for each post, which is defined as the algebraic sum of terms classified as positive or negative divided by the total number of words in the post (Hu and Liu, 2004). Then, posts are classified as ‘positive’ (score > 0), ‘neutral’ (score = 0) or ‘negative’ (score < 0). Modifier words such as negators (e.g. not), amplifiers (e.g. very), and de-amplifiers (e.g. barely) were also considered in the estimation. In this study, we used the VADER algorithm implemented in the MATLAB environment. After assigning a polarity score to each post, to ensure post polarity, posts were divided into very positive (i.e., score > 0.2) and very negative (i.e., score < −0.2). Subsequently, the classified posts were extensively read to verify the content.

2.2.5. Topic modelling and posts classification

In order to discover the topics collected in the corpus (i.e. collection of posts), a LDA model was used (Blei et al., 2003). This model assumes the existence of a fixed number of latent topics that span across multiple documents (i.e. *n* downloaded posts). Every document is defined by a fusion of themes, with each theme being defined by a discrete probability distribution across words. In other words, the probability of a specific word occurring in a textual document is contingent upon the presence of a latent topic (Büschken & Allenby, 2016). Especially, in this study, the LDA model served a dual purpose: 1) to extract the main topics from positive and negative posts, and 2) to function as a method for selecting posts related to certain topics of interest.

For the analysis, the 'filtlda.m' was used, a function integrated in MATLAB text analytics toolbox. Then, the previously pre-processed bag-of-words (unigram) was used. Initially, to determine the necessary number of topics it was ensured strong coherence among the resultant topics. To ensure the adequacy of the LDA model, the perplexity, which indicates how accurately the model describes a collection of documents, was computed. A lower perplexity indicates a better fit. Same as in previous study, adjustments were undertaken for 5, 10, 15, 20, 25, and 30 topics. Once the number of topics was established, an LDA model using the Gibbs sampling algorithm was executed (Griffiths & Steyvers, 2004).

In the present work, the 10-topic model achieved the best fit. For each topic, the top ten words with the highest likelihood of being associated with that particular topic were selected. The probabilities of observing each word in each topic of an LDA model are referred to as topic word probabilities. Additionally, the topic mixtures of the gathered documents were computed to identify the most representative posts for each selected topic.

The LDA model not only identifies the key topics but also facilitates the unsupervised classification of closely associated posts. Considering that in the LDA model, each post comprises a blend of topics, and we prioritise documents that have a higher mixture of topics, we can discern and classify the most exemplary posts pertaining to each topic. In general, for a post to be classified under a topic, it must achieve a probability equal to or greater than 0.6 of belonging to that topic. In this context, a number of posts were limited to best represent a topic. These posts form the basis for discussing the identified topics. The analysis of these posts followed a procedure similar to that of a systematic review. Initially, members of the research group read these posts, emphasising the qualitative aspects of interest in each selected post. Subsequently, the most significant aspects of each topic were shared to build a discussion for this article.

2.3. Evaluation of results, discussion and limitations

2.3.1. General user data and posts retrieved

After pre-processing, 116 051 posts were analysed. The first post included in the analysis was published in 2016. From the first post, exponential growth can be observed until 2020, after which it shows a slight decline with subsequent stabilisation (see Figure 10). However, other studies have found a continuous exponential increase in the number of posts related to cycling promotion (Das et al., 2019). Moreover, not only the number of posts related to the topic is increasing, but also the scientific production (Zhou et al., 2022). This shows that it is an issue that concerns both the scientific community and the urban population. This growth in posts can be attributed to the increased prevalence of cycling as a means of transport in cities, as policies are oriented towards promoting active and sustainable transport (Zukowska et al., 2022). Cycling accounts for a greater percentage than any other means of urban transportation (McKenzie, 2014).

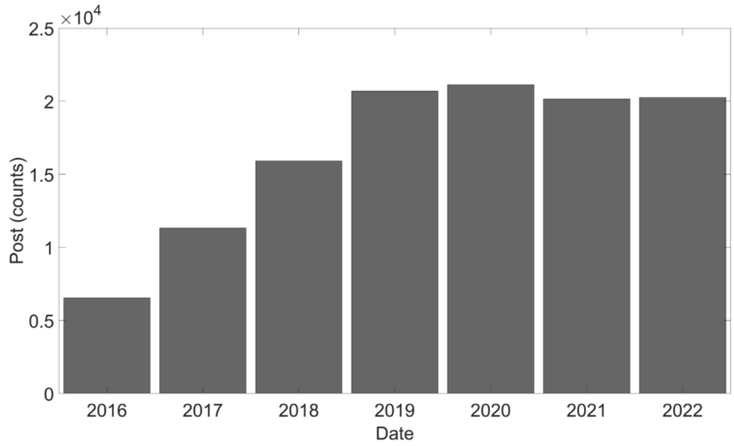


Figure 10. Number of posts related to bike and city during the studied period

Concerning the user's country of origin, the majority were in English-speaking countries, although a notable number were scattered worldwide. The primary country of origin for users was the United States, accounting for 37.93% of the total posts recovered, followed by the United Kingdom (15.86 %). Furthermore, the percentage of the authors from highest to lowest included countries, such as Canada, Philippines, Netherlands, Ireland, India, and Australia. The Netherlands has the largest cycling population (Goel et al., 2022) and a high percentage of English-speaking people (Keydeniers et al., 2022), although it is not among the countries with the most posts on this subject. Figure 11 illustrates the geolocations of different published posts.

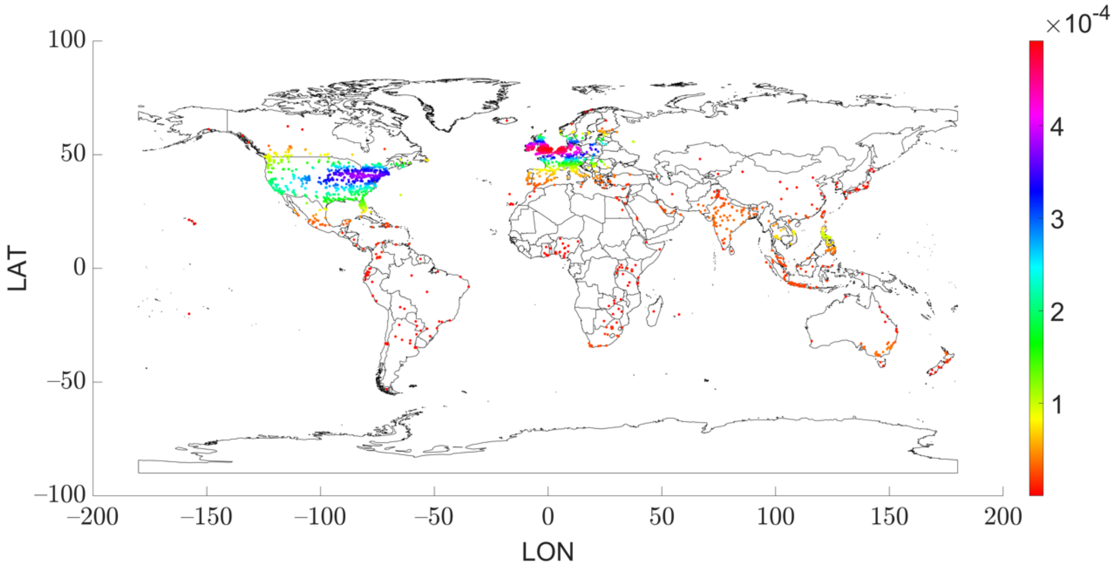


Figure 11. Geolocation of the published posts (N=10 564)

Note: The dots indicate the locations where at least one post has been published. The colour of the dots indicates the density of posts in a specific location.

Table 4 presents the statistical data detailing the number of reposts, replies, and likes garnered from the posts.

Table 4. Statistical data on the number of reposts, replies and likes

Total posts Reposts (count)	*315 057*
never reposted (%)	58.46
reposted >10 times (%)	4.32
mean reposted (reposts/posts)	2.71
Total posts Replies (count)	*80 416*
never replies (%)	74.41
replies >10 replies (%)	0.84
mean replies (replies/posts)	0.69
Total posts Likes (count)	*1 365 074*
never like (%)	30.17
like >10 like (%)	16.74
mean (like/posts)	11.76

A total of 9 641 (unique) words observed in all the posts analysed. Among these, the most frequently repeated words were ‘bike’, ‘city’, and ‘cycle’, which were part of the search strategy used. However, one of the aims of this study was to identify the key terms that appeared alongside the most frequently used ones. Figure 12 shows the word clouds of the most repeated unigrams, bigrams, trigrams, and hashtags in our document.

The most frequent unigrams, excluding those used in the search equation and accompanying verbs or prepositions, were ‘good’, ‘new’, ‘day’, and ‘great’. Among the bigrams, ‘city council’, ‘bike ride’, and ‘bike lane’ were the most repeated and ‘good city will’ was the most prominent trigram.

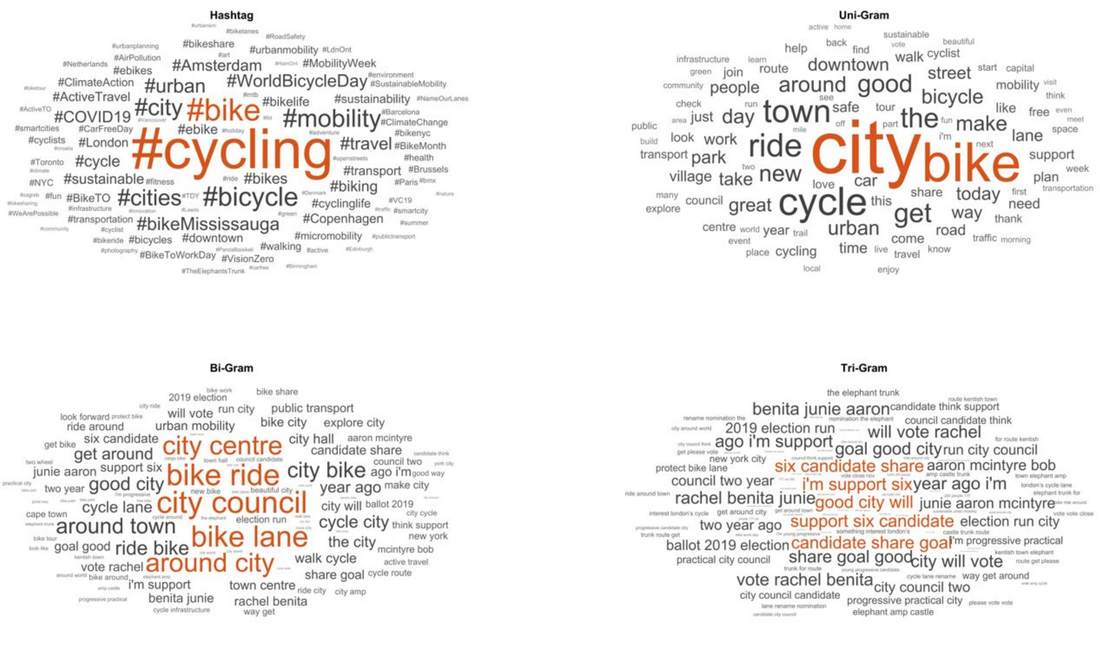


Figure 12. Word clouds of the most frequent words and hashtags found in posts

Note: A larger size represents a higher probability of appearing in the posts and a smaller size represents a lower probability of appearing in the posts.

As for the most recurrent unigrams, we have found words with positive connotations such as 'good' or 'great'. These words were among the most frequently mentioned in previous studies (Das et al., 2019). This is in line with studies that analyse cycling as a means of transport from a qualitative perspective, being perceived as good, guaranteeing physical activity and higher levels of psychological well-being, as well as environmental benefits (Lois et al., 2016). Therefore, several posts have included positive aspects related to cycling in urban environments, such as

> *It's been a while! Just a wee dam run and round the village, good to be back on the bike!* 🤘🚴♀ *https://t.co/oj5ZoJYWph*

> *Great to see so many people cycling around the city this morning!* 🚴♀🚴♂🚵

> *Cycling more isn't just good for the environment - it's great for our health and the economy too* 🚲🙌 *[...]*

Regarding bigram, 'bike lane' was the recurring theme among bicycle users, referring to cycling infrastructure. To improve the cycling experience and encourage people to cycle more, it is important to build safe cycling lanes (Hong et al., 2020). Notably, among the different systems that analyse and improve their quality (Batista & Lima, 2020), the consideration of public opinion on the subject is emphasised. It is essential to analyse what users say about cycle lanes because there is often an information gap between politicians and cyclists. Although decision-makers believe that main roads with cycling infrastructure are decisive for fast and safe cycling, cyclists also emphasise the positive effects of green spaces, the experience of the natural environment, and the healthy and recreational effects of cycling (Marquart et al., 2020). In this study, cyclists reported that they prefer to take secondary roads and are willing to take detours to integrate with the natural environment and avoid traffic jams, noise, and air pollution — aspects rarely acknowledged by decision-makers, for example:

> *Yes to Trees* 🌳*, Yes to Protected Bike Lanes,* 🚲💪 *Yes to Pedestrian Sidewalks,* 🚶♀ *Yes to Sustainable Cities, Yes to people-friendly Cities. @NMS_Kenya @KURAroads @NziokaWaita @PSCharlesHinga @Ma3Route @KenyanTraffic https://t.co/kuQkh1YNDM*

Curiously, the first 29 trigrams were related to an electoral campaign of the 'Boulder Progress' political group (Colorado, United States), which strongly emphasised the promotion of bicycles as a means of transport from a climate perspective. These results show that X is a space where people discuss political issues, including cycling in urban environments. Indeed, owing to climate emergencies, several political groups are increasingly recognising the need to redesign and rebuild cities for sustainable transport (Tschoerner-Budde, 2020). Thus, when implementing a cycling campaign, X can be an effective tool for obtaining direct user feedback. Apart from this, the trigrams that have appeared most frequently are 'New York City' and 'protect bike lane'. Despite being a city with the potential to emerge as a leading city for cycling because of its flat terrain and proximity to destinations (Pucher et al., 1999), New York faces various challenges. Issues such as heavy traffic, poor pavement conditions, poor bridge connections, vehicle exhaust fumes, lack of safe bicycle parking and theft act as deterrents to cycling (Dill & Carr, 2003), and they also provoke discussions on X. Regarding trigram 'protect bike lane', safety has been a recurring theme among users, mentioning the need to build protected cycle lanes. Cycling close to motor traffic was one of the main barriers for 1,079 citizens (cycling and noncycling populations) in Lisbon (Portugal) (Félix et al., 2019). Therefore, the removal of this barrier could enable cycling. Below are some of the user comments related to the protection of cycle lanes, as an example:

> *More bike lanes🚲 =less traffic 🚗. More bike lanes=safer streets. This isn't new information, if want safer, cleaner, and healthier cities, we need to invest in bike infrastructure https://t.co/ey1R2QYJnf*
>
> *🚲 @voxdotcom - By adding protected bike lines — separated from car lanes by a barrier for safety — biking becomes a safe, accessible alternative to shorter drives. https://t.co/YwygOh44v1 #82alliance https://t.co/d1n3bRPD4h*

As for hashtags, the most repeated ones were #cycling (4 126) and #bike (1 515). These two hashtags show that the most frequent use of hashtags is to report where they are cycling in a city. Moreover, we have found #mobility (904) among the most mentioned hashtags, which corroborates the importance of cycling as a mobility alternative in the urban environment. Another important hashtag is #WorldBicycleDay (610), indicating that X is a space to reach out to the population to promote the use of bicycles at this type of festivity. Additionally, among the most repeated hashtags was #COVID19 (460). This indicates that cycling was a topic of discussion among the issues raised by urban cyclists during the pandemic. During the pandemic, there was a significant increase in cycling in different countries owing to its characteristics (Buehler & Pucher, 2021). For future emergencies, it would be useful for policymakers to consider what users say about cycling to provide the best service in these circumstances. In addition to the hashtags mentioned above, we find different cities, such as Amsterdam and Copenhagen, the capitals of two countries, where cycling culture is deeply established (Bassett et al., 2008). This suggests that people living in these cities and cycling users are accustomed to locating their cities in the posts. This makes it easier to locate posts discussing aspects of a city.

2.3.2. Emojis

The analysis in this study included only emojis, not emoticons. A total of 3 240 unique emojis and emoji combinations were identified. Table 5 presents the most frequently emojis used (excluding those included in the search equation), with the standard emoji sentiment score, which has been included (Novak et al., 2015).

