TeMA

Journal of
Land Use, Mobility and Environment

The climatic, social, economic and health phenomena that have increasingly affected our cities in recent years require the identification and implementation of adaptation actions to improve the resilience of urban systems. The three issues of the 16th volume will collect articles concerning the challenges that the complexity of the phenomena in progress imposes on cities through the adoption of mitigation measures and the commitment to transforming cities into resilient and competitive urban systems.

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THE CITY CHALLENGES AND EXTERNAL AGENTS. METHODS, TOOLS AND BEST PRACTICES




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The cover image shows a copy of the 1987 UN report “Our Common Future – The report of the world Commission on Environment and Developments”. The picture has been taken in TeMA Lab in July 2023. On the bottom, there is a collage made up of four pictures of recent climate disasters (Source: Google images)

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Also, this second issue of the 2023 volume of TeMA Journal focuses on the challenge. The challenge that the complexity of the ongoing phenomena imposes on cities involves adopting mitigation measures aimed at reducing the adverse effects of these phenomena, and at the same time, requires an extraordinary effort from scholars, researchers, technicians, and decision-makers to develop technical methods and operating procedures for transforming cities into resilient, competitive urban systems rapidly. The three issues of the 16th volume collect articles concerning the climatic, social, economic and health phenomena that have increasingly affected our cities in recent years and, hence, require the identification and implementation of adaptation actions to improve the resilience of urban systems.

For this issue, the section "Focus" contains four contributions. The first article, titled "Sustainable mobility for urban regeneration" by Ilenia Spadaro, Chiara Rotelli, Pietro Adinolfi (University of Genova, Italy), proposes a methodological approach was defined which identifies the main phases to follow and the aspects to pay attention in order to achieve a sustainable regeneration of the territory starting from the proposition of sustainable mobility projects.

The second article of the section, titled "Suitable sites for built-up area expansion in Kamalamai municipality, Sindhuli district, Nepal" by Samin Poudel, Shahnawaz Shahnawaz, Him Lal Shrestha, Unigis Kathmandu (UNIGIS Salzburg Kathmandu, Nepal and University of Salzburg, Austria), identifies efficiently the suitable areas for built-up development in Kamalamai municipality (Nepal) using an analytical Hierarchy Process pair-wise comparison of Landsat images of 2001, 2016, and 2021 for Land Use Land Cover trend analysis.

The third article, titled "The role of peri-urban agriculture in the pandemic era. Some case-studies compared in Italy" by Donatella Ciladea (University of Molise, Italy), proposes some reflections are made on the new functions of peri-urban agriculture. The author compares the opportunities offered by the European framework with its new tools and the local regional contexts that constitute the Italian panorama.

The last article, titled "Urban open and green spaces: is Malta planning and designing them to increase resilience and sustainability?" by Sarah Scheiber (University of Malta) e Floriana Zucaro (University of Naples Federico II, Italy), focuses on the system of urban open and green spaces whose planning and design, through a systemic approach, can address current and future urban challenges such as climate change. The main aim is to provide local decision-makers with urban open and green spaces planning and design principles based on a mixed-method approach adopting Malta as a case-study.

The section "LUME" (Land Use, Mobility and Environment) contains five articles. The first is titled "Climate change-induced conflicts in Southeast Nigeria and urban food security" by Samuel Okechi Okafor, Sebastian Okechukwu Onah, George Ohabuenyi Abah and Obianuju Oranu Chizoba (University of Nigeria and Lilongwe University of Agriculture and Natural Resources, Malawi), focuses on the necessity of empirically exploring the nexus between climate change-induced conflicts and urban food insecurity in developing nations such as in sub-Saharan Africa.

The second contribution, titled "Nanoparticles measurement on electric, gas, and diesel buses in Bogotá Colombia mass transportation system", by Diego Armando Vargas, Boris Galvis Vanesa Durán Camilo Bernal (Universidad de la Salle, Colombia). The paper aims on the topic of the concentration of traffic-related air pollutants that is relevant in many megacities with high population density, heavy traffic, and prolonged travel times. The authors compare the nanoparticles measured for diesel, gas, and electric buses during their normal operation in the city of Bogota, Colombia.

The third article, titled "Remote sensing investigation of spatiotemporal land-use changes" by Kulasegaram Partheepan, Muneeb M. Musthafa, and Thangamani Bhavan (Bursa Uludag University, Türkiye), focuses on disastrous environmental and socio-economic consequences related to rapid and haphazard urbanization. The study employed geographic information systems and Landsat imagery from 1979, 2000, and 2021 to look at regional and temporal variations in Batticaloa's land use cover.

The fourth paper, titled "A platform to optimize urban deliveries with e-vans. Dealing with vehicles range and batteries recharge" by Maria Pia Valentinia, Filippo Carrese, Chiara Colombaroni, Valentina Conti, Matteo Corazza, Maria Lelli, Mostafa Mohammadi, Silvia Orchi, Fernando Ortenzi, Golman Rahmanifar, Giuseppe Tomasino, and Gaetano Fusco (University of Rome Sapienza, University of Roma Tre and ENEA, Italy), reports the results of a research targeted to develop a Decision Support System (DSS) for planning and operation of urban deliveries carried out with electric vans.

The fifth article, titled "Evaluation of sustainability of university campuses. The evaluation of Bursa Uludag University Görükle Campus according to UI Green Metric Word University Ranking" by Gamze Altun and Murat Zencirkıran (Bursa Uludag University, Turkey), aims to shed light on the progress in the development of the green Bursa Uludag University Görükle Campus (Turkey) to understand the current situation of all initiatives to run a campus that covers sustainability in all its aspects and the upgrade of the campus to a green campus.

The Review Notes section proposes five insights on the themes of the TeMA Journal. The Urban planning practice section of Review Notes, "Energy consumption vs City: The Italian Energy Communities", delves into one of the most discussed strategies to enhance energy performance of cities for the Italian context.

The second section, "Policies and practices to transition towards Renewable Energy Communities in Positive Energy Districts", by Federica Gaglione, focuses its attention on a strongly felt issue in the scientific and political debate to accelerate decarbonization and urban transitions in Europe on Positive Energy Districts (PED). The contribution highlights the critical issues present both in the modeling and simulation of different energy scenarios at district scale that in the unambiguous definition of PED, leaving open the field of existence of the various integrations in the planning processes also due to a still fragmented body of legislation. The third contribution, "New frontiers for sustainable mobility: MaaS (Mobility as a Service)" aims at delving into the issue of sustainable urban mobility through a new mobility paradigm represented by MaaS. It analyzes the potential sustainability benefits of using MaaS in the urban context by citing some interesting and significant journals and books which delved into the topic. The fourth section, "The interventions of the Italian Recovery and Resilience Plan: sustainable development", by Sabrina Sgambati, deals with the topic of sustainable development in urban environments, analysing it in the frame of the Italian National Recovery and Resilience Plan and taking into account the recent projects and initiatives that seek to improve environmental, energy, and infrastructural performance of urban areas. Finally, the fifth section, "Energy transition: pinning down the gaps between theory and practice", by Nicola Guida, focuses on the challenges urban energy planning commonly faces, identifying the gaps between the theoretical scientific progress and their practical implementation.

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Sustainable mobility for urban regeneration

NRRP, sustainability certifications in Albisola

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Abstract

The choice of the mobility system is very topical today because it determines how the territories will develop in the years to come, which infrastructures will have to be built and which lifestyles will take shape in the cities of the future.

The research presented in the paper starts from the study of sustainable mobility and the analysis of virtuous cases. From this study, a methodological approach was defined which identifies the main phases to follow and the aspects to pay attention in order to achieve a sustainable regeneration of the territory starting from the proposition of sustainable mobility projects. This approach also proposes a method and instrument for assessing the level of sustainability in line with the principle "Do No Significant Harm" presented in the National Recovery and Resilience Plan. The priorities aspect introduced concerns the integration of the quadruple helix concept, for a multi-stakeholder governance and sustainable regeneration. The illustrated research involves in fact four actors: it starts from a call for proposals carried out within the Genoa University, promoted by the Municipality of Albisola Superiore, in Liguria region, and sees the collaboration of the R2M Solution company and citizens.

Keywords

Mobility; Regeneration; Participation; Sustainability; Certification.

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1. Introduction

1.1 The sustainable mobility and urban regeneration: strategies, policies and virtuous case studies

The choice of the mobility system is very topical today because it determines how the territories will develop in the years to come, which infrastructures will have to be built and which lifestyles will take shape in the cities of the future. By virtue of the possibility of choosing mobility on the part of users, the awareness of having to diversify the transport offer has developed by encouraging solutions that are as compatible as possible with the sustainable development of society, the economy and the environment.

Sustainable mobility indicates a way of moving related to the concept of territorial sustainability and oriented towards the reduction of pollution risks and the protection of health and public space as a common good and energy saving. According to the European strategy on sustainable development definition approved in 2006 by the European Council, the objective of sustainable mobility is "to ensure that our transport systems meet society's economic, social and environmental needs whilst minimizing their undesirable impacts on the economy, society and the environment" (Council of European Union, 2006). The concept of sustainable mobility should be seen as an approach that institutions and professionals can use to guide society and govern development in a sustainable way by placing the people at the center of urban mobility (Tscherner, 2016). The main definitions found in the literature stress that it is not enough to consider the environmental aspects, but also the social and economic impacts must be considered (Gallo & Marinelli, 2020).

To understand the evolution of the concept of sustainable mobility, it is enough to retrace the path from the Aalborg Charter, with its 10 principles (1994) to the Leipzig Charter, which more than 10 years later (2007) placed new emphasis on the concept of "urban development integrated" and governance to arrive today at the new approach of urban mobility policies represented by the Sustainable Urban Mobility Plans (SUMP) (Vittadini, 2019). Plans that "builds on existing planning practices and takes due consideration of integration, participation, and evaluation principles" (Eltis, 2013).

To obtain a real development of sustainable mobility it is necessary both to encourage the diffusion of the right technologies and get people to prefer this type of modes of transport. The built environment, the existing mobility system and the perception of its inhabitants, it is now proven that they are able to influence the choice of the mode of movement (means, routes). "This choice is not only conditioned by the mere presence of pedestrian areas, cycle paths, etc..., but also by the perception of their accessibility" (Larco et al., 2012).

The infrastructures of mobility (highways, roads, bridges, cycle path, etc.) that we build today will establish the ecosystem impacts for decades to come. Therefore, we must use the more sustainable, efficiency and effectiveness existing technologies, material, to planning and delivering the most resource and energy conserving infrastructure within the limits of budgets and priorities. In addition, the sustainability of the project depends not only on its intrinsic design, but on how that design integrates and functions for the community in which it resides.

Among the solutions for environmentally friendly and smart mobility policies, there are formulation of Sustainable Urban Mobility Plans; carpooling and car sharing, strengthening of local transport, integrated planning of means of transport, Apps and systems for info mobility, construction of new cycle paths, toll and pricing policies and electric mobility but also pedestrians areas or paths.

As a consequence of a greater quantity and quality of the offer, a greater demand for sustainable mobility can be achieved with measures such as:

- incentives to promote use of local public transport and/or other forms of sustainable mobility;
- incentives to promote less use of private mobility (especially the car);
- integrated urban and transport planning.

In addition to the incentives, the participation, but also communication and sensibilization actions are measures that can act directly on the behaviour and habits of individuals and that can push them towards alternative mobility methods to the use of private vehicles (MIT, 2022). Speaking of planning and strategies to promote sustainable mobility, a fundamental role is played by the integration and involvement of the four actors of the quadruple helix concept of Carayannis & Campbell (2009), in which "technological and social innovations result, in general, from the cooperation and search for synergies among four stakeholder groups: administration (local government, government), business, science and society".

The European Union has set itself ambitious climate goals for the future, with a shared commitment by member states to reduce emissions. Naturally, urban transport is one of the factors that contribute most to CO_2 emissions into the atmosphere and for this reason, initiatives and projects for sustainable mobility have been promoted in Europe for several years now.

In recent years, some of European cities become an example to follow in the field of sustainable mobility. Stockholm, Amsterdam, Copenhagen, Paris, but also Parma and Pesaro in Italy, for example, are cities that have proposed new models to be pursued for a sustainable mobility and urban regeneration.

Stockholm, Swedish capital, has been leader on sustainable mobility for years and since 2017 has powered its bus and subway system exclusively and entirely with renewable energy. About 43% of daily commuting are made by public transport. This means that every day 800,000 people commute between home and work without generating environmentally damaging local emissions (Sjöman et al., 2020).

In Amsterdam, from 1 July 2019 and until 2025, 12,500 parking spaces in the historic centre of the city will be cancelled; the space obtained will be returned to the community through interventions to enhance cycle mobility, widening sidewalks and planting new trees. The use of public transport is facilitated by the changes to the opening hours of the underground, on which it is possible to bring your own bicycle, with the extension of access until midnight, and the introduction of the free ticket for children aged less than twelve years old.

The Dutch city is already the capital of the cycling, around 65% of people travel by bicycle. Only 22% of trips in Amsterdam are by car. Already today there is a massive presence of cycle paths, as well as a branched and efficient public transport system. Yet despite these staggering numbers, the majority of road space is still devoted to cars.

Copenhagen, Danish capital, has been awarded as a Sustainable City of the Future and is one of the "greenest" cities in Europe. Sustainable mobility is intertwined with energy and water saving initiatives, within local policies towards a society that is kinder to the environment and more liveable for its inhabitants. Copenhagen on track to become the first carbon-neutral capital in the world. The city plans to achieve the goal through various sustainable policies, based on four pillars: energy consumption, energy production, low-emission mobility, city administration initiatives.

The historic centre is entirely closed to traffic and the bicycle is one of the preferred means of transport for commuters, but also for tourists.

The city of Copenhagen has launched the first of 26 bicycle-only suburban thoroughfares: long, well-paved, cycle paths to connect the suburbs with the city centre, up to 22 km long and requiring the cooperation of 21 separate municipal administrations. The most innovative thing about the cycling infrastructure in Copenhagen is represented by the "Green Wave": a regulation of traffic lights along the main artery of the center so that the green lights are synchronized to the rhythm of the average cyclist. For the city of Copenhagen, cycling is not an achievement, but rather a highly priority political tool for creating a more sustainable and liveable city for present and future generations.

There is then other cities: Paris, Ottawa, Copenhagen, Melbourne, Barcelona and Milan for example that are working on the planning of the "15 minutes-city". This strategy proposes sustainable planning of urban space based on the concept of proximity, in order to reduce car travel within the city, promoting soft mobility. Proximity improves the quality of life of people acting, in particular, on the urban space by favoring closeness

among desired activities, and fostering accessibility though carbon-free movements such as pedestrian and cycle paths (Carra et al., 2022). Carlos Moreno (2019) identifies six essential social functions that must be rapidly accessible from anywhere in the city: housing, work, access to health care, food, learning and leisure should ideally all be reachable, within fifteen minutes, on foot or by bicycle. This innovative approach to urban planning requires ending a fragmented city, reducing the use, but also the presence of cars and leaving plenty of space to be able to plan and allocate to public space. This is a model which, albeit partly unknowingly, has been partially experimented by many citizens around the world during the pandemic period, through the practice of smart working and the application of anti-contagion rules (Moreno et al., 2020).
From the examples given, it is clear that mobility strategies can be a structural part of policies intended to allow cities, where the majority of the population now lives, to govern and contribute to the process of social, environmental and even economic regeneration, making the city more attractive. Therefore, mobility is no longer just a need for movement (of things and people), but as a project component interrelated with the various priority sectors.
Sustainable mobility and the governance processes that lead to the regeneration of our cities are therefore closely linked at "a Sustainable Urban Mobility Plan, a strategic plan that is designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life" (Eltis, 2013). Therefore, when a country develops sustainable mobility projects, it sets itself multiple objectives that must do both with ecology and environment as well as people's quality of life. The latter has a fundamental role in the success of a project, for this reason it is essential to raise awareness and involve the various actors present in the area (Administration, Research, Business and the population) to get to know and plan shared actions with those who will actually use the infrastructures and services and will thus help promote sustainability in regeneration projects.

1.2 National Recovery and Resilience Plan and sustainability certification

The Covid-19 pandemic has occurred in a historical moment in which was already evident and shared the need to adapt the current economic model towards greater environmental and social sustainability. Mobility in our cities has been greatly affected by the spread of the virus and the necessary social distancing measures (Ravagnan et al., 2022). Many cities have adopted mobility strategies for urban resilience, even implemented by tactical urbanism interventions, to face the crisis by the reorganization of urban mobility infrastructures and flows with a glance at a prevention of a massive and unsustainable return to private transport in the post-covid phase. The rethinking of urban mobility has thus raised a new awareness of authorities and citizens on a necessary "paradigm shift" on mobility systems (Ravagnan et al., 2022).
The pandemic, and the resulting economic crisis, prompted the EU to formulate a response with the launch of the Next Generation EU program in July 2020.
In the Next Generation EU, Italy has received resources relating to the Recovery and Resilience Facility (RRF) for a total amount of €191.5 billion to be used in the period 2021-2026 through the implementation of the National Recovery and Resilience Plan - NRRP (of which 51.4 billion for ongoing projects) (MISE, 2021).
As a consequence of the NGEU and consistently with the RRF, in July 2021 the National Recovery and Resilience Plan (NRRP) was approved by the Council of Ministers, which provides for an articulated set of reforms and investments that in the coming years will affect the areas of: digitization, innovation, competitiveness, culture and tourism (Mission 1); green revolution and ecological transition (Mission 2); infrastructure for sustainable mobility (Mission 3); education and research (Mission 4); inclusion and cohesion (Mission 5); health In particular, the Mission 3 of the NRRP aims to make, by 2026, the infrastructure system more modern, digital and sustainable, capable of responding to the decarbonization challenge indicated by the European Union with the strategies connected to the European Green Deal ("strategy for intelligent and

sustainable mobility", published on 9 December 2020) and to achieve the sustainable development goals identified by the United Nations 2030 Agenda.

The current transport infrastructure system in Italy suffers from shortcomings and delays that have significant effects on the country's growth potential and competitiveness. This weakness is exacerbated by the persistence of strong territorial differences, which go beyond the usual difference between North and South; but also between urban areas and internal and rural areas, which represent a strong obstacle to economic and social convergence and determine very different quality levels of transport services on the territory; they effectively limit people's movement possibilities, leaving entire communities isolated; and represent a major obstacle to economic convergence.

The topic of sustainable mobility in urban areas in the plan includes measures that deal with the strengthening of the energy redevelopment, the valorization of green public spaces, the encouragement of private action to improve the energy performance of buildings and consequently urban areas. Dealing with mobility issues is important to tackle the challenges linked to the scarcity of resources and the unavoidable consequences of climate change that threaten the future of urban systems. Measures must be accompanied, according to the NRRP, by integrated actions at the urban and metropolitan levels in order to obtain more efficient and successful results. The interventions will provide substantial benefits in terms of energy performance and environmental sustainability, but also in terms of urban attractiveness and competitiveness for companies and firms specializing in the field of energy management or production (Sgambati, 2022).

An example of an urban regeneration project financed by the NRRP concerns the Municipality of Nicotera: lands confiscated from the mafia which provides several measures including some for urban regeneration with the creation of an urban park and the inclusion of green areas. In addition to this, in the green area there will be also a cycle path and a pedestrian path. The funding is €2,484,335 and the project is presented as an innovative management model which provides for the direct participation of citizens together with the institutions and associations, thus leaving the possibility of participation by the various parties.

Another project financed with PNRR founds concerns the cycle paths of Italy with Mission 2 Component 2. For example, for the Tyrrhenian cycle path, a loan of 20 million euros is foreseen with which extraordinary maintenance of the existing cycle path from Ospedaletti to San Lorenzo al Mare and the new stretch that starts from the border between the municipalities of Imperia to Diano Marina and continue up to Andora. The goal is to connect Ventimiglia to Sarzana in 437-kilometre route along the entire arc of region, between the coast and the hinterland. The overall project of the Tyrrhenian cycle path envisages the creation of a single cycle path of more than 960 kilometres capable of joining Ventimiglia to Rome.

Thanks to the funds of the PNRR it will therefore be possible to create this cycle path, increasingly encouraging sustainable mobility.

The NRRP provides that these works must be completed by 30 June 2026.

In the framework of the European planning tools – the Recovery and Resilience Facility (NRRP) and the technical guidance of the European Commission – within the definition of objectives, principles and constraints for the elaboration of national plans, the focus is on two fundamental aspects: the assessment of direct and indirect environmental impacts of each measure in accordance with the principle of «Do No Significant Harm – DNSH» (Article 17 of EU Regulation 2020/852) and the compliance with strict time constraints for the implementation of interventions and the completion of expenditures.

The investments of the NRRP foresee significant resources for the implementation of programs as well as interventions. However, with respect to the European planning framework, the Italian context has to deal with the structural weaknesses of the existing models and procedures for the planning, design and construction of public works. The monitoring of this field often highlights an overall inefficiency and ineffectiveness with reference to the achievement of the objectives of environmental quality and respect of the implementation costs and times (Tartaglia & Castaldo, 2019).

For this criticality, the methodological approach proposed in section 2 analyzed possible tools that can be used. To produce tangible benefits for national funds for recovery and resilience, but also and above all to evaluate the sustainability of interventions from an environmental, economic and social point of view, the impacts of research must be measurable, for this reason the sustainability certification plays an important role within the presented research. Among these, the Envision protocol could be a valuable support as among the leading rating systems for assessing the level of sustainability of an infrastructure. Created in 2012 in the US by a collaboration between the Institute for Sustainable Infrastructure (ISI) and Harvard University, Envision aims to promote the design and implementation of sustainable infrastructure. The protocol then allows the level of sustainability of any infrastructure to be assessed with a single flexible and adaptable framework. Envision allows for a third-party measurement of an infrastructure's level of sustainability based on social, economic and environmental aspects, in line with the triple bottom line concept. Envision's rating system has been used in several countries, including Italy, certifying more than 142 projects with a total value of $118 billion.
The paper reports a methodology for planning sustainable mobility interventions that lead to urban regeneration, to improve the quality of life of the inhabitants, the environment and the city itself. In the proposed methodology, the National Recovery and Resilience Plan is seen as a possible financing channel and therefore useful for economic sustainability and, thanks to the sustainability certification, it is possible to quantify the sustainability of the intervention and guarantee its eligibility.

2. Methodology

The goal is therefore to create a guideline about the methods to be follow to achieve interventions that are sustainable and sources of urban regeneration for the cities in which they will be implemented.
The methodological approach proposed for a project of sustainable urban regeneration was structured according to different phases: knowledge of state of art, context analysis, planning and design part and sustainability certification.
Figure 1 shows the phases of the approach and the main questions that need to be asked in order to consider the priority aspects in the design.
Before even approaching the knowledge phase, it is necessary to ask oneself about the goal to be achieved, how to pursue it and from which examples you can take inspiration. Since sustainable mobility and regeneration are the objectives of this research, it is necessary to investigate if there are tools and strategies to ensure the sustainability of the planned projects and what funding can be drawn.
In the first phase, to define the state of art is necessary considers the territorial context and its needs, in particular it is necessary to carry out an analysis on the territory regarding the current situation of mobility. The levels of the analysis are two: the first consists in the identification of problems with a global analysis of the situation to understand the connections with the surrounding area (considering the provincial, regional but also national level) and then a punctual analysis is carried out where portions of the territory more small are taken into consideration and for each of them the critical issues are highlighted.
In order to better understand the current situation, it is necessary to involve the population, those who live in the place and therefore the first users of the services, for to fully understand the mechanisms that regulate traffic flows, mobility, availability of public transport and, more generally, the degree of citizens' satisfaction with transport and their need for services and infrastructures. The role of participation in the approach is strategic to achieve the goals of sustainable and participatory regeneration, to which all public and private actors in the area can contribute. The involvement must therefore take place during all phases of the urban planning project. The results of the participation are also transversal to all phases in the sense that it are useful and contribute to enriching the objective information, found during the cognitive and analysis phase, with subjective and qualitative information and are a valid support in the choice of interventions. As part of the approach, about involvement, two moments have been identified: during the survey it is possible to carry

out brief interviews with passers-by who meet, and online, involving a wider catchment area, a specific questionnaire has been planned and structured (an extract of the questionnaire is presented during the application, see section 3).

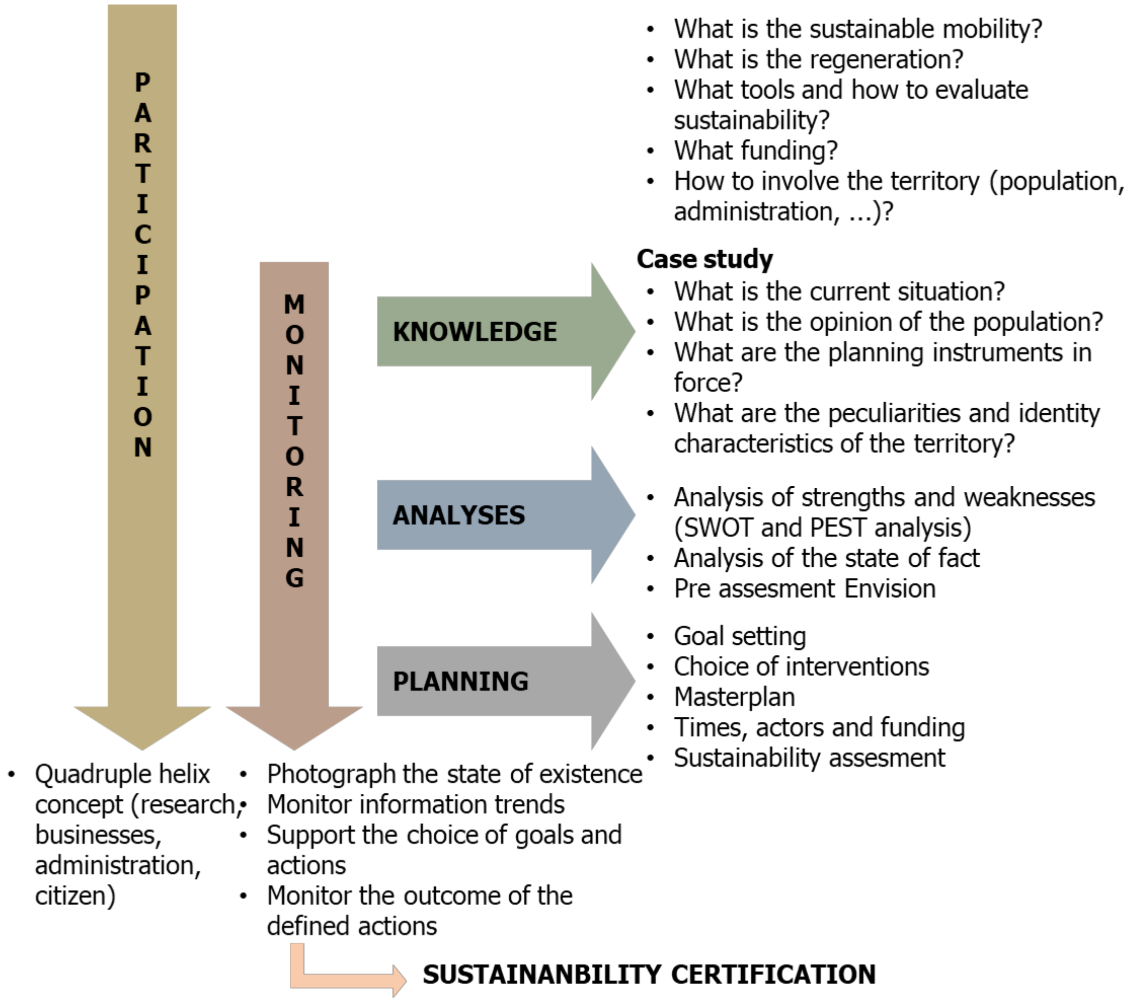


Fig.1 Methodology approach

During the knowledge phase different aspect must be considered.

To encourage the use of sustainable mobility it is essential to provide interchange car parks in which the user can park his car and use another means of transport to move around the city (for example, he could use the bicycle using specific bike sharing services). It is advisable to investigate whether there is sufficient equipment in the area capable of responding to requests throughout the year and whether, if not, there is the presence of spaces that can be used for this function.

Another important aspect to plan are the itineraries to be dedicated to soft mobility: pedestrian and cycle paths. In order to be able to identify the itineraries dedicated to soft mobility, it is advisable to analyze the activities present in the area and understand in in which areas it is a priority to pass because there are essential services to reach and connect (social functions as introduced in the 15 minute-city strategy). During the survey and in the urban planning instruments in force, it is also essential to find information about the spaces available that can be used for any new infrastructure, and it is necessary to carry out site survey in order to identify the shortcomings and strengths present.

In the cognitive phase it is also necessary to identify the peculiarities and places of interest and to analyze the urban planning instruments in force in the area. It is necessary to analyze which urban planning instruments are in force, considering the different territorial levels: regional plans, metropolitan plans and municipal plans.

The second phase consists in the analysis of the information gathered in the first phase. A significant number of analyzes exist as several scholars have pointed out, useful for outlining urban sustainability, with reference to the protection of the environment, economic impacts, participation in the life of the community. In the methodology the combined use of the two known SWOT and PEST analysis is proposed.

The SWOT analysis, short for Strengths, Weaknesses, Opportunities and Threats, provides a complete view of the state of the territory, it is also essential for identifying the strategic and operational context within which one will operate. Therefore, the SWOT analysis manages to evaluate, in the best possible way, all the factors with respect to a choice to be made and allows you to avoid errors of evaluation and make the best decisions for all parties. This happens because the first two factors, strengths and weaknesses, are closely related to the object while the second two factors, opportunities and threats, are related to the surrounding context.

The SWOT analysis begins with the definition of the objectives or goals to be achieved and then it is necessary to consider its main points:

S) Strengths: all the factors present that are useful to achieve the goal;

W) Weaknesses: all the factors present that are harmful to achieve the goal;

O) Opportunities: external conditions that are helpful to achieve the goal;

T) Threats: external conditions that could cause damage to performance.

Once the SWOT matrix has been created, it will be necessary to consider whether this purpose is achievable and, if so, the several prescribed actions will be carried out; in negative case, however, a new matrix will have to be made in order to succeed in the task (Pirlone et al., 2022).

Another tool used for analysis is the PEST analysis, short for Political, Economic, Socio-cultural and Technological. This type of analysis allows to consider aspects that otherwise would not be studied such as political and economic ones. Without them it would not be possible to provide measures and above all that they are subsequently financed. At the same time, analyzing the socio-cultural trends of the territory and the technologies present on it means that it can be considered a phase of complete knowledge in all aspects (Vardopoulos et al., 2021).

As a result of the SWOT and PEST analysis conducted, a pre-assessment of the Envision certification can be carried out. Envision certification is a protocol that aims to measure the social, environmental and economic impact of infrastructure by evaluating the project on five categories: Quality of Life, Leadership, Resource Allocation, Natural World and Climate and Resilience. These macro-areas make it possible to assess the sustainability of the project in its entirety on a scale of four levels: Verified, Silver, Gold, Platinum.

Based on what has been processed and collected from the previous analyses, it is indeed possible to verify the status of the project compared to the Envision assessment framework. Conducting an assessment in the early stages of design allows to estimate the level achieved at the state as is of the infrastructure and identify aspects that can be implemented to reach a higher level. Conducting an Envision pre-assessment at the origins of the design process allows one to understand both the technical aspects that need to be monitored and documented and to identify critical issues and/or opportunities that the project offers.

In a complementary way to SWOT and PEST analyses, Envision certification allows for assessments and criteria that address the design purposes to be developed.

Following the analysis phase, the internal and external context of the case study is now clear. In particular, for the critical points identified, it is possible to propose solutions that enhance the strengths instead.

The last phase involves planning and design part and so the creation of the masterplan with all the works and project proposals. Masterplan allows a better understanding of what will be the final scenarios, above all from a distribution point of view of the interventions on the territory. In fact, through the masterplan it is possible to have an image of what the territory will be like following the measures and therefore understand if there are weaknesses to improve and what the impact will be on the territory.

In the planning phase different design proposals are developed. To choose the most sustainable one a subsequent SWOT analysis is carried out.
After having elaborated the proposals and analyzed them all with the SWOT it is possible to identify the one that is best able to adapt to the territory and to respond to the objectives identified.
In a project whose objective is urban regeneration starting from sustainable mobility, it is necessary to point out some aspects. Urban regeneration is the first point of the strategy for reach a Circular city and ReSOLVE framework, developed by McKinsey, it can constitute a valid support in the choice of possible actions useful for improving the quality of life of our cities. The framework takes the core principles of circularity and applies them to six actions: Regenerate, Share, Optimise, Loop, Virtualise, and Exchange (McKinsey, 2015). Other important aspects are: sustainable mobility, urban furniture, new technologies, accessibility, greenery, architectural barriers and sustainability. These elements should be present in the projects and be able to mitigate the impact on the territory and, at the same time, guarantee sustainable urban regeneration projects that respect the environment and the existing territory, which reduce overbuilding and land consumption as well as to improve the quality of life.
At the end, the methodology questions how to evaluate the sustainability of the planned infrastructures and, above all, how to plan mobility and build infrastructures that help local communities to develop sustainably and therefore to regenerate.
This step takes over the concept of sustainable development, of circularity but also of a hierarchy of mitigation (Fig.2). In taking practical steps toward sustainability, it can be difficult to discern how to prioritize options or even take the first step. One way to prioritize these options is to consider the: (i) avoiding impacts by looking for alternative locations for development where impacts will be less severe, (ii) reducing or minimizing the impacts at the chosen development site, and, as a last resort, (iii) offsetting residual unavoidable damage on biodiversity (Bull et al., 2016).

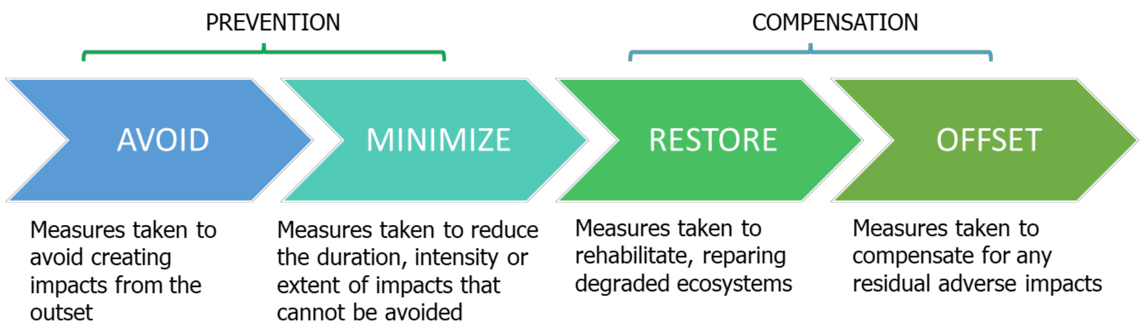


Fig.2 Hierarchy of mitigation

As well as in the world of construction there are multiple systems for assessing sustainability in building projects, various rating systems are also being developed and disseminated in the world of infrastructure. One of the main ones turns out to be Envision, which has a worldwide spread and allows for a comprehensive assessment of the project being analyzed. Envision is based on the use of a framework that applies a hierarchy across a range of topics.
The methodology aims to analyze three fundamental aspects useful for the monitoring and planning of sustainable regeneration projects. And the Envision protocol is proposed in the methodology as it precisely provides the opportunity to improve projects in these three dimensions (Fig.3).
First is the project life cycle: where trying to go beyond planning and design to the construction phase to consider operations and maintenance and also the end of useful life, such as the ability to disassemble and up-cycle materials.

Second is stakeholder collaboration: as introduced, the participation of an inclusive, representative group of stakeholders of the four main players: administration, business, science and society (quadruple helix concept) is essential to know, innovate and implement effective projects that aim at sustainability.

