

Exploring Transformations in Sustainable Urban Mobility: Insights from CityWalk 2.0 project and beyond

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Abstract (up to 125 words)

In response to societal shifts towards green and digital transitions, urban mobility emerges as a pivotal arena for change, influencing behaviour, transportation modes, as well as urban planning policies. This paper investigates the role of CityWalk 2.0 project in promoting energy-efficient urban mobility and shifting urban transport systems from car-centric to active mobility modes. Firstly, a literature review is conducted to define a framework for categorising different practices that promote active mobility. Secondly, a comparative analysis was conducted between three CityWalk 2.0 pilot cities. Despite the distinct local contexts, the results showcase the evident impact of 'soft' and 'hard' actions across various dimensions. Common walkability issues related to regulation and street design, as well as the elevation of pedestrians and cyclists to the apex of the "traffic pyramid" are highlighted in the cities' approaches to sustainable urban mobility. In conclusion, the paper provides essential guidelines for reshaping the discourse on urban mobility transformations in the 21st century.

Keywords: urban transportation, street redesign, travel behaviour, urban mobility policies

1. Introduction

In the context of the twin green and digital transition, urban mobility emerges as a driving domain for transformation (Schipper et al, 2020). A new paradigm raises around the concept of sustainable urban mobility, leveraging technological advancements and societal changes. This shift significantly impacts not only behavioural patterns and transportation modes but also shapes urban planning policies (Van Acker et al, 2016).

Urban mobility plays a pivotal role in shaping the sustainability and liveability of cities worldwide. In accordance with the European transport legislation, concerted efforts are directed towards achieving a competitive and resource-efficient transport infrastructure to align with the ambitious objectives outlined in the 2030 climate and energy framework, namely the reduction of greenhouse gas emissions by at least 40% compared to 1990 levels, the increase of energy efficiency by at least 32.5% and the increase of energy from renewables by at least 32% (EC, 2011; EC, 2013). Considering the significant proportion of European citizens residing in urban areas and the projected exponential growth of the urban population globally, estimated to surpass two-thirds of the world's population by 2050, urbanisation challenges need to be urgently addressed (UN, 2019). The exponential rise in urban population necessitates a heightened emphasis on sustainable urban mobility, as current transportation systems heavily dependent on cars causes harmful environmental effects, health risks, and a deficiency of quality public spaces in the urban context (Schipper, 2002).

Firstly, the dominance of conventional modes of urban transport, notably car-centric mobility, exacerbates these challenges, posing significant obstacles to environmental, social and economic sustainability. European cities are progressively adopting Sustainable Urban Mobility Plans (SUMP), which advocate for walking, cycling, public transportation and shared mobility services as substitutes for private car usage (Maltese et al, 2021). Generally, SUMPs tackle issues stemming from excessive car traffic, including congestion, air pollution, noise, CO2 emissions, compromised road safety and decreased physical activity levels among residents (Hudoklin et al, 2021).

Secondly, the well-being of residents is highly impacted by car traffic dominance, leading to congestion and safety hazards. Moreover, current transportation systems, heavily reliant on automobiles, contribute to adverse environmental effects, health concerns and a lack of high-quality public spaces, greenery and public amenities within urban areas (Schipper, 2002). In this context, active urban mobility emerges as a compelling solution to mitigate the adverse impacts of car-dependent transportation systems. Active forms of mobility, such as walking, cycling, and micro-mobility offer a promising pathway towards achieving sustainable urban transportation. These modes of travel not only reduce reliance on fossil fuels, but also promote public health, enhance urban liveability and foster community cohesion. Through empirical research and data-driven analysis, cities can unlock the full potential of street experiments as powerful tools for fostering sustainable urban mobility (Bertolini, 2020).

Upon this background, the CityWalk 2.0 project emerges as a beacon of innovation and collaboration, building upon the legacy of its predecessor, CityWalk (2016-2019), to pioneer new pathways towards energy-efficient urban transport. At its core, CityWalk 2.0 seeks to catalyse a paradigm shift in urban mobility, steering cities away from the entrenched reliance on energy-intensive automobile-centric systems towards a more sustainable and resilient future. The project aims to become a catalyst for transformative change in urban mobility in 10 pilot cities located in the Danube Region, particularly in the Central and Eastern part of Europe. By advocating for specific policy changes at both local and transnational levels, CityWalk 2.0 aims not only to reduce the energy footprint of urban transport, but also to foster a global network of decision-makers committed to sustainable mobility.

Literature shows that addressing the root causes of car dependency requires a multifaceted approach that extends beyond the realm of physical infrastructure and encompasses not only technological innovations, but also behavioural change interventions (García-Garcés et al, 2016). Therefore, key elements of CityWalk 2.0 include redesigning streets to encourage active mobility and discourage car use, changing the travel behaviour of citizens and strengthening the political will and commitment to implement the transformation.