Table 5. Top 20 emojis found in posts

Emoji (sentiment score [−1⋯+1]) *	Count	Emoji (sentiment score [−1⋯+1]) *	Count
🚌 Bus (0.190)	6 318	💨 Dash symbol (0.381)	2 085
🚗 Automobile (0.231)	6 109	👏 Clapping hands sign (0.520)	2 054
🌳 Deciduous Tree (0.486)	5 135	🌲 Evergreen Tree (0.385)	1 992
🛴 Kick scooter (--)	4 649	👇 White down pointing backhand index (0.247)	1 965
🚶‍♀ Pedestrian (--)	4 561	🏬 Department store (--)	1 931
🚶 Pedestrian (−0.143)	3 613	🌄 Sunrise Over mountains (0.125)	1 892
👉 Backhand Index Pointing Right (0.390)	3 527	🌊 Water wave (0.500)	1 850
😊 Smiling Face with Smiling Eyes (0.644)	3 366	🚘 Oncoming automobile (0.067)	1 836
♡ Red Heart (0.746)	3 358	🏙 Cityscape (--)	1 820
👍 Thumbs Up (0.521)	3 080	😎 Smiling face with sunglasses (0.491)	1 793
🏡 House with garden (0.436)	2 654	💚 Green Heart (0.656)	1 756
➡ Right arrow (0.147)	2 451	💪 Flexed biceps (0.555)	1 583
☀ Sun (0.465)	2 447	🚎 Trolleybus	1 577
🏘 Houses (--)	2 434	😍 Smiling face with heart-eyes (0.678)	1 566
🏛 Classical building	2 395	⚡ High voltage sign (0.177)	1 524
🏢 Office building (0.154)	2 342	🏃 Runner (0.406)	1 522
🚍 Oncoming bus (0.071)	2 239	✅ Check mark button (0.407)	1 443
🚐 Recreational vehicle (0.036)	2 223	🎉 Party popper (0.738)	1 443
🏠 House building (0.500)	2 184	🚕 Taxi (0.000)	1 370
🚶 ♂Pedestrian (--)	2 122	🌴 Palm tree (0.525)	1 357

Note: Sentiment scores are taken from the work by Novak et al. (2015) and range from −1 to 1, with −1 being the most negative possible sentiment and 1 the most positive. The textual meaning has been extracted from the emojipedia database (📙 Emojipedia — 😃 Home of Emoji Meanings 💁👌🎍😍, s. f.).

Among all the emojis found the most repeated was 🚌 (6 318 counts), excluding the ones included in the search equation. This may be because when talking about alternatives to the motor car, the bus is mentioned alongside cycling and walking, for instance:

> *There's a whole lot of work going on to improve the city right now, so this means there's more traffic on the roads. Why not try an alternative means of transport this week?* 🚲🚌🛴*. https://t.co/Ubl93lrZ4b*

The population is aware of alternatives to motor vehicles for getting around cities; however, the use of these sustainable means of transport remains far from the expected level (European Environment Agency, 2019). Thus, new policies must not only provide information about their benefits but also encourage people to use them. Reducing the use of motor vehicles in the city would make it possible to achieve SDG 7 (Affordable and Clean Energy) and 13 (Climate Action).

It should be noted that most emojis had positive sentiment scores. This is the evidence that in the posts analysed, people mostly used emojis with a positive connotation to talk about urban cycling. This is in line with studies that have analysed attitudes towards cycling in urban environments, where opinions are mostly positive (Rojas López & Wong, 2017; Tapp et al., 2016).

Among all the emojis, the pedestrian emoji in its different variants is the one that has been repeated three times, showing that it is a commonly used emoji when users talk about urban cycling. There are active transport promotion publications that offer measures applicable to cycling and walking as a means of transport (Buehler et al., 2011; Kahlmeier et al., 2011; Rastogi, 2011). This may be because walking is another way of getting around the city in an active lifestyle along with cycling; therefore, they are often proposed as alternatives.

> *I'm a little concerned that people don't know what to do if gas prices go up. You know there are ways to get around a city without a car right?* 🚲🚶

> 🚲🚶🏃 *Best way to really get to know your City.*

> *As we start to reconnect with our wonderful city we're asking everyone who is able, to consider making at least part of their journey by walking, wheeling or cycling* 🚶♿🚲

Regarding the type of emoji mainly used, we found several related to other means of transport such as buses, automobiles, and kick scooters. Thus, when users comment on aspects of cycling, they include other means of transport, which shows that, in the city, the coexistence of these means of transport in the urban environment is very common. There is scientific literature that analyses the environment of public transport stations and bicycle parking or bike-sharing stations, to optimise them to increase their usage (Oeschger et al., 2020; Poliakova & Kubasakova, 2014; Radzimski & Dzięcielski, 2021). Thus, people are likely to discuss these themes in X as follows:

> *[...] From* 🚲 *to* 🚌*, all ages can learn more about what moves people and cities from these titles. https://t.co/wIpG9XCcY9.* 📚 *#OmahaLibrary #BookList #TransportationBooks*

Other recurring emojis have been those related to natural environments such as waves (🌊), different types of trees (🌳, 🌲 or 🌴), a sun (☀️) or even a sunrise over mountains (🌄), for instance:

> *This is what a modern city should look like - everything you need is within a 15 min walk, in your neighbourhood. Less commuting, more living.* 🌳🏃🚶🚴🚲🏡 *https://t.co/SH5tg77ZeC*

> *Stop building roads for cars - build bike lanes and plant trees!* 🌳🚴 *More trees are the answer to cool down our cities | @guardian: https://t.co/MeUTrDBczt https://t.co/F8P6WW23wn*

> *Have a great holiday weekend everyone! Enjoy the amazing weather and explore our beautiful city!* ☀️🚲👍 *https://t.co/cWGRTmIMJF*

Encouraging more green spaces in the city could promote cycling, and a study revealed that 53.7% of respondents would adapt their cycling route (i.e. use a different route or even accept a longer route) to use green street lanes instead of grey ones (Nawrath et al., 2019). A higher level of green space could also play a positive role in encouraging cycling to and from metro stations, or cycling in general (Zhao & Li, 2017). Therefore, the inclusion of green spaces should be a measure adopted by policymakers to promote cycling as a means of urban transportation. This priority would also coincide with the previously mentioned SDG, in particular 'Sustainable Cities and Communities' (Goal 11) in which one of the objectives is to provide universal access to green spaces (United Nations, 2015).

2.3.3. Sentiments scores

The polarity of sentiments showed a mean score of 0.4, where 81 278 of the posts were positive, 25 924 neutral and 8 849 negative (Figure 13). For the analysis of positive posts, we selected those having a polarity score greater than 0.2 (n= 78 011) and for the negative posts a score lesser than 0.2 (n= 6 638). These results show that the majority of people who posted on the subject were positive towards cycling in urban environments; however, this was not the result of previous studies (Das et al., 2015). Nevertheless, the number of positive posts was higher than the number of negative posts, as reported in other articles (Das et al., 2019; Duran-Rodas et al., 2020).

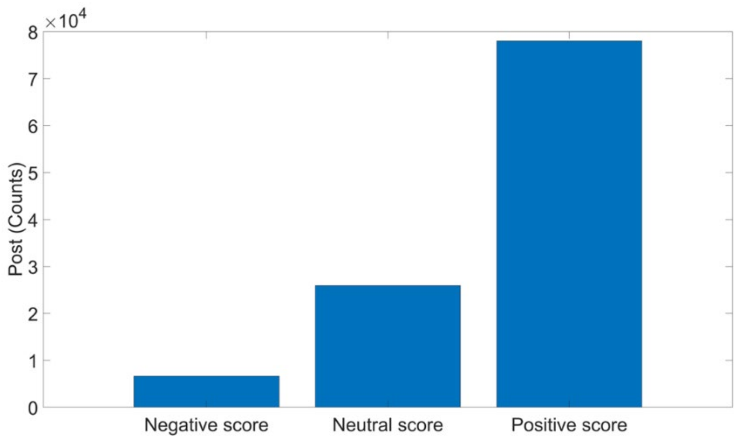


Figure 13. Polarity scores for posts

To further understand user sentiment, we determined the most frequently used words in posts classified as positive or negative. Table 6 lists the top 20 words found in positive and negative posts, excluding those included in the search equation.

Table 6. Top 20 words found in positive and negative posts

Word (positive posts)	Count	Word (negative posts)	Count
good	11 047	car	797
great	7 631	road	624
new	7 383	lane	558
day	6 715	stop	558
way	5 330	park	526
take	5 195	people	525
safe	5 146	new	514
today	5 115	street	493
park	5 085	traffic	462
support	4 927	day	426
street	4 769	time	422
people	4 767	village	357
work	4 767	way	356
lane	4 701	bad	355
share	4 582	today	347
like	4 556	work	325
free	4 245	centre	311
love	4 064	year	310

Note: Top 20 words found in posts classified as positives and negatives, excluding those included in search equation and accompanying verbs or prepositions.

As we can observe, we found words such as 'car', 'road', 'lane', and 'stop' related to negative posts. These results indicate a strong concern among bicycle users regarding cycling near cars and roads. Thus, ensuring the safety of urban cycling should be a priority for governments to increase the positive feedback from cyclists to increase cycling. In fact, improving and expanding protected cycling infrastructure is a key issue for increasing cycling in the future (Buehler & Pucher, 2021).

Another recurring word in posts classified as negative has been 'traffic'. For example, in the following post:

> *Who said this well said: if you plan cities for cars and traffic, you will get cars and traffic. If you plan for people and places, you will get people and places. Enjoyed cycling 🚲 @urban_innov #KashmirSolidarityDay #cycleIslamabad #ReImagineIslamabad*

This is an example of all the comments on X that refer to the elimination of motor vehicle traffic and mixed traffic. Most posts referred to the protection of cycle lanes to prevent traffic from these types of vehicles. Traffic reduction has also been proposed as a measure to reduce pollution, making cities healthier and more sustainable. In this sense, the scientific literature has already made efforts to address the problems generated by motor vehicle traffic alongside urban bicycles. Traffic has emerged as a relevant topic in a review of the scientific literature on urban cycling (Buehler & Dill, 2016).

Among the posts classified as positive we have found words such as ‘good’, ‘great’, ‘new’, or ‘safe’ (Resch et al., 2016). Regarding positive feelings, we found pleasure in cycling, which was probably associated with mental well-being. Cycling influences people's well-being (Leyland et al., 2019), leading them to experience positive feelings. However, words such as ‘new’ have been found in negative posts, which may be because the previous studies included only X posts about specific themes such as bike sharing (Duran-Rodas et al., 2020).

Other words found in positive posts, such as ‘love’, had been previously identified in research as being among the most mentioned, but ‘free’ was not (Das et al., 2019). This may mean that the sense of freedom that cycling provides in an urban environment is one of the strengths currently valued by the population.

2.3.4. Main topics found in positive and negative posts

Through an LDA model, the words found were classified into ten clusters, ordered from the highest to lowest probability of occurrence in the entire corpus of posts. Each topic consists of a group of words with an associated probability of appearing together in different posts. The analysis system provides a ranking of the words most related to the topic, as well as a ranking of the posts most likely to pertain to the topic in question. For this research, the most relevant posts (i.e. those with a probability equal to or greater than 0.6) related to the topic have been collected and the most relevant ones have been analysed.

Among the topics of the positive posts (Figure 14), topics 1 and 3 refer to mobility and sustainable modes of transport, suggesting that there are issues cycling population identified by their environmental benefits. In this sense, these comments provide evidence that awareness-raising policies work in parts of the population. For example:

> *New #mobility is influencing how we travel, the places we live and our communities. How do we make sure emerging services + modes are contributing to city policy goals?* 🚲🛴🚴🏢 ...

However, although this relevant topic indicates that part of the population is aware of the benefits, cycling remains far from what is expected (Buehler & Goel, 2022). This emphasises the need for the ongoing implementation of awareness-raising policies aimed at a more significant impact on the population, as current efforts remain inadequate.

Figure 14. Main topics found in positive posts

Note: Representative words of the topics found in the LDA model are ordered from left to right and from top to bottom according to their normalised values (z-scores). The word size indicates a higher probability of appearing together with the rest of the words in the topic.

Another relevant topic with a positive connotation was related to free-cycling events in urban environments (Topic 2). Among the posts on this topic, we found the promotion of events held in an urban environment where bicycles are the key elements. For example:

> *Don't forget to come our Dr Bike session, tomorrow, outside the Chiswick Town Hall! Come get your bike repaired for FREE.* 🚲🩺 *https://t.co/XGzVmJsdyh*

> *THIS WEEKEND LET'S CELEBRATE ACTIVE SCHOOL TRAVEL!* 📣 🎉 🚲 *[...]*

In this context, X has proven to be a common space for promoting cycling events that people consider positively. In this sense, these events have proven successful, as the population has shown a positive view of their celebrations. Another factor to consider is that several events are free of charge. Therefore, those wishing to promote cycling events should note that events with positive impacts should be free of charge.

Topic 4 refers to the opportunities offered by cycling to explore a city. Among these posts were the benefits of using bicycles as a means of transportation to visit cities and urban environments. Positive aspects highlighted by users include low cost, outdoor travel, enjoyment of the views and ease of mobility. For instance:

> *Walking and cycling tours are a great way to explore the city!* 🚲 *Check out some of our top picks here* 👉 *https://t.co/hM6AKezjAD #MyOttawa https://t.co/eNLUgrgGSP*

> *The best way to get to know a city is to bike through it! Check out this blog for a self-guided biking tour of GR, featuring classic Grand Rapids stops for you to check out* 😇🚲 *https://t.co/mUwMhTeuY2*

Cycling, with its remarkable sustainable advantages, is undeniably emerging as a prominent trend in tourism (Han et al., 2020). These results have shown that users consider it a positive experience, it is interesting for cities to promote this type of transport among tourists to attract and encourage sustainable tourism.

As with the positive topics, this study also analyses the negative topics that can be observed in Figure 15. We can see four of the five most relevant topics related to motor vehicles, showing how relevant it is for urban cycling to analyse the coexistence of these modes of transport. Specifically, Topic 4 included comments concerning the sometimes fatal coexistence of bicycles and cars.

> *Long way to go so that cities, in almost all the world, are more humane and less vehicular. ...Rest in peace.* 🚲

Figure 15. Main topics found in negative posts

Note: Representative words of the topics found in the LDA model are ordered from left to right and from top to bottom in order of relevance using their normalised values (z-scores). The word size indicates a higher probability of appearing together with the rest of the words in the topic.

Another negative topic that emerged was climate change, since comments on X about urban cycling included concerns about replacing cycling, which is broadly considered a way to avoid pollution.

> *#Bicycles are practically #silent. MORE #cycling and LESS #driving massively REDUCES #noisepollution in crowded #cities* 🚲*. Good Monday morning dear #BikeFriends* 🙌 🚴‍♀️🚴‍♂️🚴 💚 *https://t.co/OEd6DyoC2h*

This means that people are aware of the need to use alternative transport systems to avoid pollution, probably because some policies have been implemented for part of the cycling population. However, although people are aware of how negative motor vehicles can be, their use remains very high across developing countries, and the number of registered vehicles is constantly increasing year by year (Israel Schwarzlose et al., 2014; Pucher et al., 2007). Policies should be targeted directly at regular users of motor vehicles rather than the general population.

2.3.5. Limitations and future research

This analysis has certain limitations that warrant consideration. It should be noted that this study aimed to provide an overview of the research topic by using text mining techniques, resulting in a broadly generalised discussion. The abundance of topics necessitated a separate analysis in each subject area. This involved exploring specific urban cycling themes on X, akin to the methodologies employed in other studies (Duran-Rodas et al., 2020). Several topics identified in this study could be useful for further research.

It must be underline that the study has focused on the most frequent and common words that appear in X, as typically occurs when working with large masses of text. Nevertheless, the significance of scientific enquiry may not always align with the terms most repeated or popular among X users. Occasionally, posts incorporate neologisms or words from different knowledge domains, which may be important for cycling in urban environments. Although this study may not have captured fewer posts, they are important and merit further attention. Future studies should explore low-frequency words to identify disruptive or novel ideas that contribute substantially to the research topic. In addition, exploring the texts of other social networks would extend our understanding of the issues under study.

Finally, it is necessary to highlight the importance of not inferring conclusions solely based on the visual representation of the figures in this study, as the analysis of the documents classified by our analytical framework offers a greater depth to the interpretation of each topic.