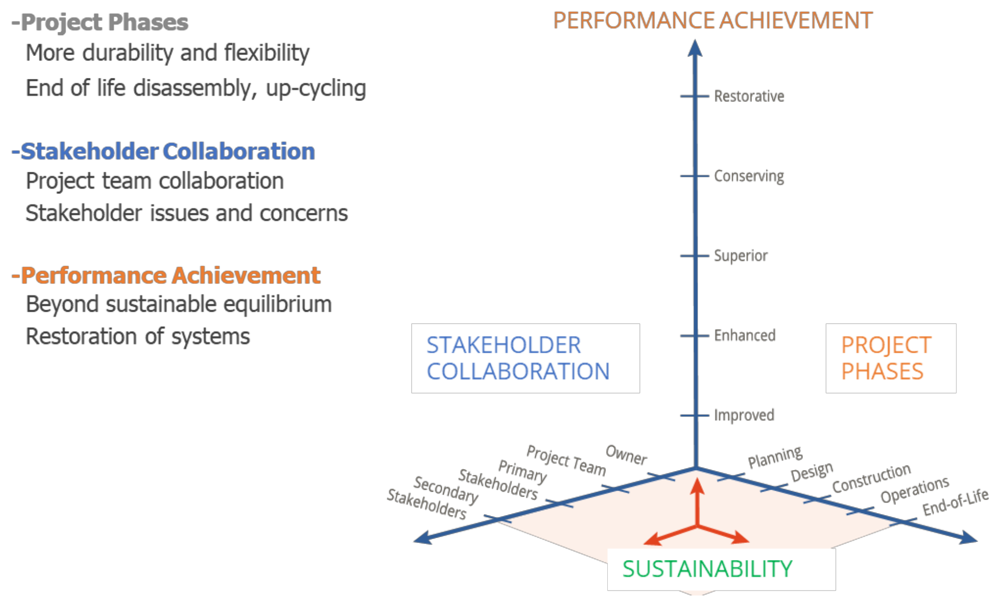


Fig.3 The three dimensions to improve sustainable opportunities in the project

Third are the levels of sustainability achievement. Envision offers credit for a wide range of sustainability success, from slight to outstanding.

This approach is reflected in the assessment metric that the Envision protocol adopts. Envision's sustainability assessment is based on five distinct categories divided into a total of 64 credits. The categories are: Quality of Life; Leadership; Resource Allocation; Natural World and Climate and Resilience (Fig.4).

Quality of Life 14 Credits	Wellbeing, Mobility, Community addresses a project's impact on host and affected communities, from the health and wellbeing of individuals to the wellbeing of the larger social fabric as a whole
Leadership 12 Credits	Collaboration, Planning, Economy encourages and rewards these actions with the perspective that, together with traditional sustainability actions such as reducing energy and water use, effective and collaborative leadership produces a truly sustainable project that contributes positively to the world around it.
Resource Allocation 14 Credits	Materials, Energy, Water is broadly concerned with the quantity, source, and characteristics of these resources and their impacts on the overall sustainability of the project. Resources addressed include physical materials (both those that are consumed and that leave the project), energy, and water use.
Natural World 14 Credits	Siting, Conservation, Ecology addresses how to understand and minimize negative impacts while considering ways in which the infrastructure can interact with natural systems in a synergistic, positive way.
Climate & Resilience 10 Credits	Emissions, Resilience The scope of this category is two-fold: minimizing emissions that may contribute to climate change and other short- and long-term risks, and ensuring that infrastructure projects are resilient. In order to be resilient, infrastructure must be informed, resourceful, robust, redundant, flexible, integrated, and inclusive

Fig.4 Envision categories

Each of these credits assesses a specific topic in a way that cross evaluates the social, environmental and economic impacts of the infrastructure. Each credit is given a variable scoring scale according to the level achieved with respect to what is required by Envision. The levels of achievement, used to allow for evaluation of specific performance and scoring for each credit, are:

- improved, above average performance;
- enhanced, performance on the right path to sustainability;
- superior, sustainable performance at the highest level;
- conserving, performance that achieved essentially zero negative impact;
- restorative, performance such as to improve the natural or social system, restoring a balance previously compromised.

Each credit is excludable if it is not applicable to the evaluated infrastructure. This is important because the final certification score is based on four distinct levels of evaluation that are related to the percentage of points obtained out of those available (and not out of the total 1000 expected).

Thus, for a project to be certified it must obtain at least 20 percent of the available points to have a Verified level, 30 percent for Silver, 40 percent for Gold, and over 50 percent for Platinum.

The certification process has two alternative paths: Path A, Design + Post Construction, and Path B, Post Construction. Within the methodology presented, reference is made to Path A, Design + Post Construction. The peculiarity of this evaluation is that the project is subject to two separate assessments, one that evaluates the design choices, Design review, and one post-construction, Post Construction Review, in which the proper execution of the project and the credits that direct the conduct of the construction site are verified.

Given this interdisciplinarity and independence of judgment, Envision is introduced to the methodological approach to measure the status of the six DNSH objectives and obtain a sustainability certification that also meets EU requirements. The Envision certification considers the environmental, economic and social part, thus satisfying the three factors of sustainability. This makes it possible to guarantee the sustainability of the intervention in favour of the disbursement of the funds of the National Recovery and Resilience Plan. In accordance with this, the guidance issued by ICMQ on the compatibility of using Envision to ensure the DNSH criteria required by the NRRP is an important publication regarding the opportunities for Envision to obtain funds provided by the Next Gen EU (Ciraci, 2022).

3. Application and Results

The methodological approach presented in section 2 is applied below to the case study of Albisola Superiore (SV).

The research starts from a call for proposals carried out within the Genoa University (February 2022, during the course of Urban Planning and Laboratory, teachers: Prof. Spadaro and Prof. Pirlone of the Master's Degree Course in Building Engineering-Architecture), promoted by the Municipality of Albisola Superiore (Ligurian Region) entitled: "Albisöa Regeneration" and develops in a subsequent degree thesis (Rotelli, 2022). This research experience leads to the concretization of the four Helix concept, promoting a sustainable regeneration project for Albisola Superiore, thanks the participation and collaboration of four actors: University of Genoa - Department of Civil, Chemic and Environmental Engineering, Municipal Administration - Albisola Superiore, Enterprise - R2M Solution and citizens.

The case study is Albisola Superiore, in province of Savona, a site that allows the coexistence of the sea and the mountains at a short distance from each other (Fig.5). Albisola Superiore together with Albissola Marina make up the territory of the Albisole, famous internationally for the manufacturing of ceramics. Its nucleus is divided into two parts: Albisola Superiore, which is 1 km from the sea, and Albisola Capo, a hamlet overlooking the sea.

Fig.5 Case study: Albisola Superiore (Ligurian Region, Italy)

The participatory project of urban regeneration and sustainable mobility was carried out following the phases: knowledge of state of art, context analysis, planning and design part and sustainability certification.

During the first phase of knowledge, information on points of interest, the mobility system, plans and urban planning tools are collected.

As regards the points of interest, there are the historic villas, the churches, the most popular places, the green areas, the school and the library (Fig.6). The city of Albisola Superiore has numerous churches, some of which are in Romanesque style and others preserve renowned artistic and sculptural works. Besides this, the municipality has interesting civil architecture, consisting of villas built between 1600 and 1700, as well as a medieval bridge.

Also, there is the Ceramics Museum, called Manlio Trucco, which was the home studio of this artist where you can admire works by contemporary painters and potters such as Luzzati, Trucco or Arturo Martini.

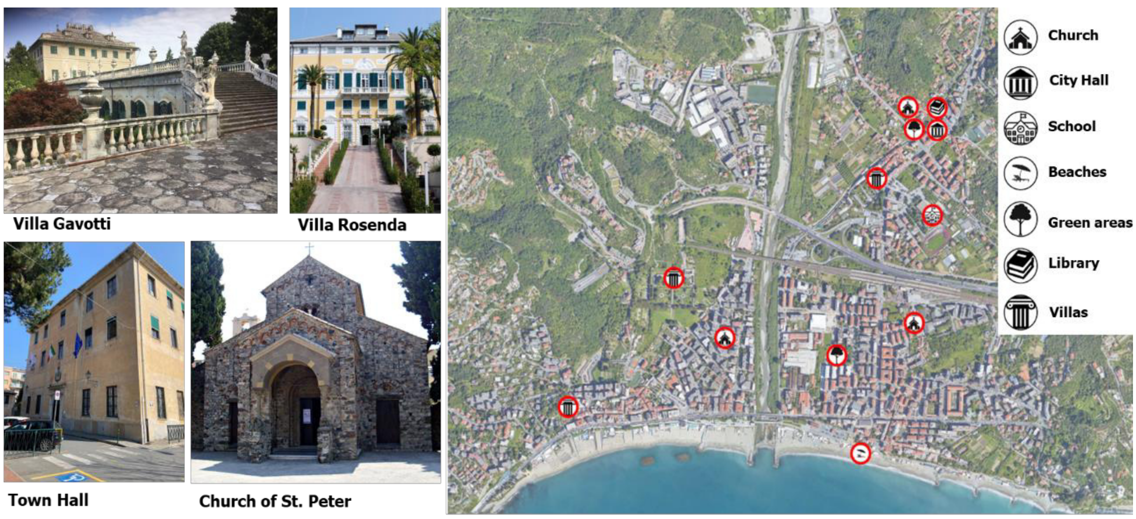


Fig.6 Knowledge Phase: Places of interest

The current state of the area was examined, through research, surveys and specific meetings and interviews with administration and population. As introduced in the approach, an important aspect is the role of

participation. In this regard at the beginning of the research an online questionnaire was set up and submitted to find out the opinion of the population, in addition to specific interviews and meetings with the administration. A questionnaire was submitted to the population to obtain an overview of the current situation of the city as well as to interview the direct users of the vehicular system and cycle/pedestrian road system of Albisola Superiore. The survey was completed by 120 people (63 Male, 57 Female), most of whom are citizens of Albisola (63%) or people who travel to the city on a regular basis (28%) (Battaglia, 2021) (Fig.7).
One of the first aspects investigated concerns the means of public transport in the area and it emerges that the population has conflicting opinions on the subject, in fact an averagely satisfied opinion prevails (59%) against 41% of voters who are not satisfied. The latter justify this response by arguing that travel by train and bus is very difficult for logistical reasons: the buses are not able to meet the demand, in the evening there are no buses to reach the more peripheral areas and the timetables are often not respected due to the heavy traffic on via Aurelia. The Via Aurelia is undoubtedly one of the major problems associated with local transport. In addition to this, there is a lack of a cycle path which could help to further relieve city traffic, at least on short routes inside and around the Municipality. The intermodality between bicycle and train would in fact make it possible to remedy most of the problems identified in the answers given above.

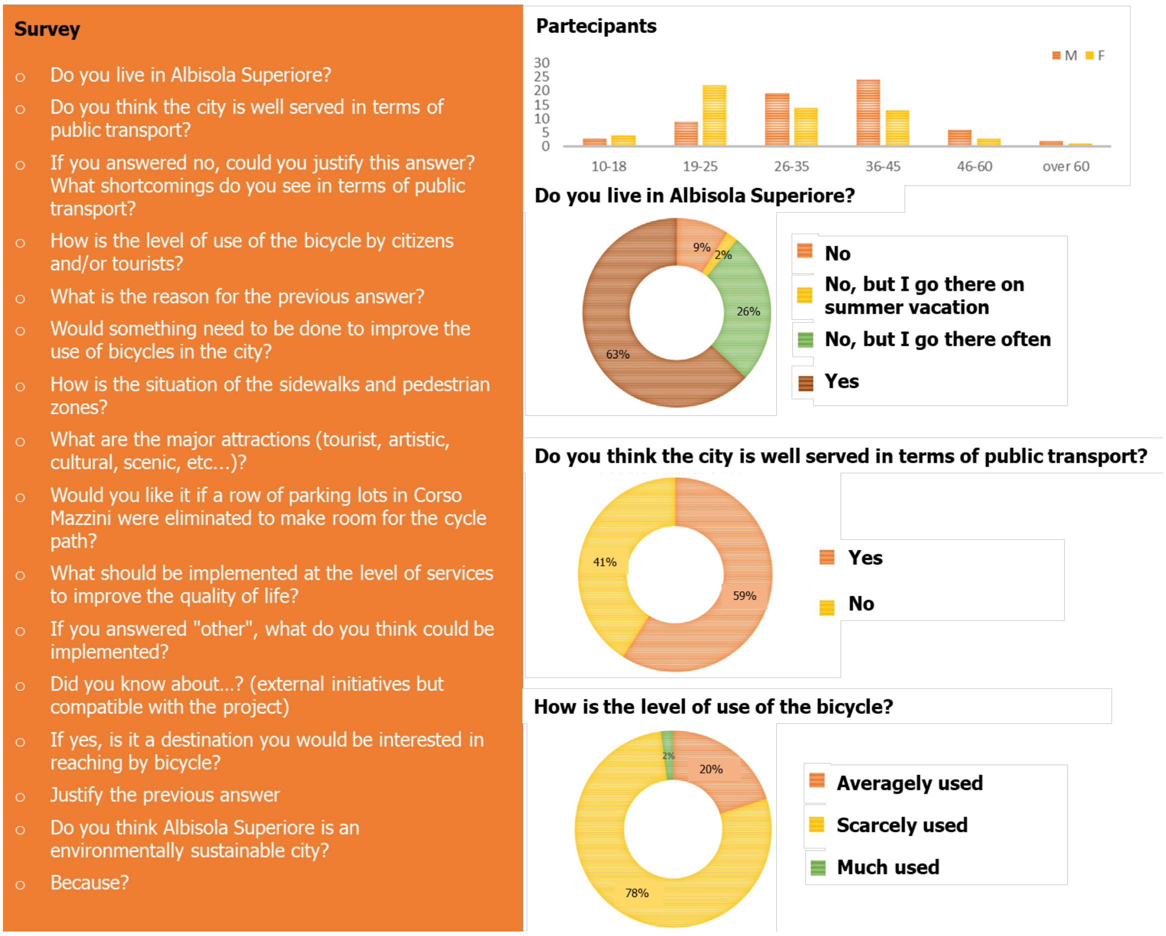


Fig.7 Participatory Phase: Extract from the survey and Graphs with some results

Currently, however, the use of the bicycle by the inhabitants of Albisola is rather low: 78% of the answers indicate that it is scarcely used, while only 20% affirm that its use is on average widespread, and a 2% believe that this medium is widely used. People who responded indicating a low use of the bicycle as a means of transport were then asked to explain why this is the trend.

The answers can be summarized in some macro groups:

- dangerousness of vehicular traffic, which makes it impossible to travel by bicycle;
- absence of a cycle route that allows cyclists to move through the city in safety;
- poorly structured connections between the center of Albisola and the surrounding hamlets;
- absence of a culture that focuses on cycle mobility.

Among the problems mentioned above, the absence of an itinerary intended for cycle traffic emerges above all. This aspect is confirmed by the results of the survey, which see the prevailing yes as a response to the need to take concrete actions to solve the problem of the lack of cycling spaces in the city.

The results of participatory phase, as proposed in the methodology, were useful in the various phases: from knowledge, analysis to the choice of interventions.

Regarding the mobility and viability system Albisola Superiore has different connecting roads with nearby towns. Albisola can be reached by car via the A10 Genova-Ventimiglia motorway and the Via Aurelia which are the main ways to reach the city. The Albisola motorway exit leads directly to Corso Mazzini, the city's main artery. In the city there are some public car parks available to both the resident and non-resident population. At the urban level, the primary road system is limited to two roads: Corso Ferrari (consisting of the urban section of the Aurelia) and Corso Mazzini (urban section of the SS 334). The rest of the secondary urban road system has a limited physical capacity and should have a local role; however, the movement surveys show that over 50% of them are crossings.

With regards to public transport, in Albisola Superiore there are several lines that pass through the city and allow to connect various points, including Albissola Marina with Albisola Superiore. In fact, 5 bus lines pass through the city, all of which connect the city with Savona and one, in particular line 30, connects the city with Celle Ligure and Varazze.

As regards rail transport, the station is located in a central and convenient position for travellers because it is only 10 minutes from the sea. The Genoa-Ventimiglia line and the Savona-Sestri Levante line pass here, thus allowing direct connection with a large part of the Ligurian Region.

Within the city of Albisola Superiore, Corso Mazzini represents the main road artery, where there are numerous services, and therefore appears to be very busy. As a consequence, this generates acoustic and atmospheric pollution problem; aspect that is demonstrated by the values that are currently recorded by a special ARPAL control unit located in this street (Fig.8).

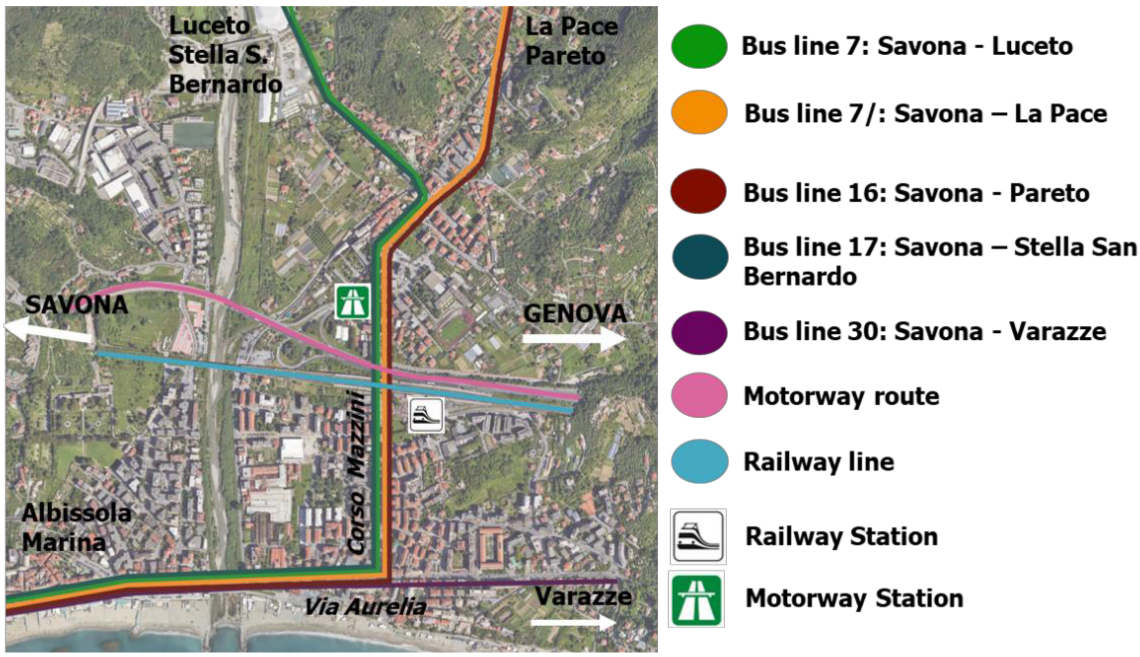


Fig.8 Knowledge Phase: Mobility system

Fundamental to the study of the territory is the analysis of planning tools and Municipal and Regional regulations.
At the urban planning level, the provisions contained in the Municipal Urban Plan (last update in 2004) are important; it provides the construction of new infrastructures. These aspects are also present in the draft version of the Urban Traffic Plan (2011). In particular, a cycle route (Tyrrhenian cycle route) and the creation of new parking lots is envisaged. The Basin Plan is also analyzed at the municipal level. Here are reported indications regarding the areas where the risk of flooding is present.
At the regional level, the Regional Territorial Plan, the Landscape Coordination Plan and the Coastal Coordination Plan have been analyzed, which provide indications at a territorial level, specifically for the coastal area and for the inland area.
In the second phase of analysis, the strengths and weaknesses present in the area emerge.
The city of Albisola Superiore has a very particular territory conformation, in fact there are flatter areas and more hilly areas not far from the sea. The infrastructure of the city does not go together with this division into zones; in fact, even if there are means of local public transport, they are not sufficient to guarantee satisfaction of the population, making connections very difficult with the different areas.
Among the main critical issues that have emerged is the lack of a square as a meeting place, there are problems in terms of noise in the main area (especially in Corso Mazzini) and therefore causes consequences on the quality of life of the population itself. This is because the city of Albisola Superiore, due to the presence of the tollbooth, represents a transit route. Today, in fact, one of the main criticalities of Albisola Superiore is the passage of cars and, above all, of heavy vehicles, which, leaving the motorway tollbooth, cross Corso Mazzini and continue on the Via Aurelia to reach the nearby city of Savona and the port of Vado. The high levels of congestion that characterize Corso Mazzini and Corso Ferrari during peak hours in fact lead to the search for alternative routes. Inevitably, this condition generates very important levels of atmospheric and acoustic pollution.

STRENGTHS

- Landscape with the concomitant presence of the sea, hills and mountains
- Presence of elements of historical, artistic and cultural interest
- Presence of public transport (bus and train)
- Presence of historic craft shops
- Presence of green itineraries and outdoor paths
- Activities such as the FAI days which promote special initiatives and itineraries in the Villas
- High presence of tourism in the summer period
- Presence of numerous bathing establishments, hotels and accommodation facilities

WEAKNESSES

- Lack of a cycle path and cycle/pedestrian paths
- Absence of multifunctional places
- Undervalued pedestrian areas
- Very busy Corso Mazzini area, even from trucks
- Corso Mazzini area with poor air quality level
- Scarce presence of playgrounds
- Absence of meeting places
- Strong impact of traffic on the urban network
- Lack of dedicated bicycle parking areas
- Exclusively seaside tourism concentrated above all in certain periods of the year

S W O T

OPPORTUNITY

- Hiking trails reopened thanks to FAI volunteers
- Funds from the PNRR
- Interest of the population for more sustainable forms of tourism
- Overturning of the motorway exit with consequent connection with the Aurelia Bis
- Upgrading of the cycle path
- Enhancement of the complex of historic villas and local excellence
- Use of renewable energy

THREATS

- Pollution and traffic concentrated in the central area of Albisola due to heavy road traffic
- Poor maintenance of road constructions
- High costs for the realization of projects
- Problems with the construction of the Aurelia Bis due to third parties
- Danger of flooding of torrents
- PNRR tenders currently closed

Fig.9 Analysis phase: S.W.O.T. analysis

By drawing up the SWOT analysis, numerous problems related to the territory emerge but also great potential to be seized. Its geographical conformation allows you to have sea, plain and mountainous territory together, a few kilometers away from each other. This turns out to be a point in favour for the city, to be exploited for all future projects and implement those already present, so as to further make the area interesting from a tourist point of view.

However, a weakness of Albisola Superiore appears to be linked to the infrastructures as the current ones are not able to fully satisfy the needs of the population, without considering the total absence of electrical infrastructure. The creation of a cycle path able to cross the city and which connects with the Borgo della Ceramica cycle path between Ellera and Luceto, built in March 2022 and inaugurated in May 2022, constitutes an opportunity so that the city has an entirely dedicated to soft mobility and which obviously connects with the neighbouring cities (Fig.9).

The PEST analysis summarizes the city's transformation forecasts: the presence of numerous urban planning tools together with the interest from various entities, ensures that there is an important guarantee regarding the realization of new ideas and the transformation of the territory. Thanks to European and national funding, and above all to that coming from the NRRP, destined for different sectors, a participatory project of regeneration can be created capable of assisting questions and answers coming from population itself, but also from productive sectors such as the production of ceramics and tourism (Fig.10).

POLITICAL

- Presence of territorial urban planning tools
- Interest of local and national authorities in initiatives for the requalification and sustainable transformation of the territory
- Coordination work between private and public subjects
- Interest on the part of the Administration in the use of funds from the PNRR to finance interventions

ECONOMIC

- Use of funds from the National Recovery and Resilience Plan
- Indirect benefits for the local economy due to regeneration
- urban
- Possible finding of European and national funding thanks to the participation of public tenders

SOCIO-CULTURAL

- Interest of the local population in relaunching Albisola's image
- Improvement of urban quality and consequently of the housing quality of the area
- Involvement and support from local associations and bodies
- Participation of citizens in mediations between institutions, municipal administration and local associations through technical tables
- Enhancement of the historic architectural fabric
- Tourism as a source of employment
- Presence of the pottery school
- Conservation of cultural tradition

TECHOLOGICAL

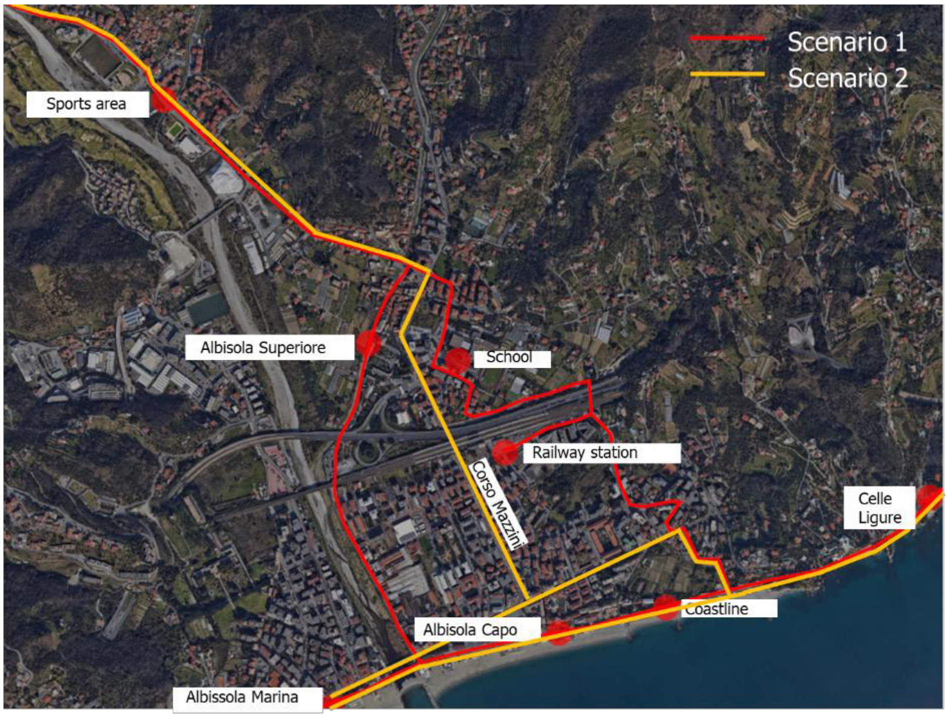
- Use of solar panels for lighting the sea promenade
- Scarce presence of recharging areas for electric cars and bicycles
- Absence of bike and car-sharing areas
- Absence of apps that allow you to orient yourself and create ad hoc itineraries for your needs
- Lack of infrastructure for electric mobility

Fig.10 Analysis phase: P.E.S.T. analysis

The third phase of planning start with the proposal of two projects, analyzed by means of SWOT analysis and, at the end, the one that is best choice is identified as able to respond to the needs and demands of the territory, the population and the Administration.

The objective of increasingly sustainable mobility to regenerate the area is one of the most important to pursue since there would be environmental, social and economic benefits by making Albisola Superiore a city not only for passing through or for seaside tourism but also to be appreciated for its services and accessibility.

The first proposal providing the construction of the cycle path on an itinerary that does not pass along Corso Mazzini and is based on the current configuration of the territory. This itinerary encourages soft mobility and allow for a better connection with the various parts of the city exploiting the existing infrastructure, making small changes. This path allows you to connect the main points of interest of the city that have been highlighted and around which the greatest flow of citizens is concentrated. These are the railway station, the historic center of Albisola Superiore and Albisola Capo, the school area with the annexed sports area and, especially in the summer months, the sea area. The cycle itinerary therefore tries to connect these key points and wants to connect to the recently built cycle path between Ellera and Luceto and then connecting with the cycling itinerary foreseen by the Tyrrhenian cycle path so as to be able to create another stretch leading to the closure of the Tyrrhenian network project which intends to connect Ventimiglia to Roma. In fact, the cycle path intends to propose a connection with the neighbouring cities of Albissola Marina, Savona and Celle Ligure because the planning is important not to be limited to the single area of the Albisola Superiore territory, but to extend in such a way as to guarantee an effective alternative to other means less sustainable transport.



SCENARIO 1	
STRENGTHS • Cycle path away from heavy vehicle traffic • Transit of the cycle path along areas with little pollution • There is no need to build new infrastructure • Go through multiple areas of the city	**WEAKNESSES** • Does not pass through the main street of the city (Corso Mazzini) • Difficult to create historical itineraries to enhance archaeological remains
OPPORTUNITY • Immediate realization • Possibility to reach the whole city by bicycle • Possibility of incentives for the use of soft mobility • Redevelopment of the station area • Cycle path that can be used to reach the beaches • Connection with the "ceramic village" cycle path.	**THREATS** • Risk of not using part of it during alerts (area along Torrente Sansobbia • The E. Montale seafront is too crowded during the summer, making transit difficult

(a)

SCENARIO 2	
STRENGTHS • Less dangerous road and therefore safer cycle route • Enhancement of the archaeological site • Transit in the main street for commerce and full of different uses • Traffic reduction during peak hours	**WEAKNESSES** • Track connecting only with the main street of the city • Transit through Corso Mazzini which currently has high levels of pollution
OPPORTUNITY • The cycle path is built in the width of the sidewalk in Corso Mazzini • Possibility of incentives for the use of soft mobility • Redevelopment of the station area • Connection with the "ceramic village" cycle path • PUMT of the city of Savona for the Aurelia Bis	**THREATS** • Medium-long term proposal linked to the construction of the Aurelia BisThe E. Montale seafront is too crowded during the summer, making transit difficult

(b)

Fig.11 Planning phase: a) SWOT analysis Scenario 1 and b) SWOT analysis Scenario 2

The second proposal, on the other hand, considers a future situation, where the end of the construction of the Aurelia Bis is assumed and therefore the reversal of the Albisola motorway exit and a connection between the two. In this second option, a transit of the cycle path along Corso Mazzini is assumed. By favouring the layout along this itinerary, it inevitably turns out to be more simplicist than in the first scenario. However, this scenario remains valid because it is equally functional in the connections between the main hubs of the city and with the hinterland (Fig.11). As in the previous scenario the connection with the neighbouring cities are proposed.
After analyzing the two scenarios with SWOT analysis it is clear that the first scenario better enhances the territorial context of Albisola Superiore and can be implemented immediately, thus allowing access to the funds made available by the National Recovery and Resilience Plan. This itinerary is also able to connect several parts of the city, also reaching secondary roads. However, it does not pass along Corso Mazzini, an element against it, but this choice has the intention of guaranteeing a safe cycle path, away from the transit of heavy vehicles.
After defining the cycle path, it should be underlined how the mobility interventions generates further urban regeneration projects within the territory. These interventions concern the station square in which is assumed a general reorganization: in particular, the construction of an interchange car park and the creation of an open space with a collective function and a special green area are planned. Moreover, the inclusion of bike sharing stations and electric recharging stations is planned within the city.
Taking the opportunity to create this interchange area, a square was also created, a need underlined by both the administration and the population (Fig.12). Inside the square there is a circular pedestrian path so that users arriving in Albisola Superiore by train can decide how to move around the area: on foot, following the pedestrian path or by bicycle using the sharing services made available; by bus as there is a stop not far away, precisely along Corso Mazzini. The station square can therefore become the starting point for visiting Albisola Superiore through sustainable means of mobility.

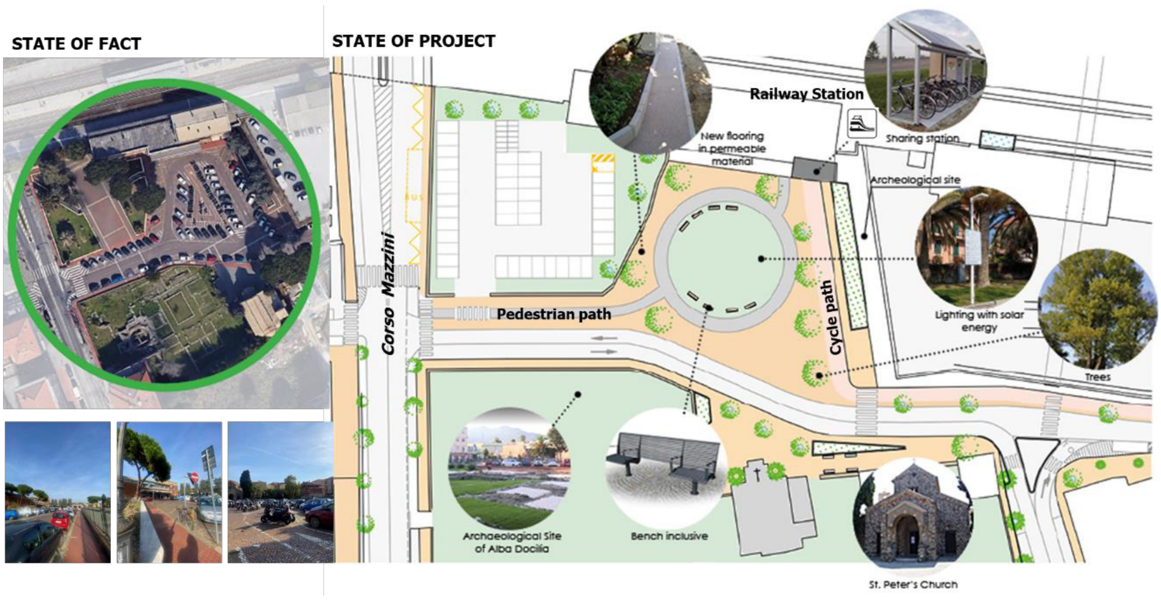


Fig.12 Planning Phase: the place of station railways (Comparison between State of fact and State of project)

After having carried out a technical feasibility assessment, having therefore exposed the project and analyzed the individual areas, an economic feasibility assessment was carried out in order to obtain a complete vision of the intervention.