Central to fostering sustainable urban mobility is the imperative to prioritise pedestrians' needs and create inclusive environments. Achieving this demands a delicate balance, ensuring equitable distribution of urban space, while enhancing conditions for walking and active transportation. By adopting a holistic approach and leveraging universal design principles, cities can cultivate socially inclusive, pedestrian-friendly spaces. Simultaneously, evaluating city street experiments and integrating 'soft' and 'hard' measures unlocks synergistic effects, propelling sustainable mobility initiatives forward and shaping resilient urban ecosystems capable of meeting diverse community needs (Anciaes and Jones, 2020; Bertolini, 2020; García-Garcés et al, 2016).

2. Methodology

The present research is conducted within the framework of the CITYWALK 2.0 project, funded under the Interreg Danube program. The project entitled "Together for Energy-efficient Urban Mobility: Decreasing Carbon Intensity of Urban Transport by supporting Shift to Active Urban Mobility through rethinking street design and changing travel behaviour" started in January 2024, building upon the foundation laid by its predecessor, CITYWALK project.

The main objective of this paper is to investigate the impact of CITYWALK 2.0 project in promoting energy-efficient urban mobility and shifting urban transport systems from car-centric to active mobility modes. Specifically, the paper highlights measures to effectively reduce carbon emissions, based on the interventions tested by three pilot cities: Nyiregyhaza (Hungary), Ptuj (Slovenia), and Valjevo (Republic of Serbia). Given the diverse geographical and cultural landscape of Central and Eastern Europe, it is crucial to acknowledge the prevailing mentality and rigidity towards change. Moreover, cultural factors also play a significant role in shaping attitudes towards change in Eastern European cities. Deep-seated cultural values, such as a preference for private car ownership as a symbol of status and independence, can pose challenges in promoting alternative and more sustainable transportation systems.

Data collection and analysis for this research were conducted through a multifaceted approach. Firstly, an extensive literature review was undertaken to synthesise existing knowledge and identify gaps in understanding the existing body of knowledge related to sustainable urban mobility practices. Based on the findings, this paper proposes a categorisation framework of different practices that fall under two main categories: street redesign ('hard' interventions) and travel behaviour change ('soft' intervention). Additionally, qualitative methods such as case studies were conducted to gather insights into the methods and pilot actions employed to stimulate a transition towards active mobility in the three Central and Eastern European cities (Nyiregyhaza, Ptuj and Valjevo). Finally, the paper suggests a list of policy recommendations for cities which pursue the objective of decreasing carbon intensity of urban transportation systems. Overall, this methodological approach enabled a robust exploration of the role of street experiments as potential triggers of systemic change in urban mobility, with a focus on moving away from motorised traffic dominance towards non-motorized travel.

3. Literature review

Based on the existing literature, this paper provides a conceptual framework for categorising transformations in sustainable urban mobility, based on current theories, concepts and practices. Urban mobility is not merely a transportation issue, it is also intricately linked to broader societal and environmental challenges. Planning for sustainable mobility typically involves fostering efficient transportation options that enhance competitiveness while simultaneously mitigating air and noise pollution, including the reduction of greenhouse gas emissions.

Existing literature highlights a notable increase in research dedicated to active mobility, coupled with the development of conceptual frameworks aimed at guiding interventions (Koszowski et al, 2019). The concept of active mobility, also known as active transportation, encompasses modes of transportation reliant on human power, notably including walking and cycling, utilised for various travel purposes (Kong et al, 2024). They advocate for the integration of active mobility into daily routines, insisting that cities should prioritise the development of infrastructure conducive to walking and

cycling. This approach embodies an urban planning ethos centred on prioritising the needs of people over specific modes of transportation. The most efficient and cheapest way is to shift from extremely energy-intensive (and inefficient) car-based mobility to active forms of mobility (walking, cycling), with micro-mobility and public transport as the primary means of transportation. Generally, strategies for facilitating a modal shift towards active transport focus on reallocating road space and creating pedestrian and cyclist-friendly environments, such as safe and extensive networks of bike lanes, pedestrian paths and accessible public spaces (Ferretto et al, 2021; Kong et al, 2024).

The literature also emphasises the positive impacts of active mobility on various aspects including health, safety, life quality, economy, environment and air quality (Koszowski et al, 2019; Ferretto et al, 2021; Pisoni et al, 2022; Kong et al, 2024). However, there are several factors which determine the adoption of active mobility, such as the built environment, infrastructure development, user perceptions and individual health (Rojas López and Wong, 2017; Ferretto et al, 2021). Psychological and neighbourhood variables play a significant role in influencing individuals' mobility behaviour, highlighting the need for comprehensive urban design tools to create healthier urban environments (Götschi et al, 2017; Said et al, 2021).

Various transportation policy measures have proven beneficial in encouraging a shift from car use to public transportation or environmentally friendly modes such as walking or cycling (García-Garcés et al, 2016). Concretely, these measures vary from reallocating road space to accommodate pedestrian and cyclist-friendly urban settings (Ferretto et al, 2021) to Travel Behaviour Change Programmes. These initiatives are designed to incentivize individuals to reduce their reliance on cars, particularly for single-occupancy trips. Numerous societal and individual benefits have been demonstrated when walking or cycling replaces car use. Such programs encompass personal travel planning, travel awareness, campaigns, workplace or educational institution travel plans and strategies like car-sharing.