2.4. Conclusions

Since the publication of SDGs in 2017, the promotion of cycling as a means of transport has become important to meet these standards. Therefore, promoting cycling as a means of urban transport has become a priority for governments. Moreover, it is important to understand what people think and discuss cycling in urban environments to optimise policy measures. To this end, social media platforms allow users to share opinions and feelings freely and instantly, providing them the opportunity to extract valuable information about an issue using mass-text analysis techniques. This article presents text analysis using text mining methods to explore the most relevant words, hashtags, sentiments, emojis, and topics related to cycling in urban environments on platform X.

Among the most relevant findings of the study, the highly repeated words in the entire text corpus were ‘great’ and ‘good’ — words with a positive connotation. This indicates that the population discussing urban cycling in X had a positive perception. Additionally, ‘bike lines’ and ‘protected bike lanes’ were the most frequently mentioned bigrams and trigrams, respectively. Another aspect analysed was the most used emojis in posts related to urban cycling. Among these, the most frequently used were emojis representing other means of transport, positive emotions, natural elements, and urban structure. Including emojis in the search equation allowed us to achieve greater precision in discerning the subject matter of the posts. In terms of the number of posts related to the subject, there has been a stabilisation in recent years after an exponential growth. Moreover, the sentiment attributed to these posts was mostly positive. Concerning the identified topics and frequently reiterated words within them, the positive themes prominently feature the advantages of cycling in urban environments, whereas the negative aspects predominantly revolve around coexistence with motor vehicles.

Lastly, this work results enables policies to be oriented towards user concerns and address them, eventually increasing the use of cycling as a means of transport in the urban context.

Finally, this study, together with the scientific review study (study 1), forms a fundamental basis for further research in this thesis by identifying the key issues that people consider relevant to urban cycling.

EXPLORING URBAN CYCLING: PHYSICAL ACTIVITY AND HARASSMENT

Study 3. Urban cycling: A non-linear analysis of transport amenities and socio-demographic and health variables

3.1. Introduction

Physical inactivity has become a major public health problem in contemporary society and a risk factor for mortality worldwide (Lee et al., 2012; World Health Organization, 2020d). Scientific community has widely demonstrated the benefits of regular PA for individuals' health and quality of life (DiPietro et al., 2019; U.S. Department of Health and Human Services, 2018). Further, the World Health Organisation (WHO) has established minimum weekly PA standards for its beneficial effects (World Health Organization, 2020d). For the adult population—aged 18–65 years—these standards consist of accumulating at least 150–300 minutes of moderate-intensity aerobic PA or a minimum of 75–150 minutes of vigorous-intensity aerobic PA. It can also be a combination of moderate and vigorous PA equivalent to 600 Metabolic Task Equivalent (MET) min/week. MET is the usual measure for calculating PA intensity based on information provided by energy expenditure during PA (Ainsworth et al., 2011). For additional health benefits, WHO recommends at least 2 days a week of moderate-to-high intensity muscle-strength activities that involve all major muscle groups. However, despite the evidence of regular PA health benefits and the establishment of minimum standards for the population, approximately 27.5% of adults do not exercise at least two days a week (Guthold et al., 2018) and 81% of adolescents (Guthold et al., 2020), do not meet the minimum PA recommendations worldwide.

As the use of active transport has been shown to increase overall PA levels (Wanjau et al., 2023) and individuals who walk or cycle are more likely to be active (Stroope et al., 2022), the WHO recommends walking, cycling, or wheeling to achieve minimum standards (World Health Organization, 2020d). Cycling offers several health and environmental benefits. In terms of physical health benefits, it improves cardiorespiratory fitness and reduces the risk of cancer, cardiovascular disease, and obesity-related mortality (Oja et al., 2011). It offers benefits for mental health and well-being (Avila-Palencia et al., 2018), such as reducing the risk of stress (Avila-Palencia et al., 2017) increasing riders' quality of life (De Geus et al., 2008), reducing psychological distress, and improving life satisfaction (L. Ma et al., 2021). Cyclists are the most satisfied commuters (Avila-Palencia et al., 2017; Singleton, 2019). Replacing cars or public transport with bicycles significantly increases psychological well-being (Martin et al., 2014). Further, urban cycling influences other health-related variables such as BMI and sedentary time. For example, individuals who use active transport generally have lower BMI values (Bassett et al., 2008; Useche et al., 2024). Its use has also been shown to reduce sedentary behaviour (Bista et al., 2020).

Despite these benefits, bicycle usage in Spain is still lower than that of motor vehicles (Garcia-Sierra et al., 2018). For instance, only 3.7% of the population uses bicycles for everyday journeys in the city of Madrid (Dirección General de Transparencia y Calidad Ayuntamiento Madrid, 2022); 3.8% uses bicycles and personal mobility vehicles in Barcelona (Mobilitat i transports., 2023); and 1.4% in Valencia (Oficina d'Estadística de l'Ajuntament de València, 2022). In Seville, 6% of daily trips are made using bicycles (Ramajo Rodríguez, 2018).

As mentioned in study 1, the use of this mode of transport is conditioned by a number of interacting factors. Socio-economic factors have impact on urban cycling, with different trends depending on income level (Bateman et al., 2021; Guerra et al., 2020), age (Laatikainen et al., 2019), social connections (Willis et al., 2015), race (Lusk et al., 2017) and gender (Pellicer-Chenoll et al., 2021). Even meeting PA guidelines often correlates with the use of active transport (Marquet et al., 2017). Also, built environment plays a crucial role, features such as vegetation or cycle lanes encourage cycling, while hillsides or bus routes reduces it (Ito et al., 2024). Analysing these complex interactions provides insights about urban environment's mobility. However, current models such as the EoT (De Vos, 2024) do not integrate relations between sociodemographic and health variables and the built environment, showing the need for further research into these relationships to improve cycling uptake and accessibility.

Understanding how these environmental, sociodemographic, and health variables interact can provide new information on how they relate to each other when cycling is chosen as the mode of transport in urban environments. This study aimed to contribute to this understanding based on two specific study objectives: (1) to examine bicycle usage in a Spanish population sample and its correlation with health-related variables, such as PA and perceived health, as well as facilities in the residential environment for, motor vehicles, and public transportation; and (2) to predict the use of cycling as a means of urban transport using the variables of the built environment, such as facilities for cycling, car, and public transport, and sociodemographic and health variables such as gender, income range, educational level, BMI, type of household, perceived health, and level of PA in three domains: leisure, transport, and work.

3.2. Methods

3.2.1. Study design and participants

The present study corresponds to descriptive correlational research with a cross-sectional design. A survey with several questionnaires was used to collect information on the level of PA, a sedentary lifestyle, and perceived health. The inclusion criteria were that the participants were of legal age and residents in one of the four most populated cities or their metropolitan areas in Spain (Madrid, Barcelona, Valencia, or Seville). The contact method was email, and 1 788 individuals completed the survey.

Before completing the survey, the participants were informed of the objectives of the study and the possibility of refusing or leaving the study at any time. Completing the survey implied giving consent to the Universitat de València for subsequent anonymous data processing. The Ethics Committee of the University of Valencia (Spain) approved all procedures and materials used in this study. The survey was completed using the Maptionnaire platform, software that allows the creation of online surveys with the possibility of collecting geographical data, such as routes and/or locations. Maptionnaire allows the mapping of environmental experiences, everyday behavioural practices, and localised knowledge and ideas for spatial development (Kahila-Tani et al., 2019), offering the possibility to independently create individualised PGIS tools (Kahila & Kyttä, 2009). This study was conducted between March and June 2024.

3.2.3. Socio-demographic and health variables

Sociodemographic variables collected from the survey included gender, age, city of residence, educational level, monthly income, type of household, and Body Mass Index (BMI). The participants' BMI was calculated by the collection of their height and weight and calculating their proportional relationship using the formula: body weight (kg)/height (m^2).

The Short-Form Health Survey (SF-12 v2) was developed to measure perceived health. This questionnaire contained 12 items with 3- or 5-point Likert-type response options. It summarises eight dimensions maintaining the conceptual model of the SF-36: Physical Function (FF, two items), Physical Role (RF, two items), Body Pain (BP, one item), General Health (GS, one item), vitality (VT, one item), Social Function (SF, one item), Emotional Role (ER, two items), and Mental Health (MH, two items). PCS and MCS scores were calculated from these dimensions. The Spanish validated SF-12v2 was used in this study (Schmidt et al., 2012).

The Global Physical Activity Questionnaire (GPAQ), developed by the WHO, was used to analyse the following three domains: activity at work, activity on the move, and activity in leisure and recreation (World Health Organization, 2021a). It also includes sedentary behaviour and consists of 16 questions. Previous studies have administered this questionnaire to Spanish populations (Bolívar et al., 2010; Rodríguez-Romo et al., 2013). This questionnaire facilitated the quantification of the amount of vigorous and moderate PA performed in the three domains in a typical week, so that METs can be calculated (Ainsworth et al., 2011). The GPAQ has been shown to be an acceptable tool for measuring changes in the activity behaviour of a population (Laeremans et al., 2017). The METs for commuting were calculated using the equivalence of 4 METs for walking, 6.8 METs for non-electric cycling, and 5 METs for electric cycling (Castro et al., 2019). Moreover, to complete the participants' PA profiles, two questions on strength training were included based on the strength training standards set by the WHO (World Health Organization, 2020d). Two days a week of moderate-intensity activity should be performed to obtain the benefits of strength training. Therefore, participants were asked about the frequency and duration of strength training.

Participants were asked to report the number of times they regularly used different means of transport every week, as previous studies did (Johansson et al., 2017). Participants were labelled as "Do not use," if they did not report using a bicycle for urban transport and as "Do use" if they reported cycling either regularly or sporadically during the week.

3.2.5. Attribution of environmental amenities for the use of transport modes and bicycle use

The location of residence was collected using the Maptionnaire's geolocalised positioning tool, with participants indicating their exact location of residence on a map. Subsequently, all reported home locations were collected and facilitators for cycling (bicycle parking and nearby bicycle lanes), motor vehicles (outdoor and indoor parking spaces by population density), and public transport (metro and bus stops) were downloaded from the OpenStreetMap platform. The maximum radius for these elements was set at 800 m, as established in previous studies analysing transport use by distance from home (Boulange et al., 2017).

To download the number of facilities, the Overpass API was used. The Overpass API is a read-only API that provides customised extracts of OSM map data. It functions as a web-based database: the client sends a query to the API and receives a dataset corresponding to the query. A script written in Matlab was used to perform the queries (see Appendix 1), automatically downloading the tags associated with nodes related to the previously described facilities.

The result of the query yielded a series of tags expressed in controlled language. Before counting the number of facilities in each area, duplicate entries—those with identical latitude and longitude—were removed. After cleaning the data, the count for each area was performed and stored for subsequent statistical analysis. Figure 16 shows an example of the analysis conducted.

Figure 16. Example of facility mapping around the respondents' residence

Note: The cross marks the approximate location of the residence. The shaded area represents an 800-meter radius around the residence. Triangles of different colours indicate facilities related to motor vehicles (5 counts), public transportation (3 counts), and bicycles (1 count). The latitude and longitude of the residence have been blinded on the map to ensure the respondent's confidentiality.

As previously mentioned, this study was conducted in Spain, specifically with individuals living in the cities or metropolitan areas of Madrid, Barcelona, Valencia, and Seville. Each city has a cycling network with unique characteristics. For each city, maps and the latest bike lane data were downloaded from the open-access databases of respective municipalities. Once these data were collected, they were entered into the QGIS programme, and a figure was prepared (see Figure 17).

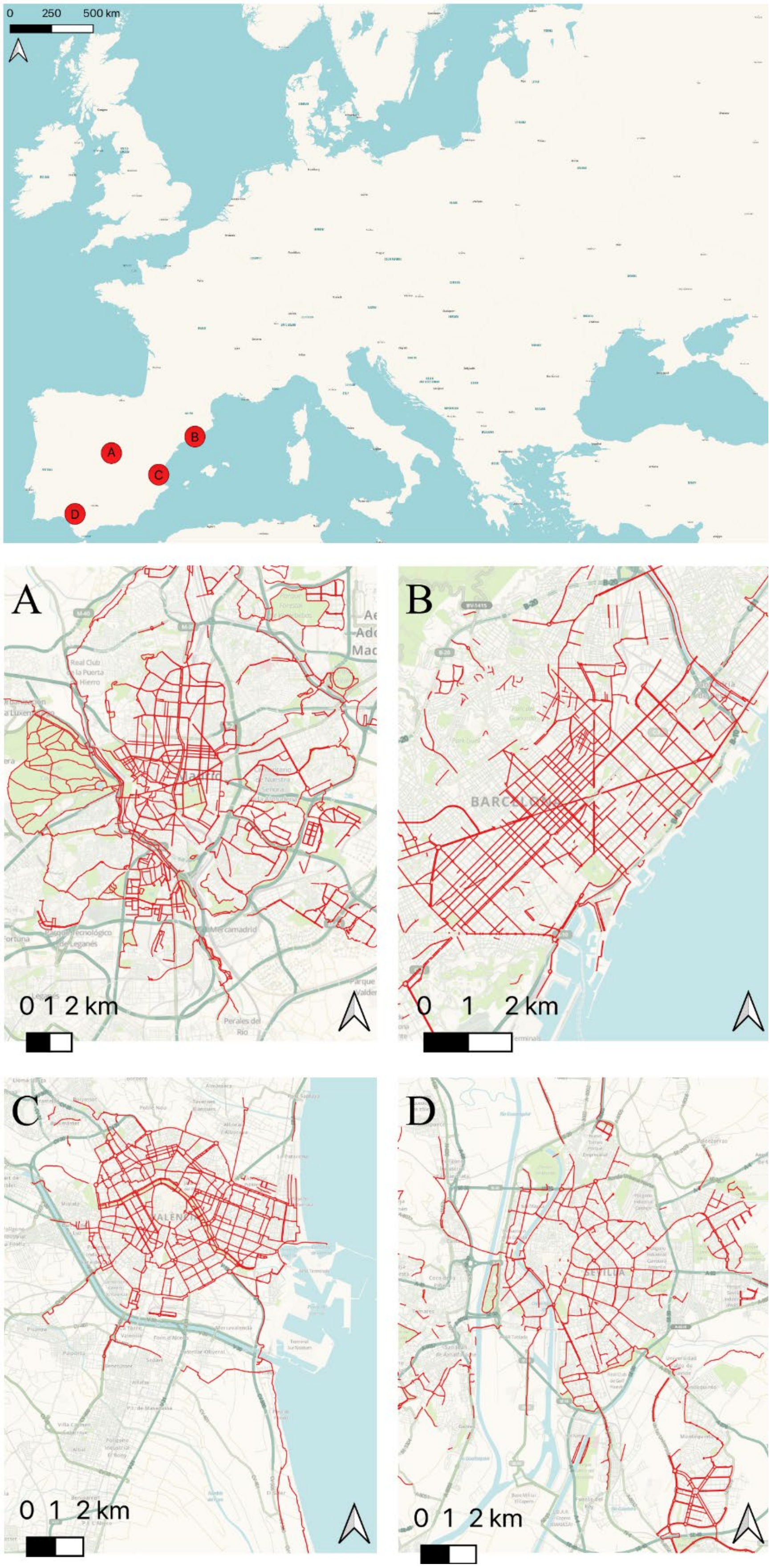


Figure 17. Geolocation of the studied cities and their bike lines

Note: (A) Madrid; (B) Barcelona; (C) Valencia; (D) Seville. Red line represents cycle lanes.

Madrid is the capital of Spain and has a high population density, with more than 6 million inhabitants including the metropolitan area, half of whom live in the capital (Instituto Nacional de Estadística, 2018). In Madrid, 33% of trips are made by private cars; 32% by public transport; 32% by walking; and 3% by other modes; however, in the city centre, individuals make 40% of trips by walking and 35% by public transport (Comunidad de Madrid, 2018). The cycling network comprises 544 km of bike lanes and the BiciMad bike-sharing system has provided 2 900 bicycles for use since 2014 (Molinares et al., 2024). More information about Madrid can be found in Pazos-Otón (2024) book chapter "The end of the Car City in Spain".