Category	Subcategory	Credit	Credit Assessment Status	Evaluation Questions Assessed: Yes	Evaluation Questions Assessed: No	Assessment Status: Improved	Enhanced	Superior	Conserving	Restorative	Points	Assessed Maximum Points Available	Total Maximum Points
Quality of Life	Wellbeing	QL1.1 Improve Community Quality of Life	Assessed	6	1	0	5	0	0	0	5	26	26
		QL1.2 Enhance Public Health & Safety	Assessed	2	4	2	0	0	0	0	2	20	20
		QL1.3 Improve Construction Safety	Assessed	4	1	0	0	10	0	--	10	14	14
		QL1.4 Minimize Noise & Vibration	Not Applicable	0	0	0	0	0	0	0	0	0	12
		QL1.5 Minimize Light Pollution	Assessed	4	2	0	0	6	0	0	6	12	12
		QL1.6 Minimize Construction Impacts	Assessed	3	3	0	2	0	0	--	2	8	8
	Mobility	QL2.1 Improve Community Mobility Access	Assessed	6	0	0	0	0	0	14	14	14	14
		QL2.2 Encourage Sustainable Transportation	Assessed	4	0	--	0	0	0	16	16	16	16
		QL2.3 Improve Access & Wayfinding	Assessed	4	0	0	0	0	14	--	14	14	14
	Community	QL3.1 Advance Equity & Social Justice	Not Applicable	0	0	0	0	0	0	0	0	0	18
		QL3.2 Preserve Historic & Cultural Resources	Assessed	5	1	--	0	0	12	0	12	18	18
		QL3.3 Enhance Views & Local Character	Assessed	5	1	0	0	7	0	0	7	14	14
		QL3.4 Enhance Public Space & Amenities	Assessed	4	0	0	0	0	11	0	11	14	14
Leadership	Collaboration	LD1.1 Provide Effective Leadership & Commitment	Assessed	1	3	2	0	0	0	--	2	18	18
		LD1.2 Foster Collaboration & Teamwork	Assessed	1	3	2	0	0	0	--	2	18	18
		LD1.3 Provide for Stakeholder Involvement	Assessed	2	4	3	0	0	0	0	3	18	18
		LD1.4 Pursue Byproduct Synergies	Assessed	0	5	0	0	0	0	0	0	18	18
	Planning	LD2.1 Establish a Sustainability Management Plan	Assessed	2	3	4	0	0	0	--	4	18	18
		LD2.2 Plan for Sustainable Communities	Assessed	2	3	0	6	0	0	0	6	16	16
		LD2.3 Plan for Long-Term Monitoring & Maintenance	Assessed	1	4	2	0	0	0	--	2	12	12
		LD2.4 Plan for End-of-Life	Assessed	0	5	0	0	0	0	--	0	14	14
	Economy	LD3.1 Stimulate Economic Prosperity & Development	Assessed	0	5	0	0	0	0	--	0	20	20
		LD3.2 Develop Local Skills & Capabilities	Assessed	1	3	2	0	0	0	0	2	16	16
		LD3.3 Conduct a Life-Cycle Economic Evaluation	Assessed	1	4	5	0	0	0	0	5	14	14
Resource Allocation	Materials	RA1.1 Support Sustainable Procurement Practices	Assessed	2	0	0	0	0	12	--	12	12	12
		RA1.2 Use Recycled Materials	Assessed	1	0	0	6	0	0	--	6	16	16
		RA1.3 Reduce Operational Waste	Not Applicable	0	0	0	0	0	0	--	0	0	14
		RA1.4 Reduce Construction Waste	Assessed	2	0	0	7	0	0	--	7	16	16
		RA1.5 Balance Earthwork On Site	Assessed	1	0	2	0	0	0	--	2	8	8
	Energy	RA2.1 Reduce Operational Energy Consumption	Assessed	2	0	6	0	0	0	--	6	26	26
		RA2.2 Reduce Construction Energy Consumption	Assessed	1	1	1	0	0	0	--	1	12	12
		RA2.3 Use Renewable Energy	Assessed	1	0	0	10	0	0	0	10	24	24
		RA2.4 Commission & Monitor Energy Systems	Not Applicable	0	0	0	0	0	0	--	0	0	14
	Water	RA3.1 Preserve Water Resources	Not Applicable	0	0	0	0	0	0	0	0	0	12
		RA3.2 Reduce Operational Water Consumption	Not Applicable	0	0	0	0	0	0	0	0	0	22
		RA3.3 Reduce Construction Water Consumption	Not Applicable	0	0	0	0	0	0	--	0	0	8
		RA3.4 Monitor Water Systems	Not Applicable	0	0	0	0	0	0	--	0	0	12
Natural World	Siting	NW1.1 Preserve Sites of High Ecological Value	Not Applicable	0	0	0	0	0	0	0	0	0	22
		NW1.2 Provide Wetland & Surface Water Buffers	Not Applicable	0	0	0	0	0	0	0	0	0	20
		NW1.3 Preserve Prime Farmland	Not Applicable	0	0	--	0	0	0	0	0	0	16
		NW1.4 Preserve Undeveloped Land	Assessed	2	0	0	0	0	0	24	24	24	24
	Conservation	NW2.1 Reclaim Brownfields	Assessed	1	3	11	0	0	0	0	11	22	22
		NW2.2 Manage Stormwater	Not Applicable	0	0	0	0	0	0	0	0	0	24
		NW2.3 Reduce Pesticide & Fertilizer Impacts	Not Applicable	0	0	0	0	0	0	0	0	0	12
		NW2.4 Protect Surface & Groundwater Quality	Not Applicable	0	0	0	0	0	0	0	0	0	20
	Ecology	NW3.1 Enhance Functional Habitats	Not Applicable	0	0	0	0	0	0	0	0	0	18
		NW3.2 Enhance Wetland & Surface Water Functions	Not Applicable	0	0	0	0	0	0	0	0	0	20
		NW3.3 Maintain Floodplain Functions	Not Applicable	0	0	0	0	0	0	0	0	0	14
		NW3.4 Control Invasive Species	Not Applicable	0	0	0	0	0	0	0	0	0	12
		NW3.5 Protect Soil Health	Assessed	2	2	--	3	0	0	0	3	8	8
Climate and Resilience	Emissions	CR1.1 Reduce Net Embodied Carbon	Assessed	3	0	0	10	0	0	--	10	20	20
		CR1.2 Reduce Greenhouse Gas Emissions	Assessed	2	0	0	13	0	0	0	13	26	26
		CR1.3 Reduce Air Pollutant Emissions	Not Applicable	0	0	0	0	0	0	0	0	0	18
	Resilience	CR2.1 Avoid Unsuitable Development	Assessed	3	3	0	6	0	0	0	6	16	16
		CR2.2 Assess Climate Change Vulnerability	Assessed	0	5	0	0	0	0	--	0	20	20
		CR2.3 Evaluate Risk and Resilience	Assessed	5	1	11	0	0	0	--	11	26	26
		CR2.4 Establish Resilience Goals and Strategies	Assessed	0	4	--	0	0	0	--	0	20	20
		CR2.5 Maximize Resilience	Assessed	0	5	0	0	0	0	--	0	26	26
		CR2.6 Improve Infrastructure Integration	Assessed	1	4	2	0	0	0	0	2	18	18
		Total Points	All Credits Assessed	87	83	55	68	23	49	54	249	692	1000

Possible Award Level: **Silver**

Fig.13 Monitoring Phase: sustainability certification

The last phase, sustainability certification, foresees the application of the Envision Protocol. In particular, the sustainability of the intervention relating to the construction of the cycle path within the municipality of Albisola Superiore and of the urban regeneration project of the railway station area is assessed.
All five macro-categories of Quality of Life, Leadership, Resource Allocation, Natural World and Climate and Resilience were analysed. In order to establish the level reached by each credit, the Envision manual was used as a support and a Pre-assessment evaluation was carried out with Envision's tool.
Operationally speaking, the Envision pre-assessment is implemented by filling out a pre-established form from the Institute for Sustainable Infrastructure, the initiating body of Envision. The document includes all sixty-four credits of the protocol and requires that all questions be answered.
Each credit was first evaluated whether or not it was applicable for the case of the Albisola Superiore project. This is a delicate and crucial step because if a credit is not applicable it is excluded from the baseline score on which to calculate the percentage of achievement that determines the score. To define whether a credit is applicable or not, the guidance given in the Envision manual that provides protocol guidelines was used.
After determining which credits are pursuable in the Albisola Superiore project, the expected scores for each were assigned. To do this step, the documentary and performance requirements that the Envision protocol requires for each credit were analyzed. Based on the analyses performed, construction practices and current regulatory requirements, several assumptions could be made that allowed different credits to be answered. At the same time, a precautionary approach was maintained where doubts arose as to whether the requirements of the Envision protocol were actually met, so as to have a more truthful overall assessment of the work.
Answering all applicable credits, assigning the level of achievement reached (Improved, Enhanced, Superior, Conserving, Restorative) and related points yielded the total points that the Albisola Superiore project scores compared to the Envision framework. Dividing this score with the maximum score applicable to the project yields the percentage that assigns the Envision level. In this case, 249 out of 622 applicable points were obtained, which is 36 percent corresponding to a Silver level, as shown in the Fig.13.
The result obtained is carried out on the preliminary project, future improvements such as to allow the achievement of a higher level are not excluded. This is a pre-assessment, in order to be awarded certification it is necessary to achieve the documentation required for Design Review and Post Construction Review.

4. Discussion and conclusion

Sustainable Development Goal (SDG) 11 of the "2030 Agenda for Sustainable Development" (UN, 2015) aims to "make cities and human settlements inclusive, safe, resilient and sustainable" and outlines a series of actions to achieve the goal, including the expansion of local public transport and a special attention on vulnerable road users (woman, children, person with disabilities and other persons). A joint strategy of urban regeneration of public spaces for mobility and services, such as the research reported in the paper, can contribute to achieving this goal. Infact, "urban regeneration processes represent an opportunity to pursue a sustainable city model and, in this perspective, the redesign of public spaces and mobility infrastructures becomes rather significant, comprising the enhancement of pedestrian and cycle accessibility to public amenities for all users, including the most vulnerable ones" (Pellicelli et al., 2022).
During the application have surfaced fundamental aspects to pay attention in order to achieve a sustainable regeneration of the territory starting from the proposition of sustainable mobility projects.
The priorities aspect introduced concerns the integration of the quadruple helix concept, for a multi-stakeholder governance and sustainable regeneration. Participation, awareness and involvement these are important actions that must follow the different project phases: planning, design and construction. This is essential to give the various stakeholders the opportunity to contribute their own ideas and learn about, and therefore be able to change, their own mobility habits. As a project progresses over time the ability to influence

its overall sustainability decreases while the cost to do so increases. Broad and effective collaboration early in a project can increase the sustainability potential at little to no cost (Fig.14).
Another fundamental aspect is technological innovation (new materials, infrastructures) but also process innovation linked to the services promoted and any incentives useful as a lever to promote sustainability.

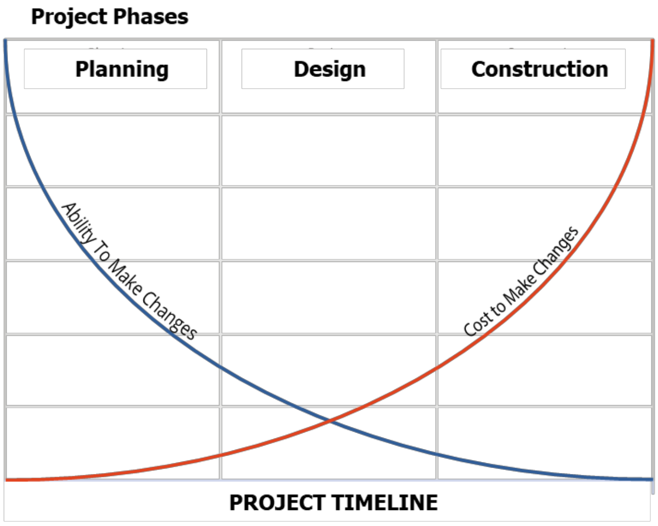


Fig.14 Relationship between costs and the ability to create changes

Finally, the training of new professional figures who are experts in the field of sustainability and in the use of useful tools to evaluate and monitor it concretely. To truly do sustainable regeneration project, you need to understand the interconnected nature of what you do, how each project connects to the community and to the characteristic of territory within which it functions. This is a richer landscape that requires much more inclusive participation and wider horizons. This new breed of sustainability engineer/practitioner must understand the wider implications of this work, and brings the judgement and skill to plan, build, and operate in this new sustainability paradigm.
The experience presented in the paper summarizes these latter aspects. The competition within the urban planning technique course in the Polytechnic School of Engineering of Genoa aims at the participation and collaboration between four fundamental players: Research - Genoa University; Public administration - Municipality of Albisola Superiore; Company - R2M Solution and Population. And it aims at training future engineers who have studied, deepened and therefore developed a sensitivity on the issue of sustainability, the closure of the life cycle and of town planning and who therefore know how to give the right weight to the priority issues to be considered in order to be able to plan urban and sustainable regeneration processes.

Author Contributions

Introduction, Methodology, Discussion and Conclusions, I.S.; Application and Results C.R. in collaboration with I.S.; Sustainability Certification P.A.in collaboration with I.S.. All authors have read and agreed to the published version of the manuscript.

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Image Sources

Figg.1-12 are elaboration of the authors.

Fig.14: "Relationship between costs and the ability to create changes.", is an elaboration of the authors start by Institute for sustainable infrastructure, 2018.

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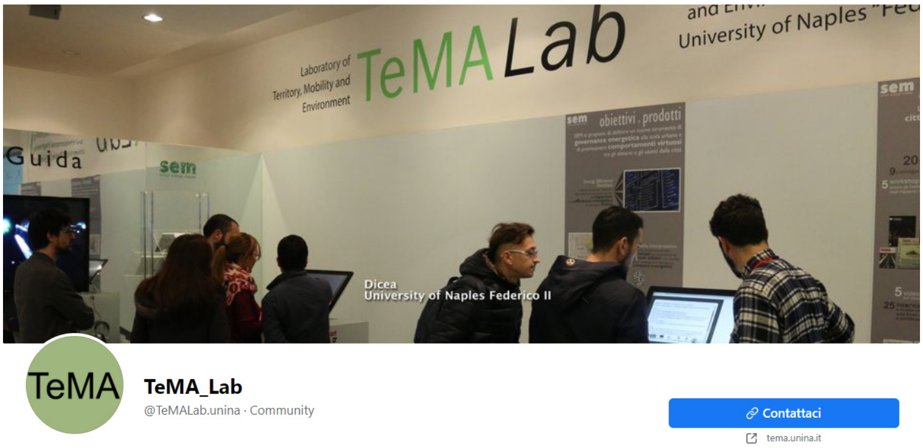

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Suitable sites for built-up area expansion in Kamalamai municipality, Sindhuli district, Nepal

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Abstract

Kamalamai municipality has witnessed significant built-up development in recent years but there has been very limited planning and regulation for controlling this trend. Haphazard built-up expansion may risk environmental sensitive areas and could sprawl in areas lacking basic facilities. Identification of suitable areas for built-up development is critical to regulate future development in an efficient manner. The main objective of the study was to identify suitable sites for built-up expansion in Kamalamai municipality. Landsat images of 2001, 2016, and 2021 were used for Land Use Land Cover (LULC) trend analysis. Suitability analysis was done based on Analytical Hierarchy Process (AHP) pair-wise comparison. Multi-layer Preceptor (MLP) neural network was used for transition sub-modeling of each LULC class to built-up. Markov model was used for future urbanization modeling in combination with constraint/incentive to redirect the change in expansion suitable areas. During 2001 and 2021 the built-up had increased from 0.5% (1.09 Km²) to 1.9% (3.95 Km²). The model predicted the built-up to increase to 2.5% (5.13 Km²) by 2031, 3.3% (6.69 Km²) by 2041, and 4% (8.25 Km²) by 2051. The region has significantly urbanized since 2016 mainly contributed by in-migration and is predicted to follow the trend in the future.

Keywords

Built-up Area; Land Suitability Analysis; GIS; Land Use Land Cover.

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1. Introduction

More than half of the world population are currently living in urban areas, and is projected to grow by 2.5 billion people between 2018 and 2050, with half of this growth concentrated in Asia and Africa (UN DESA, 2019). Similarly, the urban population in Asia is projected to be more than 55% by 2030 (Choe & Roberts, 2011). This unprecedented urban population surge especially in low-income nations have in past put immense pressure on governments inducing urban sprawl. Rapid and haphazard urbanization has been linked to devastating geo-hazards causing loss of life and property, and damaging environment (Cui et al., 2019). Moreover, the impact of unmanaged infrastructure development is widespread across many aspects of natural environment. Research over several decades have shown that urbanization has impacted atmospheric conditions, ecosystems, changes in carbon cycle throughout the globe possibly inducing climate change (Foley et al., 2005).

Nepal has remained one of the least urbanized country but at the same time is one of the fastest urbanizing country 1990’s onwards, and it is projected to urbanize at a rate of 2.0 per cent per year until 2050 (UN DESA, 2019). Urbanization scenario in Nepal has been dominated by high growth areas like Kathmandu valley and a few large and medium cities, the valleys, border towns and market towns on highways passages (Bakrania, 2019). The study area, Kamalamai municipality is a market town located along the highway between Kathmandu valley and terai plains linking India. Kamalamai Municipality is also the headquarter of Sindhuli district and a trade hub for hinterlands and rural areas in proximity of the municipality. The urbanization in Kamalamai Municipality is influenced by a variety of social-economic and political factors that shape the current and potential constraints and incentives for urban growth.

Kamalamai Municipality has experienced significant population growth, primarily driven by rural-urban migration. Factors such as limited employment opportunities, lack of basic services, and aspirations for better livelihoods have led rural residents to seek economic opportunities in and around the municipal areas. This influx of people has contributed to the rapid urbanization of Kamalamai Municipality. Similarly, the construction of the national highway connecting Kamalamai Municipality to the capital city and trade routes to India has played a crucial role in enhancing the municipality's importance as a trade hub. The improved connectivity and increased business opportunities along the highway have fueled urban growth and attracted investment in the area. Furthermore, the devastating earthquake in 2015 resulted in the displacement of many people and widespread damage to houses in Nepal. The reconstruction efforts following the earthquake have led to new construction activities in towns like Kamalamai. The need for housing and infrastructure has further contributed to the rapid built-up development in the municipality in recent years.

Similarly on political front, the decentralization and federal restructuring of Nepal in 2015 brought significant changes to the governance structure and power distribution. The centralized structure had encouraged urbanization in Kathmandu, the capital city, but with decentralized structure other central towns like Kamalamai have gained importance. The decentralization effort established towns like Kamalamai as centers of region. This transformation has influenced rural-urban migration patterns, as well as the growth and development of the town. This has opened new possibilities in the municipality with implications for urban planning, infrastructure development, and service delivery. Although urban planning and development strategy are absent in implementation level the political dynamics has put responsibility on the local planning system. The local government has new responsibilities to make policies and initiatives that promote economic activities and investment in Kamalamai Municipality to attract businesses, create employment opportunities, and drive urban growth. Furthermore, the provision of infrastructure and public amenities can further stimulate urban development.

The National Urban Development Strategy (NUDS, 2017) emphasizes the need to promote economic activities and investment in municipalities like Kamalamai by attracting businesses, creating employment opportunities, and improving infrastructure, such as transportation networks, utilities, and public amenities, urbanization. This rapid built-up surge in recent years in not planned nor regulated. The issues like air pollution, water pollution and rapid decline in green spaces has already surfaced in the municipality. Kamalamai Municipality has shown a decrease in forest area and riverbank from 1995 to 2014 while an increase in built up area and agricultural land due to the population growth (Neupane & Dhakal, 2017).

The pressure of urbanisation without any plan and regulation cannot be limited to the towns core but will eventually spill over to the hinterlands. The municipality consists of hills prone to landslides as well as plains which are prone to flooding. The current built-up development may expand inconsiderately towards flood and landslide prone areas, or areas unsuitable for development or is less desirable. Recent incidences in the country have shown that poorly planned settlements have suffered even from low level natural calamities (Bhattarai & Conway, 2021). There is an urgent need for an urban development strategy to preserve good-quality agricultural land and help conserve natural resources (Bhattarai & Conway, 2021).

As urbanization continues in a rapid manner, sustainable development increasingly depends on management of urban growth, especially in lower income countries where the most rapid urbanization is projected (UN DESA, 2019). Urban land use and environmental planning plays a significant role in urban management to obtain sustainable development. One of the pressing issue in land use planning is determining the suitability of locations for development considering physical, environmental, natural and other factors (Karim et al., 2020). Furthermore, urban future is of particular interest to urban and regional planners since the actions and policies of today can be directed towards sustainable future (Rocha & Tenedório, 2018). Urban growth processes are usually difficult to simulate (Barredo et al., 2003), and identifying suitable areas are equally challenging. In recent years, the progress in mathematical calculations and statistical model have opened a new dimension for studying cities while with the invention of computational machines and computers have revolutionized urban development and planning studies (Wahyudi & Liu, 2015). The computerized analysis of urban areas has made it possible analyzing different variables responsible for built-up expansion in a short amount of time and less user effort. The computerized spatial models that depict and re-shape the reality as per input variables have simplified complex spatial patterns (Barredo et al., 2003). (Zullo et al., 2015) emphasizes the significance of identifying areas for urban development due to the negative consequences associated with urban sprawl and its negative impacts on natural ecosystems and landscapes.

The future is uncertain but predicting it offers leverage for directing present-day plans and policies for a managed development while minimizing the associated risks. Spatial modelling is used for future scenario simulation based on historic information of geographical changes based on quantification of Land Use Land Cover (LULC) changes (Rocha & Tenedório, 2018). Land use simulation assists as a decision support system to explore the anthropogenic interference on natural environment (Liu et al., 2020) and provides the baseline scenario for predicting future patterns of development (Saputra & Lee, 2019). LULC models can be used to examine the transition among LULC categories and analyse multiple causes and consequences of change (Shen et al., 2020). With the use of model analysis and simulation of LULC, spatial pattern change can be identified along with the rate of land use change and LULC class interactions (Han et al., 2015). This modelling and prediction of future LULC and urban growth can enable to understand a futuristic view for sustainable development (Hasan et al., 2020).

Markov chain model has been incorporated with Geographic Information System (GIS) and Remote Sensing (RS) Technologies for an effective simulation and prediction of LULC change (Shen et al., 2020). The spatial modelling method like Markov model can depict the direction of LULC shifts and provide a framework for analysing land use demand on future (Han et al., 2015). The transition probability maps generated through the Multilayer Perceptron (MLP) as Markov change model provides a probability whether pixel will be converted into another land use class in annual time steps (Hasan et al., 2020). The model generates events and probability of generating subsequent observations dependent on previous state values (Hosom, 2003).

Similarly, Land suitability evaluation is a logical basis for LULC planning by predicting the suitability of land to types of land use viable in an area (Karim et al., 2020). The method integrates different factors like slope, risky areas, and prime agricultural lands, and determines sites that are more and least suitable for development. Identification of suitable areas for land development is especially relevant in hilly areas and even crucial aspect of planning (M. Kumar & Shaikh, 2013). The identification of suitable development areas can ensure economic benefits and environmental protection. Infill built-up development can minimize the pressure on green spaces and agricultural lands (Jehling et al., 2018; McConnell & Wiley, 2011; Mustafa et al., 2018). Urbanization in areas less prone to natural hazards ensures protection of lives and economic security. Suitability analysis helps identify best areas to direct the urban growth and worst areas where urban expansion should be restricted.

Multi criteria evaluation method is used for site selection as well as suitability analysis for selecting most suitable for places for development in many studies in cities of Malaysia, India and Pakistan (Gharaibeh et al., 2020). Analytical Hierarchy Process (AHP) is one of the decision-making tools involving multi-criteria analysis. AHP was developed by Saaty as a Multi-Criteria Decision Making (MCDM). The AHP is a measurement theory using pairwise comparisons and recued on experts judgement to derive priority scale (Saaty, 2008). It is designed to work on the basis of rational and intuitive to select best alternative on the evaluation of several criteria (Saaty & Vargas, 2012). It is a widely used tool for decision making across various sectors (Leal, 2020). Satty proposed AHP based on based on pairwise comparison method introduced by Fechner in 1860 and developed by Thurstone in 1927 (Chu & Liu, 2002).

Previous studies have demonstrated the capability of integrating different data sources including LULC, RS, and GIS as a method for land suitability analysis (Youssef et al., 2011). Former studies have measured spatial patterns (Fei & Zhao, 2019; Yu & Zhou, 2018) by analyzing forces driving urban expansion (Dadashpoor et al., 2019a), predicting built-up growth (Cai et al., 2020; Y. Chen et al., 2019; Xu & Gao, 2019; Zhou et al., 2020) and exploring the effects of built-up expansion (S. Chen et al., 2020; Dadashpoor et al., 2019b; Zhou et al., 2020). However there has been no suitability modelling study in the study area. Thus, the aim of this study was to analyze suitable areas for built-up expansion in Kamalamai Municipality and model expansion in suitable areas for 2031, 3041 and 2051. The suitability analysis was based on landslide susceptibility, flood susceptibility, existing LULC, slope, aspect, proximity to existing roadways, proximity to existing settlements and elevation. The LULC trend was analyzed based on Landsat-8 imagery for 2001, 2016 and 2021 by using image classification technique for LULC quantification. The model for future expansion was created using LULC 2001 to 2021 in Land Change Modeler (LCM). The suitability map was integrated to future expansion model as incentives and constraints to achieve suitable built-up areas in 2031, 2041 and 2051.

The study can be useful in urban management of the study area. The areas unsuitable for development can be avoided in future. The areas that are more suitable for development can be encouraged to residents for future development. The identified areas that may have more pressure in future for development can be prioritized for public infrastructure development so to channel the future growth in safe areas that are economic as well for local government investment. The study can be beneficial for policy makers, local government, developers, and planners for safe and sustainable urban development.

2. Study Area

Kamalamai Municipality is situated in hilly region of central-eastern Nepal (Fig.1). Administratively the municipality is in Sindhuli District, Bagmati Province of Nepal and is the largest municipality of the country according to the area. The district includes two Municipalities Kamalamai and Dudhauli Municipality, and seven rural municipalities. Kamalamai Municipality lies between latitude 27° 3′ 6″ N and 27° 16′ 17″ N and latitudes between 85° 48′ 36″ E and 86° 01′ 52″ E. The municipality is surrounded by Ranichauri, Bhimsthan, Belghari and Ranibas in the east, Bhadrakali and Dandi Gurase in the west, Bhadrakali and Ratanchura in the north and Sarlahi, Mahottari and Dhanusha Districts in the south. Kamalamai covers an area of 205 km^2 and is comprised of 14 wards.

The municipality stretches from Chure to the Mahabharata range with elevation ranging from 400m to 1600m, thus having diverse climatic conditions. The climate ranges from lower tropical to temperate regions. The average rainfall in the district is 2788 millilitres per year which is the second highest rainfall area in Nepal after Pokhara. The summer season falls between April to September and winter between October and March. The major market area of the municipality is Madhi Bazaar which is densely built with shops on both sides of the lanes. The major rivers in the municipality are Kamala, Chadaha, Gadhauli, Bhiman, Gwankhola, Buka, Labdaha and Marin River. The Kamala River which flows through the municipality is worshipped by locals as goddess Kamala. According to the census in 2001, the district had a population of 32,838 while according to census in 2011 the municipality's population increased to 39,413. The male population as per census 2011 is 18,788 (47.66%) while female population is 20,625 (52.34%). The number household was 9304 in 2011. The ethnic composition of municipality is mostly Chhetri, Tamang and Magar people while the most spoken language is Nepali followed by Tamang language. The religious practice includes Hinduism, Buddhism, Christianity, and Muslim in the municipality.

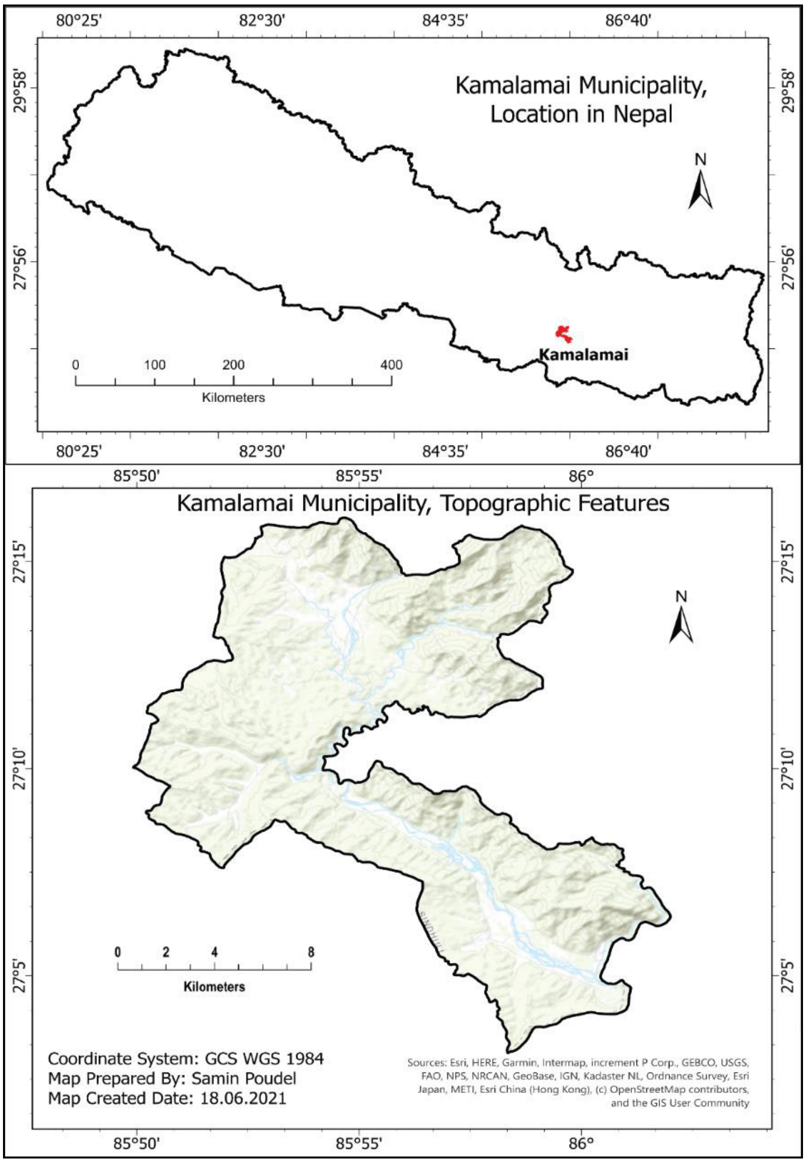

Fig.1 Location of Kamalamai Municipality in Nepal

3. Materials and Methods

3.1 Materials

Landsat images were downloaded from United States Geological Survey (USGS) website in 'Tiff' file format (Tab.1). These images covered entire study area of the municipality.

Date of Acquisition	Satellite	Spatial Resolution
18-01-2001	Landsat 7	30m
04-01-2016	Landsat 8	30m
01-01-2021	Landsat 8	30m

Tab.1 Landsat satellite images specification

Digital Elevation Model (DEM) was downloaded as Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global data. The freely available enhanced void filled elevation model with 30m spatial resolution was downloaded from USGS website. The data of municipal boundary, landslide susceptibility, flood susceptibility, roadway and settlements were acquired from Department of Urban Development and Building Construction (DUDBC), Nepal's municipal database for Kamalamai Municipality.

3.2 Image pre-processing

Typical image processing uses radiometric pre-processing, to adjust digital values for the effect of atmosphere and geometric pre-processing to bring an image into registration with another image or a map (Campbell, 2002). The ready to use surface reflectance level 2 was used as the primary imagery for the study which are corrected for operational procedure. The level 2 output products are enhanced products available for download. The downloaded file consisted of 8 spectral bands. The study area was subset to the extent of the study area in ArcGIS Pro for bands 1 to 7. The subset image was composited to single image using "Composite Bands" tool in ArcGIS Pro. The same process was used for images of 2001, 2016 and 2021.

3.3 Land Use Land Cover (LULC) classification

Image was classified using "Image Classification Wizard" in ArcGIS Pro. The supervised image classification technique was used to classify the image. Training samples were assigned for each image of 2001, 2016 and 2021. The basic classes identified were forest, shrub, water, agricultural, barren, and built-up derived from National Land Cover Dataset (NLCD, 2016). For the image of 2001 a total of 217 training samples were collected including 68 agricultural land, 13 water body, 5 shrubland, 76 forest area, 7 built-up area and 48 barren land samples with a pixel percentage of 6.31%, 0.26%, 0.25%, 91.39%, 0.20 % and 1.59%. For the image of 2016 a total of 260 training samples were collected including 90 agricultural land, 31 water body, 7 shrubland, 67 forest area, 20 built-up area and 45 barren land samples with a pixel percentage of 12.56%, 0.90%, 0.83%, 83.16%, 0.69 % and 1.86%. The image of 2021 a total of 272 training samples were collected including 97 agricultural land, 34 water body, 9 shrubland, 44 forest area, 44 built-up area and 44 barren land samples with a pixel percentage of 10.87%, 1.04%, 1.03%, 82.92%, 2.00% and 2.15%.

Support Vector Machine (SVM) was used for the classification with maximum number of Samples per class 500. SVMs have provided better classification results than classification methods like maximum likelihood and neural network classifiers while a very small training set can provide good classification result for Landsat images as well (Tzotsos & Argialas, 2008). After using classification tool, adjustments were done to correct the misclassified classes using "Reclassify" tool in ArcGIS Pro for a better classification result. This step was used for increasing the accuracy of classified image by reclassifying misclassified pixels. Two edit types for reclassification were used "Reclassify an object" and "Reclassify within a region".

3.4 Accuracy Assessment

Accuracy assessment in mapping projects related to RS data is an integral part of the study (Lunetta and Lyon, 2004). Classification error is when pixels belonging to one category and assigned to another category (Campbell, 2002). The classification errors can result from image quality, mapping units which can be quantified using accuracy assessment to know the quantified error of result (Lahoti et al., 2019). The standard form of assessing accuracy errors is error matrix/ confusion matrix which identifies overall errors for each category as well as errors misclassified by category (Campbell, 2002). Accuracy assessment was done using "Stratified random points" in ArcGIS Pro and verified using satellite imagery and google earth base map. The data was verified using confusion matrix including user's accuracy, producer's accuracy, overall accuracy, and Kappa Coefficient. "Compute Confusion Matrix" tool in ArcGIS Pro was used to get an excel table of confusion matrix. An acceptable accuracy limit of more than 85% (ThiLoi, Tuan and Gupta, 2015) was checked for classified images.

User's accuracy is computed as number of correct pixels category to total number of pixels classified to specific category which is percentage of right classification for all categories while producer's accuracy is the number of pixels correctly classified in specific category as percentage of total number of pixels belonging to that category (Schuckman & Dunne, 2020). Kappa coefficient is measured as the difference between the observed agreement two maps that are observed by the diagonal entries in error matrix as well as the agreement that might by attained by chance matching of two maps (Campbell, 2002).

The equations determining accuracy of classification are presented using equations ((1)-(4)) (Lahoti et al., 2019):

$$User's Accuracy\ in\ class\ (i) = \frac{n_{ij}}{n_{i.}} \tag{1}$$

$$Producer's Accuracy\ in\ class\ (i) = \frac{n_{ij}}{n_{.j}} \tag{2}$$

$$Overall\ Accuracy = \frac{(\Sigma \mathrm{k}^{\mathrm{i}} = 1 n_{ij})}{n} \tag{3}$$

$$Kappa\ Coefficient = \frac{(n\Sigma \mathrm{k}^{\mathrm{i}} = 1 n_{ij} - \ \Sigma \mathrm{k}^{\mathrm{i}} = 1 n_{i}.n_{j}\ )}{(n2 - \ \Sigma \mathrm{k}^{\mathrm{i}} = 1\ n_{i}.n_{j})} \tag{4}$$

where K represents number map to be 1,2,….,k;

n_{ij} = number of sample units belonging to class i in reference to class j;

$n_{i.}$ = sum of elements in row;

$n_{.j}$ = sum of elements in column;

n = total unit number of samples.

3.5 Analytical Hierarchy Process (AHP)

AHP is a multi-criteria decision-making method developed by Prof. Thomas L. Saaty in 1970s which has been extensively used for pair-wise comparison since. The multi-criteria programming with AHP helps to make decisions in complex scenarios where many variables or criterions are considered, and the prioritization of these variables are different from one another (Vargas, 2010). The fundamental comparison scale (Tab.2) is used to make judgement of paired comparison.

1	Equal Importance	Two activities contribute equally to the objective
2	Weak	-
3	Moderate Importance	Experience and judgment slightly favor one activity over another
4	Moderate Plus	-
5	Strong Importance	Experience and judgment strongly favor one activity over another
6	Strong Plus	-
7	Very Strong or Demonstrated Importance	An activity is favored very Strongly over another, its dominance demonstrated in practice
8	Very, Very Strong	-
9	Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation

Tab.2 Fundamental Comparison Scale (Satty and Vargas, 2012)

The scale has been validated for its effectiveness in many applications (Saaty & Vargas, 2012). The steps of measuring inconsistencies; consistency index (CI) and Consistency Ratio (CR) are used to improve the consistency of judgements (Saaty & Vargas, 2012). CI is given by (5) and CR (6) where, Random Index (RI) is the average value of CI and CR must be < 0.1 (Saaty & Vargas, 2012) for correct decision.

$$CI = \frac{(\lambda \max - n)}{(n-1)} \tag{5}$$

$$CR = \frac{CI}{RI} \tag{6}$$

3.6 Suitability Analysis

The suitability analysis was based on flood and landslide susceptibility, existing LULC, aspect, slope, road proximity, settlement proximity and elevation. The DEM was used to derive slope and aspect of the study area using "Slope" and "Aspect" tools in ArcGIS Pro. AHP was used to derive weights to each suitability layers. "Reclassify" tool in ArcGIS Pro was used to categorize the parameters into required classes for each layer. Each weighted class were reclassified between the values of 1 and 0. The weighted overlay method was used for analyzing the values of each variable to find suitable areas for built-up expansion.