There is a wide range of concepts and theories that address the issue of active mobility, always placed into two basic categories, commonly referred to as 'hard' and 'soft' interventions (Anciaes and Jones, 2022; Bertolini, 2020; García-Garcés et al, 2016). The first category of 'hard' interventions refers to street redesign, involving tangible alterations to the physical infrastructure. The second category of 'soft' interventions refers to travel behaviour change, which targets individual habits and choices. These interventions offer distinct yet synergistic avenues towards achieving safer, more efficient and equitable urban transportation systems.

3.1 'Hard' interventions - Street redesign

Street redesign refers to a process of altering the physical layout, infrastructure and amenities of roads and streets within urban or suburban areas. This approach aims to improve various aspects of street function, such as safety, accessibility and efficiency. Street redesign projects often involve modifications to road geometry, traffic flow patterns, signage and markings, pedestrian infrastructure, cycling facilities, landscaping and street furniture (Lahart et al, 2013; Anciaes and Jones, 2022).

In numerous urban centres, a sustained trend is emerging towards allocating increased space for pedestrians, reflecting a novel paradigm in transportation and urban governance centred on promoting health, well-being and urban liveability (Anciaes and Jones, 2020). The reconfiguration of streets to prioritise pedestrian access yields

various advantages, encompassing enhancements in local economic communities and environmental sustainability (Bertolini, 2020).

Street redesign has the potential to achieve greater cost-efficiency by addressing driver behaviour, thereby effectively managing traffic speeds. Enhanced public spaces not only instil a sense of civic pride, but also attract private investment, thus stimulating employment opportunities and enhancing commercial and retail activity. Promoting pedestrian and cyclist-friendly environments, accessible to individuals of diverse ages and physical abilities, fosters street vitality and social interaction (Tmou and Rodi, 2023). Moreover, prioritising improved street redesign contributes to enhanced value for investment towards social inclusivity (Lahart et al, 2013).

Several subcategories of possible interventions fall under the street redesign measures, each serving distinct purposes within the urban planning and transportation policies (Figure 1).

(1) *Pedestrian-only streets*, designated exclusively for pedestrian traffic, not only encourage walking and active transportation, but also contribute to community cohesion and economic vitality when used as public spaces which accommodate certain activities (Lahart et al, 2013; Bertolini, 2020). (2) *Shared space streets* eliminate barriers hindering movement between transportation modes, cultivating vibrant urban environments with outdoor activities for children and pleasant spaces for walking and cycling (Lahart et al, 2013; Peters, 2017). Another requirement for streets to become shared spaces in residential areas is to host less than 100 vehicles per hour during the afternoon peak (Hamilton-Baillie, 2008). (3) The transformation of boulevards from main roads focuses on revitalising *avenues* to prioritise aesthetics, pedestrian-friendly infrastructure and versatile utility, serving their initial scope (Jacobs et al, 2002). (4) *Promenades* serve as expansive avenues, blending leisure walking with recreational activities, offering lively environments for public activities (Miaux and Garneau, 2016). (5) *Low-speed streets and slow zones* aim to reduce injuries and enhance safety and comfort for non-motorized users by reducing vehicle speed limit up to 30 km/h and prioritising pedestrians and cyclists (Neki et al, 2021). Moreover, traffic calming interventions include adjustments to road geometry, such as horizontal and vertical modifications, as well as lane narrowing and insertion of slow zones near sensitive land uses like schools or parks. (6) *Parklets* repurpose on-street parking spaces into (semi-)public areas for alternative uses, promoting walking, cycling, social interaction and economic activity (Speck, 2018; Bertolini, 2020). Parking-space installations gather basic structures that provide amenities such as seating, bike racks, public art or exercise equipment. (7) *Cycling infrastructure* optimises the use of limited public space, mitigates climate change, and improves accessibility, emphasising systemic interventions to cultivate sustainable transportation environments (Hofmeister and Stibe, 2017; Tosics et al, 2022). (8) *Urban signage* embodies various codes and elements such as architectural, compositional, graphical, colour, to guide movement and facilitate a user-friendly navigation within cities (Sokolova, 2018). (9) *Urban furniture/ amenities* encompass aesthetic and comfort-oriented elements that contribute to city liveability, comfortable and secure environment, urban identity and guide movement through elements such as public art, lighting, seating and bicycle parking amenities (Lahart et al, 2013; Bolkaner et al, 2019).