Barcelona, Spain's second-most populated city, is located northeast of the Mediterranean Sea. It is a dense city, with a population of approximately 1.6 million inhabitants (IDESCAT, 2020). It has an extended public transport network and has established a BSS with a fleet of 7 000 bikes since 2007 (Soriguera & Jiménez-Meroño, 2020). This development has a compact pattern with extensive cycling infrastructure (Marquet & Miralles-Guasch, 2018), specially it cycling network comprises 264 km of bike lanes (Ajuntament de Barcelona, 2024).

Valencia is the third most populated city, located in Eastern Spain and a population of approximately 800 000 individuals. Among its main economic activities we can find tourism. It has had a bike-sharing system since 2010 and provides a cycling network of 218 kilometres of bicycle lanes (Ajuntament de València, 2024).

Seville, located in southern Spain, has approximately 684 000 inhabitants. (Instituto Nacional de Estadística, 2023). It is primarily a flat city with a gentle slope. Further, it has a climate with little rainfall and warmth, especially between May and September, when the temperature and solar radiation are high. Seville's bike lane network consists of 190 km and has three bicycle-sharing or rental systems with a fleet of approximately 2 600 bicycles and 260 stations throughout the city (Vázquez-Hisado, 2021).

3.2.5. Statistical analysis

After all data were collected, pre-processing was applied to them, and non-normal or incomplete cases were discarded. To predict the use of bicycles as transport, a decision tree was applied using sociodemographic variables, health, PA, and the number of amenities in the residential environment for the use of different means of transport (car, public transport, and bicycle). For this analysis, bicycle use was categorised as the variables of using or not using a bicycle. Those who did not report using bicycles in the urban environment as transport, either regularly or sporadically, were labelled as 'do not use'. Conversely, those who reported cycling both regularly and sporadically during the week were labelled as 'do use.'

Subsequently, a matrix was generated by combining the variables included in the study, where the rows represent individuals included in the analysis and the columns represent the used variables. Both response variables and input variables (predictors) were included in the matrix. This matrix was entered into R-studio software (R 2023.12.1) and a decision tree analysis was performed using the CART algorithm. The entries (rows) of the matrix were randomly divided into two groups: a larger group with 80% of the data for training the tree and a smaller group with the remaining 20% for assessing cross-validity. After the tree was generated, the performance values and percentage of relevance of each variable within the analysis were calculated. Table 7 shows the performance of the decision tree in classifying the usage in the training and validation datasets.

Table 7. Performance variables of decision tree in training and validation datasets

	Decision tree	
%	**Training**	**Validation**
Accuracy	0.83	0.78
Sensitivity	0.46	0.24
Specificity	0.94	0.91
Positive prediction value	0.71	0.39
Negative prediction value	0.85	0.83
Precision	0.71	0.39
F1	0.55	0.3

3.3. Results and discussion

3.3.1. Descriptive and inferential data

After preprocessing, 957 participants (36.8% male, 62.9% female and 0.3% other) aged 18–87 years (M=37.89; *SD*=13.16) remained for analyses. Once information was collected from each participant, percentages were obtained for each variable (see Table 8).

Table 8. Sample characteristics (N=957)

Continuous variables	**M**	**SD**
Age	37.89	13.16
BMI	25.09	5.49
Categorical variables	**N**	**%**
Gender		
Male	352	36.8
Female	602	62.9
Other	3	0.3
Educational level		
No studies	2	0.2
School graduation	40	4.2
High School Certification	125	13.1
Technical college qualification	241	25.2
Bachelor's degree	347	36.3
Postgraduate college	202	21.1
Income range		
No income	106	11.1
< 1 000 €	145	15.2
1 000 € - 2 000 €	419	43.8
2 000 € - 3 000 €	205	21.4
> 3 000 €	82	8.6

Table 8 Sample characteristics (N=957) (Continued)

Categorical variables	N	%
Cohabitation type		
Not independent	366	38.2
Independent with no children	345	36.1
Independent with children	246	25.7

Table 9 shows the measures of the central tendency and dispersion of continuous variables. Because the sample distribution was non-normal, these results were discussed using the median.

Table 9. Measures of central tendency and dispersion of the variable: health, PA, and transport amenities

Variable	M	SD	Md	IQ
PA work (METs)	1 011.44	1 497.36	360	1 440
PA leisure (METs)	1 327.67	1 436.799	960	1 680
PA transport (METs)	727.929	886.22	552	1 200
Sedentary time (mins/day)	257.27	197.09	240	330
BMI	25.09	5.49	23.87	6.05
PCS	69.64	17.71	71.87	25
MCS	53.39	12.31	53.12	18.75
Car amenities	6.15	6.55	4	8
Public transport amenities	2.17	2.47	1	4
Bike amenities	19.39	21.24	12	30

Among the measures of central tendency, we observed how the median METs per week in different domains showed different values. Only the median METs during leisure time were found to be above the basic PA recommendations, and both work and transport were below. However, in other countries, such as the Netherlands, active transport counteracts sedentary time (Fishman et al., 2015). Furthermore, individuals with sedentary jobs should follow recommendations for transportation or leisure activities to reduce risks associated with a sedentary lifestyle, such as metabolic syndrome (Browne et al., 2017).

The median and average sedentary time were more than 200 min/day. These results conform to those of Macías et al. (2014) in a Spanish population, in which 76.3% of those who were surveyed reported a sedentary lifestyle. According to the WHO, a more sedentary lifestyle is associated with higher all-cause mortality, cardiovascular mortality, cancer mortality, and the incidence of cardiovascular disease, cancer and diabetes type 2 (World Health Organization, 2020d). High levels of sedentary lifestyles can also impair cognitive function and quality of life (Saunders et al., 2020) and are associated with strong symptoms of depression (Feng et al., 2024). The use of active-transport vehicles is shown to reduce these risks by reducing sedentary time and sedentary behaviour (Bista et al., 2020).

In terms of perceived health, we can see how the values of the physical and mental components (PCS and MCS, respectively) show different values at the median, with the latter being lower, as in previous studies (Jacob et al., 2021). Mental health has become a relevant topic in recent years and its implications for physical health have been highlighted (Prince et al., 2007). Therefore, measures to promote improved mental health should be considered. Regular cycling can help reduce psychological distress and improve life satisfaction (L. Ma et al., 2021).

BMI showed a median of 23.87, which is within the range of normal weight close to overweight. These results accord with the median obtained by Aranceta-Bartrina et al. (2020) among a Spanish adult population. In Spain, one in two adults has a BMI of over 25 kg/m2 (Aranceta-Bartrina et al., 2005). As countries where the population uses more active transport generally are proven to have lower BMIs (Bassett et al., 2008), active-transport strategies are recommended to reduce overweight and obesity.

Regarding the facilities of the means of transport, we can observe how the amenities of cycling show a standard deviation with an interquartile range with much greater margins than public transport and cars. This shows that in densely populated Spanish environments, there is a much greater difference in facilities for cycling than those for other means of transport, depending on individuals' place of residence. Consequently, this difference results in an unequal offer for the population depending on the place of residence.

Regarding the interaction between sociodemographic variables and the use of bicycles as transport, the Chi-square test was statistically significant for gender (X_1^2= 19.101; $p <$ 0.01; V= 0.141) and income range (X_1^2= 12.000; $p < 0.05$; V= 0.112). Figure 18 shows the percentage of bicycle use for each characteristic.

Men were found to use bicycles more than women, as shown in previous studies conducted in Spanish populations in Valencia (Pans et al., 2023; Pellicer-Chenoll et al., 2021), Madrid (Julio & Monzon, 2022), Barcelona (Roig-Costa et al., 2024) and Seville (Marqués et al., 2016). The perception of safety is lower than what is shown in previous results, as women are especially affected by this factor when choosing an active means of transport, such as cycling (Emond et al., 2009; Heesch et al., 2012). In fact, it has been observed that women use bike-sharing systems less at night than during the day in both Valencia and Barcelona (Cubells et al., 2023; Pellicer-Chenoll et al., 2021). Therefore, safe cities in these places should be prioritised and their benefits would be extended to all persons in Spanish society, turning cities into more equitable environments with the aim of achieving gender equality as emphasised in the SDGs (European Union Agency for Fundamental Rights, 2015).

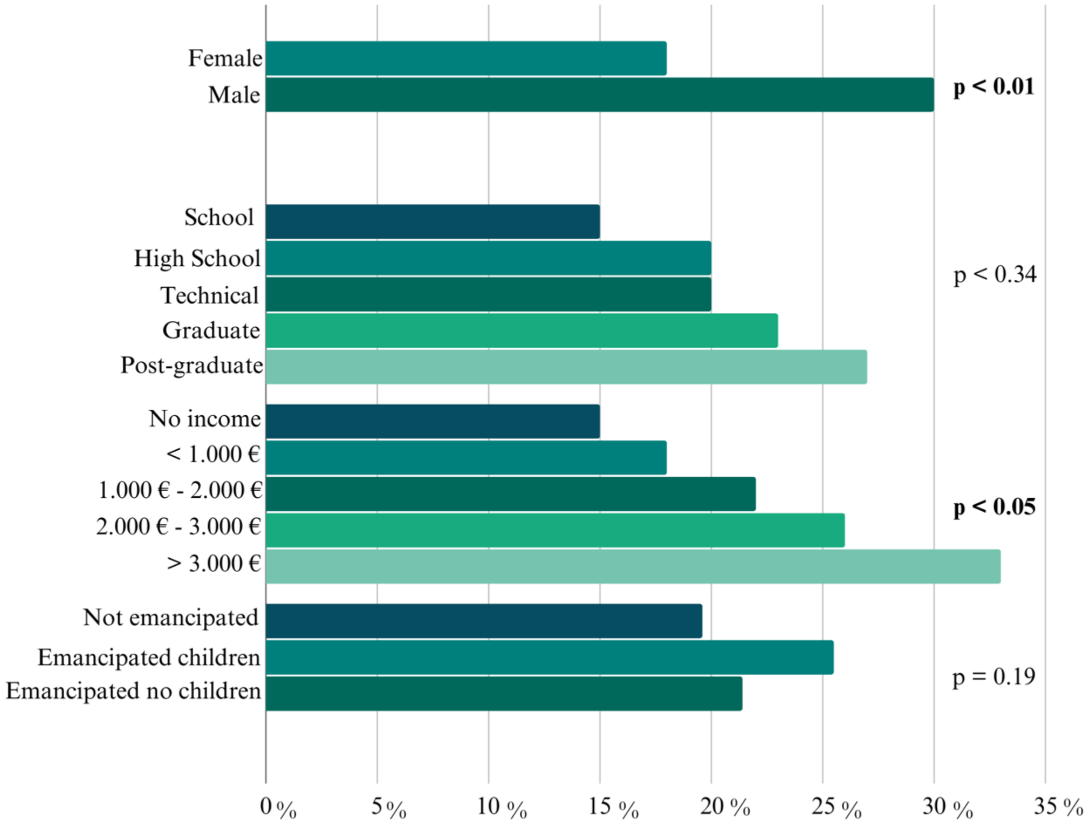


Figure 18. Percentage of bicycle usage according to socio-demographic variables

Note: Proportion of respondents using bicycle for category

The second sociodemographic variable that showed significant differences in bicycle use was income range. This result conforms to that of Caspi and Noland (2019) who indicated that individuals who earn the highest income are found to use BSS the most. This may be because the central areas of cities where high-income earners reside are the most bicycle-friendly zones, and city centres often contain the most bike-sharing stations (Bateman et al., 2021). However, other studies have shown that individuals with fewer resources are more likely to use bicycles (Guerra et al., 2020), partly because they do not have access to their own motor vehicle (Reilly et al., 2020). This forces them to cycle in areas that are less safe or have poor infrastructure, whereas providing good facilities transforms cycling into a safe and accessible experience for all.

3.3.2. Decision tree

The decision tree (see Figure 19) generated contained 957 individuals who were divided into two main branches and 18 prediction nodes. A majority of the sample was grouped into three nodes: a) 38 % was grouped into node 18, which belongs to right branch; b) 14 % was grouped into node 12; c) 11 % was grouped into node 11—the second and third nodes belong to the left branch. Specifically, these nodes comprise individuals who do not cycle in urban environments. In contrast, nodes with individuals who perform cycles are more heterogeneously distributed. For better understanding, Table 10 lists the characteristics of the nodes.

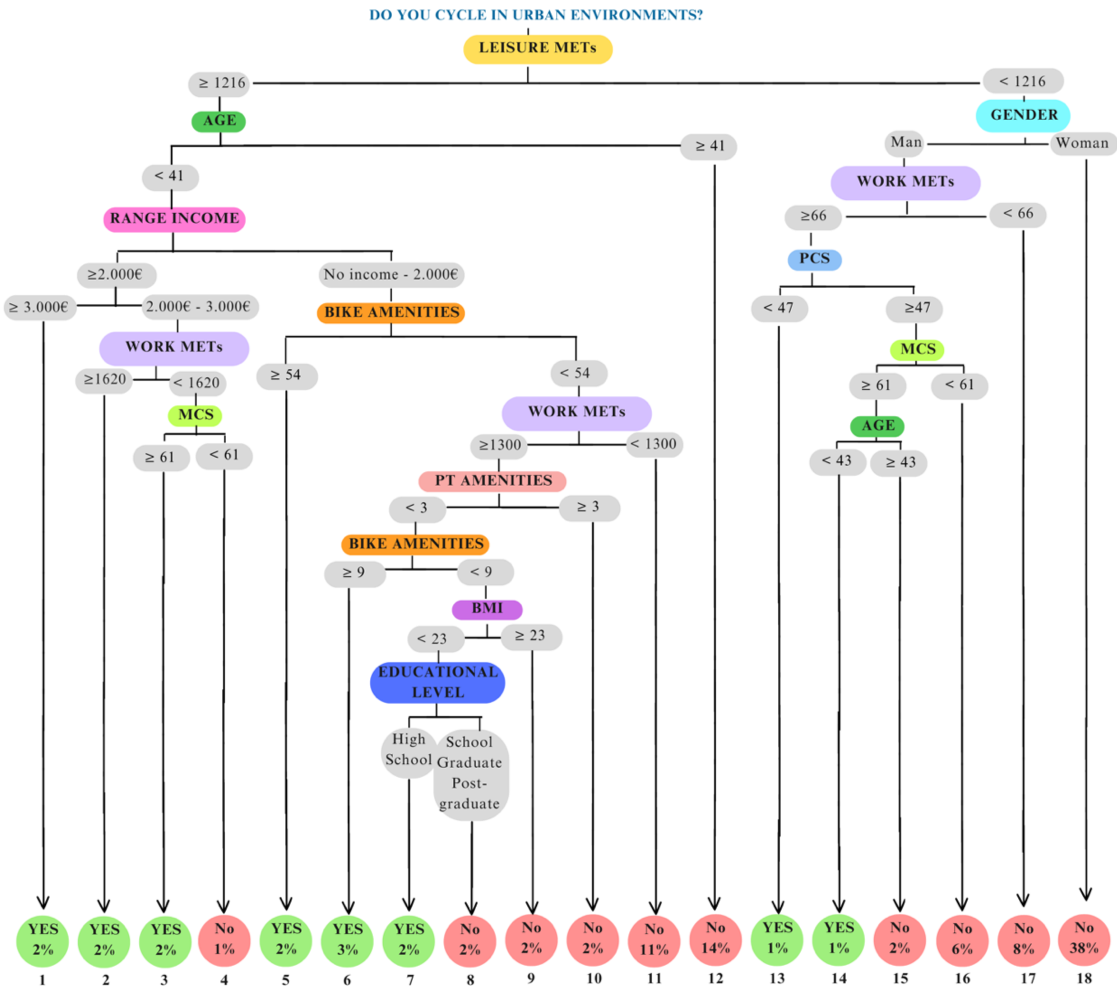


Figure 19. Decision tree for predicting cycling

Table 10. Terminal-node characteristics of the decision tree

	Leisure METs	Work METs	Gender	Range income	Age	PCS	MCS	Educational level	PT Amenities	Bike Amenities	BMI
G1(Yes)	≥ 1 216		-	≥ 3 000€	< 41	-	-	-	-	-	-
G2 (Yes)	≥ 1 216	≥1 620	-	2 000€ – 3 000€	< 41	-	-	-	-	-	-
G3 (Yes)	≥ 1 216	< 1 620	-	2 000€ – 3 000€	< 41	-	≥ 61	-	-	-	-
G4 (No)	≥ 1 216	< 1 620	-	2 000€ – 3 000€	< 41	-	< 61	-	-	-	-
G5 (Yes)	≥ 1 216		-	No income – 2 000€	< 41	-	-	-	-	≥ 54	-
G6 (Yes)	≥ 1 216	≥1 300	-	No income – 2 000€	< 41	-	-	-	< 3	54 – 9	-
G7 (Yes)	≥ 1 216	≥1 300	-	No income - 2.000€	< 41	-	-	HS	< 3	< 9	< 23
G8 (No)	≥ 1 216	≥1 300	-	No income – 2 000€	< 41	-	-	S; G; PG	< 3	< 9	< 23
G9 (No)	≥ 1 216	≥1 300	-	No income – 2 000€	< 41	-	-	-	< 3	< 9	≥ 23
G10 (No)	≥ 1 216	≥1 300	-	No income – 2 000€	< 41	-	-	-	-	< 54	-
G11 (No)	≥ 1 216	-	-	No income – 2 000€	< 41	-	-	-	-	< 54	-
G12 (No)	≥ 1 216	-	-	-	≥ 41	-	-	-	-		-
G13 (Yes)	< 1 216	≥66	Man	-	-	< 47	-	-	-		-
G14 (Yes)	< 1 216	≥66	Man	-	< 43	≥47	≥ 61	-	-	-	-
G15 (No)	< 1 216	≥66	Man	-	≥ 43	≥47	≥ 61	-	-	-	-
G16 (No)	< 1 216	≥66	Man	-	-	≥47	< 61	-	-	-	-
G17 (No)	< 1 216	< 66	Man	-	-	-	-	-	-	-	-
G18 (No)	< 1 216	-	Woman	-	-	-	-	-	-	-	-

One of the key findings shown by the decision tree, is that the groups of individuals who use bicycles in urban environments were more heterogeneously distributed in the sample. However, those who did not use bicycles constituted a larger percentage of the sample. Furthermore, among the relevant variables, age is a key factor among highly active individuals. Nevertheless, gender emerged as the primary variable for less active individuals.