3.7 Land Change Modeler (LCM)

The modelling of LULC was done in Terr-set Land Change Modeler. LCM Change Analysis was first used to analyze changes in LULC from 2001 and 2016. Transition variables i.e., proximity to roadway, proximity to settlements, elevation, slope, flood susceptible areas, landslide susceptibility, aspect were used to calculate transition potential maps using MLP neural network for water to built-up, barren to built-up, shrub to built-up, agricultural to built-up and forest to built-up.

The change prediction was done using Markov module analyzer, Markov Chain prediction process with prediction date 2021 using transition sub-models for all five possible transition classes, then model was run to obtain hard and soft prediction map for 2021. The model was then used for transition of 2016 to 2021, 2031, 2041 and 2051.

To predict the LULC model for 2031, 2041 and 2051 the constraints and incentives regions were assigned in accordance with suitability map. The maps and models created in Terr-set were added as layers in ArcGIS pro. The map data was calculated in ArcGIS Pro and exported for further data analysis in Excel and maps were prepared in ArcGIS Pro.

3.8 Markov Model

Markov model is convenient tool for simulating landscapes and processes for modelling LULC changes, where future state is simulated based on immediate state (S. Kumar et al., 2014). The Markov model theory which is based on the formulation of Markov random process for the prediction and optimal control theory, while the model explains the quantified conversion states between land use types as well as the transfer rate among the different LULC (Sang et al., 2011).

The model is related to dynamic distributed lag model which consists of two components; transition matrix and transition probability matrix that represents the number and probability of land changing from one land use class to another in the observed period (Han et al., 2015). A Markov model can be specified as having "S" states interconnected with some or all states while each state generates an observation o^{s}_{t} where "s" is the state in time "t" and transition occurs in some specified probability from one state to another (Hosom, 2003). The LULC change prediction in Markov Model is calculated as (7).

$$S(t+1) = P_{ij} \times S(t) \tag{7}$$

Where, S (t) and S (t + 1) are system status at time, t and t + 1 and Pij.is transition probability matrix in a state calculated as (8).

$$\begin{bmatrix} P_{11} & P_{12} & \dots & P_{13} \\ P_{12} & P_{22} & \dots & P_{2n} \\ \dots & \dots & \dots & \dots \\ P_{11} & P_{12} & \dots & P_{1n} \end{bmatrix}$$

$$(0 \leq P_{ij} < 1 \, and \, \textstyle\sum_{j}^{N} = 1 \, P_{ij}, (i, j = 1, 2, \dots.. n)) \tag{8}$$

4. Results

4.1 Classification Results

The Landsat images of 2001, 2016 and 2021 were classified for the study area of Kamalamai Municipality (Fig.2).

The built-up areas accounted 0.5% (1.09 Km²) in the municipality in 2001. The municipality consisted largest area of forest with 73.1% (149.89 Km²) followed by agricultural land 20.4% (41.93 Km²). In 2016 the forest decreased to 70.1% (143.81 Km²) and agricultural area increased to 23.7% (48.51 Km²) while built-up had an increment to 0.8% (1.64 Km²). In 2021 the municipality consisted of 70.9% (145.46 Km²) forest while agricultural area decreased from 2016 to 17.3% (35.40 Km²). The built-up increased considerably from 2016 to 1.9% (3.95 Km²). The analysis of land use change revealed significant transformations in Kamalamai Municipality from 2001 to 2021. The built-up areas exhibited noticeable growth, particularly in the central part of the municipality. Forest cover decreased over time, while orchards, croplands, and settlements increased.

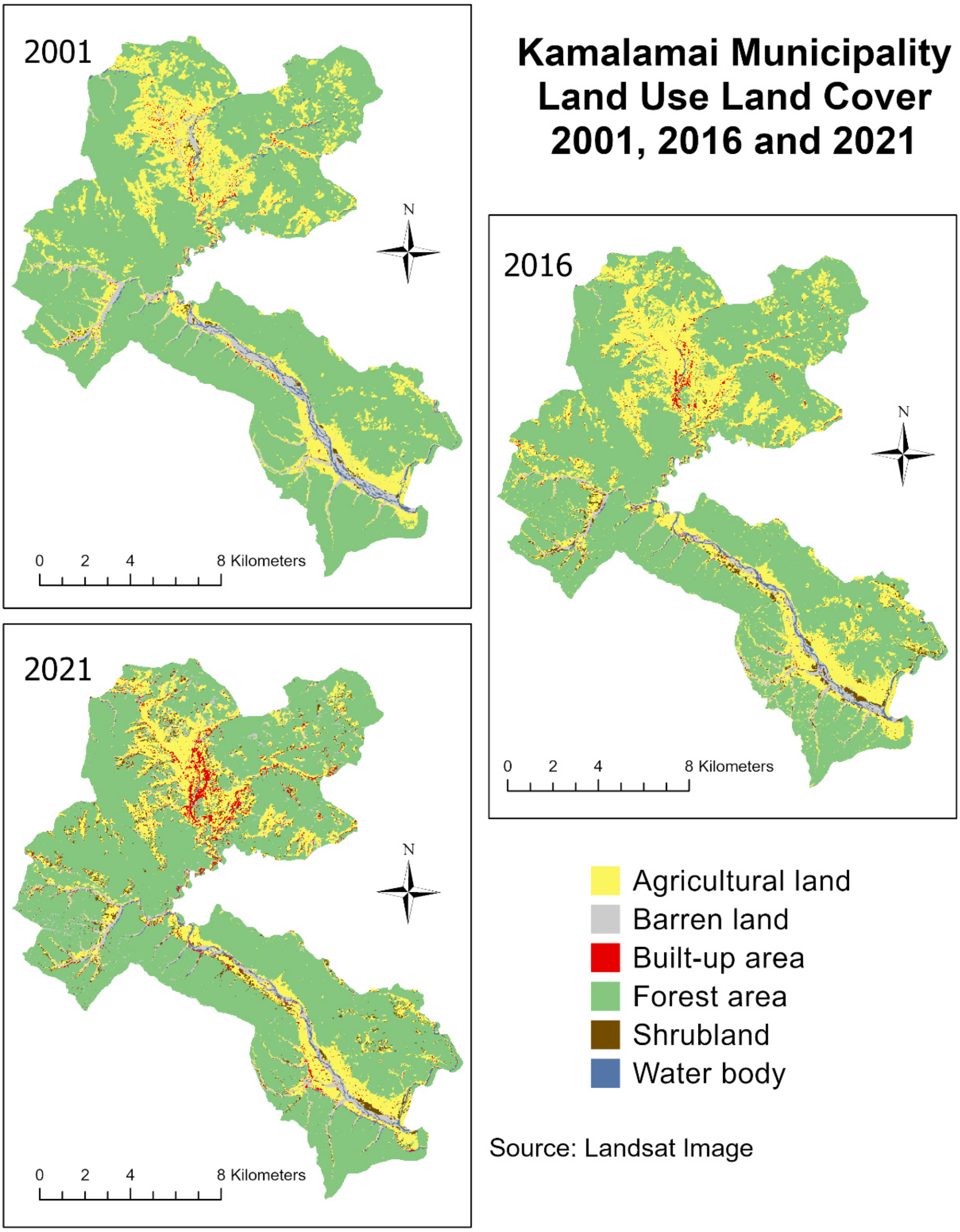

Fig.2 Kamalamai Municipality: Land Use Land Cover 2001, 2016 and 2021

4.2 Accuracy Assessment

The accuracy for each classification was found to be within the acceptable limit of 85% ovearall accuracy (ThiLoi et al., 2015) (Tabb. 3-5).

Class Value	Water Body	Built-up Area	Barren Land	Forest Area	Agricultural land	Shrubland	Total	User's Accuracy	Kappa
Water Body	9	0	0	0	1	0	10	90%	0
Built-up Area	0	4	0	1	3	2	10	40%	0
Barren Land	0	0	18	0	1	1	20	90%	0
Forest Area	0	0	0	362	3	0	365	99%	0
Agricultural Land	0	0	3	1	95	3	102	93%	0
Shrubland	0	0	0	0	0	10	10	100%	0
Total	9	4	21	364	103	16	517	0%	0
Producer's Accuracy	100%	100%	86%	99%	92%	63%	0%	96%	0
Kappa	0	0	0	0	0	0	0	0	0.92

Tab.3 Confusion Matrix: Land Use Land Cover 2001

Class Value	Water Body	Built-up Area	Barren Land	Forest Area	Agricultural land	Shrubland	Total	User's Accuracy	Kappa
Water Body	10	0	0	0	0	0	10	100%	0
Built-up Area	2	5	1	0	2	0	10	50%	0
Barren Land	0	0	12	0	1	0	13	92%	0
Forest Area	0	0	0	351	0	0	351	100%	0
Agricultural Land	0	1	4	10	98	5	118	83%	0
Shrubland	0	0	0	0	1	9	10	90%	0
Total	12	6	17	361	102	14	512	0%	0
Producer's Accuracy	83%	83%	71%	97%	96%	64%	0%	95%	0
Kappa	0	0	0	0	0	0	0	0	0.89

Tab.4 Confusion Matrix: Land Use Land Cover 2016

Class Value	Water Body	Built-up Area	Barren Land	Forest Area	Agricultural land	Shrubland	Total	User's Accuracy	Kappa
Water Body	8	0	0	0	1	1	10	80%	0
Built-up Area	0	9	0	0	0	1	10	90%	0
Barren Land	0	0	22	2	2	1	27	81%	0
Forest Area	0	0	1	353	1	0	355	99%	0
Agricultural Land	0	1	1	3	78	3	86	91%	0
Shrubland	0	1	0	2	3	11	17	65%	0
Total	8	11	24	360	85	17	505	0%	0
Producer's Accuracy	100%	82%	92%	98%	92%	65%	0%	95%	0
Kappa	0	0	0	0	0	0	0	0	0.90

Tab.5 Confusion Matrix: Land Use Land Cover 2021

4.3 Pairwise Comparison

The pairwise weightage was assigned based on fundamental pairwise comparison (Table 2), for suitability parameters, landslide susceptibility, flood susceptibility, existing LULC, aspect, slope, proximity to slope and proximity to settlement (Tab.6).

	Landslide	**Flood**	**Existing LULC**	**Aspect**	**Slope**	**Road**	**Settlement**	**Elevation**
Landslide	1	1	4	5	6	7	8	9
Flood	1	1	4	5	6	7	8	9
Existing LULC	0.25	0.25	1	3	4	6	7	8
Aspect	0.20	0.20	0.33	1	2	5	6	7
Slope	0.17	0.17	0.25	0.50	1	4	5	7
Road	0.14	0.14	0.17	0.20	0.25	1	1	3
Settlement	0.13	0.13	0.14	0.17	0.20	1	1	3
Elevation	0.11	0.11	0.13	0.14	0.14	0.33	0.33	1

Tab.6 Deriving Priorities for Suitability

The CI was obtained to be 0.114 and CR 0.081. The relative values obtained for each class was, landslide susceptibility = 0.3, flood susceptibility = 0.3, existing LULC = 0.15, aspect = 0.10, slope = 0.07, distance from existing roads = 0.03, distance from existing settlements = 0.03, and elevation = 0.02. The obtained values are further split for each suitability parameters.

4.4 Suitability Analysis

Tab.7 shows the weighted values for each parameter for suitability assessment of the study area.

Suitability Level: Landslide		**Aspect**	
High	2.1	High- (157.5 to 202.5)	0.5
Medium	0.9	Medium (112.5-157.5 and 202.5-247.5)	0.3
Low	0	Low (90-112.5 and 247.5-270	0.2
Suitability Level: Flood		None (0-89.5 and 271-360)	0
High	2.1	**Distance from Existing Road**	
Medium	0.9	High- Up to 100m	0.21
Low	0	Medium- 100m to 150m	0.09
LULC-2021		Low- Above 150m	0
High- Built-up, Barren, Shrub	1.35	**Distance from Existing Settlement**	
Medium- Agriculture	0.15	High- Up to 250m	0.21
Low- Forest, Water	0	Medium- 250m to 500m	0.09
Slope		Low- Above 500m	0
High- Up to 15°	0.49	**Elevation**	
Medium- 15° to 30°	0.21	High- Up to 500m	0.14
Low- Above 30°	0	Medium- 500m to 1000m	0.06
		Low- Above 1000m	0

Tab.7 Weightage for Suitability Parameters

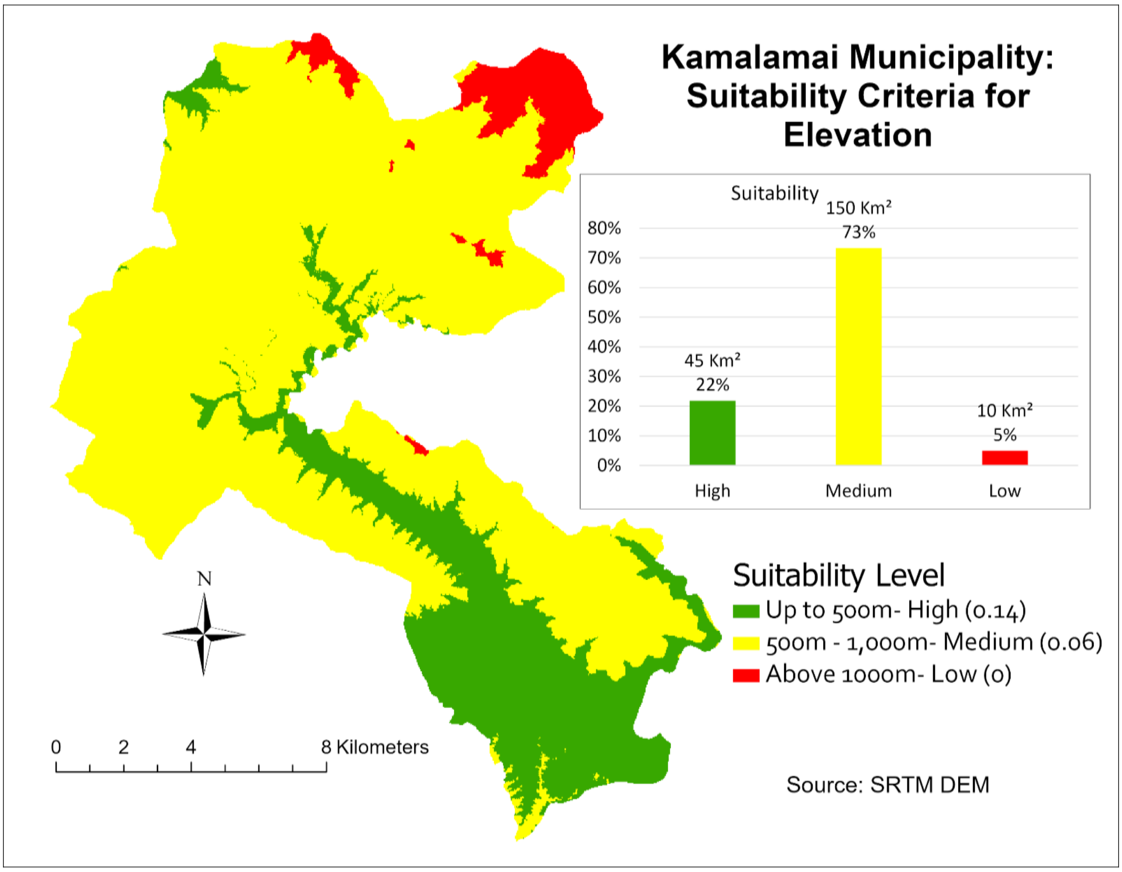

Fig.3 Kamalamai Municipality: Suitability Criteria for Elevation

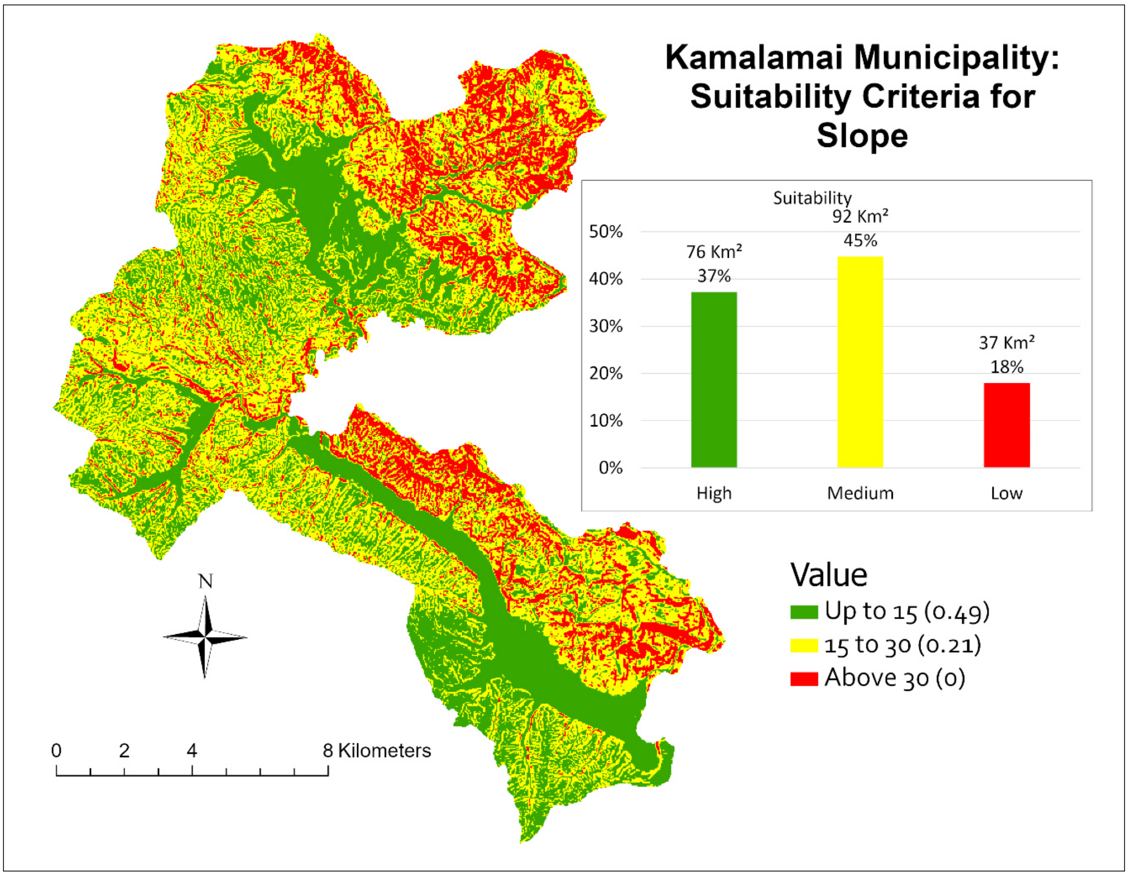

Fig.4 Kamalamai Municipality: Suitability Criteria for Slope

The suitability criteria for elevation included areas of high elevation (Above 1,000 m) as least suitable, the areas between 500 m and 1,000 m as medium suitable and areas up to 500 m as highly suitable. 22% (45 Km^2) area was highly suitable, 73% (150 Km^2) area had medium suitability and 5% (10 Km^2) had low suitability for built-up expansion (Fig.3).

The suitability criteria for elevation included areas of high elevation (Above 1,000 m) as least suitable, the areas between 500 m and 1,000 m as medium suitable and areas up to 500 m as highly suitable. 22% (45 Km^2) area was highly suitable, 73% (150 Km^2) area had medium suitability and 5% (10 Km^2) had low suitability for built-up expansion (Fig.3).

The suitability criteria for Slope included area of high slopes (Above 30°) as least suitable, medium slope (15° to 30°) and low slopes (Up to 15°) as highly suitable. 37% (76 Km^2) area was highly suitable for built-up expansion, 45% (92 Km^2) area had medium suitability and 18% (37 Km^2) had low suitability for built-up expansion (Fig.4).

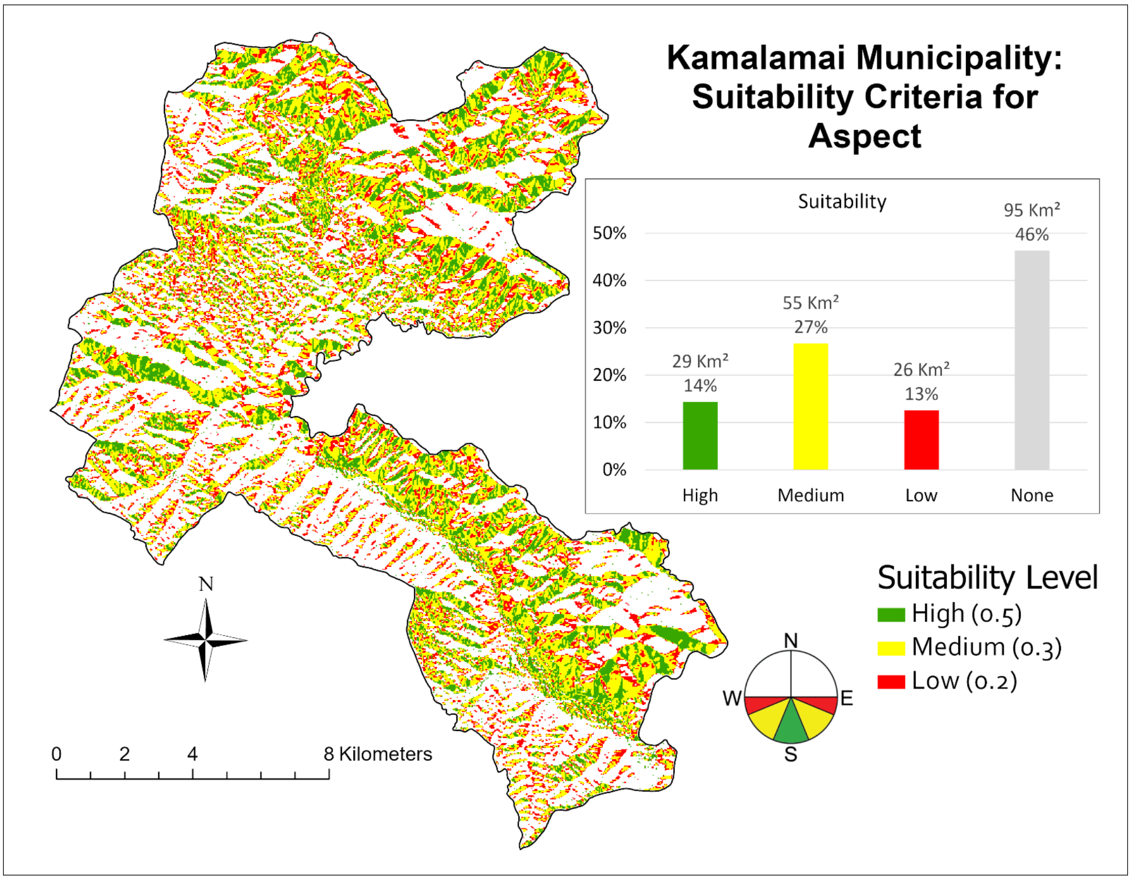

Fig.5 Kamalamai Municipality: Suitability Criteria for Aspect

The suitability criteria for aspect included areas of northern aspect (0-89.5 and 271-360) as not suitable, eastern (90-112.5), and western (247.5-270) aspect as least suitable, south-western (202.5-247.5), and south-eastern (112.5-157.5) aspect as medium suitable and southern aspect (157.5 to 202.5) as most suitable. 14% (29 Km^2) area was highly suitable for built-up expansion, 27% (55 Km^2) area had medium suitability and 13% (26 Km^2) had low suitability for built-up expansion, while 46% (95 Km^2) was not suitable (Fig.5).

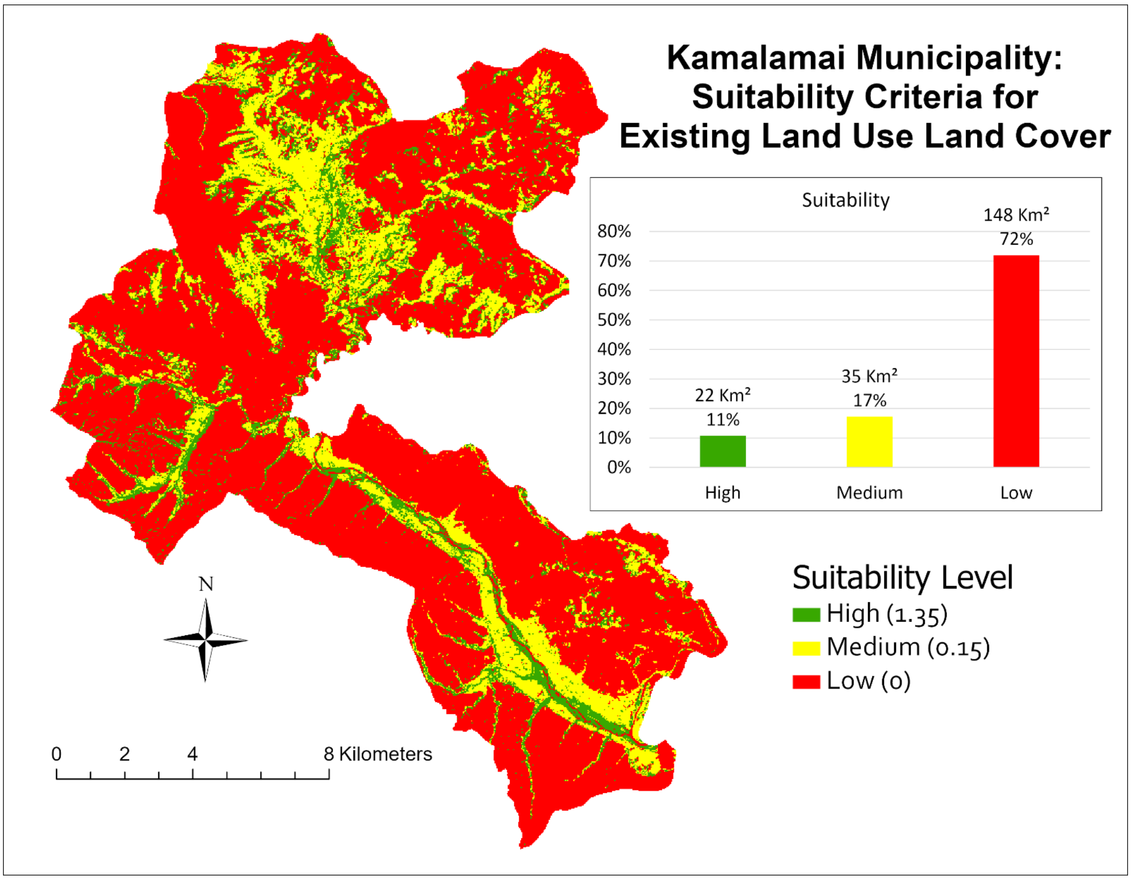

Fig.6 Kamalamai Municipality: Suitability Criteria for Existing Land Use Land Cover

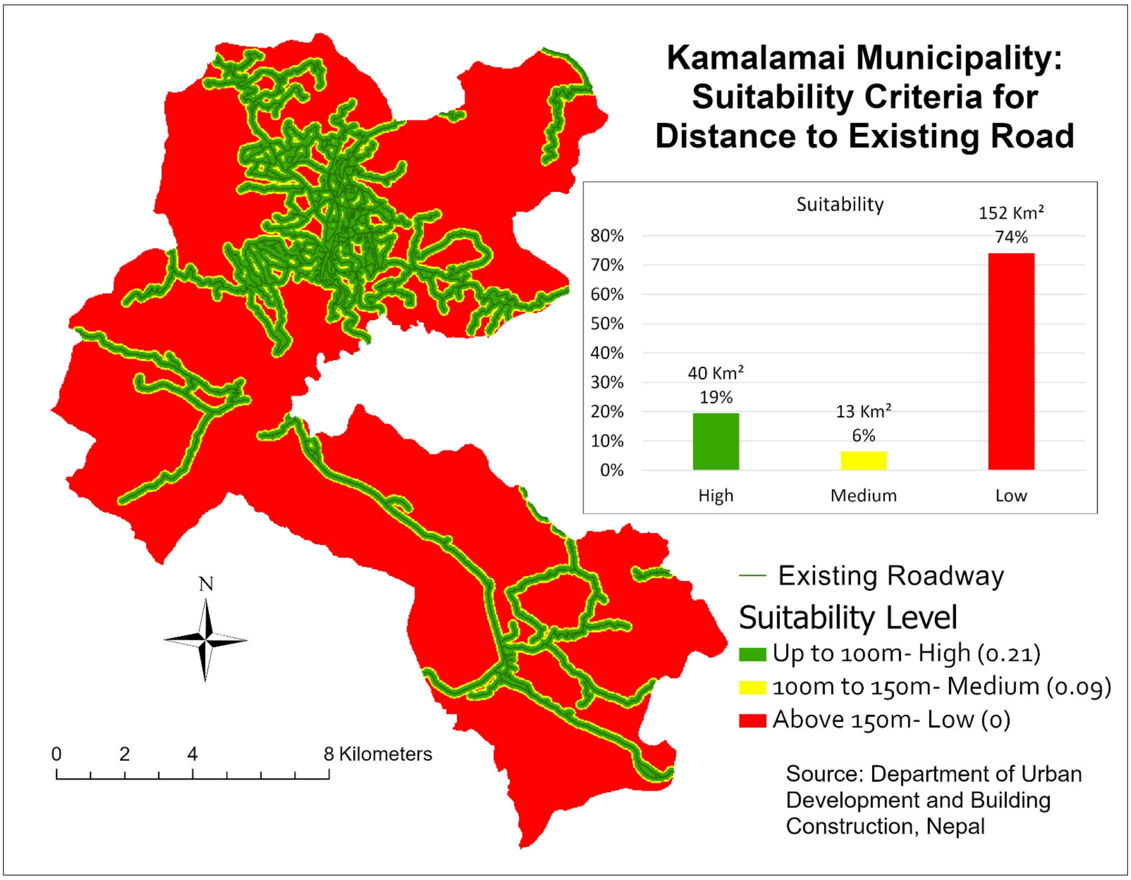

Fig.7 Kamalamai Municipality: Suitability Criteria for Distance to Existing Roadways

The suitability criteria for existing LULC included built-up areas, barren and shrubland as highly suitable, agricultural area as medium suitable and waterbodies and forest as low suitable. 11% (22 Km²) area was highly suitable for built-up expansion including infill in existing built-up, 17% (35 Km²) area had medium suitability and 72% (148 Km²) had low suitability for built-up expansion (Fig.6).

The suitability criteria for roadway proximity included areas farther from the existing roadway (more than 150 m) as not suitable, areas between 100 m and 150 m from the roadways as medium suitable and areas up to 100 m from the roadway as highly suitable. 19% (40 Km²) area was highly suitable, 6% (13 Km²) area had medium suitability and 74% (74 Km²) had low suitability for built-up expansion (Fig.7).

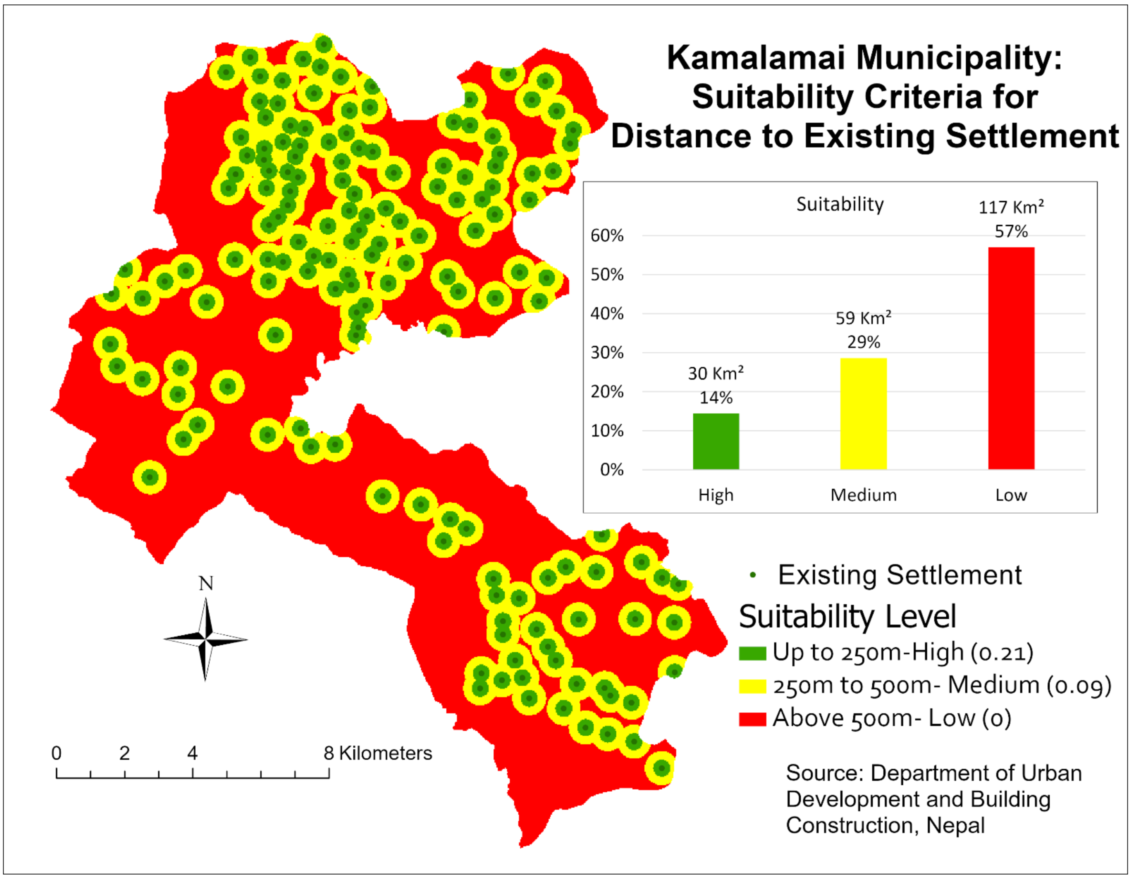

Fig.8 Kamalamai Municipality: Suitability Criteria for Distance to Existing Settlements

The suitability criteria for settlements proximity included areas farther from the existing settlements (more than 500 m) as not suitable, areas between 250 m and 500 m from the settlements as medium suitable and areas up to 250 m from the settlements as highly suitable. 14% (30 Km²) area was highly suitable, 29% (59 Km²) area had medium suitability and 57% (117 Km²) had low suitability for built-up expansion (Fig.8).

The landslide susceptibility data indicated areas prone to landslide as highly susceptible which were assigned low suitability values, areas where landslide would rarely occur as medium prone areas were assigned medium suitability values and areas where it was unlikely to be affected by landslides as highly suitable. 53% (109 Km²) area was highly suitable with low landslide risk, 29% (59 Km²) area had medium suitability and 18% (37 Km²) had low suitability for built-up expansion and high landslide risk (Fig.9).