| Street redesign | | |
|-----------------------------|---|--|
| Sub-category | Definition | Source |
| Pedestrian-only streets | Pedestrian-only streets, designed exclusively for pedestrian traffic, not only encourage walking and active transportation, but also contribute to community cohesion and economic vitality when used in public spaces which accommodate certain activities. | Lafuri et al. 2018, Bertolini, 2020 |
| Shared space | Shared space streets eliminate barriers hindering movement between transportation modes, cultivating vibrant urban environments with outdoor activities for children and pleasant spaces for walking and cycling. | Lafuri et al. 2018, Peters, 2017, Haverkort-Bullis, 2008 |
| Boulevards from main street | Boulevards are broad streets that divide large urban areas into connected zones, acting as a barrier between the edges of commercial or residential streets and fast-moving traffic lanes. They achieve this by incorporating multiple lanes and through roads. | Jacobs et al. 2002 |
| Promenades | Promenades serve as expansive avenues, blending leisure walking with recreational activities, offering lively environments for public activities. | Milau and Gernieu, 2016 |
| Low speed-limit street | Low-speed streets and slow zones aim to reduce injuries and enhance safety and comfort for non-motorised users by reducing vehicle speed limit up to 30 km/h and promoting pedestrians and cyclists. | Nash et al. 2021 |
| Parklets | Parklets can be defined as the temporary transformation of on-street parking spaces into semi-public areas by installing simple structures like seating, bike racks, public art, or exercise equipment. | Bertolini, 2020; Speck, 2018 |
| Cycling infrastructure | It contributes to maximising the use of linked public space, addressing climate change, reducing air and noise pollution, promoting public health, and enhancing overall accessibility. | Tedesco et al. 2022; Hoffmeister and Spöck, 2017 |
| Urban signage | An urban sign integrates various elements like verbal, architectural, graphic, and pictorial aspects, reflecting a pressing concern in modern urban planning, requiring an interdisciplinary approach. | Sokolova, 2018 |
| Urban furniture | Urban furniture encompasses aesthetic and comfort elements that reflect a city's identity and enhance urban livability by improving comfort and meeting resident needs. | Bellurue et al. 2019; Lafuri et al. 2018 |

Figure 1. Categorisation framework for interventions that encourage active mobility: 'hard' interventions (source: authors)

3.2 'Soft' interventions - Travel behaviour change

Without any doubt, robust infrastructure is pivotal in urban planning to reduce individual car dependency. Despite vital elements like public transport networks, pedestrian-friendly infrastructure and cycling facilities, addressing transportation behaviour complexity is crucial. Human behaviour significantly shapes travel patterns, often maintaining car reliance despite alternative options. Changing this behaviour requires diverse interventions such as awareness campaigns, modal shift incentives, education and policies encouraging alternative travel modes. While infrastructure forms the backbone, a comprehensive approach addressing social, cultural and psychological factors is key to achieving meaningful behaviour change.

In addition to altering the travel environment, behavioural strategies like mobility management have been implemented to raise awareness and influence psychological factors, encouraging voluntary shifts from car dependency to non-auto travel modes. These strategies often involve providing tailored information on public transportation, launching travel campaigns and offering travel education programs (Fujii and Taniguchi, 2014).

Several subcategories of possible interventions fall under the travel behaviour change measures, each targeting distinct aspects of individual and collective transportation choices (Figure 2).

(1) *Educational campaigns* represent an encouragement strategy for active mobility, aimed at raising awareness of multimodal and sustainable travel practices (Haufe et al, 2016). (2) *Zoning regulations* delineate permissible land use and operational activities to shape transportation patterns within comprehensive master or zonal plans (Chriqui et al, 2016). (3) *Parking policies* aim to optimise parking utilisation and turnover, often through strategies such as time restrictions, paid parking zones and

workplace parking fees to discourage car commuting (Tosics et al, 2022). (4) *Congestion pricing* aims to align driving costs with demand dynamics. This mechanism typically involves elevating the cost of driving on congested routes or within densely populated downtown areas to better reflect demand patterns, thereby incentivizing the use of alternative modes of transportation (Speck, 2018). (5) *Incentives and rewards* engage stakeholders in tracking and rewarding sustainable mobility habits, encouraging sustainable travel behaviour through a system of rewards facilitated by merchants and mobility service providers, often employing ICT technologies to monitor citizens' mobility habits - i.e. GPS tracking systems (Ricci et al, 2020). (6) *Behavioural nudges* represent subtle interventions designed to influence individuals' transportation choices and encourage more sustainable travel behaviours by providing information and manipulating specific factors to encourage desired outcomes (Barr et al, 2021). (7) *Technology solutions* promote alternatives to single-occupancy vehicle trips. These solutions encompass various techniques, including sensor-driven lighting, enforcement and security measures, as well as real-time data collection, all aimed at enhancing street efficiency and encouraging sustainable travel practices (Duncan et al, 2016). Together, these interventions form a comprehensive toolkit for fostering behavioural change and promoting more sustainable urban mobility patterns.