Among 18 identified nodes, we particularly focused on the nodes that contained the largest number of samples: nodes 18 (38%), 12 (14%), 11 (12%), 17 (8%), and 16 (6%) for better understanding. First, the tree generated two main branches; the left branch had 12 nodes (≥ 1 216 leisure METs), and the right branch had 6 nodes (< 1 216 leisure METs).

The first important differentiating variable in the tree was the amount of PA performed during leisure time. This created two large groups of individuals: those who were very active in their leisure time, and those who were moderately or minimally active. This implies that the amount of PA performed during leisure time determines individuals' use of bicycles for urban transport. These results agree with those of previous studies, which showed that individuals who walk or cycle as transport were more likely to comply with PA recommendations (Marquet et al., 2017; Stroope et al., 2022). Further, among those who were very active in their leisure time, the age of less than 41 years was a determining factor of bicycle use, while those greater than this age did not report using a bicycle as transport. The group of individuals above 41 represented one of the most numerous nodes, accounting for 14% of the sample (Node 12). This finding conforms to those of other studies, which showed that older individuals used active transport very little to move (Laatikainen et al., 2019). In such cases, the importance of the built urban environment in facilitating the use of active commuting as a means of transport is even greater (Cerin et al., 2017; Laatikainen et al., 2019; Marquet & Miralles-Guasch, 2015). The health benefits of switching to active transport are greater for older individuals than for younger ones (Mueller et al., 2015).

In contrast, among those under the age of 41 years, the income range created two large groups. Among those with little or no income, cycling facilities have proven to be key to cycling. These results partially conform to those of previous studies that individuals with fewer resources are those who use active transport, specifically bicycle-sharing systems, for the longest periods of time (Pans et al., 2023), possibly because among low-income individuals, not owning a car is a common situation (Klein et al., 2023). In contrast, in other studies, those with the highest income were more likely to use bicycles, particularly in bike-sharing schemes (Caspi & Noland, 2019; Médard de Chardon, 2019). However, among those who have few or some facilities for cycling, the amount of PA at work conditions includes bicycle use, and those who are somewhat or not very active do not use bicycles; this last group represents 11% of the sample (Node 11). Although this profile does not use bicycles as transport, it meets the WHO recommendations. This suggests that this population is already considered sufficiently active and that some environmental facilities do not motivate them to use this mode of transport (World Health Organization, 2020d).

In the other large branch of the decision tree, we identified individuals who were moderately active or not very active. The first key variable in this group has turned out to be gender; women do not directly use the bicycle as transport. A large part of the sample was found at this node, accounting for 38% of the total (Node 18). These results are consistent with those obtained in previous studies in which women showed less use of bicycles in urban environments (Böcker et al., 2020; Pans et al., 2023; Pellicer-Chenoll et al., 2021; Reilly et al., 2020). This again demonstrates the existing inequality, and the reasons women do not use bicycles need to be addressed. Studies such as Garrard et al. (2008) have shown that women are more sensitive than men to the risks associated with cycling in urban environments, leading them to avoid cycling in areas perceived as dangerous or lacking adequate infrastructure. Misra and Watkins (2018) show that women tend to avoid cycling routes they perceive as dangerous, either because of heavy traffic or lack of adequate lighting. Another barrier reported especially among women is that women often face what is known as 'trip chaining', which involves making multiple stops in a single journey to carry out tasks related to family and home care (Gauvin et al., 2020), while men tend to make direct trips between home and work. Aldred et al. (2016) highlight that women are more likely to make trips that involve combining several activities in a single trip. Another barrier reported by the scientific literature is the possibility of being victims of harassment or violence in public spaces, as women are more likely to experience verbal or physical harassment while walking or cycling, which further limits their willingness to use this mode of transport in their daily lives (Mosquera et al., 2012). Harassment in public spaces is also a factor that disproportionately affects women. Ravensbergen et al. (2020) document that women experience aggressive behaviour and harassment from motor vehicle drivers more frequently than men, which reinforces their sense of vulnerability and limits their willingness to cycle. This negative experience on the streets perpetuates gender inequality in urban mobility and discourages women from choosing cycling as their main mode of transport. In a study conducted in Valencia, it was shown that women forgo peripheral, heavily trafficked and/or poorly lit areas of the city, especially at nighttime slots (Pellicer-Chenoll et al., 2021). To address these problems, it is essential that urban mobility policies focus on improving both real and perceived safety. Therefore, to detect whether this perception of safety coincides with a higher prevalence of harassment situations in active travel, the study 4 will aim to provide information on these events.

On the other hand, different profiles were created for moderately active men. Their perception of good physical and mental health has been found to determine cycling. If they perceived poor or moderately poor mental health, then they did not cycle (Node 16). This conforms to the finding of previous studies that a sedentary lifestyle was related to factors such as a negative self-perception of health (Martins et al., 2021). However, paradoxically, the use of this mode of transport allows them to improve their perceived mental health, as shown in previous studies (Avila-Palencia et al., 2018). In contrast, men with very little or no active work did not use bicycles (Node 17). This would be a profile that is not very active either at work or during leisure time. Jobs are mainly sedentary or those that require light physical activities (Church et al., 2011). Thus, cycling should be encouraged in this type of work to combat sedentary lifestyles not only during leisure time but also at work.

Regarding the order of relevance of the studied input variables (Figure 20), it was observed that four variables had most relevance: METs at work, age, bike amenities, and METs during leisure time.

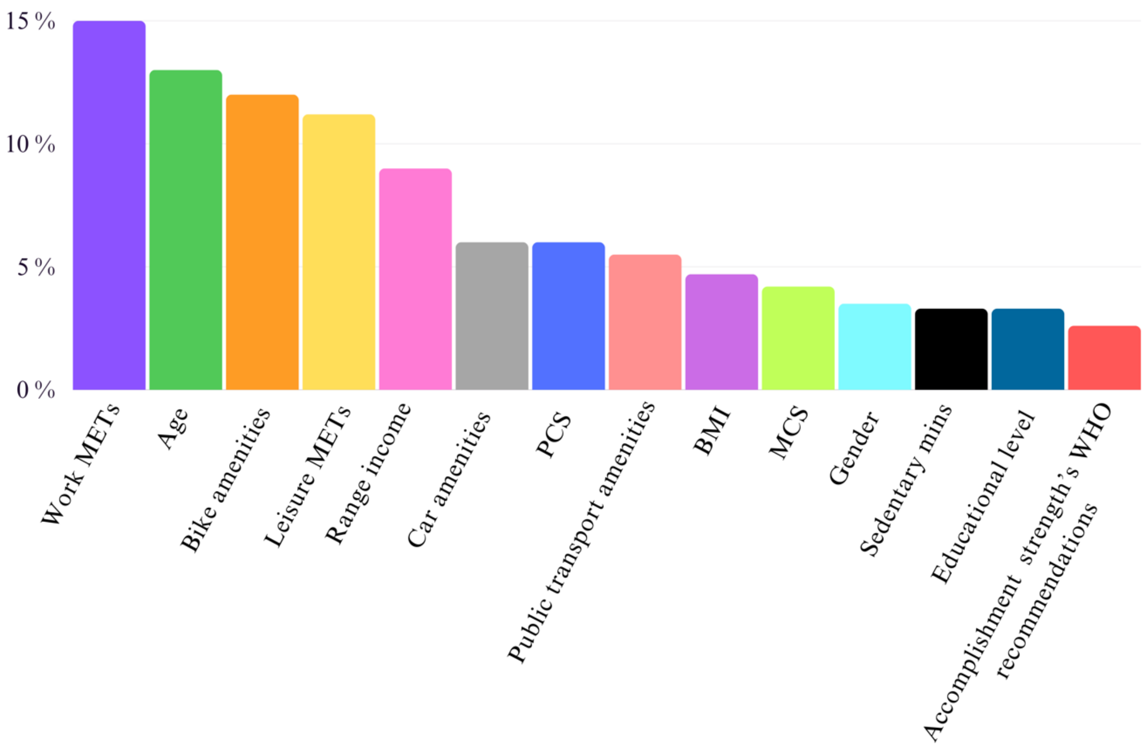


Figure 20. Percentage of relevance of the variables included in the cycling prediction

The variable with the greatest importance in predicting cycling in urban environments was PA during work time. As low levels of PA at work are linked to the risk of suffering symptoms of depression (Marchand et al., 2016; Ryu et al., 2022), the use of active transport may help reduce mental issues. Additionally, not being active in leisure and work time may cause individuals to use cycling to meet PA WHO recommendations, due to active transport increases MVPA and reduces sedentary time (Bista et al., 2020). Age was the second most relevant variable. This means that the age of a city's population must be considered when programmes are planned to promote cycling. Depending on their age range, individuals have different needs and characteristics which must be considered. For example, older individuals tend to cycle more frequently in areas with a higher percentage of green spaces (Reilly et al., 2020). Therefore, promotion policies should address these differences and adapt the infrastructure to resident population needs. The third most important variable was the amenities in the residential environment for cycling. These results coincide with those of previous studies which showed that access to a separate cycle lane (Mertens et al., 2016), a bike-sharing system with a large capacity to meet the users' demands (Alvarez-Valdes et al., 2016) and adequate secure parking (Larsen, 2015) were relevant to the use of bicycles as transport. It has been observed that individuals who change their residences to areas with more cycling facilities increase their bicycle use (Beenackers et al., 2012). Finally, we found METs during leisure time. These results accord with the objectives of studies showing that individuals with an active lifestyle use more active means of transport (Stroope et al., 2022).

3.4. Conclusions

The present study had two main objectives: first, we examined bicycle use in a Spanish sample and how it correlated with PA, perceived health and urban transport amenities around residential areas. Second, we predicted cycling in urban environments through a decision tree using sociodemographic variables, the amount of PA at work and during leisure time, the perceived level of health, and factors of the residential environment as facilitators of the space for the use of public transport, bicycles and cars.

The most notable finding about the measures of central tendency was that PA in transport showed the lowest values compared to leisure and work. In addition, the BMI is close to being overweight, and the sedentary time is more than 200 minutes per day. Additionally, perceived mental health was lower than physical health by approximately 20 points. In terms of statistical inference, significant differences in bicycle use were found according to gender and socio-economic status. Men and individuals with high income used bicycles the most.

One of the most relevant results shown by the decision tree is that 38% of the individuals are women who had a low or moderate PA profile during leisure time, and do not use bicycles as transport. This is a high percentage of predictions that question the effect of cycling facilities on women's bicycle use, suggesting a wider gender perspective beyond facilities to promote bicycles as transport among women. Thus, to promote cycling, measures should be considered from a gender perspective that favours the use of active means of transport. Among the specific barriers identified by the scientific literature, harassment and fear of harassment are among the most prominent for women. Therefore, this study has led to study 4 to explore whether there are different trends among men and women in this sample in experiencing harassment on active trips. Another relevant finding was that the age of > 41 years was a risk factor of not using bicycles as transport. Moreover, the variables that were most important in the decision tree for predicting cycling in urban environments were the amount of PA at work, age, bike amenities, and METs during leisure time.

Furthermore, this study explored relationships between facilitators of the use of different means of transport and different variables, such as perceived health, PA level, and BMI. Moreover, a nonlinear analysis such as a decision tree was used to explore how these variables innovatively interact with each other. It may also encourage new studies to include a humanistic perspective in the analysis of spaces, where not only the configuration of the environment but also the individuals who live there are considered.

Finally, this study shows the importance of the interaction between the facilities of different means of transport close to individuals' place of residence and their sociodemographic characteristics, and between health and PA level and bicycles as transport. Thus, to develop plans to promote the use of active modes of transport, changes in urban infrastructure and in the habits of individuals, should be considered.

3.4.1. Limitations and future perspectives

This study has some limitations. First, the participants were the residents of a concrete sample of Spanish cities, which did not allow the results to be extrapolated to less concentrated environments, to other cultures, or even to the resident populations in these cities. Therefore, future studies should consider different Spanish areas and cultures as the characteristics of the population vary according to the area of residence. This will facilitate the analysis of the ways these variables interact with different individuals and environments. Thus, active transport promotion programmes that can be more effective should be developed depending on the population and environment.

In addition, the number of variables introduced in the decision tree could add variables, such as life satisfaction or environmental variables, and facilities at the workplace or nearby green spaces. Furthermore, for future studies, facilities in the urban environment alone cannot predict the use of bicycles as transport. Rather, the interaction of these facilities and the characteristics of individuals facilitates the prediction.

Study 4. Street harassment in active transport: A geolocation perspective

4.1. Introduction

As we have seen in the study 3, women are less likely to cycle in urban environments. Among the specific barriers faced by women identified by the scientific community, fear of harassment was mentioned as one of the most relevant. These results have led to the need to analyse whether this corresponds to reality in the dissertation's sample. For this purpose, it is first necessary to establish a theoretical basis.

Different definitions of street harassment can be found in the scientific literature. According to Gardner (1995), street harassment groups different forms of abuse, harassment and annoyance in public places provoked by someone in public presence. Bowman (1993) describes it as a set of verbal, non-verbal and physical behaviours of a sexual nature, perpetrated in public places such as streets, footpaths, roads, parks and public transport by someone who does not know the victim. No matter the severity level, shouting, sexual comments, whistling or groping in public spaces weakens the victim's freedom to move freely into public spaces without fear (Baptist & Coburn, 2019). These harassment situations are a problem worldwide, especially for women, girls, lesbian, gay, transgender, bisexual, intersex and queer people (LGTBIQ), persons of colour (Stop Street Harassment, 2015), people who are overweight (Johns et al., 2017) or with disabilities (Shaw et al., 2012). Being harassed on the street causes persons to feel anxious, depressed, less secure or even unwilling to participate in social life (Stop Street Harassment, 2015). Women are especially concerned about being victims of street harassment regardless of their previous experience (Mellgren & Ivert, 2019). According to the study by ElSherief and Belding (2015), the most frequently used word in the Holloback app's reports of harassment is walking, which shows that many of these situations occur during active trips. The same study even found that the Walkability Index was positively correlated with incidents. It has also been investigated in other active transport modes such as cycling (Ravensbergen et al., 2020), where among participating cyclists, most repeated fears are fear of injury and fear for personal safety. As a result of this situation, research on the experiences and consequences of street harassment in general has increased in the last 10 years (Fairchild, 2023).

This type of street harassment is not usually experienced equally by men and women. This inequality has been studied in different cities worldwide and occurs among all ethnicities/races (Herrera & McCarthy, 2023). For example, in a study conducted in Australia, 87% of the women surveyed reported experiencing physical or verbal harassment in public (Johnson & Bennett, 2015). In addition, in Stop Street Harassment's latest report (Raj et al., 2024), in which the American population participated, 73% of women reported having experienced harassment in public spaces. Moreover, in a study in which almost 1 300 women were asked to state what made them most afraid of being harassed, it was found that being alone at night on the street, on public transport, or in a public park made them feel the most afraid of being harassed (Fairchild, 2010). However, men also sometimes report these situations, as is the case in Davis et al. study (2024), where most participants (84.2%), including both men and women, reported at least one form of harassment while running in the streets.