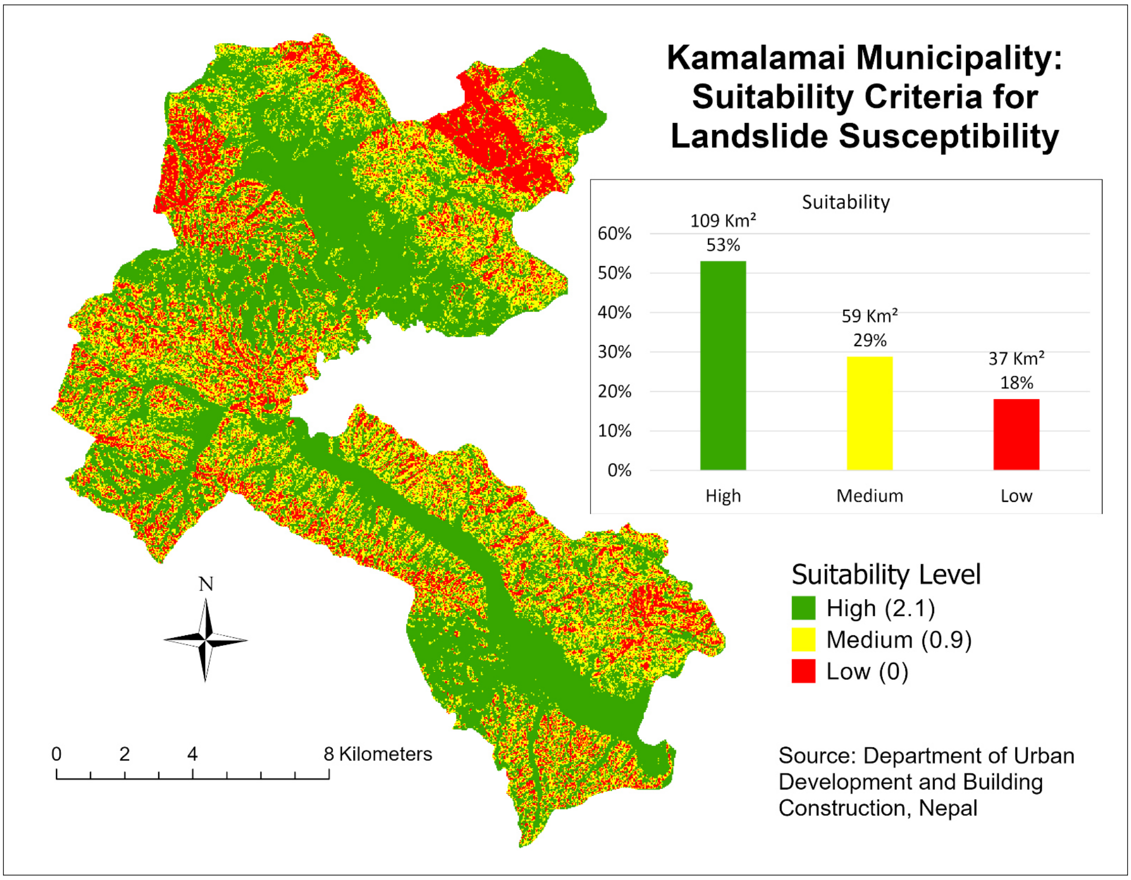

Fig.9 Kamalamai Municipality: Suitability Criteria for Landslide Susceptibility

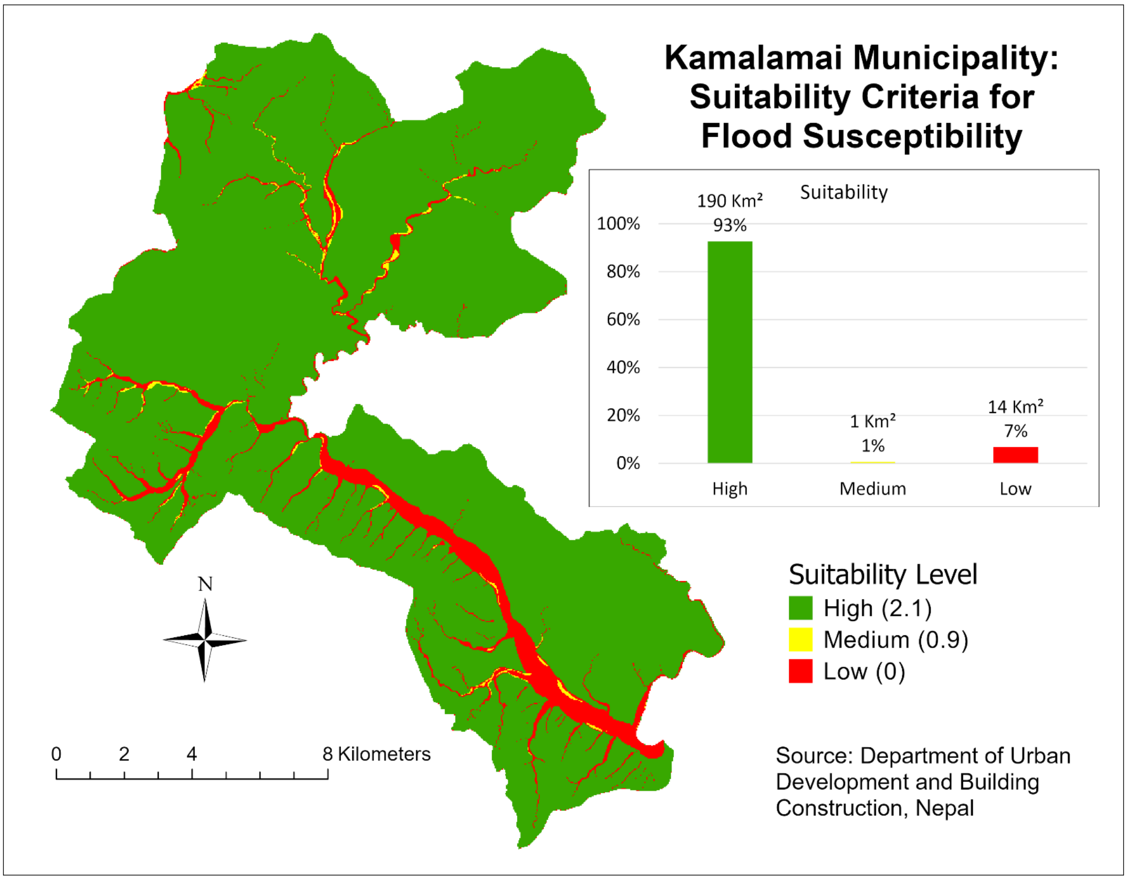

Fig.10 Kamalamai Municipality: Suitability Criteria for Flood Susceptibility

Similarly, the flood susceptibility data indicated places prone to flooding as high flooding areas with low suitable values, places near riverbanks with medium flooding areas as medium suitable and areas where flood was unlikely to occur as highly suitable. 93% (190 Km²) area was highly suitable with low flood risk, 1% (1 Km²) area had medium suitability and 7% (14 Km²) had low suitability for built-up expansion and high flood risk (Fig.10).

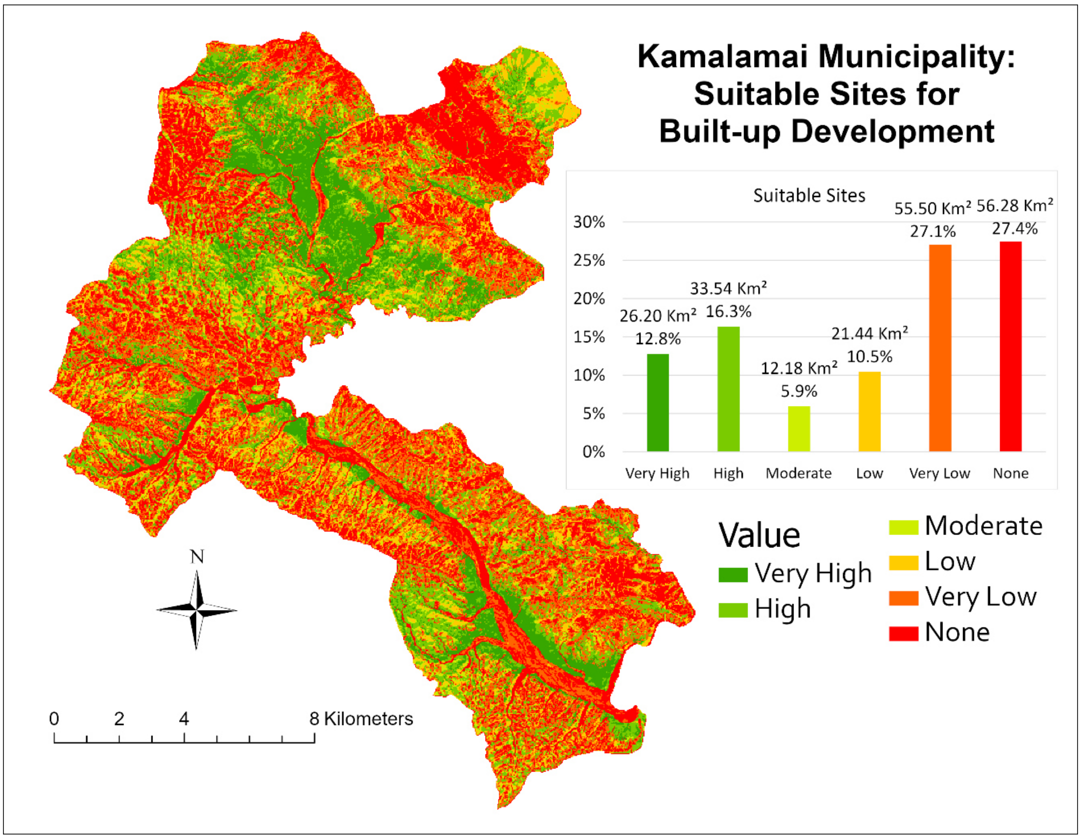

Fig.11 Kamalamai Municipality: Site Suitable for Built-up Expansion

The suitability analysis showed that 27.4% (56.28 Km²) area of the municipality had no suitability for built up expansion 27.1% (55.50 Km²) had a very low suitability, 10.5% (21.44 Km²) had a low suitability while 5.9% (12.18 Km²) had a moderate suitability, 16.3% (33.54 Km²) had a high suitability and 12.8% (26.20 Km²) had a very high suitability (Fig.11).

The suitability analysis revealed that elevated regions in the eastern and southern parts of the municipality were less suitable for built-up expansion due to steep slopes and potential landslide susceptibility. The central part of the municipality, with its flat terrain and proximity to existing infrastructure, showed high suitability for urban expansion.

4.5 Transition Potential Modelling

The study used a land change transition model to predict the potential transition from various land classes to the built-up class. MLP Neural Network was used to develop sub-models for each transition and predict future development. The sub-models were specifically selected for transitions from water, shrub, barren, forest, and agriculture to built-up, excluding other parameters. The models were trained automatically with dynamic learning rate training parameters. The results of the models were evaluated based on accuracy and skill measures. The results show the parameters and performance of each sub-model, including the number of neurons in the input, hidden, and output layers, requested samples per class, learning rate, momentum factor, acceptable RMS, iterations, training and testing RMS, accuracy rate, and skill measure. The model accuracy ranged from 70.68% to 78.30%, with skill measures varying from 0.4135 to 0.5661.

The sensitivity analysis identified the most and least influential variables for each transition, indicating their impact on model accuracy. A backward stepwise analysis was conducted to determine the variables necessary to achieve the same accuracy as the full model. Maps were generated to visualize the transition potential from each land class to built-up (Fig.12).

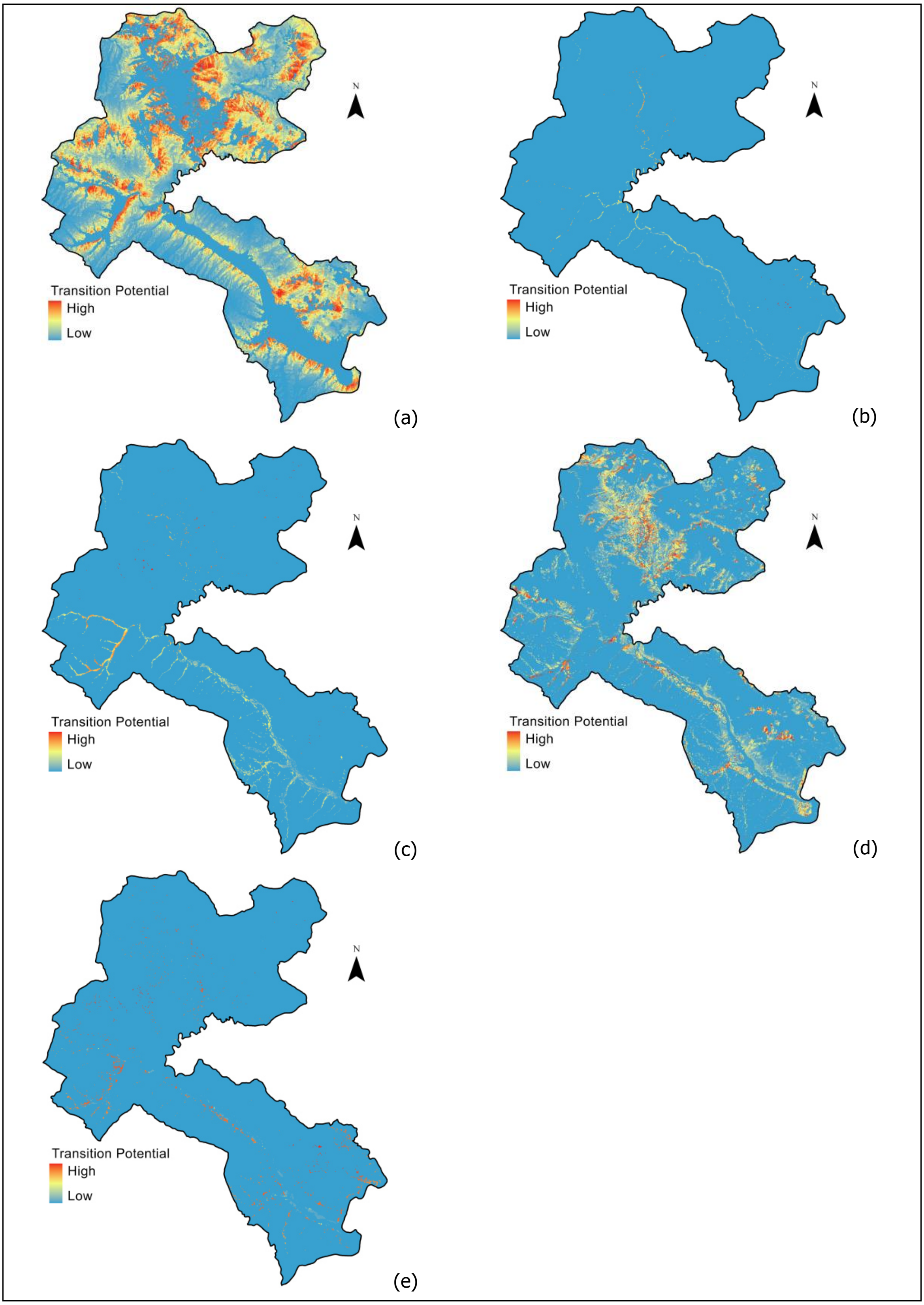

Fig.12 Transition Potential (a) Forest to Built-up (b) Waterbodies to Built-up (c) Barren to Built-up (d) Agriculture to Built-up (e) Shrubland to Built-up

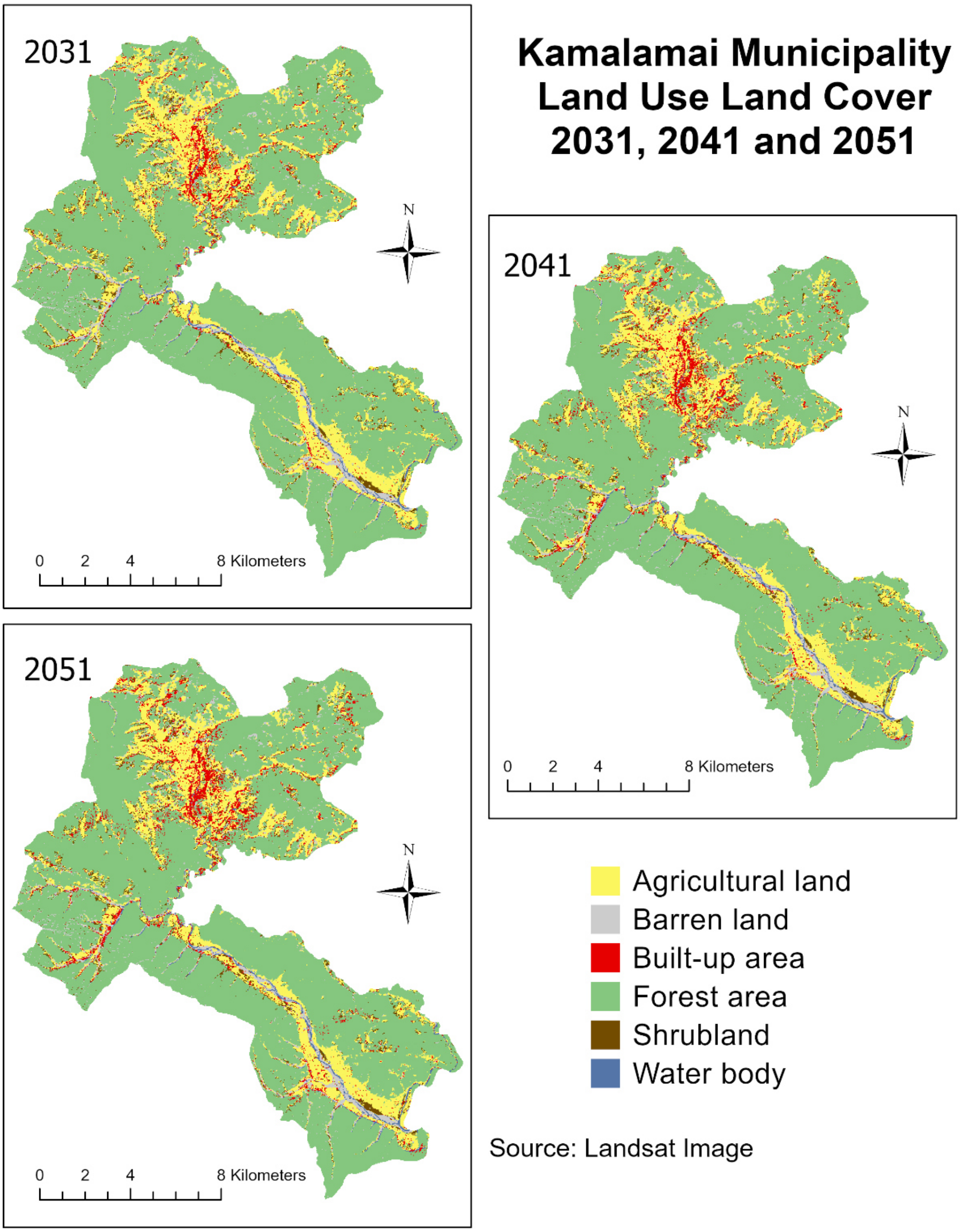

Fig.13 Kamalamai Municipality: Simulated Land Use Land Cover 2031, 2041, 2051

The suitability map was used for incentives and constraints for the simulation of built-up to 2031, 2041 and 2051 (Fig.13). The suitable areas being incentives and unsuitable areas being constraints. The simulated LULC showed that the built-up could increase from 1.90% (3.95 Km²) in 2021 to 2.5 % (5.13 Km²) in 2031 in first stage, then built-up could increase to 3.3% (6.69 Km²) in 2031 and in final stage could reach 4.0% (8.25 Km²) (Fig.14).

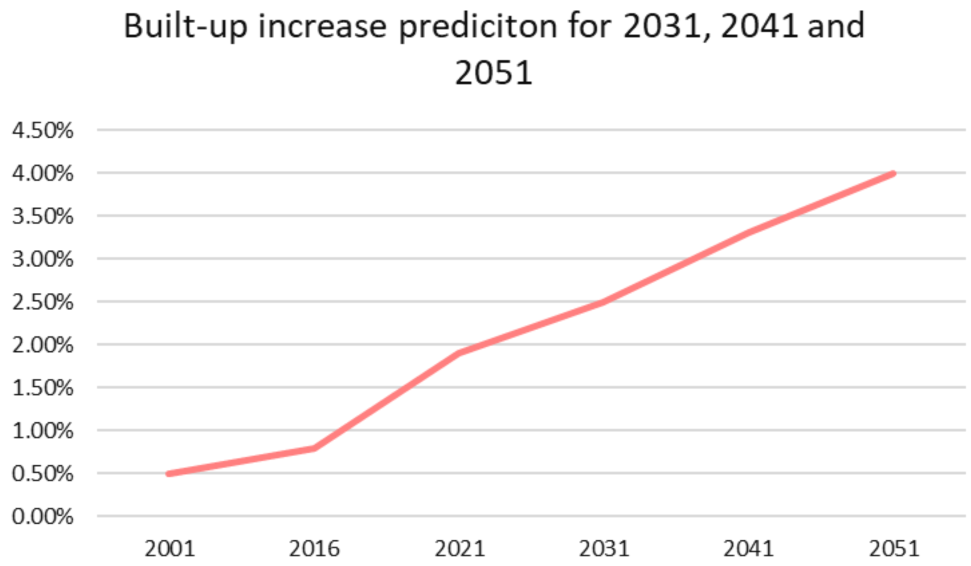

Fig.14 Built-up Transition 2001-2051

5. Discussion

Rapid urbanization in combination with exploitation of natural resources have had significant impact on ecosystem creating a fragile urban region (Deng et al., 2009). Land use suitability analysis can assist in identifying future land use to specific preferences, requirements and predictors of some activity (Collins et al., 2001; Hopkins, 1977; Malczewski, 2004). Similarly, the simulation of future LULC is of significant importance to maintain sustainable future (Wang et al., 2018). The built-up expansion suitability with integration of future simulation provides a decision support overview for an effective management of urban areas. (Santos & Moura, 2019; Ustaoglu & Aydınoglu, 2019)highlight the use of suitability analysis using AHP, multicriteria assessment and weighted sum as methods for land analysis. Urban areas can be vulnerable to various risks, primarily influenced by three key factors: location, proximity to coastal regions, major rivers, and low-lying zones prone to coastal erosion, flooding, sea-level rise, and other related hazards (Zucaro & Morosini, 2018). This study has integrated LULC study with risk factors and infrastructure availability to deliver a holistic simulation result. The analysis of land use change in Kamalamai Municipality revealed significant transformations over the study period. The observed increase in built-up areas, accompanied by a decrease in forest cover, highlights the ongoing process of urbanization and agricultural expansion. These changes are indicative of the growing population and the corresponding need for infrastructure development and land for agricultural purposes. The expansion of settlements and orchards can be attributed to changes in people's occupation and economic activities. The analysis showed that the built-up was mainly concentrated in the central part of the municipality, which is also the market area and few scattered settlements in other parts of the municipality in 2001. The agricultural lands were mainly around the built-up area and along the riverbanks of the municipality.

The built-up areas in the municipality had increased from 2001 to 2016, with the expansion of built-up in the central part of the municipality and new settlements development around the municipality. The study found that the forest area had decreased while orchards, cropland and settlement increased from 2001 to 2016 in-line with the previous study by (Neupane & Dhakal, 2017). There was considerable increase in Shrublands in the same period which may be attributed to the change in people's occupation and resulting changes in agricultural lands to shrub lands. The barren and water areas changes can be because of the seasonal rivers flow change. The built-up change as not significant till 2016 but tater, the built-up areas increased significantly in 2021. This increase could be attributed to the completion of highway from Kathmandu to

Terai plains through the municipality increasing the in-migration seeking commercial opportunities as well as the earthquake in 2015 which displaced many rural population to nearby towns.

The lack of urban form and structure in built-up expansion highlights the problem of lack of effective implementation of the local planning system. Despite the presence of a planning system required (NUDS, 2017), it appears that it is not being utilized adequately to control land use changes and guide sustainable development. Weak rules and regulations related to urban planning could have contributed to haphazard growth and uncontrolled land use changes. In relation to the broader national planning system of Nepal, the findings of this study shed light on the existing mechanisms for urban and land use planning and control. The effectiveness of the local planning system in Kamalamai Municipality is influenced by the broader national planning framework and its implementation.

The national planning system provides the legal and institutional framework for land use planning and management at the local level. However, it seems that the national planning system in Nepal has faced challenges in terms of coordination, capacity building, and enforcement. Also, the full implementation of decentralized planning and effective coordination between different levels of government is yet to be achieved.The weak enforcement and implementation of rules and regulations related to urban planning at the national level have also had an implication for local planning practices. In the case of Kamalamai Municipality, the limited effectiveness of the local planning system may be attributed, in part, to the broader challenges faced within the national planning system. This may have affected the ability of the municipality to enforce land use regulations, monitor development activities, and guide sustainable growth.

The simulation results of land use and land cover for 2041 and 2051 offer a glimpse into the potential future scenarios based on current trends and patterns. (Iacono et al., 2015) suggested that the integration of transportation networks and land use could provide a more comprehensive understanding of the dynamics of land use change which was implemented in the study. The suitable built-up simulation till 2041 showed that the southwestern area of the municipality could have more expansion along with northwestern region of municipality along the river corridor. The modelled LULC 2051 showed that the built-up expansion could expand mostly in the southwestern, north-western and the central town region of the municipality with expansion of small settlements along the north-eastern hilly areas and south-eastern areas along the riverbank and on the edge of the municipality on the south-western front and north-western edge of the municipality. The projected increase in built-up areas and the continued loss of forest cover emphasize the need for sustainable urban development practices. These findings could have several implications for future urban development and land use planning.

To encourage sustainable land use and construction practices, incentives including providing tax benefits or grants for developers and property owners for developing within the provided suitable development scenarios for 2041 and 2051 as identified in the study. The maps can be used for strengthening local planning system to create regulations for sustainable town development. The scenarios could be a effective material to review and update existing land use regulations to ensure their effectiveness in guiding urbanization and development. This study can guide an urban development strategy to preserve good-quality agricultural land and help conserve natural resources.

Moreover, future planning efforts should focus on promoting compact and efficient urban growth, integrating green spaces, and adopting sustainable land use policies. Considering the potential impacts of climate change, future land use planning should also incorporate measures for adaptation and resilience. The projected expansion of built-up areas may increase the vulnerability of the municipality to natural hazards and extreme weather events. Integrating climate change considerations into land use planning can help identify areas prone to risks and develop strategies for resilient infrastructure and disaster preparedness. Given the challenges within the national planning system, future efforts should focus on improving the integration between national and local planning authorities. Strengthening coordination mechanisms, enhancing capacity at the local level, and aligning the local planning system with national goals and strategies are essential for effective land use planning. The projected scenarios for 2041 and 2051 highlight the need for sustainable practices, effective governance, climate change adaptation, community engagement, and integration between national and local planning efforts. These learnings can guide policymakers, planners, and stakeholders in shaping a more sustainable and resilient future for the municipality.

6. Limitation

The study concentrated on the landslide susceptibility, flood susceptibility, current LULC, slope, aspect, distance from existing roadway, distance from existing settlements and elevation as parameters for suitability assessment. The factors for suitability assessment have other essential components such as environmental factors, climatic effects, and fire risk for determining the suitable areas for built-up development. But lack of data collection possibility and lack of available data meant these could not be analyzed as these analyses were not possible during the research. The transition was also modelled for built-up category only, but transition of other land use classes is important as well but were not covered within the scope of this report. The research was based on geographic analysis of LULC and its future prospect. The aspects of LULC change in the municipality, suitability for built-up expansion were incorporated in this study. This was though not sufficient to present a socio-economic prospect, health prospects and ecological prospects of LULC changes. The transition to public spaces could not be modelled as the scope of the study focused mainly on built-up expansion yet the future study could emphasize on the planning of service infrastructure and public spaces within the identified suitable expansion areas.

The study was conducted based on medium resolution Landsat image. The spatial resolution of image of 30m affected the classification process. In some cases, multiple LULC was classified in a single pixel. The course resolution meant that water bodies like rivers were mapped as discrete entities rather than continuous river polygons. The small objects in the municipality did not show in the classified image. Similarly, the coarse resolution of classification image can also impact the modelling of LULC.

The methods used for the study was effective in identifying built-up expansion area in consideration of suitable areas in the municipality. Future studies can make use if high resolution imagery for analysis of LULC. Similarly, more geographic data could make the study more effective like soil property in the area, ecological indicators, and socio-economic factors. Similarly, more risk datasets like fire hazards, thunderstorms, soil erosion, drought could be used within suitability mapping for more holistic overview. Future research could consider not only built-up change simulation but change from each land use category to another and simulation in consideration of all land use class changes.

7. Conclusion

There has been considerable built-up increase in Kamalamai Municipality, but the increase has not been regulated or planned which could spill to the environmentally sensitive areas, disaster prone areas and/or economically unfeasible areas. The study has presented a future model for Kamalamai Municipality, focusing on addressing the challenges of urbanization and land use planning. Through a detailed analysis of the urbanization trend, suitability analysis and simulation results, future development scenarios have been identified for the sustainable development framework for the municipality. The identified suitable built-up areas for 2041 and 2051 urban scenario model can enable effective building control by providing guidelines and regulations for construction activities. It can be integrated into zoning regulations, ensuring appropriate building permits, and promoting safe and sustainable construction practices. This aspect could contribute to the orderly growth of the municipality and prevents haphazard urban expansion.

The model incorporates the protection of environmentally important areas. By enforcing building control measures, the model aims to prevent haphazard and unplanned urban expansion. The model incorporates environmental considerations such as protection of forests, shrublands and vegetated areas while focusing development on existing settlements. This ensures that development activities are carried out in a manner that minimizes negative ecological impacts and promotes sustainability. The proposed model recognizes the interdependence between construction activities, the provision of essential services, and the creation of public spaces. It emphasizes the integration of infrastructure development, such as transportation networks to create well-connected, functional, and aesthetically pleasing urban environments.

Integrating construction and services within the modeled built-up area could promote the development of well-planned and efficient urban infrastructure. This leads to improved connectivity, accessibility, and functionality within the municipality. The study provides a comprehensive framework for managing and planning urban development in Kamalamai Municipality. By focusing on building control, considering environmental constraints, and integrating construction, and services, the proposed model offers a holistic approach to sustainable urbanization. The expected results include orderly urban growth, environmental sustainability, and enhanced quality of life for residents. The adoption of this model could contribute to the municipality's long-term prosperity and serve as a valuable reference for urban planners and policymakers in Nepal and beyond.

The use of RS data and GIS techniques can assist in identification and planning of built-up expansion area. The Landsat images of 2001, 2016 and 2020 were used to map LULC change in that period using supervised image classification technique. ArcGIS Pro was used for preprocessing and classification of satellite imagery. The use of DEM made it possible to map elevation, slope, and aspect of the study area. The integration of flood susceptibility, landslide susceptibility, existing LULC, slope, aspect, proximity to roadways, proximity to settlements, and elevation was used for suitability analysis in the municipality for built-up expansion using AHP weighing method. The LULC change maps were used for change simulation for 2031, 2041 and 2051 while suitability map was used as incentive/constraints for built-up expansion. The technique has helped identify suitable areas for future built-up expansion by channeling the change in desired locations. The built-up expansion suitability model can be used by planners and policy makers for land use intervention.

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Image Sources

Fig.1 - Fig.14: All figures are created by the Authors.

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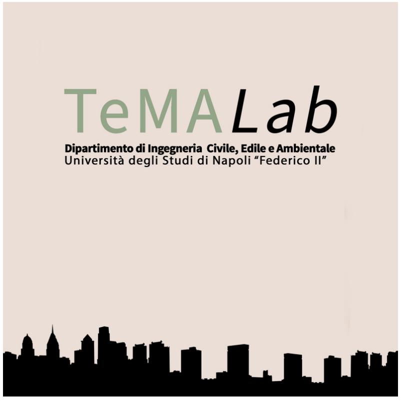

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The role of peri-urban agriculture in the pandemic era

Some case-studies compared in Italy

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Abstract

The relationship between agriculture, territory and the city has always been an object of interest for legislators due to the multiplicity of factors involved. In this paper some reflections are made on the new functions of peri-urban agriculture. The premise being that the rural landscape cannot be separated from the analysis of production factor needs. The control mechanisms of landscape variation, therefore, should take into account the main local features and the needs of the most recent phenomena. Often, however, the new land uses occurred through the progressive erosion of rural space from its original agricultural purposes. The logic behind this dismissing the loss of rural space in quantitative terms and, above all, in qualitative terms. The needs of the new panorama, which saw us forced to live with the pandemic that afflicted us in recent years, can, however, also be an interesting opportunity to improve agricultural development models, especially in suburban areas. This paper compares the opportunities offered by the European framework with its new tools and the local regional contexts that constitute the Italian panorama.

Keywords

Peri-urban agriculture; Landscape; Well-being.

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1. Introduction

At European level, general issues have been declared over the last few decades, and individual States have faced the marginalisation of agricultural activities in different ways. In Italy, at the end of the 1940s the legislator laid the foundations for the protection of the landscape, sanctioning - in an innovative attitude compared to other countries - that it was a Common Good. At that historical moment, agriculture really was a "primary" activity and was considered a cornerstone of the Italian economy. Many things have changed over the years involving radical changes. Only recently, attention is no longer dedicated only to landscape value areas, but also to "those significantly compromised or degraded", to the point of safeguarding both "UNESCO heritage sites" and "agricultural areas". Starting from international visions, the research identifies five fundamental issues, to which many open questions correspond: the recovery of the territory with new functional values, the relationship between agriculture and the city, the instability of the territory, the theme of Common Goods, and ultimately which conformations can be encouraged in the agricultural field.

Historically, agriculture was really a "primary" activity and it was considered a cornerstone of the economy; later, it became almost the obstacle to territorial development. Policies paying attention to landscape values were then developed, which seemed to be increasingly prominent. Only recently, with the refinement of planning intentions towards both of these factors (production and safeguarding aspects), attention is no longer dedicated only to areas with high landscape value, but also to "those significantly compromised or degraded". This dissertation refers first to the problem at the international level, with particular reference to the relationship between the city, the territory and agricultural activities, highlighting the main problems at a global level, and then goes into the details of the case in question, that is Italy, in the belief that each country has approached the problem in a different way, based on its morphological and production characteristics. Some case studies will be examined which, according to the criteria that will be specified later, have represented cornerstones in the approach to this issue.

1.1 Contexts and main issues

There are many factors that come into play in the relationship between agriculture, landscape and the city.

The literature addresses this issue on the one hand by deepening the perspectives dealing with the land productivity (agronomic aspects, also connected to the incentive of Ecosystem Services), on the other by enhancing the cultural importance of traditional agricultural landscapes.

As regards production aspects, the agricultural territory - precisely when it is productive and therefore generates food products - is able to play an important role also towards the environment, as it contributes to the purification of the air and at the same time contributes to the control of floods and to the filtration of water soil (Pasher et al., 2013; Pangbourne & Roberts, 2015; Ying-Chieh et al., 2018; Pilogallo et al., 2029; Leone et al., 2020). The progressive transformation from agricultural land to building land (which soon became "built environment") has naturally altered the balance. Agriculture, for years now, has been in a difficult situation, due to progressive restriction of available land. At the same time, however, it must guarantee the production of food and, above all, it has the task of preserving natural resources (Swinton et al., 2007; Bretagnolle et al., 2018; Schaller et al., 2018).

In this field, research has produced considerable ideas and reflections. Many of them are focused on the need to guarantee biodiversity and emphasise the importance of Ecosystem Services, seen from the perspective of producers of sustainable agriculture. Food production is always a fundamental need, but - alongside it - also the production of Ecosystem Services as a non-marketable public good type, aimed at satisfying the needs in the socio-cultural field, occupies a relevant place. Their more or less positive effects are naturally related to the local mechanisms of rural development, in which policies in place in the individual states - and also in the individual regions composing them - play an important role (Bethwell et al., 2022; Haines-Young & Potschin, 2010; Dissart & Vollet, 2011; Manrique et al., 2015; Schaller et al., 2018).

In the application field, Ecosystem Services - as classified since 2005 (MEA, 2005) - constitute a test bed for those who practise agriculture, who are pushed to adopt agricultural production practices aimed at providing these services, understood as environmental public goods. However, it is true that these practices are never unidirectional and certainly the supply of some of them inevitably involves the consumption of others. In this sense, general agricultural policies, but above all those dictated by local authorities, become important. The classification of the aforementioned Millennium was then integrated by the Institute for European Environmental Policy (Russi et al., 2013) and is also progressively updated by the European Environment Agency analysing benefits that people derive from them (i.e. "what ecosystems do" for people): in version V5.1, in addition to the outputs of the biotic ecosystem, the feedback from the user community was also addressed to the abiotic outputs (Haines-Young & Potschin, 2018).

Many studies, therefore, deepen these elements and their interdependencies, referring to the repercussions they have on general urban planning tools and their strategic environmental assessments, also reinforcing the interpretation of the evolution of land use in the different territories, the seat of their research. (Ostrom & Ostrom, 2014; Syrbe & Walz, 2012; Rozas-Vásquez et al., 2016; Cervelli et al., 2017, 2018; Blackstock et al., 2021).