| Travel behaviour change | | |
|-------------------------|---|---|
| Sub-category | Definition | Source |
| Educational campaigns | Educational campaigns represent an encouragement strategy for active mobility, aimed at raising awareness of multimodal and sustainable travel practices. | Hauke et al, 2014 |
| Zoning regulations | Zoning regulations delineate permissible land use and operational activities to shape transportation patterns within comprehensive master or local plans. | Chiqui et al, 2016 |
| Parking policies | The parking policy, within an organization, is the set of regulations governing parking lot management. Its aim is to improve parking management through the implementation of diverse strategies and functions, tailored to address specific challenges as they arise. | Tosics et al, 2022 |
| Congestion pricing | Congestion pricing is a strategy aimed at aligning the cost of driving with its inherent value by increasing fees for driving on congested routes or within densely populated downtown areas, thus reflecting demand dynamics more accurately. | Speck, 2018 |
| Incentives and rewards | An incentive-based solution in the mobility sector entails a specialized business model centered on a tracking and reward system involving four primary stakeholders: citizens, municipalities, merchants, and mobility service providers. | Ricci et al, 2020 |
| Behavioural nudges | Behavioural nudges in Travel Behaviour Change encompass subtle interventions strategically crafted to sway individuals' transportation decisions and foster the adoption of more sustainable travel behaviours. | Thaler and Sunstein, 2008; Barr et al, 2021 |
| Technology solutions | These solutions utilize advancements in information technology, data analysis, and communication to shape travel behavior and advocate for alternatives to single-occupancy vehicle trips. | Duncan et al, 2016 |

Figure 2. Categorisation framework for interventions that encourage active mobility: 'soft' interventions (source: authors)

Integrating 'soft' and 'hard' measures maximises effectiveness in driving cities towards sustainable mobility patterns, mitigating the adverse effects of car reliance and promoting a culture of sustainable mobility (García-Garcés et al, 2016). Therefore, the combination of street redesign actions, targeted incentives, educational campaigns and zoning regulations offers a powerful tool for encouraging active mobility and discouraging car use, changing the travel behaviour of citizens, as well as strengthening the political will and commitment to implement the transformation. As such, CityWalk 2.0 project relies upon these elements in its approach to promote energy-efficient urban mobility, encompassing interventions at both the city and citizen levels. Moreover, the project aims to stimulate political will and commitment to drive

systemic change, recognizing that effective urban mobility transformations require a collective effort from policymakers, stakeholders and the broader community.

4. Case studies of Active Mobility interventions in CityWalk 2.0 Pilot Cities (Nyiregyhaza/ HU, Ptuj/ SL, Valjevo/ RS)

The CityWalk 2.0 project has brought together a consortium of pilot cities to explore innovative approaches aimed at promoting sustainable urban mobility and enhancing the pedestrian experience. Across diverse urban landscapes, these pilot cities have embarked on a collective journey to reimagine streets as vibrant public spaces, prioritising the needs of pedestrians and fostering active transportation modes. Through collaborative efforts, each pilot city has implemented in CityWalk project a unique set of strategies and interventions tailored to its specific context and mobility challenges, continuing these efforts in CityWalk 2.0. The three selected case studies namely Nyiregyhaza (Hungary), Ptuj (Slovenia) and Valjevo (Republic of Serbia) (Figure 3) implemented actions in CityWalk and proposed a set of actions for CityWalk 2.0 which cover the two main intervention categories, respectively street redesign and travel behaviour change.

4.1 Active mobility in Nyiregyhaza, Hungary

Nyíregyháza, located in northeastern Hungary, holds the status of a city with county rights and serves as the capital of Szabolcs-Szatmár-Bereg. With a population of around 118.000 residents, it holds the seventh position among Hungary's largest cities and it is the second largest in the Northern Great Plain region. Its historical evolution positions it as a significant economic and cultural centre in the area. Nyíregyháza developed the Sustainable Urban Mobility Plan in 2018, which sets the proper context for the CityWalk objectives. Its main actions include the completion of walking and cycling infrastructure and the induction of zoning regulations.

Firstly, the 'Downtown Pedestrian Streets' project in Nyíregyháza addressed the challenge of excessive car use in the city centre, leading to air pollution and traffic accidents. The solution involved a comprehensive pedestrianisation effort spanning from 1987 to 2012. The downtown area was transformed into a car-free pedestrian corridor adorned with green spaces, restaurants, cafes, fountains and sculptures. This created a peaceful urban oasis suitable for outdoor events and featuring Hungary's largest bridge between buildings. Emergency and cargo vehicles are the only authorised vehicles, ensuring barrier-free traffic for pedestrians and cyclists. The investment resulted in decreased car traffic, greener and safer surroundings, attracting more pedestrians and cyclists who contribute to the local economy by frequenting restaurants and outdoor cafes.

Secondly, the purchase of technological equipment for passenger counting (sensors) and user feedback (tablet with suitable software) is vital for the pilot activity in Nyíregyháza. It aims to assess public transport utilization and user experiences, with the goal of improving public transport service quality. The pilot seeks to provide the city with current data on public transport usage and gather feedback on satisfaction, problems and needs. Ultimately, it aims to boost public transport usage indirectly. The device will be deployed on local government-owned buses operated by Volánbusz Zrt, promoting a change in the citizens' travel behaviour.