In addition to gender, there are other socio-demographic characteristics which also influence the risk of being harassed. Specifically, women with fewer economic resources are the ones who walk more often than men (Levy, 2013); thus, they are more likely to share spaces with strangers, which affects their transport experiences and perception of safety (Quinones, 2020). Furthermore, women living in urban spaces experience higher levels of insecurity (McIlwaine, 2016), making their mobility in urban settings relevant to creating just cities (Levy, 2016). This inequality leads to different trends in active mobility patterns based on gender. To star, women have an “mobility care” pattern (Madariaga, 2013) but men tend to show a work-home one (Smith, 2008). Regarding the routes, women avoid riding in dark areas (Kash, 2019) and isolated places (García-Carpintero et al., 2022), especially during nighttime hours (Pellicer-Chenoll et al., 2021). As for the environment characteristics in which harassment occurs, ElSherief and Belding (2015) found harassment to be more prevalent in pedestrianised and crowded areas. However, it is not only gender or socio-demographic characteristics that influence the risk of suffering from these situations, but also the built environment or evidence of incivility (Khademi et al., 2024). In addition, the presence of abandoned buildings can also contribute to crime by encouraging antisocial behaviour and attracting potential criminals (Spelman, 1993).

Specifically, in Spain, according to the Safer Cities for Girls (2021) report, 569 experiences of harassment have been reported by women in Madrid, 193 in Barcelona, and 117 in Seville. Of these experiences, 43% took place on the street. Regarding harassment while cycling, in the latest report produced by the *Institut Metròpolità* de Barcelona (2024), 35% of the urban women cyclists surveyed reported having suffered harassment while cycling, 65% verbally or gesturally. Even among female non-cyclists who did not cycle because of insecurity, 19% reported that this was due to fear of harassment. This fear of crime, defined as an “emotional reaction of dread or anxiety to crime or symbols that a person associates with crime” (Ferraro, 1995, p. 8) deters people from choosing active transport such as walking to get around (Foster et al., 2014). Therefore, one of the main factors encouraging people to use active transport is that they perceive it as a safe means of transport (Speck, 2012).

Given the observation that interventions to promote the use of active transport must address behavioural, environmental, and infrastructure factors (Roaf et al., 2024), ensuring that people feel safe when actively moving around should be a priority. Based on previous studies it is necessary to mention that there is limited literature on male victims of harassment (Mgolozeli & Duma, 2019), so this study will provide new insights into this and offer comparisons from a gender perspective. Therefore, analysing the spaces where harassment occurs, including the sociodemographic profile of those who suffered it, will allow us to detect the factors that can prove to be risky factors for suffering these situations. In this way, when designing or modifying urban spaces, political institutions can consider these variables so that cities can become safe spaces for people who use active transport, especially women. Given this background, this study’s main objectives were to: (1) describe harassment situations reported in the Spanish context during active trips from a gender perspective, (2) describe the built environment in which these experiences have occurred and predict the risk of harassment situations based on these characteristics.

4.2. Material and methods

4.2.1. Participants

This study starts with the sample that in the previous study 3. However, the number of participants varies due to the requirements of inclusion in the pre-study on data cleaning of the included questionnaires. Finally, after preprocessing, the sample of 1 788 (38.1% men, 61.5% women y 0.4% other) showed an average age of 37.78 (SD =13.86) years, where a total of 233 experiences of harassment during active transport were reported. Of the 208 people who experienced harassment, 68 were male, 138 were female and 2 people were self-defined as other. Table 11 shows the characteristics of the population along with the percentage of the population who experienced harassment.

Table 11. Sample characteristics and prevalence of street harassment during active trips (N=1 788)

Variable	**N (%)**	**Suffered Harassment (%)**
Gender		
Male	681 (38.1)	10%
Female	1 099 (61.5)	12.6%
Other	8 (0.4)	25%
Recognised disability		
Yes	112 (6.3)	15.2%
No	1 676 (93.7)	11.4%
Residence		
Valencia	281 (15.7)	10.7%
Madrid	548 (30.6.)	13.5%
Barcelona	462 (25.8)	13.9%
Seville	126 (7)	16.7%
No response	371 (20.7)	5.1%
BMI (kg/m^2)		
Underweight (<18.5)	93 (5.2)	9.7%
Normalweight (18.5-24.99)	974 (54.5)	13%
Overweight (25-29.99)	457 (25.6)	11.2%
Obesity (≥30)	258 (14.4)	7.8%
Range income		
No income	223 (12.5)	11.7%
< 1 000 €	298 (16.7)	12.4%
1 000 € - 2 000 €	763 (42.7)	12.2%
2 000 € - 3 000 €	350 (19.6)	9.7%
> 3 000 €	154 (8.6)	11.7%
Educational level		
No studies	6 (0.3)	0%
School graduate	120 (6.7)	10%
High school certificate	283 (15.8)	11.7%
Technical college qualification	463 (25.9)	12.5%
Bachelor's degree	583 (32.6)	10.3%
Postgraduate degree	333 (18.6)	13.5%

Table 11 Sample characteristics and prevalence of street harassment during active trips (N=1 788) (Continued)

Variable	N (%)	Suffered Harassment (%)
Cohabitation type		
Independent with no children	662 (37)	12.1%
Independent with children	621 (34.7)	9.7%
Not independent	505 (28.2)	13.5%

4.2.2. General procedure

As was explained in study 3, all participants were informed of the objectives of the study and filling in the survey implied giving consent to the Universitat de València for subsequent anonymous data processing. Participants had the right to refuse or drop out of the study at any time. All procedures and materials used in the study were approved by the Ethics Committee of the Universitat de València (Spain).

The data collection in this work was carried out following the same procedure as described in study 1 section 1.2.2. in the same questionnaire integrated in the Maptionnaire platform, questions related to harassment situations were included.

The type and frequency of harassment were collected, as done in previous studies (Quinones, 2020). Once all data from the questionnaires were collected, they were downloaded and pre-processed. First, once the locations where the harassment situations occurred were retrieved, a structured download of the description of the space at a maximum distance of 50 metres from the OpenStreetMap database was performed. Tags describing locations were obtained for each geolocated harassment situation. The text was pre-processed and analysed.

4.2.3. Geolocation analysis

To characterize the areas with the highest number of harassment cases, several steps were undertaken. First, the space of each city was divided into hexagons using the H3 system (https://h3geo.org/).

H3 is a hexagonal hierarchical geohash software library originally developed by Uber Technologies, Inc. It is designed to work with geospatial data and divide the world into a hierarchical grid of hexagonal cells. Its purpose is to provide an efficient and flexible tool for spatial analysis, such as point clustering, proximity analysis, and area modeling.

This method of dividing surfaces allows for hexagons of different sizes to be selected. Specifically, for this study, we used a resolution level of "7" meaning that the hexagons had an average hexagon edge length of 1.22 km (see Figure 21).

Once the space was divided, the number of incidents in each hexagon was quantified. Only hexagons with more than seven recorded cases were considered for further analysis.

These areas were labelled as harassment zones. Additionally, to define harassment-free zones (labelled as control zones), nearby areas with no recorded incidents were selected.

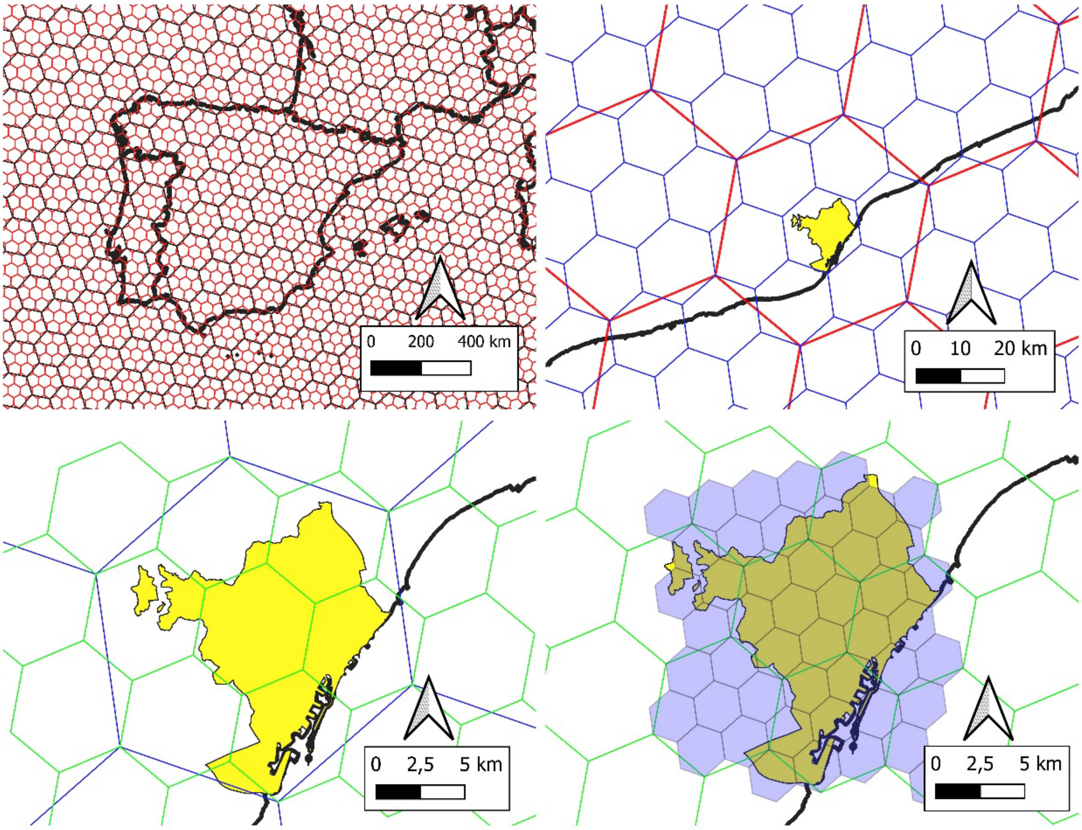


Figure 21. Example of the different resolutions of H3 zones

Note: Top left panel (Spain view): Resolution levels 3 (black line; 59.81 km) and 4 (red line; 22.61 km). Top right panel (region of Catalonia view): Resolution levels 4 (red line; 22.61 km) and 5 (blue line; 8.54 km). Bottom left panel (municipality of Barcelona view): Resolution levels 5 (blue line; 8.54 km) and 6 (green line; 3.23 km). Bottom right panel (municipality of Barcelona view): Resolution levels 6 (green line; 3.23 km) and 7 (shaded area; 1.22 km).

After selecting both groups of hexagons (harassment zones and control zones), the areas were characterized by downloading the main tags (keys and values) describing the geolocated spaces using the Overpass API (see Table 12). The operation of this database has already been detailed in previous sections of this document (see study 1 section 1.2.5.). Queries were performed using a MATLAB script, which automated the download of all tags associated with the nodes and ways present in the areas of interest.

As a result of the query, a set of tags expressed in controlled language was obtained. For data extraction, the following keys were sought: 'highway,' 'building,' 'land use,' 'natural,' 'amenity,' 'leisure,' 'shop.' For each key, the values present in each area were extracted. The frequency of each value was quantified, and the resulting vector was saved for further analysis.

Given the large number of keys and values in OSM (i.e., OpenStreetMap contains over 96 000 distinct keys and over 155 million distinct tags), only values that appeared in more than one area were considered. As a result of this phase, a data vector was obtained for each area containing the number of nodes and ways in each zone.

Table 12. Overpass query in JSON format

```
query = [
'[out:json] [timeout:10000];',  # Specifies the output format (JSON) and sets a timeout of 10,000 seconds for the query.
'(',  # Opens a block for grouping multiple queries.
# Searches for nodes tagged with "highway" within the defined polygon.
'node["highway"](poly:"', coords, '");',
# Searches for ways (lines or paths) tagged with "highway" within the defined polygon.
'way["highway"](poly:"', coords, '");',
# Searches for nodes tagged with "building" within the defined polygon.
'node["building"](poly:"', coords, '");',
# Searches for nodes tagged with "landuse" within the defined polygon (e.g., residential, industrial, forest).
'node["landuse"](poly:"', coords, '");',
# Searches for nodes tagged with "natural" within the defined polygon (e.g., trees, water bodies).
'node["natural"](poly:"', coords, '");',
# Searches for nodes tagged with "amenity" within the defined polygon (e.g., schools, hospitals, parks).
'node["amenity"](poly:"', coords, '");',
# Searches for nodes tagged with "leisure" within the defined polygon (e.g., sports facilities, parks).
'node["leisure"](poly:"', coords, '");',
# Searches for ways tagged with "leisure" within the defined polygon.
'way["leisure"](poly:"', coords, '");',
# Searches for nodes tagged with "shop" within the defined polygon (e.g., stores, malls).
'node["shop"](poly:"', coords, '");',
');',  # Closes the block grouping the queries.
'out body;'  # Outputs the results in body format, which includes the full geometry and tags for the matched elements.
]
```

Coords are the coordinates of the vertices of the hexagon ("lat1 lon1 lat2 lon2 lat3 lon3 ... lat1 lon1").

4.2.4. Statistical analysis

Descriptive and inferential statistical analyses were performed using SPSS (Version 28; SPSS Inc., Chicago, IL, USA) and descriptive figures were created using Canva (*Canva Design*, s. f.). The Kolmogorov-Smirnov test showed a non-normal distribution. For cross-sectional inference, the Chi-square test was used, with a significance level set at 0.05.

To determine the most important built environment predictors of harassment, a binomial logistic regression model (harassment yes/no) was developed. The input variables for the model were calculated for the environment extracted from Open Street Map. In addition, given the large number of input variables, a bidirectional stepwise selection procedure was employed to automatically select the most important variables for prediction.

We began with a model that included all input variables. Iteratively, a variable was added and/or removed from the model (whichever improved the model the most when added or removed). The selection of variables to be included or excluded was based on the Akaike Information Criterion (AIC), which considers both the fit and complexity of the model. This process continued until a model was reached that did not improve with the addition or removal of any available variables. These analyses were performed using R Studio (R Studio, Inc., part of the R statistical software package, version 3.2.2, Development Core Team, Boston, MA, USA).

4.3. Results

4.3.1. General data on harassment situations by gender

Regarding people who reported some harassment, significant associations were found through the Chi-square test in the BMI variable (X_1^2= 4.38; p < .036; V=0.050), where people with obesity suffered more frequent harassment compared to non obese. The types of harassment reported by the participants showed different trends based on gender: women experienced a higher percentage of verbal harassment (60.5%) than men, whereas men reported visual and verbal harassment equally with women (31.1% for both). Additionally, concerning the active mode of transportation used, both genders categories reported the highest number of harassment experiences while walking. However, women experienced a higher percentage of harassment while walking (84.1%) compared with other modes of transportation. Table 13 shows the percentages of each type of harassment and mode of transportation divided by gender.

Table 13. Type of harassment and means of transport used in gender-based harassment situations (N=233)

Harassment situations	**Gender**	
	Male (%)	**Female (%)**
Type of harassment		
Verbal	31.1	60.5
Visual	31.1	21
Physical	17.6	7.6
Stalking	13.5	9.6
Exhibitionism	2.7	0.6
Missing	4.1	0.6
Means of transport used		
Bicycle	16.2	4.5
Walking	68.9	84.1
Manual wheelchair	2.7	1.9
Skateboard/Skates	6.8	6.4
Missing	5.4	3.1

Figure 22 shows the density of harassment situations according to the time of day when they occurred. It displays that more bullying situations occurred during the night.