With regard, therefore, to the restoration of ecosystems, the interventions called Nature-Based Solutions (NBS) provide practical applications useful for increasing the sustainability of territories and environments (EEA, 2021; Seddon et al., 2021; Zucaro & Morosini, 2018; Francini et al, 2021). At present, they are widely applied in urban, natural forest or wetland ecosystems, but they can also be applied in agricultural landscapes. NBS in the agricultural sector are proposed as "the use of natural processes or elements" to improve the ecosystem functions of the environments and landscapes affected by agricultural practices and to improve livelihoods and other social and cultural functions, on various scales, temporal and spatial" (Simelton et al., 2021; Cialdea et al., 2020).

As regards the second aspect, that is the cultural importance of traditional agricultural landscapes, it is necessary to refer to the classifications of the World Heritage Convention which since 1972 has highlighted the need to protect the great variety of landscapes that are representative of the different countries in the world. In it, the strategic objectives are defined as the 5 Cs, or "Credibility" (Strengthen the Credibility of the World Heritage List, as a representative and geographically balanced testimony of cultural and natural properties of outstanding universal value); "Conservation" (Ensure the effective Conservation of World Heritage properties); "Capacity-building" (Promote the development of effective Capacity-building measures, including assistance for preparing the nomination of properties to the World Heritage List, for the understanding and implementation of the World Heritage Convention and related instruments); "Communication" (Increase public awareness, involvement and support for World Heritage through communication); and "Communities" (Enhance the role of communities in the implementation of the World Heritage Convention): the fifth C was introduced later, in 2007.

This document recognizes the importance of interactions between man and the environment and the great variety of these interactions: to this end, it introduces the concept of "cultural landscape", providing for the inclusion of sites encountering specific criteria in the World Heritage List.

As stated in the Convention, the term "cultural landscape" embraces a diversity of manifestations of the interaction between humankind and its natural environment. "Cultural landscapes often reflect specific techniques of sustainable land-use, considering the characteristics and limits of the natural environment they are established in, and a specific spiritual relation to nature. Protection of cultural landscapes can contribute to modern techniques of sustainable land-use and can maintain or enhance natural values in the landscape. The continued existence of traditional forms of land-use supports biological diversity in many regions of the world. The protection of traditional cultural landscapes is therefore helpful in maintaining biological diversity" (UNESCO, 1972, 2002).

It is therefore believed that this heritage should be preserved because of their exceptional qualities: it can be considered to be of "Outstanding Universal Value" and as such worthy of special protection against the dangers which increasingly threaten them. To this end, UNESCO, with periodic reviews and updates, publishes the Operational Guidelines to reflect the progressive decisions of the World Heritage Committee. The work of this international committee is to identify, on the basis of Tentative Lists and nominations submitted by States Parties, cultural and natural properties of Outstanding Universal Value which are to be protected under the Convention and to inscribe those properties on the World Heritage List (UNESCO, 2012, 2021; Rössler, 2008; Rössler & Manz, 2009; Cameron & Rössler, 2012; Taylor, 2014; Luengo, 2013).

Moreover, FAO, in 2002, launched the GIAHS (Globally Important Agricultural Heritage Systems) Programme in order to detect the presence of important agricultural systems. They are defined as "agroecosystems inhabited by communities that live in an intricate relationship with their territory" (FAO, 2002-todays) and more than 60 have been selected from all over the world. In them the role of their management by farmers, herders, fisher folk, and forest people is important (Tscharntke et al., 2005; Scheurer et al., 2018; Santoro et al., 2020; Pallotta et al., 2022).

In this paper, the greatest attention is given to the rural environment in a broad sense: the main goal was to clarify the meaning of the agricultural space related to its context. But what context? There are many contexts. In European countries, the phenomenon of the aggression towards rural spaces by the built environment is undoubtedly the most pressing element. Next to it, and connected to it, there is the phenomenon of the large number of abandoned areas that are no longer able to find their own identity. The innovativeness of this research was the analysis of application cases chosen in order to relate the maintenance of "agricultures" - deliberately defined in the plural because they are differentiated according to the vocation of the places and the economies of each production system - with maintaining the landscape features. To this end, the following paragraph defines the situation of the case in Italy.

1.2 The Italian framework

General criteria of national planning were set by the still current national urban planning law L. 1150/42 (Repubblica Italiana, 1942) which has remained, despite its additions, the benchmark, while however the outline changed and with it also the planning criteria. Before its enactment, the attention of the legislation was essentially aimed only at the regulation of private built-up areas and at defining the legislation for the construction of urban settlements. In the phase of the so-called first industrialisation, which involves the first half of the last century, the city does not really undergo new structures: only its surface area increases but there are no significant phenomena. The cited law establishes that the area around the city assumes an equally important role than the city itself. For this reason, it aims at defining a supra-municipal planning tool, which however has a very poor application in fact and therefore fails in its intent, because the administrations immediately focus on the drafting of municipal level plans.

Last century, particularly between the seventies and the eighties, the agriculture purpose was the optimisation of product quantity and the main aim was to favour agricultural land maximum "exploitation" - also to force the natural vocations of sites. It should also be emphasised that different rotations and changes in crops lead to new images of the agricultural landscape with radical variation, such as the case of specialised monocultures that already after World War II had begun to be establish on the national territory, with the enhancement of some areas and some products, such as flowers for the Liguria Riviera or apples for the Trentino Region.

More recently, the importance of the environment emerges strongly: needs for safeguarding it are focused, while agriculture changes its objectives and turns towards an improvement in quality. It is aimed towards both environmental recovery and site enhancement, especially in mountain areas, traditionally out of the mechanism of exasperated productions. The territory, therefore, as a scenario of social transformations but also a place of environmental resources, must become the object of attention by planning activities in order to be able to contrast the most dangerous phenomena: soil subtraction by the urban system and the strong impoverishment of the environmental system. Therefore, urban planning for long-time paid attention only to urban phenomena showing interest in the agricultural land only as a possible place of expansion for the city itself.

However, it occurs that, while cities expanded on the rural land by modifying its structure, great changes also arose in agricultural activity techniques. Analysing rural areas cannot be separated from analysing production needs. Instead, in reality, areas traditionally dedicated to crops - even with good profitability - disappeared, compromising the balance of local physical-environmental resources. The economic development begins and the land performance changes: the urban growth is related to the abandonment of agricultural areas in which it is not possible to introduce mechanisation. Even the agricultural policy - supported by the launch of the Community Agricultural Policy mechanism - aims to develop activities in which it is possible to increase the production, providing assistance mechanisms for the weaker areas. At the same time, a desire arose to recover inland areas, present above all in the southern part of the country. In the 80s, there was a great turning point in the concept of the objectives of agricultural activity, oriented to the improvement in product quality. The environmental crisis, already existing at the end of 70's, culminates in 90's, when the errors of forcing strong production specialisations are brought into focus, including the stressful effects of the widespread monoculture surfaces which have had the serious consequence of definitively separating the zootechnical cycle from the productive-vegetable one (Cialdea, 2018).

Regarding landscape planning, the original approach derives from the 1940s aiming to enhance the aesthetic aspect with a strong focus on the "panorama": the first law introducing these concepts is Law no. 1497/1939 (Repubblica Italiana, 1939). It introduced the "landscape restriction" and a list must be drawn up for interventions in these restricted areas.

In the mid-80s Law 431/85 was enacted (Repubblica Italiana, 1985), introducing new concepts for the protection of areas with environmental interest. Furthermore, the 431/85 law has the great merit of obliging, for the first time, the Regions to carry out an organic and systematic protection of their territory: later the new Code focuses on the territory enhancement, fulfilling the dictates of the reform of Constitution Title V (Repubblica Italiana, 2001) which distinguished the activity of "protection" from that of "enhancement". The protection and enhancement of the landscape safeguard the values it expresses as perceptible manifestations of identity" (Repubblica Italiana, 2004). Moreover, the European Landscape Convention (Council of Europe, 2000) expects individual European States to develop their own evaluation methodologies for the management of their territories, including their different physical contexts (Roe, 2007; Busquets Fàbregas & Cortina Ramos, 2017; Council of Europe, 2017; Cialdea & Pompei, 2021a,b, Cialdea et al., 2022). The fundamental issue is how the State favours regional strategy implementation. This problem emerges particularly in Italy: the Landscape Plan intervenes, according to the Convention's principles, proposing not only the protection rules but also the land development proposals.

The article, therefore, is organised in this way: this first introductory section is followed by the second, in which the investigation methodology is explained and the questions to which this dissertation tries to give answers are specified, taking the cues from the elaborations carried out by some Italian regions. These examples have been chosen because these examined regions currently have landscape planning at the most advanced level, both in terms of urban planning tools for the landscape already approved - or at least adopted - and in terms of innovativeness of the territorial analyses carried out. Section 3 follows with the discussion of the results and a subsequent Section 4 contains conclusions, also highlighting the still open questions, which may be a starting point for the regions that are still addressing this topic.

2. Comparison methodology

This work is based on the research carried out on the actions undertaken by Local Authorities who have drawn up urban plans in which agricultural policies have been taken into account. The aim was to look for examples of Regions that in recent years have elaborated documents with a vision of urban planning policies not only based on the principles of urban sustainability but on the principles of "territorial" sustainability. This made it possible to compare plans referring to policies linked to the recent EU provisions. In fact, as is clear from the examination of the previous paragraph, European policies increasingly express the importance of agriculture as an engine for improving land management and guaranteeing environmental and socio-economic development of rural areas. In this context, we have also seen the role that the provision of environmental services from agriculture - through agri-environmental schemes and measures aimed at addressing the priorities identified by the EU - also bring positive effects to the fight against climate change, the improvement of biodiversity and the guarantee of water quality. In addressing these policies, contexts play an important role, namely "policies", "places" and "times". Therefore, the 21 Italian regions were grouped according to these criteria (Tab.1).

TOPICS	CONTENTS
CONTEXTS: – POLICY CONTEXT – PHYSICAL CONTEXT – TEMPORAL CONTEXT	Analysis of regional policies (with attention to agricultural policies) Agricultural conditions in plain and in mountain areas Recent documents (period 2000-2020)
DATA COLLATION	Good data availability: – from Official Documents – from Geographical Information Systems
KEY FINDINGS	Good answers to main agricultural issues

Tab.1 Selection Criteria for case studies

From this first screening five fundamental questions emerged and therefore the results of five case studies analysed are reported in the work: they seem to have given concrete answers to these five identified issues, namely (Tab.2).

KEY FINDINGS	QUESTIONS
FUNCTION	Recovery: New Functional Values?
RELATIONSHIP	Agriculture and the Urban areas' Greenbelt?
AGRI-URBAN	"Agri-Urban": Unsettled Landscape?
COMMON GOOD	Common Goods: Useful for the Community?
DIFFERENCES	Which landscape and which agricultural activity?

Tab.2 Key Findings Outputs

The first question is: Recovery: new functional values? It addresses the issue of "territorial decommissioning", all the more important in Regions (whose agricultural use is still a predominant factor on the territory as there are many in our country, albeit with different connotations and characteristics). The ultimate goal is to strive for a recomposition of the landscape with new functions always directly or indirectly linked to agriculture.

The question "Agriculture and the Urban areas' Greenbelt?" addresses the issue of urbanisation of the countryside which has produced the degradation of both environments, rural and urban. In this case the territorial vision must be integrated by a vision also at a local scale, since the relationship with urban centres is important. Agriculture in many cases surrounds the urban settlement area but fails to establish a relationship with it.

The third issue is "Agri-Urban": Unsettled Landscape?". In the relationship between the city and its countryside, the weak point is not only the marginal area between these two environments but attention must be paid to

a more extensive transition area between the city in its most compact form and the rural environment, and in agricultural detail. The question arises: Can agriculture restore stability to the landscape? Can it itself be a promoter of these actions? A fundamental role must be played by "people" who live and produce activities in the area.
The issue “Common Goods: Useful for the Community?” addresses the question of what the concept of "civic use", in the past recognized as a basic element for survival, can still be used today. There is no doubt that the theme of civic uses represents the close bond of communities with their own territory and that they themselves have determined the shape of the land and affected the landscape. Land intended for civic use is recognized as a “landscape good” and can represent an opportunity for sustainable local development.
Ultimately, the main theme is inevitably connected to the choice on what type of agriculture can be foreseen in a given territory: Which landscape and which agricultural activity? For this purpose, it is interesting to examine how many choices potentially envisaged (or in many cases "prohibited") by the regional landscape tool are accepted by the agriculture world.
Answers to these five questions have been put forth from analysed documents of the Italian regions. In the wake of the analysis of the question, regions that seemed to have suggested with their position a possible answer to the five questions were identified.

3. Results and discussion

Following the above indicated method, the research work has tried to catalogue all information deriving from Official Documents and from Geographic Information Systems databases, where available. Subsequently, in order to clarify results of this work, a comparison table has been created detailing the five case studies.
They have been summarised as follows (Tab.3).

TOPIC	AGRICULTURAL FUNCTION	BEST PRACTICE SAMPLE	SOLUTION	REGIONAL AGRICULTURAL USES EVOLUTION
Each topic corresponds to each of the five fundamental questions	Identification of a potential agriculture role, functional to relative questions.	The regional context that seems best to solve main emerging issues.	The planning tool useful to highlight best practices in the identified regional context.	Strength and role of land use for agricultural purposes

Tab.3 Final Key Findings and their description

The table in the first instance constitutes the passage from theoretical reflections to practical solutions, that is, it explains how to pass from the theoretical point of view to the practice of the solutions identified.
Therefore, the first three columns of the table refer to:
Topic: This column shows the five fundamental questions on the role that agriculture could play.
Agricultural Function: indicates what appears to be the agricultural function useful for answering the question. And therefore the identification of a best practice that could be functional to the solution of the problem is described in the *Best Practice Sample* column.
The last two columns of the table analyse these answers, comparing the solution and the agricultural environment, to deepen in which context the practical solution is inserted.
In the *Solution column*: an image of the analysed regional context is shown, in a map identified as the one that can best illustrate what has been highlighted in the research. Naturally, it is not exhaustive but must be seen together with the text of the considerations that are set out in this paragraph.
And finally the *Regional Agricultural Uses Evolution* column contains a map illustrating - in the examined regional context - how the agricultural component is relevant.
The following sub-paragraphs describe the table contents, as a result of the considerations made on the basis of the identified methodology.

3.1 Recovery: new functional values?

The first issue investigates the potential new functions that can be implemented through the recovery of lost activities. In this regard, the Lombardy Region has been identified because, through the Regional Green Network (RVR, Rete Verde Regionale) it wants to reinvent itself in a new system logic. Regarding planning tools, this Region presents an interesting approach combining two tools, the General Territorial Plan (PTR, Piano Territoriale Regionale) and the Landscape Plan (PPR, Piano Paesaggistico Regionale). The PTR, drawn up in accordance with the regional law for the territorial government (Regione Lombardia, 2005) has the "nature and effects of a territorial landscape plan" according to the provisions of the aforementioned new Italian Code: "the Regional Landscape Plan thus becomes a specific section of the General Territorial Plan, regarding landscape discipline, while maintaining a complete unity and identity" (Regione Lombardia, 2017).

The Regional Landscape Plan is, therefore, the reference framework for the choices made by local planning and landscape protection Authorities and in practice has a direct impact on all the municipalities' plans included and on their projects (Pedrazzini, 2015a). Furthermore, the recent debate about climate change - as a new challenge involving the landscape - has increasingly strengthened the idea that plans must have ever closer relations with programmes and policies favouring the improvement of landscape quality. In this sense, agricultural landscapes, as elements both tied to the past and to the future, play a fundamental role for the regional territory enhancement.

In fact, Lombardy is well suited for agricultural policies, as 43% of its surface is for agricultural use (Pedrazzini, 2015b; EupolisLombardia, 2016; Regione Lombardia, 2021). Within the landscape plan, it is very clear that it is necessary to refine the knowledge of the agricultural sector, because it is the sector in which the greatest transformations have taken place in the last 20 years. "The Regional Landscape Plan aims to highlight the different types of agriculture characterising the landscape, the rural building heritage at risk of abandonment and an artificial irrigation system unique in Europe" (Regione Lombardia, 2017).

Moreover, the PPR identifies the RVR as a recomposition and enhancement project of the Lombard landscape: this green network includes both valuable elements and also compromised, degraded and/ or abandoned areas.

The RVR (Regione Lombardia, 2016) analyses three main systems:

- the existing system of protected natural areas (i.e. Natura 2000 Network and Regional Parks), strengthening the links and relationships between the different areas characterised by different degrees of ecological and landscape quality, activating in particular projects for the conservation and recovery of abandoned and compromised natural, agricultural and peri-urban landscapes;
- the system of sustainable mobility routes, for which it provides for the improvement of its usability;
- the hydrographic system – including primary watercourses and the secondary network – identifying river landscapes, which very often is the only existing connection in territories mainly fragmented by anthropization and infrastructures.

In fact, the RVR project recognizes the structural elements and characters of the landscape, outlining a strategic unitary design. It constitutes an articulated project in relation to the tourist-fruition and recreational vocations of the natural, agricultural and anthropic (historical-cultural) landscape. The agricultural system is heavily analysed also thanks to the creation of the SIARL (Agricultural Information System of the Lombardy Region).

Therefore, agriculture in this case has clearly been identified as a resource able to regenerate the territory. Its new function, linked to the maintenance of its old activities but revised as a driving force for the recovery of abandoned or degraded areas, has been defined as a necessary "presidium" for the development of the territory.

3.2 Agriculture and the urban areas' Greenbelt?

The second theme concerns the intrinsic relationship between agriculture and the city. The Apulia Regional Landscape Plan has been analysed, focusing in particular on the "ancient areas" and enhancing their role in the projects at local level.

An interesting note is that this regional plan was the first approved in Italy (pursuant to the aforementioned Code), in 2015 (Regione Puglia, 2015a). In addition to this, it was highly innovative because it linked planning to the enhancement of social and cultural values, favouring planning oriented towards the exaltation of the most recognized values for the various territorial areas of the region. The link between the opportunities that the planning tool produces and the real feasibility of concrete territorial acts has been at the centre of the planners' thoughts, who foresee interventions on waterways, on the old paths of the sheep tracks, on the areas of abandoned quarries, all acts aiming to recover rural historical values. At the same time, it tried to promote activities that would also solve social problems, counteracting the phenomenon of abandonment of agricultural land, linked to the increasingly widespread movement of migration of young people and paying great attention to the coastal environment which constitutes a large part of the regional territory (Barbanente, 2011; Albrechts et al., 2020).

But, above all, this plan deeply analysed the relationship between the city and the countryside.

The Plan consists of a rich Strategic Scenario (Regione Puglia, 2015b), to which some Strategic Projects are connected, linked to the Five territorial projects for the regional landscape that the Plan itself has identified which are: The Regional Ecological Network, The City-Countryside Pact, The infrastructural system for soft mobility, The enhancement and integrated requalification of coastal landscapes and territorial systems for the use of patrimonial assets. In particular, the City-Countryside Pact is centred on the redevelopment of suburbs and peri-urban agricultural areas (Regione Puglia, 2013).

It aims to create a new alliance between these two adjoining settlements, and "different countryside typologies" for their future planning. The Strategic Scenario has been identified by the Region (and then actually proposed in other areas of further regions as well) with the aim of clearly defining these two environments and bridging the gaps that each of them now inevitably presents. The urban environment, here as in many other Italian regions, no longer has clear margins and it is also necessary to recover its own identity and quality, both in building and in urban planning, while the rural environment has witnessed the urban enlargement unarmed and progressively lacking identity.

For this reason, the City-Countryside Pact identifies some planning tools, each of them linked to a well-identified territorial typology. They are: The Urbanised Countryside, The Inhabited Countryside, The "ristretto" Countryside and The Deep Countryside. For these different agricultural land typologies, the Plan also formulates practical proposals: the Multifunctional Agricultural Park (to be implemented for improving ecological, social and cultural values, oriented to redevelopment or to enhancement) and the Co2 Park (to be implemented near industrial areas with urban forestry operations for environmental compensation, constituting barriers to noise and to dust to protect adjacent residential settlements) (Regione Puglia, 2013, 2015c).

The planning example reported, therefore, may be relevant for two reasons: the first concerns the attention to methodology creation for settlement typologies seen in the close relationship that they have created (or imposed) on the surrounding agricultural land and relative rural space. The second reason consists in the fact that this approach has also meant rethinking the overall planning perspective according to the values that the territory represents, which are identifiable in their vocation, as well as in the main features of the agricultural space: that is, the plan was able to clearly highlight the close relationship between the ecological network and the spaces around the cities.

The City-Countryside Pact "had the primary objective of stopping the long-lasting destruction of the countryside by seemingly endless new urban expansions." Moreover, the solid theoretical structure allowed the project experiments on the territory to be carried out in a short time: what these projects have in common is "an experimental and exploratory nature, which implies a propensity to learn all together in a co-productive effort to "do things" differently than usual." (Albrechts et al., 2020; Barbanente & Grassini, 2019, 2022).

3.3 "Agri-Urban": unsettled landscape?

The main question of this third issue is whether agriculture can restore stability to the landscape. Certainly agriculture can be a promoter of positive action, with the aim of safeguarding the territory even in its physical component (stability) and it may also be able to define a new territorial structure.

In this case, the behaviour of the Municipality of Bologna has been analysed, because it has paid a lot of attention to the question of urban agriculture. In the recently approved City Masterplan (Comune di Bologna, 2021), ample emphasis is placed on improving the quality of the environment, quality of life and infrastructure. This Plan addresses three main strategic objectives: the first one concerns environmental protection and focuses on the recovery and redevelopment of the existing asset against the expansion outside the urban space. The second thematic axis concerns living, and the related quality of life both in the urban centre and in its suburbs, to create a liveable and inclusive city. The third axis concerns infrastructure, with the idea that the regeneration of the city is only possible starting with major investments in the most important infrastructures.

In this context, it proposes urban and local strategies and most of them are related to the presence of urban agriculture.

On the other hand, also the previous City Masterplan (Comune di Bologna, 2008) had identified the rural territory as a primary field for experimenting pilot interventions in areas of agricultural, landscape and ecological interest. Therefore, an interesting case to emphasise is the experience of a participation process activated in the Bologna Municipality specifically referring to agriculture uses. Inhabitants, who live and produce activities, play a fundamental role. The case of the Laboratory, created in the Emilia Romagna Region for the area around the city of Bologna, analyses new potentialities deriving from the relationship of collaboration between public/private and local community and proposes two interesting solutions, the "countryside park" and the "migrant agriculture".

The activity of the Laboratory has investigated conflicts starting from the role played by the protagonists of the future transformation and the ability of agriculture to promote a process of protection and regeneration of the landscape. Through the Scenario tool, participants simulated different future possibilities and questioned needs and problems for a new spatialization of the city-countryside border as a transitional area, it will be possible to locate a place or a sequence of places specifically dedicated to the relationships between urban and rural areas (Branduini et al., 2016; Scazzosi, 2016).

In 2017 the Laboratory was created, based on the Agro-Urban Area Agenda: it produced lots of business projects by single actors or networks of actors. It was named "Hybridizing Public Processes". The aim of this Laboratory project was to create a new model of agriculture that, through culture, could be able to rediscover the value of tradition. In this way they think it is possible to start a global process of regeneration of agricultural spaces, giving it back the role not only of agricultural production but also of cultural production. It involved the north-east agricultural zone of Bologna City.

Two hypotheses, considered compatible with each other, emerged: the first one concerns the theme of memory and foresees the conservation of the existing signs and the recovery/restoration of main features of the Bologna countryside before mechanisation ("park-countryside"). The planting of hedgerows and the farm grid are re-proposed to reproduce the historical landscape that can be attractive and productive at the same time, in which ancient fruit crops are also included. The second proposal, with a stronger social impact, was defined as "migrant agriculture" and plans to start, with the collaboration of non-EU local inhabitants, the cultivation of vegetables that are not produced in Italy but that immigrants commonly use in their traditional kitchen, buying them imported at the expense of quality and price.

The activity also has strong social and economic impacts: cultivated products - exotic and quality - are also of interest for the F.I.CO (the Italian Farming Factory) catering activities, offering fresh local products not very widespread and known in the ordinary market. The landscapes of memory merge with the new landscapes of a multi-cultural and multi-cultivated city" (Regione Emilia Romagna, 2017).

3.4 Common goods: useful for the community?

The fourth theme concerns civic uses. As a strong guarantee of the relationship between local communities and their own territory, they have had great importance in the past also in terms of maintaining the traditional landscape shape.

With regard to this issue, the case of the Regione autonoma Friuli Venezia Giulia has been investigated: it is also one of the five regions with the new Regional Landscape Plan (PPR-FVG) approved, pursuant to the aforementioned Code (Regione Autonoma Friuli Venezia Giulia, 2018a). The PPR-FVG is organised in a Statutory part, a Strategic part and the last one dedicated to Management. In particular, in the General Report of the Plan, civic uses are explicitly cited as heritage of the territory's identity: "citizens want a Friuli Venezia Giulia region that knows how to combine new needs with the maintenance of its own landscape identity, which enhances its own historical, cultural (eg: civic uses) and natural resources in terms of sustainability." (Regione Autonoma Friuli Venezia Giulia, 2018b).

In Italy, civic uses were introduced by the Italian legislator in 1927: they are goods of public interest and provides that the community benefitting from them also has the obligation to preserve them, as a good for everybody. The community, in fact, shares rights and duties with respect to a system of resources that concern two categories: a) land that can be conveniently used as a forest or as a permanent pasture; b) land that can be conveniently used for agricultural cultivation. The principles on which these goods are based are very firm, which are, in addition to the constraint of agro-forestry-pastoral use, the inalienability of goods (the integrity of collective property is considered to be of public interest), their indivisibility and no usucapion possibility (in line with the principle of inalienability). For them, finally, the law establishes the imprescriptibility of the civic use right (Repubblica Italiana, 1927).

In more recent years, the aforementioned law 431/85 highlights them as it subjects them ope legis to the landscape constraint. It states: "all portions of territory burdened by civic use or collective property are subject to the landscape constraint", as then also taken up by the Code of Cultural Heritage and Landscape (Repubblica Italiana, 1985, 2004).

Finally, civic uses are also referred to by the framework law on protected areas (Repubblica Italiana, 1991) which highlights their importance, precisely because they are a testimony of the integration between man and the natural environment and their conservation is necessary to safeguard a collective interest but also to maintain the correct landscape shape, also enhancing its environmental function, in terms of biodiversity conservation. In practice, the issue of maintaining these goods is dealt with in a non-univocal way in the various regions and there is a general tendency to sanction their cancellation, i.e. many regions have enacted regional laws that allow for "declassification". However, this is not what happens in some regions, such as Friuli Venezia Giulia. The huge regional patrimony of these goods, corresponding to more than 7% of the regional surface, has been subject to verification since the end of the 90s. For them, the multiplicity of functions has been highlighted, from ecological to productive (Carestiato, 2015). In general, they are in small communities (hamlets or small mountain and hilly municipalities) in which the collective resource is mostly represented by woods and pastures. Of course, the use of wood is no longer as frequent as in the past, as today's heating systems use diesel or methane, but its use is still constant, especially in mountain areas (Carestiato, 2008; Daici, 2021).

In the region in question, economic contributions are envisaged for the maintenance of these goods and the aforementioned Regional Landscape Plan-FVG not only provides for their protection and enhancement, but also a viable way of managing them (Regione Autonoma Friuli-Venezia Giulia, 2016).
Furthermore, the primary public function of collective ownership, namely nature conservation, also offers new possibilities linked to the start-up of tourist and agritourism economic activities. This is what happens, for example, in areas dedicated to winter sports: a very interesting case is that of the ski resorts of Madonna di Campiglio in the Trentino Region, where the Comunità delle Regole di Spinale e Manez directly manages its own areas (47 sq km) consisting of woods, pastures, unproductive areas and areas used for skiing: in fact the land is given in concession to the Società Funivie Madonna di Campiglio S.p.A. (Carestiato, 2015) and is known to everyone as one of the most beautiful areas for skiing in Italy.

3.5 Which landscapes and which agricultural activities?

This last issue raises the question of how many conflicts and ambiguities can arise in relation to the decisions made for agricultural activities. In this case, Local Authorities' choices are fundamental, called upon to decide whether to favour the protection of their landscape or the development of their territories. An example can be the case of Tuscany with respect to the possibility of planting specialised crops, such as those destined for the wine production.
The Landscape Plan of this region was the second to be approved in Italy (Regione Toscana, 2015a). In this case the Region choice was to have a single plan, the Piano di Indirizzo Territoriale (PIT): it is configured as a regional planning tool containing both territorial and landscape dimensions, in which the landscape component still maintains its own clearly recognizable identity.
There are four territorial structural invariants, related to different landscape features: hydro-geomorphology (the strong geodiversity and articulation of the hydrographic basins origins urban and rural landscapes), ecosystem (the dominant matrices are mainly forest or agricultural, which are associated with high levels of biodiversity and important naturalistic values), polycentric and reticular settlements layout (as historical settling from the Etruscan period to modernity organised in networks of small and medium-sized cities of high artistic value) and Tuscan rural asset (with the close and coherent relationship between the settlement system and the agricultural land). As regards this fourth invariant, the Plan provides the recognition of the historical rural landscapes, aimed at promoting protection, requalification and restoration interventions, in consideration of their vulnerability and the compromising risk factors. The catalogue offers descriptive indications on the main rural landscapes and their socio-economic, landscape and settlement characteristics: they are useful for identifying traditional features in today's rural landscapes, despite the transformations that have taken place (Regione Toscana, 2012, 2015a,b).
However, there are numerous other aspects that mutually link landscape and development, and some of them are particularly relevant: new professions related to the knowledge economy and to social issues oriented to collective well-being. And on the other hand there are productive activities of excellence for high quality supply chains (oil, wine, typical products), located in rural contexts and settlements of high historical testimonial value.
This point was the subject of disputes between planners and agricultural operators. The landscape plan identifies some threats relating to the abandonment of agriculture on the one hand and the processes of agricultural intensification and specialisation on the other.
The criticism addressed by the agriculture world is that the only model to be pursued is the traditional agriculture: "Agriculture is not considered "as such" as a response to the degradation of the territory and as a landscape resource, but only if it responds to abstract canons of "traditionality", with respect to which every transformation is classified as a criticality to counter." By contrast, they reply that there is therefore no risk, in any area of Tuscany, of a "wild" specialisation towards monocultural models, such as to justify the alarmist

tones and the consequent restrictive guidelines (CIAToscana, 2014, 2015). The issue is linked to viticulture areas. It is relevant because Tuscany is among the Italian regions with the highest wine production, together with the Piedmont region. Anyway, in the specific situation, in reality many of the observations of the agricultural world have been accepted and after a negotiation the restrictions have been widened and the critical issues resolved. Here the example was given as evidence of the dynamism of the plan, which was able to accommodate the needs of production, while having the primary interest in safeguarding the territory (Poli, 2015a,b; Carta et al., 2022).
In the final table (Tab.4) conclusion remarks of the total comparison.

4. Conclusions

The landscape protection, therefore, is strictly correlated to different functions of agricultural activities, whose multifunctional character is emphasised. Their role remains fundamental as they strongly affect the landscape components and continue to be the result of the anthropic activity on it. Consequently, they are the most responsible for the modifications of the visual assets also towards urban agglomerations that progressively overrun them. Changes in rules, made by the legislator in recent years, have not yet managed to significantly affect operational phases of planning tools.
The aforementioned European Landscape Convention, whose intentions have been pursued also by the Code of Cultural and Landscape Heritage, emphasising the landscape perception peculiarities, highlights the need to intervene both on the "landscapes of everyday life and on degraded landscapes". It also fits well with the principles of the Rural Development Programs, indicating the landscape as a strategic objective of the agricultural sector (Frank & Pilutti Namer, 2021).
In Italy, the Landscape Plan tool, which all regions must use, does not always manage to integrate well with the will to develop agricultural policies. Practical applications of the European Landscape Convention principles often did not give the expected results, even if the potential of the Landscape Plan could be greater than that of the local planning of the individual municipalities with their own Masterplans (Cialdea & Pompei, 2021c; Barbanente et al., 2021).
The major problem, highlighted by this work, arises in the comparison between documents aimed at safeguarding the landscape and programs providing incentives for the agricultural sector. In countries, such as Italy, where a large part of the territory is subject to landscape constraints, the presence or the will to incentivize specialised crops can be an occasion for conflict (Soulard et al., 2017; Perrin et al., 2020).
The need to find a balance, or rather to create a "new" balance, between these two needs is more necessary than ever in agricultural areas, but especially in peri-urban agricultural areas. The concept of agri-urban must find support in new forms of governance, which take into account specificities of individual territorial contexts. These new forms of landscape capable of fulfilling new functions may be the turning point for the new equilibrium (Gottero et al., 2021).
The case examined in Italy presents very different situations, as also highlighted by the European documents: they underline how much it is a country with highly diversified agro-ecosystem conditions. They also note that "in Italy there are plenty of traditional landscapes, which are an important factor for rural areas for both environmental and economic aspects. The main threats are intensification, abandonment and landscape fragmentation. High natural value areas cover potentially around 16% of the UAA (Utilised Agricultural Areas) taking in consideration national estimations for the most valuable class: the most important typology being mosaic areas with low intensity farming and semi-natural elements" (European Commission, 2020, 2021).
From this work, it emerged how important the role played by Local Authorities - and in particular by the Regions – is. In this first research phase, the cases chosen were able to account for the diversity of territorial situations: the physical condition of Italy passes from reality of the mountain range of the Alps (we have seen the cases of the northern regions of Lombardy and Friuli Venezia Giulia) to the other mountainous context of

the Apennine chain (which crosses central Italy examined with the cases of Emilia Romagna and Tuscany) up to the condition of a Southern Region of Apulia which has a complex environment being also crossed by the Apennines, but with large flat areas and a long strip of coast on the Adriatic Sea.

"Agricultures" therefore are varied: from the use of agricultural land with extensive activities to the presence of large grazing or arable land areas up to the areas abandoned by agriculture and without a new identity. For all the examined cases, the aggression of agricultural land by the expansion of the settlement system, with cities of different sizes and different conformations, is the greatest problem. The other constant factor, found in all the examples, is the value of the landscapes in which these agricultural areas are inserted, which often have high values of biological diversity and almost always of high perceptive value (with the consequent constraints that these conditions impose).

The salient results from the examination, inevitably linked to the landscape planning tool, can be summarised as follows:

a. necessary close connection between the vast area planning tool for landscape protection (the Landscape Plan) with mechanisms that can favour practical projects (a great contribution emerged from the case examined for the Issue 2)
b. great need for exhaustive cognitive frameworks (also with regard to aspects of historical rural landscapes (as clearly emerged from Issues 1 and 5)
c. need to enhance (and not cancel as is increasingly the case) of civic uses (of which the case used for Issue 4). Issue 3 bears witness to what, besides planning of a vast area, can be done on a local scale.

Ultimately, this work has attempted to relate some of the solutions indicated in the Italian regions and the opportunities offered by planning tools for the landscape that they have adopted in order to verify how much they, in their different approaches, have been able or not to favour in practice, an enhancement of agriculture.

TOPIC	**ISSUE 1** **Recovery: New Functional Values?**
AGRICULTURAL FUNCTION	**Agriculture =** **Landscape Praesidium** Agriculture is a resource capable of regenerating the land. Agricultural areas Recovery: new functional values for **abandoned or underutilized settlements**, no longer able to be only places of food production but which can reinvent themselves. The **goal** is: to govern the transformation of the agricultural asset by integrating the landscape component into agricultural policies, especially in regions where the percentage of land dedicated to agriculture is high.
BEST PRACTISE SAMPLE	**Local Context**: the **Lombardy Region** Landscape Plan, in which 43% of the regional territory is agricultural. The main aim is to strengthen connections and relationships between areas characterised by **different degrees of environmental and landscape qualities**, in particular activating projects for the conservation and recovery of abandoned and compromised natural, agricultural and peri-urban landscapes. The Lombardy Region through the RVR (**Regional Green Network**) wants to reinvent itself in a system logic: - protection of natural environments - safeguarding regional biodiversity and the continuity of the ecological network - protection and enhancement of natural hydrography - **recomposition and protection of rural cultural landscapes and woods** - containment of conurbative processes and urban dispersion - landscape recomposition of peri-urban contexts - landscape requalification of compromised and degraded areas.
SOLUTION	The Landscape Plan, in its "Prescriptive Design Component" dedicated to green infrastructures, defines the Regional Green Network as a strategic project aimed at protecting, restoring and enhancing the quality of the landscape, through operations for the recreational-tourist-use enhancement of its landscapes (natural, agricultural and historical-cultural).