4.2 Active mobility in Ptuj, Slovenia

The city of Ptuj, situated in northeastern Slovenia, serves as the administrative center. As Slovenia's oldest documented city, Ptuj traces its roots back to the late Stone Age and evolved from a Roman military stronghold. Positioned strategically at the intersection of the Drava River and a historic trade route linking the Baltic Sea with the Adriatic, Ptuj holds significance in the traditional region of Styria and was historically part of the Austria-Hungarian Empire. The Municipality of Ptuj adopted in 2017 the Sustainable Urban Mobility Plan for the Maribor Functional Urban Area, of which it is a part. The main objectives of SUMP are: (i) to have a better traffic planning and management (ii) to promote walking as one of the most important ways of travelling, (iii) to further promote cycling and creation of additional cycling infrastructure in the city, (iv) to improve public transport to be more appealing and (v) to enforce rational use of motorized vehicles (Letnik et al, 2019).

In the first CityWalk project, Ptuj focused on a single action, combining both street redesign actions such as completion of pedestrian streets (walking infrastructure) and low speed-limit streets with zoning regulations that encourage travel behaviour change. The renovation of Ptuj's city marketplace, completed in 2020, addressed limited pedestrian accessibility due to interior and exterior poor conditions. The comprehensive solution included renovation, new facility establishment and traffic regulation adjustments. The outcomes of this actions were increased attractiveness, equitable access, as well as cultural and economic stimulation.

For CityWalk 2.0, Ptuj City pilot investment will introduce an innovative strategy to tackle travel behaviour challenges and gather insights beneficial to the program area. With a focus on enhancing pedestrian infrastructure, encouraging walking, minimising car dependency and fostering behaviour change, this small-scale initiative aims to advance urban mobility development. The proposed intervention will promise a fresh visual identity for the city while enhancing safety and mobility for residents and tourists alike through the implementation of parklets, urban furniture/ amenities and behavioural nudges. By addressing traffic concerns, it aims to cut CO2 emissions caused by congestion. This initiative will highlight the power of urban design and small interventions to enrich an area and address various issues resulting from neglectful urban development.

4.3 Active mobility in Valjevo, Republic of Serbia

Valjevo serves as both a city and the administrative hub of the Kolubara District in western Serbia. As of the 2022 census, the administrative region of Valjevo boasted a population of 82.169 residents, with 56.145 residing in urban areas. The Sustainable Urban Mobility Plan for Valjevo was designed under the first CityWalk project and it aims to enhance walking conditions to reduce emissions, noise and enhance safety, fostering sustainable urban transport, particularly walking and cycling (Danilović and Đorić, 2020).

Within the first CityWalk project, the City of Valjevo focused on traffic calming measures, urban signage and furniture, as well as zoning regulations. Therefore, a pilot action for active mobility was undertaken to enhance the city's walkability and promote healthier lifestyles. This initiative encompassed the design and implementation of thematic walking routes, accompanied by clear signage and signalization for pedestrians, cyclists, and tourists. Furthermore, recognizing the need to educate citizens on traffic safety and the benefits of walking and cycling, a series of educational workshops and promotional events were organized.

The pilot action envisaged by the City of Valjevo in CityWalk 2.0 project refers to tactical urbanism and street design interventions, aimed to regulate pedestrian, bicycle and vehicles traffic and parking, enhance mobility, increase safety and improve the appeal of the Valjevo's central area. By implementing innovative solutions, the city centre will benefit from reduced emissions, green areas and infrastructure dedicated to walking and cycling. The main challenge addressed by the Čika Ljubina Street refers to the lack of organisation and usage regulations for pedestrian, bicycle and car traffic intersections. The proposed action will renovate the physical infrastructure and green areas, differentiating between car and pedestrian routes and includes horizontal markings for pedestrian pathways. Additionally, the city will acquire equipment like solar decorative lighting, vertical signalling, traffic calming devices and bicycle parking facilities. Upon completion, the area will be more walkable, attractively designed, safer and friendlier for pedestrians and cyclists.

4.4 Comparative analysis

Despite the distinct local contexts of these cities, positive outcomes have been demonstrated through actions such as improvements in traffic safety, adoption of active mobility means and diversified transport modes. The three pilot's concepts, methodologies and tools can be replicated or adapted in other EU cities facing similar challenges, accelerating efforts to improve urban mobility. Therefore, documenting results, challenges and successes can serve as a valuable resource for other cities, aiding knowledge sharing and understanding of potential benefits.

In this context, a brief comparative analysis has been conducted between the approaches of the CityWalk 2.0 pilot cities. The results showcase the evident impact of 'soft' and 'hard' actions across various dimensions. Common walkability issues, as well as the elevation of pedestrians and cyclists to the apex of the "traffic pyramid" are highlighted in the cities' approaches to achieve sustainable urban mobility. The comparative analysis reviews the pilot actions in the three cities according to five main criteria: (1) effectiveness of implementation, (2) impact on urban mobility patterns, (3) socio-economic benefits, (4) accessibility/ inclusivity measures and (5) sustainability and resilience of the initiative (Tabel 1).