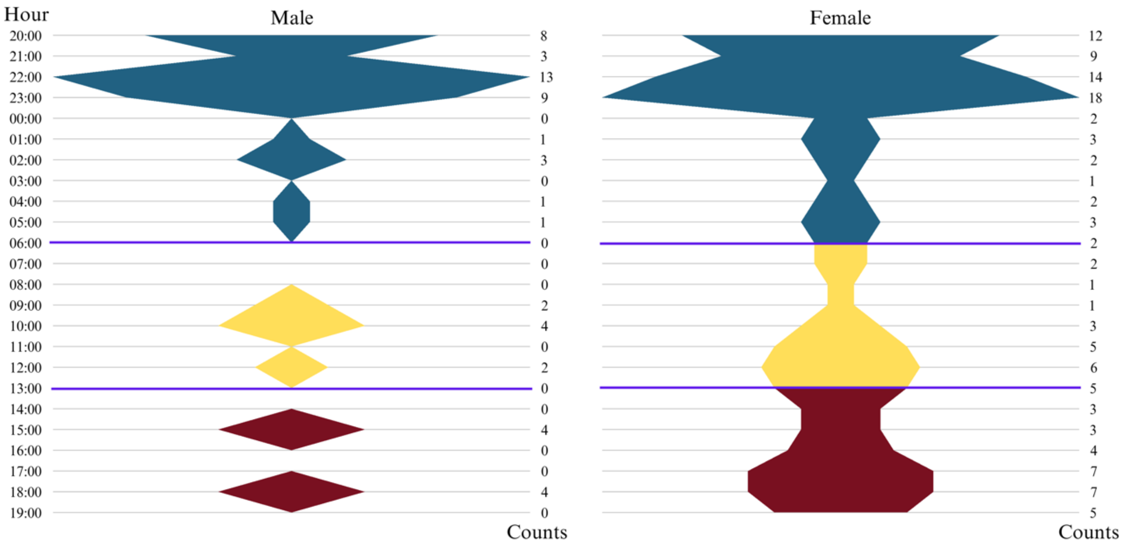


Figure 22. Number of harassment experiences by hour and gender (N=205)

Note: Blue corresponds to nighttime, yellow to daytime and maroon to evening. The daytime slots are according to previous studies in Spanish cities (Pellicer-Chenoll et al., 2021).

Other information collected from the harassment situations included the day on which it occurred. Figure 23 shows the number of harassment situations reported per month. The winter months (January, February, and March) had the highest frequency of harassment.

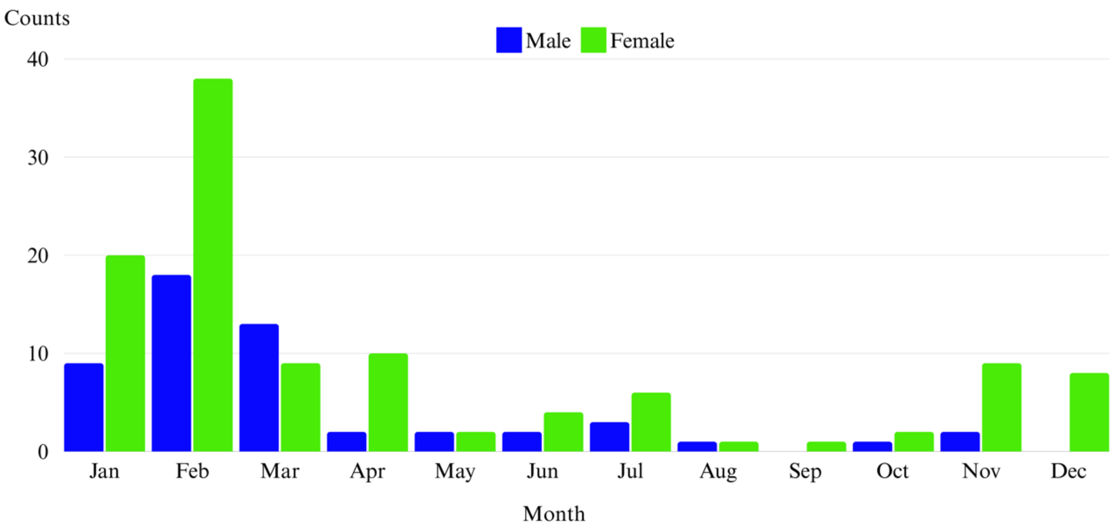


Figure 23. Harassment experiences by month and gender (N=163)

4.3.2. Geolocation of harassment by gender

The geolocations where the harassment occurred are shown in Figure 24. Harassment events were mainly located in the central areas of the cities under study.

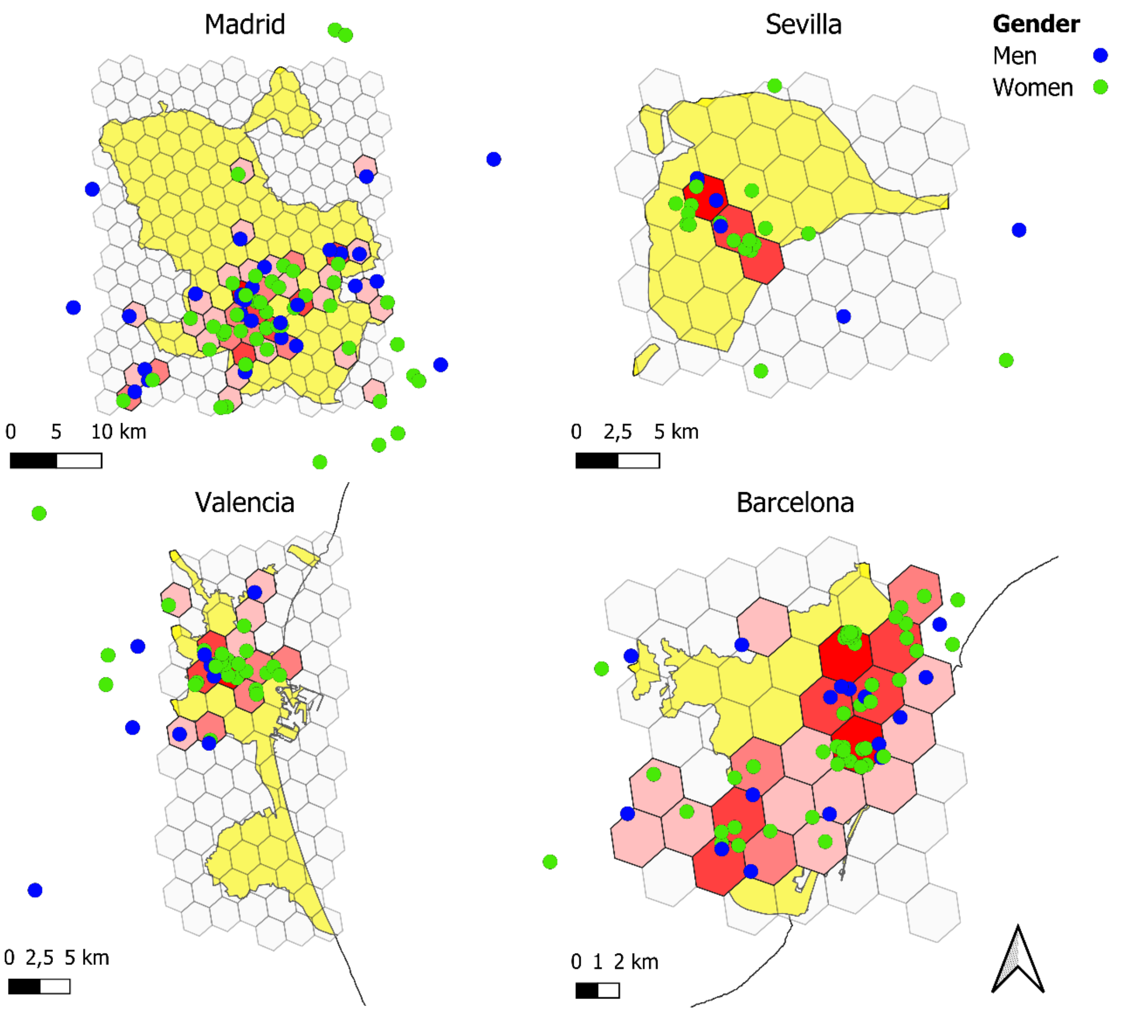


Figure 24. Geolocation of the harassment situations in the 4 cities included in the study by gender

4.3.3. Prediction of harassment experiences

The binomial logistic regression model that was used to predict harassment included 22 potential predictors (Table 14). The final model achieved an AIC value of 506.22, while the initial model had an AIC value of 563.35. Table 15 presents the confusion matrix of the model and the main predictive values.

Table 14. Predictors and coefficients of the model

Tags	Tag description	Estimate	Std. Error	z value	p-value
(Intercept)		-0.32	0.16	-2.00	**0.05**
highway=crossing	Trails which get crossed	0.13	0.05	2.83	**0.00**
highway=footway	A path mainly or exclusively for pedestrians	-0.03	0.02	-1.96	**0.05**
highway=pedestrian	Areas and roads mainly/exclusively for pedestrians	0.12	0.08	1.45	0.15
highway=secondary	A highway linking large towns	0.12	0.09	1.39	0.17
highway=steps	Steps on footways, paths and areas	0.18	0.12	1.54	0.12
highway=track	A minor land-access road like a farm or forest track	-0.29	0.18	-1.63	0.10
traffic_signals1	A traffic signal (or a set of those) for regulating circulation	-0.15	0.08	-1.82	0.07
building=retail	A building primarily used for selling goods that are sold to the public	0.36	0.25	1.45	0.15
building=terrace	A single way used to define the outline of a linear row of residential dwellings, each of which normally has its own entrance, which form a terrace	0.18	0.33	0.53	0.59
building=yes	Presence of buildings	0.01	0.01	1.17	0.24
landused=farmland	An area of farmland used for tillage (cereals, vegetables, oil plants, flowers)	-0.65	0.33	-2.00	**0.05**
amenity=bench	A bench to sit down and relax a bit	-0.11	0.07	-1.51	0.13
amenity=drinking_water	A water fountain is a place where humans can obtain potable water for consumption	0.68	0.32	2.14	**0.03**
amenity=motorcycle_parking	Parking for motorcycles	-0.36	0.18	-2.06	**0.04**
amenity=pharmacy	A shop where a pharmacist sells medications	0.63	0.45	1.40	0.16
amenity=recycling	Recycling facilities (bottle banks, etc.)	-0.16	0.08	-2.07	**0.04**
amenity=restaurant	Restaurant (not fast food)	0.22	0.13	1.66	0.10
amenity=school	School and grounds - primary, middle and secondary schools	-0.71	0.38	-1.88	0.06
leisure=garden	A place where flowers and other plants are grown in a decorative and structured manner or for scientific purposes	0.19	0.09	2.02	**0.04**
leisure=park	A park, usually in an urban (municipal) setting, created for recreation and relaxation	0.43	0.21	2.06	**0.04**
leisure=pitch	An area designed for practising a particular sport, normally designated with appropriate markings	0.32	0.16	2.07	**0.04**
leisure=playground	A playground: an area designed for children to play	-0.51	0.30	-1.71	0.09

Table 15. Confusion matrix and predictive values

		Actual harassment	
		No	**Yes**
Predicted harassment	**No**	162	83
	Yes	38	150
Predictive values			
Accuracy = 0.72	Sensitivity = 0.81	Specificity = 0.64	F1 = 0.73

4.4. Discussion

The present study's main objectives were to identify and describe situations of harassment during active commuting in the Spanish context and predict the risk of harassment during active commuting using characteristics of the built environment.

Regarding the prevalence of harassment situations according to sociodemographic variables, women showed the highest prevalence value. These results coincide with those of previous studies in which women showed a higher percentage of harassment than men (Herrera & McCarthy, 2023; Johnson & Bennett, 2015; Raj et al., 2024). This indicates that this inequality is also a reality in the Spanish population. Safety on Spanish streets must be a priority so that active travel is safe and does not become a barrier, especially for women. Therefore, any plan to promote the use of active transport should include program-specific measures to address street harassment from a gender-based perspective. Additionally, people with a disability also had a higher prevalence than those who did not declare a disability. These results are partly in line with studies that have found that people with disabilities are at higher risk of being harassed (Shaw et al., 2012). Along this vein of sociodemographic variables, overweight people showed a higher prevalence of harassment situations compared to the other BMI categories. Furthermore, significant differences were found between obese and non-obese people (underweight, normalweight and overweight). These results were consistent with those of Johns et al. (2017), in which being overweight increased the probability of women being harassed. Regarding income, those with low incomes had a modestly higher prevalence than participants with high incomes. These results agree with those obtained by Levy (2013). Finally, among the different types of households, those who were not independent or did not have family responsibilities showed a higher prevalence than independents with children. Due to their characteristics, these people are likely younger than those who are emancipated and have family responsibilities. These results partially accord with those showing that young people, especially girls, encounter barriers for moving freely and equally than boys in public spaces and internalise daily practices to avoid different types of street harassment (Plan International, 2021).

Regarding the description of harassment situations, the types of harassment experienced showed different trends for men and women. Verbal harassment was the most prevalent type of harassment against women, whereas visual and verbal harassment had the highest prevalence among men. These findings are consistent with those of the Stop Street Harassment (Raj et al., 2024), and the Safer Cities for Girls reports (2021), in which non-contact harassment was the most prevalent generally. Regarding the active mode used when harassment was experienced, walking was much more prevalent among women than other modes as found in ElSherief and Belding (2015) study. This indicates that it is necessary to focus on walking safety, particularly among women. For both men and women, harassment occurred more during the winter months. This may be because in Spain, the hours of daylight throughout the day are shorter during these months; daylight is a variable that causes security among users of active transport, especially for women (Kash, 2019). In addition, most situations occurred in the evening or at night, that is, at times of the day with little or no natural light. These results correspond with those obtained in the Safer Cities for Girls report (2021), in which more harassment was reported in the evening, night, and early morning. In another previous Spanish study, women also avoid cycling at night (Pellicer-Chenoll et al., 2021).

Regarding the location of the harassment, men and women showed different trends. However, most of the harassment situations occurred in the urban centres of the four cities. This main result is in line with a study that found street harassment occurs mainly in crowded areas (ElSherief & Belding, 2015). Regarding the risk of harassment prediction, places that reduce risk include pedestrian-only paths, recycling areas, and agricultural land for cultivation. These studies differ from ElSherief and Belding (2015), which found that most harassment occurred in areas with a high walkability index. Conversely, environmental features that increased the risk of harassment included road crossings, fountain areas, plant cultivation areas, urban parks, and public sports areas. These results are in line with those of the Safer Cities for Girls report (2021), in which 12% of the reported harassment situations were in parks and gardens.

All these investigations agree with the inequality that exists in the use of urban space by different people and the insecurity experienced mostly by women, influencing the use of active means of transport. This problem is global. Since it has a high relevance, access for all people to safe transport systems with special attention to women, children, people with disabilities, and the elderly is one of the targets of Sustainable Development Goal 11, 'Sustainable Cities and Communities' (European Union Agency for Fundamental Rights, 2015). However, much work must still be done despite this fast-growing research topic (Fileborn & O'Neill, 2023).

4.5. Conclusions

This article explored and described the situations of harassment experienced in four Spanish cities (Madrid, Barcelona, Valencia, and Seville) during active travel (walking or wheeling). It also applied a predictive analysis to detect the characteristics of the built environment where harassment occurred during active travel.

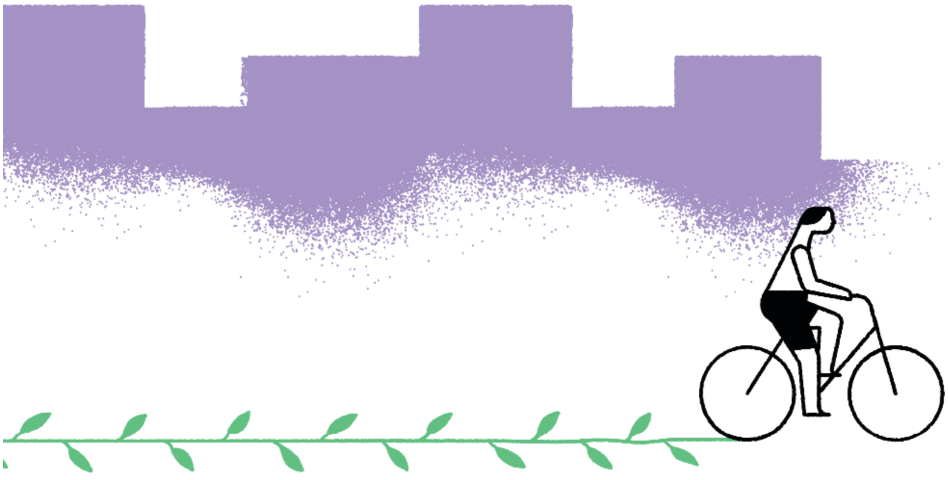
Among the key findings, women were more likely to report experiencing street harassment during active travel than men. Verbal harassment was the most prevalent among women, and visual and verbal harassment was the most prevalent among men. Walking was the most prevalent context for harassment generally. More situations were reported during the night and during the winter months of the year. Moreover, when people with and without obesity were compared, the Chi-square test showed significant differences, where obese people suffered more harassment compared to non-obese. In all four cities, harassment mainly occurred in urban centres. Concerning the predictive analysis, according to the characteristics of the spaces in which harassment occurred, those that reduced risk included pedestrian-only paths, recycling areas, and agricultural land for cultivation. Environmental features that increased the risk of harassment included road crossings, fountain areas, plant cultivation areas, urban parks, and public sports areas.