	It identifies the following areas: "RVR dell'alta pianura" (High Plain areas): Naturalistic and Agriculture Main Feature; "RVR alpina" (the Alps area): Naturalistic Main Feature; "RVR pre-alpina" (the pre-Alps area): Naturalistic and Historical/cultural Main Feature; "RVR collinare" (Hilly areas): Naturalistic and Historical/cultural Main Feature; "RVR bassa pianura" (Low Plain areas): Agriculture Main Feature; "RVR Oltrepò Pavese" (the Oltrepò Pavese area): Naturalistic, Historical/cultural and Agriculture Main Feature. **Sources**: Pedrazzini, 2015a,b; Regione Lombardia, 2005, 2016, 2017, 2021; EupolisLombardia, 2016
REGIONAL AGRICULTURAL USES EVOLUTION	The region, despite having numerous areas subjected to considerable anthropic pressures, still has strong characteristics of rurality and naturalness. The diachronic analysis of agricultural areas over the last twenty years shows a decrease in agricultural areas, but above all in areas with a lower agricultural tradition. **Sources**: Regione Lombardia, 2021

TOPIC	**ISSUE 2:** **Agriculture and the city: Urban areas' Greenbelt?**
AGRICULTURAL FUNCTION	**Agriculture =** **Pact with The City** Agriculture is characterised by the relationship between **the city and the countryside**, increasingly linked by a compromising physical proximity. The most widespread condition is that the two environments, urban and rural, find themselves facing each other without dialogue and often the same rural building remains "disoriented" in the sub-urbanity. The **goal** is: to link Landscape and Rural issues through new design tools including the so-called "Restricted Countryside".
BEST PRACTISE SAMPLE	**Local Context**: in the **Apulia Region** Landscape Plan, where "antichi ristretti" (green belt surrounding city) exist. the "Co-design Pact" between the Landscape Plan and the Rural Development Plan that restores environmental quality to both territories, urban and rural. **Current conditions:** - urbanisation of the countryside - growth of the degradation of the urban living environment - increase in the degradation of the rural living environment **Possible solutions:** - social gardens - suburban parks - proximity markets - educational farms, - "green hands on the city".
SOLUTION	The Landscape Plan identifies the so-called City-Countryside Pact scenario (with a model later followed by other regions as well) with the aim of clearly defining the two environments and bridging the gaps that each of them now inevitably presents. It identifies some design tools that are each linked to a well-identified territorial area on the regional territory. They are: - The Urbanised Countryside, - The Inhabited Countryside, - The "ristretto" Countryside, - The Deep Countryside. **Sources**: Regione Puglia, 2013, 2015a,b,c; Albrechts et al., 2020; Albrechts et al., 2020; Barbanente, 2011; Barbanente & Grassini, 2019, 2022.
REGIONAL AGRICULTURAL USES EVOLUTION	The Plan identifies the areas affected by the different types of transformation and persistence of agro-forestry and urban uses. In it emerge the extensifications in agriculture and the processes of recolonization of spontaneous vegetation, the intensifications in dry and irrigation and the deforestation for grazing and cultivation and the persistence of agricultural use. **Sources**: Regione Puglia, 2015c

TOPIC	ISSUE 3: **"Agri-Urban": Unsettled Landscape?**
AGRICULTURAL FUNCTION	**Agriculture =** **Solution to instability** Agriculture is the meeting place **between land and people**, useful for creating new contemporary landscapes: the park-countryside project is also a new possibility for creating a quality brand related to local production. The **goal** is: to create a new model of agriculture able to rediscover the value of tradition. In this way, it is possible to start a global process of regeneration of agricultural spaces, giving it back the role not only of agricultural production but also of culture production.
BEST PRACTISE SAMPLE	**Local Context**: **Participatory process** started in Bologna in **Emilia Romagna Region**, in order to underline agriculture's role in the city. The Bologna Municipality, which through the activities of a recent Laboratory, has deepened the study of the area around the city of Bologna. In the hypothesis of also being able to involve existing companies in gathering around a project and a brand, the hypothesis is made of a new version of the "**Countryside Park**". In it: the topic of memory (**historical rural landscape**) and the topic of innovation (**"migrant agriculture"**) coexist and complement each other.
SOLUTION	The Regional Landscape Plan identifies the landscape units and describes the presence of agricultural contexts close to the urban context areas for the city of Bologna. The survey area is representative of the characteristics of the entire agricultural wedge north-east of Bologna. The set-up originated from centuriation, with a road grid and a rather regular farm grid. This portion of territory, to be valorised and rediscovered, brings together a set of contiguous farms delimited by minor road infrastructures. **Sources**: Regione Emilia Romagna, 2017; Comune di Bologna, 2021; Branduini et al., 2016; Scazzosi, 2016.
REGIONAL AGRICULTURAL USES EVOLUTION	The rural asset designed by the Laboratory retains numerous typical elements of the traditional agricultural landscape (rows of trees, hedges, ditches, canals). There are also historic manor villas which represent an interesting plot for more structured itineraries. **Sources**: Comune di Bologna, 2021

TOPIC	ISSUE 4: **The Common Goods: Useful for the Community?**
AGRICULTURAL FUNCTION	**Agriculture =** **Common Good** The problem concerns the issue of the recovery of common goods (**civic uses** in favour of the community). The current situation, in recent decades, has seen total inattention paid towards these areas and the progressive cancellation of the restrictions intended for collective use. The **goal** is: to ensure that the lands intended for civic uses, recognized as a "landscape good", can represent an opportunity for sustainable local development**.**
BEST PRACTISE SAMPLE	**Local Context**: the **Friuli Venezia Giulia Region** Landscape Plan pays great attention to Collective Properties. In the theme of the overall **renaissance of landscape and environmental protection** a role could also be played by common goods, that is the **Civic Uses** mentioned to invoke the binding and restraining aspect of the development of a certain area. They can play a role in hill or mountain contexts and could make the restoration of a part of the agricultural landscape possible.
SOLUTION	In the General Report of the Landscape Plan, civic uses are explicitly mentioned as an identity heritage of the territory: "to combine the new needs with the maintenance of its landscape identity, which enhances its resources historical, cultural (e.g. civic uses) and natural in terms of sustainability."

	In several cases that have already been tested, the ancient civic use value has been transformed into exchange value: common goods, e.g. the forest, have acquired a market value and are today the lever that makes it possible to implement new projects. Thus a virtuous process has been triggered which seems to lay the foundations for starting a new development of the territory and which can also be replicated in other regions. **Sources**: Regione Autonoma Friuli Venezia Giulia, 2018a,b; Carestiato, 2015, 2008; Baccichet, 2020; Daici, 2021.
REGIONAL AGRICULTURAL USES EVOLUTION	From an estimate by the Commissioner for civic uses of Trieste, the collective landed property in Friuli would correspond to 7% of the entire regional territory = 7,846 km². The estimate includes all assets held in the community's various names, managed and unmanaged, or yet to be verified. **Sources**: Regione Autonoma Friuli Venezia Giulia, 2018a

TOPIC	ISSUE 5 What landscape and what agricultural activity?
AGRICULTURAL FUNCTION	**Agriculture =** **"agricultures"** It appears of fundamental importance to analyse the **current and past uses** of agricultural territories. The **goal** is: Much attention deserves the "quality agri-food chains" in the historic agricultural sectors still characterised today by strong dependence on external markets and companies.
BEST PRACTISE SAMPLE	**Local Context**: the Territorial Management Plan holding the value of a Landscape Plan of the **Tuscany Region**. For this purpose, it is interesting to examine how much the choices potentially envisaged (or in many cases "prohibited") by the landscape tool are - or not - accepted by the world of agriculture. An example can be the one that has been determined in the Tuscany Region with respect to the possibility of planting **specialised crops**, such as those destined for the production of wine.
SOLUTION	The Landscape Plan identifies the various systems based on their geological, environmental and physical features, as well as their fruition characteristics. It also suggests the creation of a river contract with the same value as an agricultural park along the banks of the Arno, on the Florentine plain. **Sources**: Regione Toscana, 2012, 2015a,b; CIAToscana, 2014, 2015; Poli, 2015a,b; Carta et al., 2022.
REGIONAL AGRICULTURAL USES EVOLUTION	Tuscany is the most important and best-suited wine region in Italy together with Piedmont. **Sources**: Regione Toscana, 2012a

Tab.4 Conclusion Remarks Comparison

The open question concerns the planner's choices. They must select between vast area and local projects to combine the factors of valorisation and competitiveness of the agricultural sector, especially in sites with strong naturalistic and landscape values.

However, peri-urban agriculture can fulfil the objectives of economic and environmental sustainability, especially if local and regional policies prove to be adequate for improving the functions of metropolitan agriculture and exploiting its potential.

Furthermore, the promotion of agriculture in peri-urban areas today assumes a strategic significance beyond the productivist or landscape aspect, becoming a theme of a "cultural" nature.

In fact, these "border areas" represent a unique opportunity for a closer comparison and dialogue between local culture and metropolitan culture and therefore can become a "laboratory" for new social, economic and productive relationships, crucial for a re-evaluation of the new rural reality.

At the same time, the fact of having such an important, close and attractive market for agricultural products as represented by the urban centre, gives the peri-urban area the potential of great productive opportunity: in fact, urban consumption trends show a growing attention towards short agricultural product supply chains. Recalling what was illustrated in the introduction, studying incentive mechanisms of Nature-Based Solutions also improves the quality of urban life.

This is what happens when, for example, urban agricultural parks are created in the city, with a view to increasing the well-being deriving from the reevaluation of urban green spaces, creating, at the same time, technical solutions to safeguard the territory.

Due to the pandemic, "urban green" is a growing necessity in our cities (Gaviglio et al., 2021). In fact, with respect to what was outlined by the EU AGRI Committee (Piorr et al., 2018), the agricultural park can be considered an important vector of connections between different systems, including economic and physical factors, involving the city and its surrounding areas. Moreover, the role of the pandemic shouldn't be overlooked with regards to its impact on some characteristics of entrepreneurship, which can be further implemented given their beneficial effects on the landscape. These new forms are increasingly gaining ground in urban areas: for example, numerous farms have developed forms of direct sales compatible with the pandemic scenario (organised shopping packages, supply to solidarity purchasing groups) which can also be combined with delivery with low environmental impact vehicles.

Finally, the ever-increasing diffusion of forms of experiential tourism (paying to have an agricultural work experience, together with the hospitality and catering), which due to site capacity is naturally offered to a limited number of users, is leading to a sharp reduction in crowds, vital when considering public health.

The multiplicity of elements involved requires situations examined on a case-by-case basis, factoring territorial contexts. However, it is equally important that a unitary framework be defined at national level for the promotion policies of agricultural activities in areas that are sensitive from a landscape point of view. And it is even more important that land use plans are implemented, as is already the case in many other European countries: they contribute to a good cognitive framework of the territory, above all because they are constantly updated. The agricultural tradition is a background of many European contexts, but certainly in Italy it represents a very significant reality, which however has been strongly distorted in too many cases. This work, as the first phase of an ongoing research, wanted to contribute to increasing the reflections useful for identifying new strategies for the agricultural territory so that it is not just a result of building developments.

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Urban open and green spaces: is Malta planning and designing them to increase resilience

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Abstract
2030 has been set as the target for achieving most of the sustainable development goals and in this path urban open and green spaces have been identified as drivers and accelerators for increasing resilience and adapting cities to climate change. The pandemic has acted as a further catalyst for the reorganization and re-assessment of the role of open spaces. This work focuses on the system of urban open and green spaces whose planning and design, through a systemic approach, can address the current and future urban challenges such as climate change. The main aim of the paper is to define the key elements for the planning and design of urban and open green spaces, starting from the EU referring framework and the case study of Malta. The outputs can support the local decision-makers in increasing the sustainability and resilience of urban areas by improving the provision of these physical elements. Findings suggest that EU and international strategies advocate urban open and green spaces as an indisputable requirement for increasing resilience, energy sustainability and adaptive capacity of urban systems. However, in comparison, there is still scope for improvement when considering Malta's planning framework. While there is a growing sentiment for the appreciation and need for green open spaces from the users, important characteristics are still lacking within planning processes.

Keywords
Urban open and green space systems; Urban sustainability; Climate change; Urban resilience; Urban design.

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1. The role of urban open and green spaces in addressing urban sustainability

By 2030 local policy and decision-makers should be able to accomplish most of the 17 SDGs goals, as «64% of the policies related to them are to be implemented in cities» (ESI ThoughtLab, 2021). Unfortunately, since their definition 8 years ago no country is on track to reach the main purpose of ending poverty, fighting social and economic inequalities and tackling climate change (Swain, 2018; UN, 2022). Numerous reports mainly developed by non-governmental bodies tried to justify this due to the pandemic situation, but scholars have raised numerous questions about the effective attainability of the SDGs targets through their quantification and monitoring, relating them to different territorial and urban contexts (Ustaoglu & Aydınoglu, 2019). For instance, Bali Swain et al. (2020), Butcher et al. (2021) and Hickel (2019) brought out the contradictions across the goals and the still existing imbalance between socio-economic characteristics of cities in developing countries. Nevertheless, a mounting body of scientific studies is engaged in overcoming these impasses to pursue urban sustainability goals that are compatible with available resources. On one side, a field of research has been identifying barriers and gaps of the governance process to provide tools and guidelines for building dialogues with local stakeholders and communities (Alberti & Senese, 2020; Hansson et al., 2019; Waage et al., 2015). On the other side, scholars are also trying to support the choices of urban sustainable transformations to reorganise cities in the most efficient way (Krellenberg et al., 2019; Lai et al., 2021; Patterson et al., 2021; Zucaro & Carpentieri, 2019). In this last perspective, there is a wide consensus on the role of green and urban open spaces as drivers and accelerators of sustainable urban development, urban regeneration and moreover climate change adaptation. Various attempts have been made to develop a framework aimed at illustrating how urban open spaces can contribute to these issues (e.g. Kremer et al., 2019; Monte-Mór, 2018). For instance, in relation to resilience and climate, using urban open green spaces as a form of green infrastructure represents an important pillar for the 'climate proofing' of UK towns and cities who first began to work in this direction and similarly for energy efficient cities worldwide (Gargiulo et al. 2017; Pilogallo et al., 2019; Shirgir et al., 2019). Hansen et al. (2017) advocate that urban open and green spaces «can play a key role in strategies for climate change adaptation and – to a lesser degree – mitigation…Importantly, planned adaptation is more cost effective than emergency measures and retrofitting». (Hansen et al., 2017, p.8). Through the shading and evapotranspiration of tree vegetation, the temperature in the summer months can decrease to such an extent that it improves the feeling of thermal comfort inside the buildings that benefit from these effects, due to their proximity to greenery, with the consequent lower need for air conditioning and thus leading to a reduction in energy consumption and climate-changing emissions (Tan et al., 2021; Yu et al., 2018). As a result of these strategies, there are an increasing number of urban regeneration projects based on the widespread presence of green areas and rows of trees both in densely built-up portions of the city and in the more peripheral and degraded areas, so as to also contribute to improving the quality of life of the inhabitants (Łaźniewska et al., 2021). A careful distribution of green areas on an urban scale can make a strong contribution to solving energy-environmental problems, such as the heat island, and help improve air quality and provide pleasant spaces for social inclusion (Salata & Yiannakou, 2023). Through an extensive literature review the potential role that urban open spaces play in relation to the three dimensions of sustainable development was identified (Scheiber, 2021). Fig.1 summarises the value of urban open spaces from the environmental, social and economic points of view, by referring them to current and near-future urban challenges too. Reducing the risk of flooding; mitigating the urban heat island effect; contributing to better health and increased well-being; guaranteeing social cohesion; increasing local competitiveness; boosting the real estate values (Fig.1) can be identified as some of the main reasons for realising greener cities through the appropriate design and transformation of open spaces (Spiiker & Parra, 2018; Stobbelaar et al., 2022).

	Value Category	Key Principle	Authors
Environmental value	Micro-climate	Urban open spaces with appropriate vegetation can mitigate the urban heat island and improve micro-climate conditions.	(Bell, 2012; Atiqul Haq, 2011; Loibl, et al., 2014; Forest Research, 2010; Chang, Li, & Chang, 2007)
	Air Quality	Urban greening can reduce the level of air pollutants as particles can be absorbed by vegetation. Attractive urban spaces influence residents' decisions to live or spend free time in the city thus reducing travel. Attractive and appropriately design urban spaces, in particular streets, facilitates the use of sustainable travel modes.	(Bilgili & Gokyer, 2012; Atiqul Haq, 2011; Forest Research, 2010; Holden & Liversedge, 2014; Brodhead, 2009; Banister, Watson, & Wood, 1997)
	Noise Pollution	The presence of green space with appropriate vegetation, in urban areas can significantly reduce noise pollution.	(Senate Department for Urban Development and Housing, n.d.; Atiqul Haq, 2011; Peng, Bullen, & Kean, 2014; Brodhead, 2009)
	Ecology, Ecosystems & Biodiversity	Urban green spaces have an important relation with ecology and can provide various ecosystem services such as: cleaning the air, water purification, cycling nutrients, generating soils, regulating climate, sequestering carbon, habitat provision, etc. Urban open spaces particularly in the form of GI can influence ecosystem services and hence biodiversity by increasing habitat area; increasing populations of some protected species; and by increasing species movement.	(Austin, 2014; Forest Research, 2010; Atiqul Haq, 2011; Lafortezza, Davies, Sanesi, & Konijnendijk, 2013; Stiles, 2009)
	Water Management	Urban open spaces if appropriately designed (use of SUDS), can contribute to: reducing flood risk; improving water quality; reducing water usage; replenishing ground water and reducing costs for water drainage infrastructure. SUDS reduce rainwater runoff by increasing permeability, infiltration and storage capabilities of urban areas.	(Beatley, 2012; Hoyer, Dickhaut, Kronawitter, & Weber, 2011; Forest Research, 2010; Austin, 2014; Duffy, et al., 2008)
	Food Production	The presence of open spaces or GI in urban areas has the potential to create space for food production. This has environmental benefits due to the decreased carbon footprint when food is produced locally but it can also have social (community engagement) and economic (job creation) benefits.	(Hansen, Rall, Chapman, Rolf, & Pauleit, 2017)
Social value	Social Interaction & Cohesion	Green areas and natural features increase the use of outdoor areas, which in turn facilitates social interaction and thus cohesion. UGI can counteract social exclusion e.g. through participatory community greening activities.	(Jain, 2013; Priego, Breuste, & Rojas, 2008; Gehl, 1987; Forest Research, 2010; Sullivan, Kuo, & DePooter, 2004; Brodhead, 2009; Hansen, Rall, Chapman, Rolf, & Pauleit, 2017; Ambrose-Oji, et al., 2017)
	Recreation & Well-being	Urban green spaces provide a source for relaxation and recreation. Urban nature is a provider of a social service essential to the quality of human life. Open space can also affect the legibility of an urban area which is important for ensuring a sense of well-being.	(Atiqul Haq, 2011; Chiesura, 2004; Beatley, 2012; Krcmarova, 2009; Stiles, 2009)
	Human Health	Access to some form of ´nature´ is a fundamental human need. The provision of urban open spaces contributes to positive health by increasing opportunities for physical activity. Green urban spaces have the added benefit of contributing to stress reduction. The presence of green spaces alone is important as a mental space, and in this sense, they are valuable even simply due to their availability, even if not used.	(Thompson, 2002; Austin, 2014; Forest Research, 2010; Brodhead, 2009)
Economic value	Energy Savings	Increasing green space and tree planting in temperate climate cities is a cost-effective reason for reducing the energy cost of cooling buildings. Shading from trees can act as a barrier to solar radiation thus decreasing air and surface warming.	(Sadeghian & Vardanyan, 2013; U.S. Department of Energy, 1995; Bilgili & Gokyer, 2012)
	Infrastructure Savings	The design of urban open spaces, such as streets, affects the ways in which people choose to travel. Infrastructure provision for sustainable transport modes such as walking, cycling and public transport vs private vehicles is more cost effective. While using open space to provide for SUDS may be considered a cost in itself, such systems reduce the demand for traditional infrastructure to provide increasing capacities for infrequent yet high intensity storms. The collection and re-use of rainwater for activities such as irrigation, is also a cost saving technique in terms of reducing expenditure for water consumption.	(Hoyer, Dickhaut, Kronawitter, & Weber, 2011; Beatley, 2012; Stiles, 2009)
	Real Estate Value	Well-designed/maintained open spaces can have an impact on the property market by creating an enhancement value due to their amenity and aesthetic properties.	(Bilgili & Gokyer, 2012; Fausold & Lilieholm, 1996; Forest Research, 2010)
	Tourism, Commercial and Local Regeneration Value	Urban open spaces are essential for events such as concerts or markets take place in urban open spaces. Other activities such as eating out, lingering and drinking coffee are also capitalised on depending on the success and attractiveness of a space and thus the willingness of people wanting to spend time and money as a result. Attractive green spaces also improve a city's competitiveness as a destination for new residents, businesses and tourists. Investment in GI can be used to stimulate local economic regeneration. The investment in green open spaces can create high quality environmentally friendly living and working environments thereby attracting high value industries and skilled workers to a region.	(New York City: Department of Transportation, n.d.; Hansen, Rall, Chapman, Rolf, & Pauleit, 2017; Natural Economy Northwest, 2008; Baycan-Levent & Nijkamp, 2009; Brodhead, 2009; Tuset, 2016; Forest Research, 2010)
	Productivity Value	The presence of urban open spaces has also been linked to increased worker productivity by improving people's ability to concentrate.	(Beatley, 2012; Stiles, 2009)

Fig.1 Main roles of open and green spaces in relation to the different components of sustainability (Scheiber, 2021)

Additionally, (Scheiber, 2020) developed a theoretical framework identifying design principles grouped into twelve main categories (Tab.1) through which urban open spaces can provide the social, environmental and economic value presented above and thus fulfil their potential in contributing to sustainable development and mitigating or adapting to climate change challenges. As stated by Latinopoulos (2022) and Wang & Foley (2021) the pandemic has acted as a further catalyst for the reorganisation of the urban environment by city dwellers and thus for a re-assessment of the role of open spaces as relevant components for building green networks. In other words, well-planned and designed open spaces and moreover their integration as part of a network of green open spaces can contribute to defining a system of physical elements through which the adaptive capacity of cities can be improved together with increasing the functionality and value of these otherwise "urban voids" (Gargiulo & Zucaro, 2023).

According to this scientific framework, this work focuses on the system of urban open and green spaces whose planning and design, through a systemic approach, should be addressed to provide multipurpose places that are vital to urban resilience, as well as sustainability, health, safety, and well-being (Gargiulo et al., 2023).

Design categories	Sub-categories
Spatial & structuring qualities	Open spaces as structuring element, connectivity
Contextual relationships	Physical, functional, socio-cultural
Character & form	Typology, visual interest, spatial proportion & enclosure, responding to site & identity
Activities & functionality	Recreational facilities & functionality, user preferences, diversity, multi-functionality & flexibility, supplementary equipment
Accessibility	Vicinity & availability, legibility, movement
Climatic response	Responding to seasonality, micro-climatic comfort
Water management & use	Surface water drainage, ground coverage & storage areas, use of water
Use of vegetation	Presence, location, form & type
Lighting	Energy efficiency
Resources management	Locally sourced & recyclability, durability
Maintenance & management	Operations, roles & responsibilities
Community involvement	Voluntary schemes, participation during the design & planning process

Tab.1 Categories of the design principles for open and green spaces to contribute to sustainability (Scheiber, 2020)

Their spatial organization and usability can have a positive impact on people's sense of wellness and contentment, influencing how they mingle in these areas. Improving both the quality of physical characteristics of open spaces and their spatial relationship with the urban fabric where they are located is essential for creating a well-designed open space that attracts people, supports their activities, and encourages them to spend more time outside. In addition, they help to define urban identity, serving as a tool for municipal branding and promotion.

In this perspective, the main aim of the paper is to define the key elements for the planning and design of urban and open green spaces, starting from the EU referring framework and the case study of Malta. The outputs can support the local decision-makers in increasing the sustainability and resilience of urban areas by improving the provision of these physical elements. The work is a first step to answering the following questions: how can the planning and design of urban open and green spaces be improved according to the new climate energy and resilience needs of urban systems? Looking at the case study of Malta, are these requirements in line with the European Framework?

The paper is structured as follows: section 2 provides an overview of the main European (2.1) and Malta (2.2) planning strategies aimed at a sustainable and green transformation of urban areas and territories; section 3 illustrates the proposed quali-quantitative method; section 4 describes the outputs from the Malta case study; section 5 draws the conclusions to answer the research questions.

2.1 European planning frameworks for urban open and green spaces

Considering the multiple benefits which green and open spaces can provide for cities, the choice of localization, distribution and design of these areas within different kinds of urban fabrics should integrate dimensional and performance criteria (related to the urban load) with more effective ones of resilience, energy saving and overcoming social inequalities (Gargiulo et al., 2017; Gargiulo & Zucaro, 2020). This "new" approach is advocated by IPCC and EEA reports too, as well as the most recent EU documents, such as the Green Deal and the Recovery Fund Next Generation, which constitute the main strategic and financial axes for initiating the ecological transition of member countries. The EU also introduced the requirement for Urban Greening Plans for cities with over 20.000 inhabitants, supporting their development through the Urban Greening Platform to facilitate the transfer of scientific evidence into practical greening transformations. Furthermore, this platform is among the dissemination initiatives promoted within the Green City Accord aimed at accelerating the implementation of relevant EU energy, climate and environment targets at the local level.

The Urban Greening Plans do not represent an additional top-down requirement defined by EU, rather they suggest an operational framework aimed at facilitating: (i) the implementation of linear, punctual and area greening interventions through the development of new skills, (ii) the dissemination of funding opportunities including from private parties, (iii) the trigger of a cultural change amongst all stakeholders when it comes to the inclusion of green or retention of the existing natural environment in project planning and management. Actually, the role of urban open and green spaces to improve the city's resilience to climate and sustainability issues has been recognized by the EU since the report "Soil and Sustainable Land Use Management" (2012). In fact, the EU refers to open spaces as relevant physical elements to guide sustainable land use planning and favour the maintenance of environmental services associated with hydrological and thermoregulation functions. Following this, the "European Strategy to Adaptation to Climate Change" (2013) identified open and green spaces as solutions for climate-proof, resilient and resource-efficient urban systems. The "EU Greening Infrastructure Strategy" (2013) and the document "Towards an EU Research and Innovation Policy Agenda for Nature-Based Solutions & Renaturing Cities" (2015) emphasised how urban well-being and sustainable development are inseparable from the spread of these kinds of spaces in cities. In particular, the second report was in line with a previous document "Renaturing cities: systemic urban governance for social cohesion" (2014) that underlined the key role that green areas can play in reorganising urban systems, by acting on its natural resources. In addition to the development of strategic documents to support member states, the EU tries to facilitate the networking of local decision-makers and research communities to fill knowledge and implementation of green and open area gaps through Horizon 2020 programs. The "URBAN GreenUP" (2017-2022) is aimed at defining "ad hoc" greening and open space interventions in the 2 involved cities mainly to adapt them to floods and UHI. EU research programs also aim to upscale urban greening and open space sustainable transformations from EU to worldwide. "CLEARING HOUSE" (2019-2023) and "INTERLACE" are oriented to enhance the adaptive capacities of urban areas with higher exposure to social inequalities and disaster-climate events, by sharing technical, policy and procedural capacities and thus contributing in filling the gap between developed and developing countries.

Summarising, it can be stated that the EU has dedicated substantial funding for research and development projects on UGI, and more recently for the related concept of nature-based to address these deficits. However, the integration among greening, cohesion and design in a systemic and local-level planning vision can ensure the effective pursuit of the outlined objectives. There is currently a lack of understanding about how to implement a green open space system that supports the forestation and the climate adaptation goals at the EU level.

2.2 Malta's planning framework for urban open and green spaces

Malta has the highest population density of EU Member States: in 2021, the population was 519,562 implying a density of 1,649 persons per km² (NSO, 2022) and 95% of the population lived in urban areas (World Bank, n.d.). Additionally, Malta can be defined as an entirely urban area (Antikainen, 2005; Zammit, 2010) with a surface of 316 km². Complementary to the EU strategies are Malta's national and local policies that seek to realise appropriate urban transformations to balance sustainability and urban development that is more pronounced in a small but densely populated and already urbanised area such as Malta. A review of Malta's planning framework (data collection 2a) served to investigate whether national strategies and spatial planning policy (see Tab.2) address the planning and design of open and green space systems. This step is useful to identify the different or common goals in relation to European Frameworks.

Name of document	Type of document
Malta's National Biodiversity Strategy and Action Plan 2012-2020 (NBSAP) (GoM, 2012a)	Strategy & action plan
Malta's National Strategy on Climate Change Adaptation (GoM, 2012c)	Strategy
A Sustainable Development Strategy for the Maltese Islands 2007-2016 (GoM, 2006) due to be replaced by Malta's Sustainable Development Strategy for 2050 (MEEE, 2023)	Strategy
National Environmental Policy (GoM, 2012) due to be replaced by National Strategy for the Environment 2050 (ERA, 2022)	Strategy
Investing in the multi-functionality of Green Infrastructure (GI) – An Information Document to support GI Thinking in Malta (ERA, 2019)	Information document
Strategic Plan for Environment and Development (SPED) (GoM, 2015)	Strategic spatial plan
Guidelines on Trees, Shrubs and Plants for Planting and Landscaping in the Maltese Islands (GoM, 2002)	Policy
The Development Control Design Policy, Guidance and Standards 2015 (DC 2015) (GoM, 2015b)	Policy
Malta's Second Water Catchment Management Plan 2015-2021	Plan
Local Plans (1995-2006)	Land use plans

Tab.2 Malta's most relevant strategies and plans in relation to urban open and green spaces

National strategies exist, such as Malta's National Biodiversity Strategy and Action Plan 2012-2020 (NBSAP) (GoM, 2012a), Malta's National Strategy on Climate Change Adaptation (GoM, 2012) and A Sustainable Development Strategy for the Maltese Islands 2007-2016 (NCSD, 2006). The latter is in the process of being updated by Malta's Sustainable Development Strategy for 2050 (MEEE, 2023) which has recently been published for public consultation. The National Environment Policy (GoM, 2012b) identified the importance of the quality of urban open spaces (UOS) in relation to sustainability. This is also due to be replaced by the National Strategy for the Environment 2050 recently published for consultation (ERA, 2022).

It can be noted that older strategies such as the NBSAP 2012-2020 and Malta's National Strategy on Climate Change Adaptation (GoM, 2012c) do not recognise the potential role which the planning and design of open spaces within urban areas may play. On a positive note, however, the newly published National Strategy for the Environment (ERA, 2022) places a strong emphasis on the importance of urban green and open space systems. On the other hand, while the public consultation draft Sustainable Development Strategy for 2050 (MEEE, 2023) does acknowledge the importance of open spaces, when considering implementation and monitoring of the strategy, there are no specific targets set such as for other sectors e.g. sustainable mobility. A draft version of the National Biodiversity Strategy and Action Plan to 2030 (ERA, 2023) has also just been published. Unfortunately, there is still no real focus on the potential role and importance to be played by open spaces in urban areas. Considering green infrastructure (GI), the Environment and Resources Authority (ERA) document on GI in Malta concludes that there are potential research opportunities for adopting a «multifaceted planning approach to GI and building expertise and experience in this regard» (ERA, 2019, p. 52). Ultimately different social and environmental goals are identified within strategic documents which could be addressed by urban open and green spaces. These include: improving liveability and urban quality; increasing soft and active mobility; addressing health issues related to obesity due to lack of physical activity; mitigating or adapting to climate change; improving air and water quality; and addressing the loss of biodiversity. However, there is scope for the potential role which urban open and green spaces play to emerge more strongly.

In relation to spatial planning documents, The Strategic Plan for Environment and Development (SPED) (GoM, 2015) is the document that at the highest planning scale (national level) seeks to address territorial and urban transformations. Due to the island's size, policy is often developed at a national scale, also considered to be the city scale, since the size of the Principal Urban Area is comparable to that of a medium-sized European city. The national and local scales, therefore, interact in a manner specific to the Maltese context. This requires specific responses when considering the planning and design of urban open and green spaces. Principles of urban open and green space planning often require a regional approach to address the integration of different scale levels. The importance of connectivity means that the planning of such open and green spaces systems needs to happen at the city and regional scales and the role of various spaces as part of a wider network/system needs to be determined. Malta's particular scale means that locality sizes are small and it is the combination of localities which create a city or regional scale. It would also be more efficient to coordinate certain aspects such as: provision of expertise; monitoring and maintenance (to some extent); or funding and implementation programs at a more regional level while still retaining strong local input and facilitating bottom-up initiatives. Developing the right framework and set-up for coordinating and integrating the different scales for the planning and design of urban open and green spaces is therefore crucial (Scheiber, 2020). Included in the SPED (GoM, 2015), is the organisation and transformation of unbuilt open spaces as given Malta's size, and the scarcity of land as a resource, the issue of regulating them is crucial, also due to the fact that these border developable areas. Undeveloped land which is classified as outside the limits to development for planning purposes, does exist within the urban conurbation. This land forms strategic gaps of open spaces within a very dense urban environment and are under constant pressure for development (GoM, 2003; Zammit, 2010; ToM, 2016; The Malta Independent, 2016). The SPED defines these as areas of 'High Landscape Protection', 'Areas of Landscape Protection' and 'Strategic Open Gap to be Retained'. Strategic planning of such open spaces does not exist. The SPED recognises the importance of open spaces when increasing densities and that the low provision of urban green spaces in Malta does not encourage healthy lifestyles (GoM, 2015). The inclusion of urban green and open space systems oriented to guarantee sustainable development is however still quite lacking (Scheiber, 2021).

While planning documents mention the need of increasing and preserving the presence of both kinds of spaces and improving their management, proactive spatial and systemic visions or plans for the use and management of open spaces, especially in urban areas, do not, unfortunately, exist. As a result, the planning of areas such as the 'strategic open gaps' for example, is limited to a conservationist approach with no proactive frameworks for increasing the value of open and green spaces. This leads to a lack of use and management of such spaces, resulting in their undervaluation and lack of appreciation. Similarly, Coastal Zones for example, are simply described as 'Predominantly Urban Coast or Rural Coast' giving no further indication as to what the breakdown of the qualities and functionality of these places might be. Provisions relating to the implementation of interventions like reforestation, regeneration of open spaces, etc. are present in the documents as single and possible interventions, lacking an integrated approach. Supplementary planning documents also exist that set out guidance and policies, such as the ´Guidelines on Trees, Shrubs and Plants for Planting and Landscaping in the Maltese Islands´ (GoM, 2002). Such guidance is generally applicable at a national scale. The Development Control Design Policy, Guidance and Standards 2015 (DC 2015) (GoM, 2015b) is a document which Zammit (2014) advocates sets a new approach for Malta in urban design by starting with improved streets. Despite this, the document provides limited policy and guidance for urban open spaces (Scheiber, 2021). Considering the design categories (Tab.1), there is no overall strategy to guide the functionality or character of open spaces in terms of hierarchy or typology. There is also no guidance on the use of materials, or street furniture and the boundary treatments of open spaces are only addressed with respect to front garden walls. Climatic comfort is also overlooked and policies relating to the use of vegetation are limited to the allowable type of species and permitting process for removal or pruning of trees.