Tabel 1. Comparative analysis results

| Criteria | Nyiregyhaza (Hungary) | Ptuj (Slovenia) | Valjevo (Serbia) |
|--|---|--|---|
| Effectiveness of implementation | Successful pedestrianization efforts | Renovation of city marketplace | Enhanced city's walkability |
| | Proactive measures to improve public transport services | Low speed-limit streets with zoning regulations that encourage travel behaviour change | Promotion of healthier lifestyles |
| Impact on urban mobility patterns | Likely shift towards reduced car traffic and increased walking/ cycling | Potential positive changes in urban mobility patterns | Improvement in pedestrian routes and signage for different traffic categories |
| Socio-economic benefits | Improved air quality, increased foot traffic for local businesses | Stimulated economic activity and cultural events, increased attractiveness | Urban design improvements |
| | Enhanced public space utilization | Benefited local businesses and residents | Citizens' education and awareness-raising campaigns |

| | | | |
|--------------------------------------|--|---|---|
| Accessibility and inclusivity | Improved accessibility for pedestrians and cyclists | Planned enhancements for barrier-free environments | Improved accessibility for pedestrians and cyclists |
| | Promotion of inclusivity and community engagement | Creation of inclusive environments for diverse user groups | Prioritization of pedestrian safety and accessibility |
| Sustainability and resilience | Alignment with sustainability goals and long-term resilience | Contribution to sustainability and resilience in urban mobility | Promotion of active transportation modes |
| | Investment in sustainable mobility solutions | Preparation for future environmental and social challenges | Enhancement of the city's resilience to future challenges |

Source: authors.

In what concerns the effectiveness of implementation, Nyiregyhaza's pedestrianization efforts have been successfully implemented over several years, transforming the downtown area into a car-free pedestrian corridor. Additionally, the city's proactive measures to improve public transport services through the acquisition of equipment for passenger counting and user feedback demonstrate effective implementation strategies. Ptuj's intervention of city marketplace renovation and the planned initiatives for CityWalk 2.0, indicate a commitment to enhancing pedestrian infrastructure and addressing traffic concerns. Valjevo's interventions have been effectively implemented to improve pedestrian accessibility and safety.

Regarding the impact on urban mobility patterns, Nyiregyhaza's pedestrianization project has likely led to a noticeable shift in urban mobility patterns, with reduced car traffic and increased walking and cycling. While the full impact may require longitudinal studies, initial observations suggest positive changes in travel behaviour. The proposed interventions for Ptuj aim to encourage walking, minimize car dependency, and enhance safety, potentially leading to positive changes in urban mobility patterns. However, the true impact will depend on the effectiveness of CityWalk 2.0 initiatives in promoting active transportation modes. Valjevo's interventions have likely influenced urban mobility patterns by improving pedestrian accessibility and promoting healthier lifestyles. The city's focus on sustainable mobility solutions indicates a commitment to creating a more walkable and bike-friendly environment.

As far as socio-economic benefits are concerned, Nyiregyhaza's transformation of the downtown area has likely generated socio-economic benefits, such as improved air quality, increased foot traffic for local businesses, and enhanced public space utilization. These benefits contribute to economic vitality and social cohesion within the city. Ptuj's interventions, including the renovation of the city marketplace, are expected to stimulate economic activity and cultural events, benefiting local businesses and residents. By creating vibrant public spaces, Ptuj enhances the city's appeal and promotes community engagement. Valjevo's interventions have likely resulted in increased attractiveness of the urban space and an increased awareness of citizens in what concerns the importance of active mobility.

In terms of accessibility and inclusivity, Nyiregyhaza's pedestrian-friendly environment improves accessibility for pedestrians and cyclists, ensuring equitable access to transportation services. By prioritising active transportation modes, Nyiregyhaza promotes inclusivity and fosters a sense of community within the city. Ptuj's planned interventions for CityWalk 2.0 aim to enhance pedestrian infrastructure, making the city

more accessible and inclusive for all residents and visitors. These efforts contribute to creating barrier-free environments and promoting social inclusion. Valjevo's interventions have likely improved accessibility for non-motorized traffic participants, creating urban environments that accommodate diverse user groups.

Sustainability and resilience are present in all three pilot cities. Nyiregyhaza's focus on reducing car dependency and promoting active transportation aligns with sustainability goals, contributing to long-term environmental resilience and resource efficiency. By investing in sustainable mobility solutions, Nyiregyhaza enhances the city's ability to withstand future challenges. Ptuj's interventions, particularly those aimed at reducing CO2 emissions and enhancing safety through pedestrian infrastructure improvements, contribute to sustainability and resilience in urban mobility. By prioritizing sustainable transportation options, Ptuj prepares for future environmental and social challenges. Valjevo's pilot actions contribute to sustainability by improving environmental quality and promoting active transportation modes. These efforts enhance the city's resilience to future challenges and support long-term environmental goals.