This article identifies the common characteristics of urban spaces in the Spanish context where harassment occurs as well as the sociodemographic characteristics of people at risk of suffering it. These results can guide urban policies to reduce the risk of harassment during active trips so that the environmental characteristics do not become barriers to use. While the entire population can benefit from such policies, women may be the group that achieves the greatest benefits.

4.5.1. Limitations and future research

To accurately interpret these study results, some potential limitations need to be considered. First, the sample size was small. This may have been because people are reluctant to report harassment due to negative experiences and feelings of shame that emerge when remembering them. In fact, in most cases of harassment, victims do not report what has happened or seek help (Raj et al., 2024). Second, these situations were reported in the Spanish context, which does not allow the results to be extrapolated to all cultures or spaces. So, future research could analyse the spaces at risk of harassment in different cultures and identify the needs of each space and city. Third, harassment was measured using a survey based on participants' perceptions rather than using an objective measure based on researchers' observations. Applying objective data collection techniques would be helpful to obtain unbiased information from participants in an emotional way after they have experienced the event. Forth, it is worth noting that our participants were asked whether they had experienced harassment during a specific period (last 12 months) rather than ever and not whether they had experienced harassment. Exploring longer periods would allow more information to be obtained on this phenomenon and to analyse how it fluctuates over time. Fifth, only quantitative methods have been used to analyse the situations. Therefore, in order to obtain a comprehensive picture of the street harassment issue on active trips, mixed methods combining quantitative and qualitative analyses could be applied (Heyvaert et al., 2013). Finally, harassment experienced during active travel could be specially analysed in groups that have also been shown to be at high risk of harassment, such as the LGTBI group, persons with disabilities or different ethnicity/race. Particularly among people with disabilities, there is no extensive scientific literature about this topic and also sample sizes are usually small (Fileborn & Vera-Gray, 2017). Therefore, generating more scientific evidence on these populations would make possible to analyse the differences between varied types of people and then adapt policies to each.

GENERAL CONCLUSIONS, POLICY IMPLICATIONS AND FUTURE PERSPECTIVES



General conclusions

Although relevant findings have been presented in each study, some key conclusions need to be highlighted here.

On one hand, the first two studies provide an overview of the issue of urban cycling, one from the perspective of the scientific community and the other from the perspective of the population. As main conclusions, there has been an exponential increase in research on cycling in urban environments, especially in China and the United States. This is probably due to the need to convert urban spaces into healthy environments, that prioritise active means of transport over motor vehicles. Specifically, the most recently addressed topics that most concern researchers are smart urban mobility, bike-sharing systems, cycling infrastructure and cycling behaviour. Alongside this concern of the scientific community, the analysis of posts published on the social network X about cycling and the city has reflected a general positive sentiment towards urban cycling. Moreover, this public perception, based on words, hashtags and emojis emphasises the importance of safety and infrastructure, especially about segregated lanes. This analysis offers policymakers the opportunity to adjust interventions according to users' concerns.

On the other hand, both studies 3 and 4, based on same sample, highlighted not only elements of the built environment to encourage cycling, but also the specific challenges faced by certain groups, particularly women, in relation to safety. Regarding study 3, built environment characteristics showed an impact on cycling use as a means of transport. To start, the availability of cycling facilities close to the place of residence can be a determining factor in the choice of cycling. Moreover, socio-demographic and health variables, as gender, age and PA levels were crucial in quantifying cycling. In addition, women have showed lower urban cycling use and a low or moderate PA level during leisure time compared to men, which illustrates that women faced additional barriers in active transport use and access to PA. Related to study 4, it has been identified specific urban spaces characteristics that increase harassment risk, such as street crossings or recreational areas. Besides that, women have been particularly affected, limiting their options to choose active transport. This suggests that to promote active transport, both infrastructure and personal characteristics need to be addressed in urban policies together. Also, this study highlights the importance of designing spaces that not only facilitate cycling but also minimise harassment risk. It is therefore essential that active transport policies include a gender perspective that not only improves infrastructure but also addresses safety and equal opportunities issues.

Finally, the applied methodology in both studies has shown the importance of the urban space characteristics and the impact on human behaviour, specifically in the use of bicycles. This is a novel aspect that responds to the need to develop promotion plans adapted to specific spaces, considering the population that uses them. Ultimately, both studies suggest that policies to promote active transport, in particular cycling, should consider infrastructure, accessibility and safety in the urban environment in an integrated manner. Also, decision-makers should consider both demographic and health needs, as well as perceived risks in the environment, especially in areas where people report experiences of harassment. This will help to create a more inclusive and safer environments that encourages active transport as a viable, safe, healthy and attractive option for the entire population.

Policy implications

As mentioned previously, each study has specific implications detailed in each section. However, it is interesting to highlight some general policy implications that can be derived from this dissertation.

Firstly, it has become clear that the relationship between urban built environment and the population's characteristics are crucial. This means that plans to promote active transport should not only focus on improving urban infrastructure, such as increasing bicycle lanes, expanding public bicycle facilities or increasing parking spaces. It is also essential to consider how these infrastructures interact with human behaviour and factors such as PA levels, perceived health or socio-demographic characteristics. This has been possible due to the analysis of human behaviour analysed from a geolocalised perspective, which is one of the novelties proposed in this dissertation.

Secondly, experiences during active travel have a direct impact on future use. Therefore, minimising bad experiences, such as harassment, as much as possible is essential to effectively promote active transport, especially among women. In this regard, the design of the built environment should be modified to reduce harassment risks and create safe spaces that offer confidence to users, thereby promoting greater interest of active transport.

Other contributions and future perspectives

As mentioned in the Introduction, this dissertation is part of the project called 'Sustainable transport in Valencia: Socio-environmental, urban and health analysis of the Valenbisi service' PROMETEO 2021-026. The general aim of this project was to analyse the trip data of people using the Valenbisi service (Valencia, Spain). Furthermore, this data has been analysed together with other urban, health and socio-environmental data and its population. This project has resulted in some studies that are not included in this dissertation, but that have helped me to develop and enrich the process of writing this work. Some of them have already been published or accepted:

- Seifert, R., Pellicer-Chenoll, M., Antón-González, L., Pans, M., Devís-Devís, J. & González, L.M. 2023. Who changed and who maintained their urban bike-sharing mobility after the COVID-19 outbreak? A within-subjects study. *Cities 137*
- Pans, M., Antón-González, L., & Villarrasa-Sapiña, I. (2023). Análisis de edades, género y nivel socioeconómico del tiempo de uso del sistema de bicicletas compartidas de València (España). *Retos*, *48*, 277–283.
- Villarrasa-Sapiña, I., Antón-González, L., & Pans, M. (2023). Aplicación del análisis mediante mapas auto-organizados (SOM) para estimar el uso de la bicicleta compartida: una nueva perspectiva. *DYNA*, *98(3)*, 294.
- Villarrasa-Sapiña, I., Antón-González, L. & Marco-Ahulló, A. (2024). Exploring bike-sharing systems in Europe and North America. *Journal of Sport and Health Research*.

These articles have been elaborated using the Valenbisi database and enriched with other databases, as it has been done in studies 3 and 4 included in this dissertation. Even though this project ends in December 2024, there are studies in preparation related to the project and data derived from the doctoral thesis that are still pending analysis and that will be the core of future research.

Apart from that, one of the future lines of research arising from this dissertation is the analysis of active mobility patterns in urban environments of people with disabilities. This approach is the result of my participation in the project 'Moving with Spinal Cord Injury' during the preparation of this work. As I was involved in the analysis of barriers to PA in people with Spinal Cord Injury, we found that some of the difficulties were in commuting to PA practice in urban spaces. Therefore, to obtain data in this regard, variables related to disability and active transport were included in the process of designing the questionnaire to be completed by the sample participating in the thesis studies. So, this possible line of research would focus on developing a study of urban mobility and active transport of people with disabilities, going beyond accessibility, which is the focus of the current literature. The aim would be to quantify and characterise daily trips, estimate the associated energy expenditure and analyse the social, personal and environmental factors that influence mobility. It could also compare energy expenditure between those who use active transport and those who do not, considering variables such as gender or socio-economic level. In short, the results of this future research could make proposals to improve the mobility, accessibility and autonomy of people with disabilities, with positive effects on their health and reduction of social isolation. It is also expected to contribute to the development of inclusive policies and the design of more accessible urban environments, thus promoting a fairer and more equitable society for all.

Another possible line of future research could focus on analysing patterns of urban active mobility from a gender perspective. As the empirical data in this thesis and the scientific literature show, women are less likely to use the bicycle as a means of transport and are also more likely than men to have negative experiences during active travel. Then, there is a need to make public spaces safe and equitable. In this sense, this possible future research would focus on characterising the urban spaces used for active travel by identifying the barriers experienced by women. Identifying and analysing these specific barriers will enable the design of safer and more equitable public spaces where women can use active transport more often. This research will not only bring a more inclusive approach to the study of urban mobility, but it will also contribute to creating more accessible, safe and comfortable environments for all people, promoting equitable use of public spaces and promoting gender equality in urban planning policies.

In conclusion, this dissertation has proved to be the beginning of an active journey towards urban equality and accessibility.

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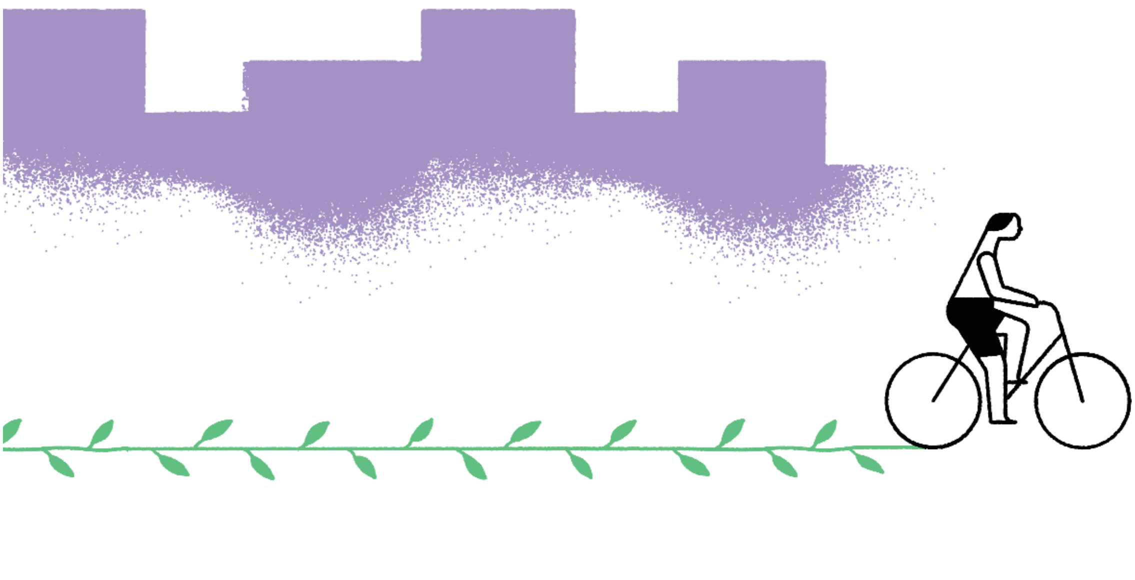

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Appendix

```
%% Carga de datos de OpenStreetMap y procesamiento de amenities
% Este script procesa datos de OpenStreetMap para obtener y analizar
% puntos de interés relacionados con bicicletas, transporte público y coches.

%% Configuración inicial
% Definición de variables iniciales
clear; clc;

% Parámetros de configuración
resultados1 = {};
resultados2 = {};
resultados_finales = {};
distancia = '800'; % Radio de búsqueda en metros

%% Bucle principal para procesar los datos
% Recorre cada caso en las coordenadas especificadas
for caso = 1:length(residencia_lat_lon_num)

    % Coordenadas para el caso actual
    latB = residencia_lat_lon_num(caso, 1); % Coordenada latitud real
    lonB = residencia_lat_lon_num(caso, 2); % Coordenada longitud real

    %% Consulta 1: Amenities relacionados con bicicletas
    overpass_query_bike = [
        '[out:json][timeout:600];' ...
        '(' ...
        '  node(around:' distancia ',' num2str(latB) ',' num2str(lonB)
')[amenity=bicycle_parking];' ...
        '  node(around:' distancia ',' num2str(latB) ',' num2str(lonB)
')[amenity=bicycle_rental];' ...
        ');' ...
        'out body;' ...
        '>;' ...
        'out skel qt;'
    ];

    % Procesar datos de bicicletas
    cuantas_amenities_bike(caso, 1) =
procesar_amenities(overpass_query_bike);

    %% Consulta 2: Amenities relacionados con transporte público
    overpass_query_transport = [
        '[out:json][timeout:600];' ...
        '(' ...
        '  node(around:' distancia ',' num2str(latB) ',' num2str(lonB)
')[amenity=bus_station];' ...
        '  way(around:' distancia ',' num2str(latB) ',' num2str(lonB)
')[amenity=bus_station];' ...
        '  relation(around:' distancia ',' num2str(latB) ',' num2str(lonB)
')[amenity=bus_station];' ...
        '  node(around:' distancia ',' num2str(latB) ',' num2str(lonB)
')[public_transport=station];' ...
        '  way(around:' distancia ',' num2str(latB) ',' num2str(lonB)
')[public_transport=station];' ...
        '  relation(around:' distancia ',' num2str(latB) ',' num2str(lonB)
')[public_transport=station];' ...
```

```
        ');' ...
        'out body;' ...
        '>;' ...
        'out skel qt;'
    ];

    % Procesar datos de transporte público
    cuantas_amenities_public_transport(caso, 1) =
procesar_amenities(overpass_query_transport);

    %% Consulta 3: Amenities relacionados con coches
    overpass_query_car = [
        '[out:json][timeout:600];' ...
        '(' ...
        '  node(around:' distancia ',' num2str(latB) ',' num2str(lonB)
')[amenity=fuel];' ...
        '  node(around:' distancia ',' num2str(latB) ',' num2str(lonB)
')[amenity=parking];' ...
        '  node(around:' distancia ',' num2str(latB) ',' num2str(lonB)
')[amenity=charging_station];' ...
        ');' ...
        'out body;' ...
        '>;' ...
        'out skel qt;'
    ];

    % Procesar datos de coches
    cuantas_amenities_car(caso, 1) = procesar_amenities(overpass_query_car);

end

%% Guardar resultados
% Guardar datos procesados en un archivo .mat y exportar tabla a Excel
cd('guardar'); % Cambiar a la carpeta deseada
save('amenities', "cuantas_amenities_car",
"cuantas_amenities_public_transport", "cuantas_amenities_bike");

% Crear tabla y exportar a Excel
Tabla = table(cuantas_amenities_bike, cuantas_amenities_public_transport,
cuantas_amenities_car);
writetable(Tabla, 'tabla_AF_tresvariables_amenities.xlsx');

%% Función auxiliar para procesar amenities
default_options = weboptions('Timeout', 60); % Configuración de opciones para
solicitudes web

function num_amenities = procesar_amenities(query)
    global default_options;

    % Realizar solicitud a la API de Overpass
    overpass_url = ['https://overpass-api.de/api/interpreter?data='
urlencode(query)];
    osm_data = webread(overpass_url, default_options);

    % Verificar y procesar elementos
    if isfield(osm_data, 'elements')
        elements = osm_data.elements;
```

```
        % Filtrar elementos válidos con coordenadas
        coords = arrayfun(@(x) [x.lat, x.lon], elements, 'UniformOutput',
false);
        coords = vertcat(coords{:});

        % Eliminar duplicados y aplicar filtros de proximidad
        coords = round(coords, 3);
        coords = unique(coords, 'rows', 'stable');

        % Contar amenities restantes
        num_amenities = size(coords, 1);
    else
        num_amenities = 0;
    end
end
```