To sum up, the comparative analysis of interventions in the three cities sheds light on the effectiveness of various strategies in promoting sustainable urban mobility. Each city's approach, tailored to its specific context and mobility challenges has demonstrated notable successes in improving pedestrian infrastructure, reducing car dependency and enhancing the overall quality of urban mobility. From successful pedestrianization efforts in Nyiregyhaza to the revitalization of public spaces in Ptuj and Valjevo's interventions of urban streets' signage, these interventions have generated socio-economic benefits, improved accessibility and contributed to long-term sustainability and resilience. While challenges remain, such as the need for longitudinal studies to assess the full impact of interventions and ongoing efforts to address cultural attitudes towards transportation, the comparative analysis underscores the importance of proactive measures and collaborative approaches in creating more liveable, walkable, and inclusive urban environments.

Lessons learned from the CityWalk pilot cities' interventions can inform future initiatives aimed at advancing sustainable urban mobility and fostering resilient cities for all. To achieve this goal, a set of five key policy recommendations are proposed for other cities based on the results of the CityWalk 2.0 pilot actions, tools and methodologies:

1. Encourage active transportation through investments in dedicated bike lanes, pedestrian-friendly streets and safety measures.
2. Expand public transportation accessibility, reliability and affordability to incentivize its use over private car ownership.
3. Implement congestion pricing schemes to discourage single-occupancy vehicle trips and alleviate urban traffic congestion.
4. Create standard street design models for various urban street categories, prioritizing walking, cycling and public transport over personal vehicle usage.
5. Implement behavioural strategies like mobility management to influence psychological factors, encouraging voluntary shifts from car dependency to non-auto travel modes.

By adopting these policies, cities can effectively reduce carbon emissions, enhance urban liveability by prioritizing pedestrian-friendly infrastructure, cycling networks and create more resilient urban environments for their citizens.

5. Conclusions

In conclusion, the literature review underscores the multifaceted nature of sustainable urban mobility, highlighting its significance in contemporary urban planning and transportation discourse. Current mobility policies aim to reduce car usage and promote changes in travel behaviour among car users, driven by the recognition of the social costs associated with car dependency, such as traffic congestion, accidents, air pollution and global warming. Furthermore, the synthesis of existing literature reveals a growing emphasis on active mobility as a pivotal component in promoting sustainable transportation systems. Active mobility interventions, encompassing both 'hard' interventions like street redesign and 'soft' interventions like travel behaviour change programs offer promising avenues for fostering more equitable, energy-efficient and environmental-friendly urban mobility. Strategies such as pedestrianization, cycling infrastructure development, educational campaigns, zoning regulations and congestion pricing demonstrate the diverse approaches cities can adopt to promote sustainable urban mobility. Furthermore, the integration of 'soft' and 'hard' measures emerges as a key strategy for maximizing the effectiveness of urban mobility interventions. By combining infrastructure improvements with initiatives aimed at influencing individual travel behaviours, cities can create more walkable pathways.

In summary, the comparative analysis of the CityWalk 2.0 pilot cities located in Central and Eastern Europe (Nyiregyhaza, Ptuj, and Valjevo) reveals a diverse array of interventions aimed at promoting sustainable urban mobility. Each city has implemented unique strategies tailored to its specific context and mobility challenges, encompassing both 'hard' interventions such as street redesign and 'soft' interventions like travel behaviour change programs. Despite their differences, all three cities share a common commitment to promote active mobility as a core strategy. The findings highlight the importance of adopting a holistic approach that addresses infrastructure improvements, behavioural change and political commitment. Through collaborative efforts, the CityWalk 2.0 pilot cities are pioneering new pathways towards energy-efficient urban mobility, serving as beacons of innovation and inspiration for other cities dealing with similar challenges as decreasing the carbon intensity of urban transportation systems.

The outcomes of CityWalk pilot cities' interventions can inform future initiatives aimed at advancing sustainable urban mobility through the following policy recommendations: promote active transportation infrastructure, enhance public transport accessibility and reliability, introduce congestion pricing, develop standardized street designs prioritizing walking, cycling, and public transport, as well as implement behavioural strategies to reduce car dependency.

In future research, it is essential to delve into the longitudinal effects of sustainable urban mobility initiatives on various aspects of community well-being, including health outcomes, economic growth and environmental resilience. Understanding the interplay between these factors over time can provide invaluable insights into the effectiveness and sustainability of different mobility interventions. Additionally, initiatives should prioritize the integration of emerging technologies, such as smart transportation systems, flow counting sensor and electric mobility solutions to optimize the efficiency, accessibility and environmental impact of the urban transportation.

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Appendix 1. Map of analysed pilot cities from CityWalk 2.0 project



Figure 3. Geographical distribution of case studies (source: authors)

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