Where policies do exist, these tend to be strategic, primarily in the form of objectives which without additional standards or guidelines are open to interpretation. Additionally, implementation mechanisms are lacking. So, while numerous objectives and policies exist requiring for example the prioritisation of pedestrians, traffic calming and increased connectivity, they are not actively implemented. This is also the case in relation to: creating ecological corridors and introducing sustainable water drainage systems. Additionally, policy inadequacies exist. With respect to mobility, for example, the requirement of minimum parking standards as opposed to maximum parking standards in inner urban areas still exists. Additionally, terms such as 'the need to provide a garden setting' in particular spaces are used, without a proper definition or understanding of what this really means. At a land use planning level, seven local plans exist which define regions in the Maltese Islands for which urban spatial development policies are determined. These cover land use, building heights, conservation, open space, and transportation aspects amongst others. A review of the current local plans had been announced due to the introduction of the SPED (GoM, 2015a) which introduced a hierarchy of urban areas, namely the ´Principal Urban Area´ (PUA), Regional Urban Settlements and Small Urban Settlements. At the time of writing, there is still no indication as to the framework or scale which will be adopted for the next planning level under the SPED (GoM, 2015a). It is unclear how, when and whether this will support the necessary strategic planning of urban open and green spaces.

What is clear, however, is that compared to international planning frameworks (Beatley, 2012; Ritchie & Thomas, 2003), strategic planning, standards and design guidance for urban open spaces are lacking. Due to the lack of research concerning urban open spaces (UOSs) specific to the Maltese context, Scheiber's (2021) work proposes a research methodology with the intention of developing a framework for the planning of UOSs for improving their contribution to sustainable development.

3. Methodology

This work adopted a mixed methods research approach (see Fig.2) for supporting decision-making processes. This is deemed appropriate in the context of urban planning and design, because it «allows to follow the subsequent phases of project formulation and it allows to have a dataset built on the results of the previous one» (Berta et al., 2018). This together with the intent to research a specific context suggested qualitative research strategies (Creswell, 2014; Groat & Wang, 2013). The pragmatic nature of the research also concluded that a mixed method strategy would be appropriate, since when considering pragmatic orientations, the idea is to use whichever research type might be suitable to understanding the problem at hand (Creswell J. W., 2014). According to Palinkas et al., (2019) «each set of methods plays an important role in achieving the project's overall goals and is enhanced in value and outcome by its ability to offset the weaknesses inherent in the other set and by its engagement with the other set of methods in a synergistic fashion». Using Creswell and Piano Clark's (2011) definition of 'Exploratory Sequential Mixed Method Strategy', an adapted version was used starting with an inductive qualitative phase and a second qualitative phase rather than quantitative. The work and method presented are from the first phase of the Malta case study (steps 1 & 2 in Fig.2) which is further developed in relation to a review and comparison to European Planning Frameworks (steps 3 & 4 in Fig.2) so as to further understand the areas which Malta should focus on as outlined in the research question for this paper (see Section 1). The five data collection techniques of the Malta case study (see Fig.2) are: a review of existing strategies and policies (2a) physical surveys of existing open spaces (2b); interviews with local councils (2c); an online user survey (2d); and an in-depth qualitative review of three case study open space projects (2e).

Firstly, to understand urban open space design policies and identify gaps, a policy review (2a) of national strategies, policies and spatial planning documents and guidelines. Next, in order to identify design principles or themes relevant and specific to the design of urban open and green spaces in Malta and their potential to contribute to sustainable development physical surveys (2b) of a sample of existing urban open spaces were carried out. This may be seen as across-case research gathering quantitative data (Neuman, 2014). Additionally, semi-structured interviews (2c) with five local councils provide further insight into some of the themes which could not be investigated on site. The localities and participants were selected through purposive sampling. Through this technique, the specific instances are chosen such that they have the potential to reveal the most relevant data (Yin, 2018). Since maintenance was one of the aspects to be further investigated, data from the physical surveys were analysed to inform the choice of localities. The relationship between maintenance level and localities was tested using the Chi-Square test, however, none was established. Nonetheless, the cluster diagram did reveal some patterns/extremities where localities were categorised as follows: A = Leans towards badly maintained; B = Leans towards well maintained; and C = No pattern. It was decided to choose a selection of localities representing both badly maintained and well-maintained spaces.

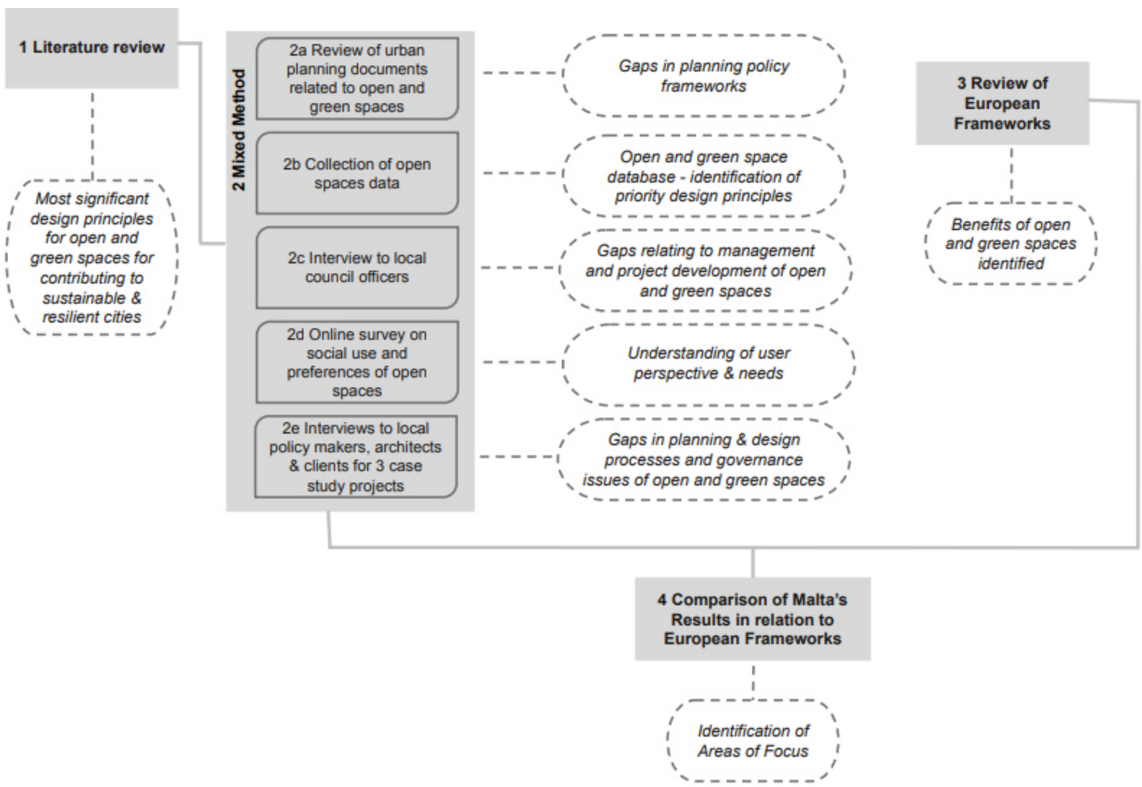

Fig.2 Diagram of the mixed-method

An online survey (2d) was carried out to gather data on the user perspective with regard to how urban open spaces are responding to user preferences and needs. From the theory (see Tab.1), the categories where the user perspective is more relevant are: accessibility and use; character and identity; and functionality. In total 127 responses were collected. The target sample size was calculated using an online tool (Creative Research Sytems, n.d.). Based on a population size of 493,559 (NSO, 2019) and assuming a confidence level of 95% and confidence interval of five, a sample size of 384 would be required assuming that this would be normally distributed. The survey was therefore left open for as long as was feasible, approximately two months, with constant sharing of the link every few days. With a sample size of 127 and confidence level of 95% the confidence interval which was eventually achieved was 8.69. This suggests a limitation, in terms of representativeness of the sample due to size, however as part of a mixed methods approach it still served to provide useful insight into the user perspective on urban open spaces in Malta. Additionally, three case studies of recently designed and implemented urban open spaces in Malta were chosen and studied in detail (2e). Here, the focus is on qualitative data. This is seen as suitable, as it allowed the linking of the micro-level (the design of urban open spaces) to the macro-level (the planning of urban open spaces) (Neuman, 2014). It also made it possible to understand how spatial planning policy is failing to support the design of urban open spaces with the potential to contribute to sustainable development. An initial list of projects was developed and shortlisted using purposive sampling. The cases are considered paradigmatic, that is, they were selected because they have prototypical value (Brink et al., 2017). The criteria considered projects implemented in the last 10-15 years (to have a good number to choose from) and which are representative of typical spaces. The first selection was then reduced to the final three using convenience sampling. This was necessary to make sure that planning permits were available for the projects to be analysed, and that the persons concerned were willing to participate in the research. Some of the shortlisted spaces did not respond, so the three which did were chosen.

Ultimately, the integral review of the literature (oriented both to urban design principles and European frameworks) supported the identification of possible gaps and/or weaknesses of urban transformation strategies, by considering the wider goals of climate adaptation and energy sustainability. In particular, steps (2b-2e) contribute to answering the first research question, by investigating the strengths and weaknesses of urban open and green spaces in Malta that should be enhanced through the adoption of the proper design principles. Finally, a comparison of the results of the Malta case study (including step 2a) with the principles extracted from EU frameworks, identifies the possible and desirable relationships between the strategies outlined by the EU and the planning documents adopted by Malta's decision-makers, according to the second research question.

4. Results

4.1 Physical on-site survey of existing open and green spaces

The results from data collection method 2b, provide evidence on the extent to which the design principles identified through the literature review (Tab.1) are present in the existing open spaces. It is clear that many aspects are lacking for example connectivity; thermal comfort; usability and sustainable water management. Fig.3 below summarises some of the key principles which require attention in the planning and design of the green and open space system.

In terms of connectivity, the quality of connections is poor in terms of pedestrian infrastructure and spaces are not designed and exploited as places to walk through.

Additionally, the connectivity of vegetated open spaces and hence connectivity of habitats is not facilitated. So, while it can be said that there is the potential to create a network of green open spaces, this is currently not being exploited in the individual design of the open spaces due to the quality of connections and the physical boundaries of the open spaces. Moreover, the relationships between the open spaces and surrounding buildings need to be addressed as often open spaces are isolated due to road carriageways and on-street parking and the buildings do not interact with the open spaces. Concerning character, open spaces are predominantly urban (64%).

There is scope to: increase the sense of refuge (24% scored positively), provide spaces which give a sense of being in touch with nature (12% scored positively); reduce the impact of vehicular traffic (43% were characterised by ´traffic´) and provide more playful and adventurous spaces. There is also the need to consider the provision of more attractive amenities and features and detailing of street furniture and materials and their impact on the aesthetics of a place. There is the need to improve circulation paths, particularly on the approach to open spaces (streets) and within natural / semi-natural areas (Fig.4). Footpath widths need to increase together with the provision of seating and vegetation. When considering activities, there is the need to provide spaces which allow for a more varied type of activity such as formal and informal recreation, physical exercise and flood mitigation. Children's play areas need to increase the variety of playscapes on offer with more informal, adventurous, interactive and unstructured play. There also needs to be more provision for 16-20-year-olds/youths, and spaces which facilitate community activities.

There is also scope for providing more spaces which mix compatible user groups rather than, for example, separately/isolating children's play areas.

Overall, smaller spaces (< 3,000m²), tend to be readily available within the required vicinity (400m) while the availability of larger spaces (> 3,000m² and > 2 ha) requires attention. District parks greater than 20ha are lacking altogether. In order to provide local parks (i.e. parks > 2ha), the potential of valleys and other semi-natural spaces needs to be considered. Existing open spaces also require attention in terms of climatic comfort.

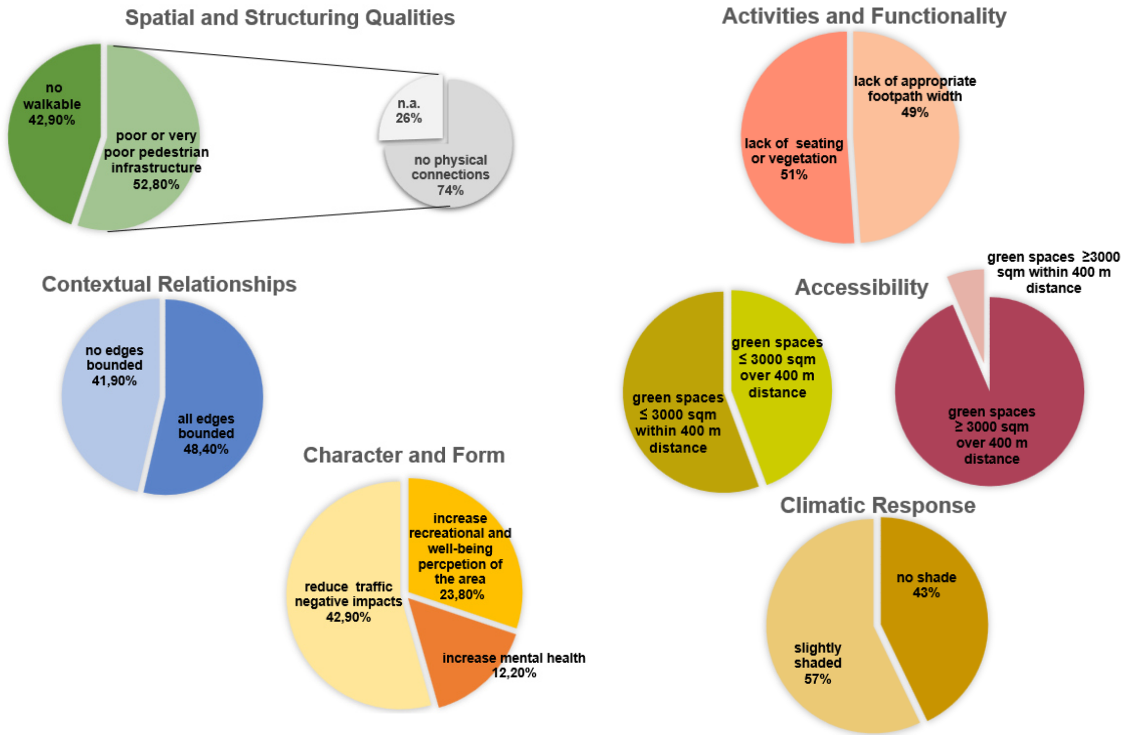

Fig.3 Overall qualities and activities in Malta's open and green spaces: outputs of the physical surveys

This would mean providing more areas which are shaded and usable during warmer months, while still retaining some areas to enjoy the sun during colder periods.

Gardens/parks and natural areas are the typologies which tend to perform well while children's playgrounds, civic squares and main streets do not. Stormwater management needs attention, particularly with regard to the use of sustainable approaches such as water infiltration, storage and re-use. 92% of the spaces did not have an irrigation system (Fig.5).

The presence of vegetation should also be maximised. In 30% of the cases, less than 10% of the area was allocated to vegetation, with a further 30% having between 10-30% of the area as vegetation. The type of vegetation present was also analysed. With respect to trees, attention should be paid to their potential to provide shade. With respect to ground cover, there is scope to increase this so as to provide a greener environment as well as provide benefits such as noise mitigation, wind protection and mitigate air pollution. There is also scope to improve the level of visual interest and to consider types of planted vegetation which require lower maintenance levels.

Fig.4 Images illustrating open spaces with minimal vegetation, shade, vehicular orientation / dominated space and the lack of sustainable urban drainage systems

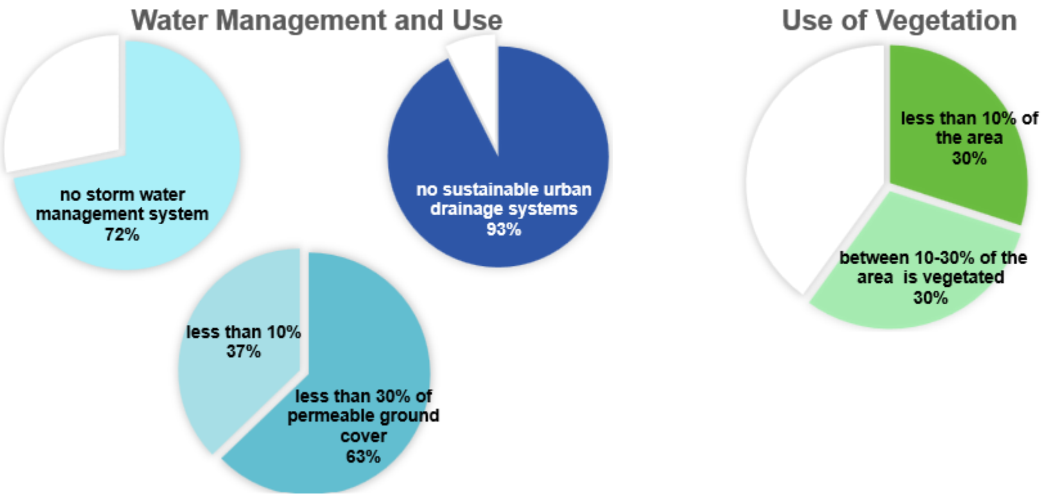

Fig.5 Sustainable water management and presence of vegetation in Malta's open and green spaces: outputs of the physical surveys (2b)

4.2 Interviews with local councils

To expand on a number of themes which could not be easily analysed through on-site visits, five interviews (data collection 2c) were carried out with local councils in the study areas. The themes requiring more input were: Social Context and Use; Water Management and Use of Water; Maintenance and Management; and Community Involvement. The opportunity was also taken to gain insight on some additional aspects emerging through the policy review, these being: the local council´s experience with the planning process and use of policy; and issues encountered when embarking on projects for public open spaces.

The findings can be summarised in terms of three themes: socio-cultural; process barriers; and sustainable management.

- Socio-cultural: Public open spaces are valued and used in various ways (informally, structured activities & traditional practices) by different demographics and are seen as important assets for cultural integration, with local councils organising events to promote community cohesion. Open spaces are however lacking, in particular gardens and green areas and spaces which facilitate the integration of different age groups.
- Process Barriers: Local councils (LC) do not play an active role in implementing local plan policies. They lack expertise and resources to do so; they prefer their own ideas and feel that local plan policies don't address the community's needs; and there is a lack of positive engagement and relationships with the authorities e.g. Planning Authority and the Environment & Resources Authority (ERA). Community participation during the development of project ideas is limited. There exists a genuine effort by LC's however since this often results in a tedious and difficult process, and resources are limited, this can be sometimes neglected. LC's also lack the staff resources required for implementing new projects, as well as, the lack of available contractors, suppliers and expertise when it comes to developing and implementing small projects. There could be a platform which local councils would turn to for advice and expertise on planning aspects and developing project ideas.
- Sustainable Management: Local councils require expertise and assistance especially for the sustainable use of vegetation and water management. The development of guidelines on these aspects would be helpful. There is also scope to provide centralised resources to assist local councils on technical issues. Local councils are responsible for the upkeep and maintenance of local open spaces but their resources are very limited. They do not have sufficient funds or expertise to go beyond embellishment. Repairs beyond general maintenance are problematic as it is difficult to find contractors for small jobs or the process for engaging them is lengthy. A system which facilitates this is required – possibly on a more regional level. Schemes to support and encourage grass root initiatives or civil society involvement in the voluntary care and management of their own neighbourhoods are also lacking.

4.3 User survey: the user perspective

The data from the online user survey (data collection 2d), allowed some key themes as to the user's views about existing open spaces to be extracted. The 127 respondents came from 43 different localities. With respect to the participants' characteristics, there was a higher response from the 35-44-year olds, and the majority of the respondents, 60.6%, were full-time employed (Fig.6).

It can be said that open spaces are valued and used by the Maltese population. 43% of respondents used open spaces at least once a week with a further 26% using them once or twice a month. Spaces are mostly used for walking and taking children out to play.

However, they are also used for a variety of activities. Relaxing/quiet time was another common use meaning that people are searching for places of refuge.

The quality of open spaces however does not match what users expect and 86% felt they were missing something (Fig.7). Greenery/Trees/Nature emerged clearly as a missing characteristic. Respondents mostly like open spaces which provide qualities associated with nature such as: trees and greenery, peacefulness, fresh air, wilderness, sea views and a sense of openness.

Qualities which they disliked were: lack of cleanliness and maintenance; too much traffic; too crowded or too small. They also lack the presence of different uses. A number of lacking activities/functionalities were identified, the most common being: picnics, reading in peace, training options, long walks, trekking/hiking; biking and skating (kids), jogging, cycling, and ball play. The lack of spaces which facilitate physical activity is therefore evident.

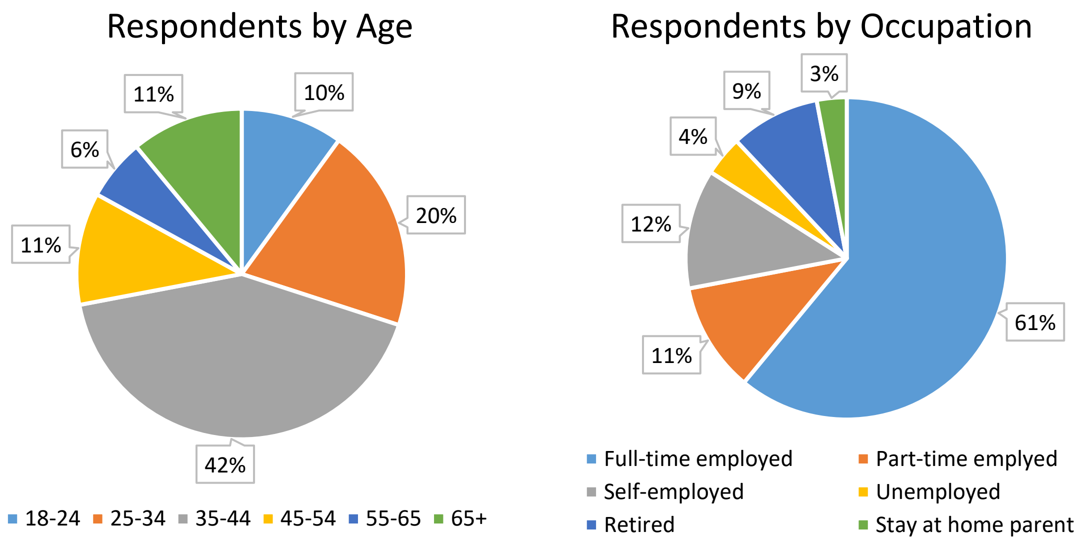

Fig.6 Demographics of the survey respondents

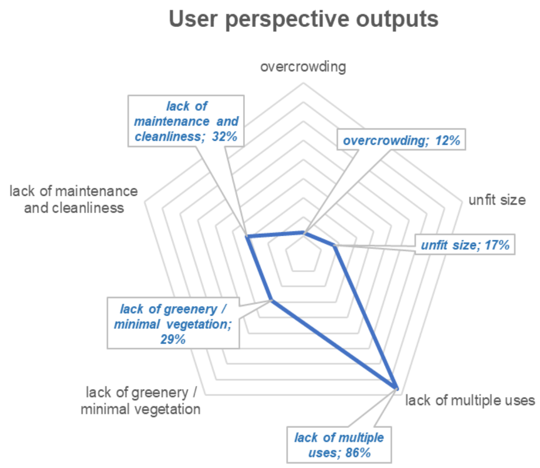

Fig.7 Malta's urban open and green space quality, according to the user surveys

4.5 Review of 3 case study projects

Through the purposive sampling outlined in section 3, three case studies (data set 2e) were chosen which represented the typologies of open spaces being studied. The case studies were:

- Pembroke Garden: The project was part of a number of projects aimed at upgrading the tourism product in Tourism Zones. The open space is a public garden which provides informal recreational areas and formal play areas for children of different ages. It is surrounded by different uses including: 5-star hotels; residential areas, sports fields and a natural stretch of coastline. The size of the space studied is about 7,300 sqm;
- Cospicua Waterfront Regeneration of an Industrial Dock: This is a waterfront space which includes different typologies including: a promenade; informal recreational / garden areas; civic squares and a local street. The waterfront was previously closed off as an industrial dock. The size is about 33,200 sqm;
- Paola Square: This open space is a town centre civic square which already existed in a different form and the project consisted of its transformation. In general, it retains the function of a civic square and aims at improving the quality of the place through improved traffic management. The size is about 10,500 sqm.

Analysis of the interviews with the client, design architect and planning officers of each of the 3 case studies provided insight into three main aspects: addressing the design principles during the design process;

addressing the design principles during the planning permitting review process; as well as gaps in relation to planning and governance frameworks.

Design Principles during the design process

Through analysing the interview transcripts, it was possible to understand which of the design principles extracted through the literature (see Tab.1) where taken into consideration during the design process. Based on the 3 projects studied, it was clear that some of the themes were in fact given due attention. This meaning they were discussed throughout the design process and were given importance by the designers. Other themes were identified as requiring more attention. In such cases these design principles were either not considered, were considered in a limited manner or deserve more attention especially when considering their potential importance in contributing to the sustainability of urban areas (Tab.3).

Design principles given due attention	Design principles requiring more attention
Open space as a structuring element	Socio-cultural contextual relationship
Connectivity	Spatial proportions and enclosure
Physical contextual relationship	Supplementary equipment
Functional contextual relationship	User preferences
Typological/Character of space	Moment with respect to reducing the vehicle prioritisation
Visual interest	Climatic response
Recreational facilities and functionality	Sustainable water management
Multi-functionality and flexibility	Use of vegetation: presence, location, form and type
Vicinity and availability	Lighting in relation to energy efficiency
Legibility	Resource management
Access to all	
Use of water: aesthetics/feature	

Tab.3 Malta's urban open and green space quality, according to the user surveys

For example, regarding vegetation, in the Pembroke Garden, the idea was to create a 'natural' space, but vegetation was limited to certain areas so as to prioritise views to the sea, or to create underground storage areas which in fact has never been used. In the Paola square, even though the project sought to create a 'garden setting' or an 'urban garden' the planting of trees was actually restricted to a small part of the site.
Attempts to address climatic comfort is also limited. When this issue was raised during interviews some mentioned the need to mitigate the sun when walking, an architect mentioned the introduction of canopies, although admitting that these were also primarily an architectural feature. In all cases the spaces are pretty much exposed to the sun and the use of trees to provide shade is quite limited. One particular site is quite windswept and even though the architect raised this point himself, the design did not seek to address this to create comfortable conditions. It was accounted for simply when choosing vegetation which could resist the wind. In this project in fact retaining clear view paths to the sea was more important than using more trees to create more shaded areas for the climatic comfort of the space. Tab.3 gives an overview of which design principles can be said to have been given due attention and which require more attention.

Design themes during the planning project review

Analysis of each of the three project's planning application process was carried out to understand to what extent the various design categories were considered when projects were reviewed when applying for a planning permit.
When considering spatial and structuring design objectives, comments during planning review are limited to connectivity for pedestrians and connections between open spaces. Developing connectivity between

vegetation to facilitate habitat creation and biodiversity did not feature. With regards to contextual relationships discussions were limited to physical relationships. Responding to functional and socio-cultural contexts did not really feature. In terms of character and from, the interpretation of objectives varied depending on the case officer and architect since no guidelines exist. For example, for one project planning policy required the provision of a ´garden setting´. The architect felt that since more trees and soil were provided than previously this was sufficient. The planning officer also felt that such a policy was subjective and that since a number of trees had been proposed then this policy had been respected.

With respect to functionality, the provision of particular uses and activities is not guided by planning policy, and so it does not form part of wider planning objectives. Rather it is based on the architect's interpretation. Creating visual interest and the spatial proportions and enclosure of the space did not really emerge in the discussions. Meanwhile, responding to the site and the identity of the place featured as an important aspect. This was mostly about responding to historical contexts and respecting archaeological findings. This is sometimes too focused on ensuring traditional use of materials and finishes. Additionally, policies intended for buildings are being applied to open spaces and the extent to which contemporary design which responds to a historical context is considered appropriate depends on the case officer.

When considering the provision of supplementary equipment, discussions were limited to the provision of fire hydrants in one of the projects. Concerning other functional aspects, the discussion primarily focuses on the use of materials. Details are sometimes requested but it is not clear against what they are assessed. Mostly the discussions related to contextual suitability rather than functionality. The use and allocation of space, seating, provision of facilities etc. are not really part of the discussions. A review of use value could be considered non-existent. The suitability of the design to respond to user needs/preferences, the type of activities which are provided for, the multi-functionality, flexibility or adaptability did not feature. In terms of access to open space, no discussion existed regarding whether the type of open space proposed is important for the locality or at which scale, or how it relates to other open spaces in the locality. When considering movement, the focus was on vehicular access. The transport authority does not seem to concern itself with pedestrian access. The PA also doesn't comment on the suitability of pedestrian provision. The focus is also on ensuring parking provision rather than restricting vehicular access. Meanwhile, "Access for All" was an important focus reviewed by an independent entity.

Climatic comfort and suitability through design did not feature. Regarding water management, requests for the use or provision of water reservoirs generally come through other entities other than the PA. If there are requests from the PA this is dependent on the case officer's views. There are no guidelines as to what sizes should be requested or what is considered appropriate. There is a lack of awareness and expertise as part of the planning review process in this area. It is also not clear who is responsible for reviewing such aspects. Even though the use of water as an amenity featured in all projects, no discussions emerged during the review process.

The planning review doesn't really go into the design or use of vegetation. The fact that some vegetation was provided seemed to be sufficient. It also emerged that ERA should be responsible for reviewing such aspects however their role and if it is happening was not so clear. Requests by PA are limited to the type of species. The potential benefits of vegetation for environmental aspects or climatic comfort did not feature. Requirements for the maintenance of vegetation varied from project to project. While adherence to landscape proposals is checked, these can vary and the suitability of any changes is at the discretion of those checking the compliance.

With regards to lighting, engineer reports are sometimes requested but it is not clear what guidelines are being followed, and how reports are assessed. It seems to be self-regulation. Cut-off lighting emerged as the main requirement. There was also no real focus in terms of resource management. The SPED objective to be "energy and water efficient" is not really understood or followed up.

Gaps in planning and governance processes

Vagueness and lacuna of guidelines regarding open spaces: This can lead to frustrating processes and waste of resources by applicants as it is not clear what is considered acceptable. It was felt that initiatives to improve open spaces are not always facilitated by the Planning Authority. Additionally, this lacuna should not necessarily be addressed by policy but also through guidelines, awareness/knowledge building or standards. There was a general feeling that creating more policies would be restrictive and reduce flexibility in allowing a contextual response.

Lack of creative planning: Interviews with architects identified that the planning process lacks a formal opportunity for applicants or architects to present and explain their design ideas to the planning officers or board. It was felt that the review process is more about responding to technicalities, clarifying the submission documents and making amendments to satisfy stakeholder requests. When design discussions do take place they tend to focus on subjective aesthetic and contextual considerations. Finally, the feedback received from the planning commission/planning board tends to be just before a decision for the planning application is taken and can be quite ad hoc, depending on the board's opinions at the time.

Lack of consistency: Open space projects are allocated to planning officers according to whether it is a major project, a project within a development scheme or within an Urban Conservation Area (UCA), resulting in differences when applying policies. Additionally, the planning process allows for applications dealing with minor amendments. These applications are reviewed by a different team so the planning officer may not be fully aware of all the issues which might have arisen under the main application leading to potential gaps in the assessment.

Stakeholder Participation - Design Process: This could be more structured and broader. Currently, the extent of participation varies depending on the architect and client. This is especially the case for community and local council involvement. Hesitation to involve local councils, when they are not leading the project, stems from anticipating their objection to the project. Discussions with the transport authority also need to be facilitated so as to reduce the impact of vehicles/vehicular flow on the quality of public spaces. Even though various policies exist to promote pedestrian priority or traffic calming schemes, the case studies revealed that there is still a tendency to prioritise vehicular provision and parking before anything else. Existing objectives and policies do not seem to count for much. Dealing with utility companies can also be difficult as they are not always organised and ready to provide input. Consultation with the Superintendence of Cultural Heritage (SCH) and the Commission for the Rights of Persons with Disability (CRPD) seemingly happened at an early stage in the process and was always given importance. On the other hand, consultation/participation of environmental NGOs during the design process was minimal. This happened for one project and mainly for public relations concerns.

Stakeholder Consultation - Planning Review: Stakeholder input during project review tends to focus on comments regarding: transportation (TM); cultural heritage (SCH); Access for All (CRPD); and civil protection (CPD). Input from utility services is limited. Environmental input and review are also lacking or limited to the requirements for: transplanting/tree removal permits; compensatory planting; and the use of species (invasive/non-invasive). The role of the Environment and Resources Authority as a consultee is not very evident. Additionally, it is not clear which policies or guidelines are being used to assess the design of urban open spaces, other than the Guidelines on Trees, Plants & Shrubs for Planting and Landscaping in the Maltese Islands (2002). There is also a lack of clarity on who is reviewing aspects related to water and energy and according to which guidelines. Opportunities for public participation are very limited. The public has the right to submit representations in writing; however, the extent to which these affect the outcome of a project application is quite limited. Additionally, proactive community engagement is non-existent.

Lack of driving entity & adequate resources: There is a lacuna in terms of the governance of urban open spaces. There is seemingly no entity or process to manage and facilitate the development or transformation of public areas. This is not the role of the PA or ERA. The local councils are responsible for the upkeep and maintenance of urban open spaces within their locality; however, their resources are extremely limited. The case studies illustrated that the presence of an authority leading the project with direct access to the central government was an important model for realising projects of significant size and complexity. The authority varied in all three projects: The Grand Harbour Regeneration Corporation; The Consultative Council for the Southern Region; and the Malta Tourism Authority. These entities all had specific goals, with the necessary drive and resources. Additionally, National or EU funds (rather than simply local council funds) are required to carry out projects which go beyond embellishment to bring about change and substantial improvement. These entities all had the remit to be allocated or resources to tap into such funds. Other themes which emerged include: the need to facilitate the use of Private Public Partnerships; the lack of enforcement which was one of the reasons why entities did not like introducing 3rd parties into the operations of public spaces; the tendering process which emerged as a limiting factor in realising innovative solutions; and addressing complications when transforming open spaces across local council boundaries.

Maintenance and Management: The provision of funding for maintenance is not generally sourced upfront. National funds were required to keep up with commitments once projects were finalised. Local councils do not under normal circumstances have the resources and funds to manage and maintain open space projects of a certain level.

5. Discussion and conclusions

European and international strategies advocate urban open and green spaces as an indisputable requirement for increasing resilience, energy sustainability and adaptive capacity of urban systems. Nevertheless, a mismatch between policy and the operational level seems to characterise the spatial planning of these spaces (Ganzleben et al., 2020; Orsetti et al., 2022). Among these, two elements are interesting with respect to this work: (i) the numerous functions which create competing demands on land and resources (Chatzimentor et al., 2020): urban open and green spaces need to: be liveable; be accessible to the population; contribute to improving thermal comfort; and increase the permeable capacity of a city. These goals represent different kinds and priorities of intervention, according to both their localization and their specific characteristics (e.g. surface, vegetation, …). The last two aspects require particular attention to the (ii) design and planning of these spaces since their shape, configuration and composition, and their distribution in the urban area, contribute to the desired performance of the urban system in terms of climate, energy and sustainability issues (Gargiulo & Lombardi, 2016; Graça et al., 2022; Papa et al., 2014; Scheiber, 2021).

To contribute to filling these gaps, the main aim of this work was to investigate the spatial planning and design of urban open and green spaces in Malta. Following on from this the intention being to understand the results in relation to European Frameworks, to identify whether there is scope for the spatial planning system to facilitate their potential to add value to the built environment and develop recommendations for improving the contribution to urban sustainability, resilience and climate change adaptation or mitigation. It is worth noting that in Malta's planning there is a general lack of consideration of urban open and green spaces as elements of the same system. This can be due to the fact that green infrastructure grasped the attention of climate goals leaving out the additional benefits that open spaces can provide through careful planning and design. Referring to Fig.8, it clearly shows that while EU strategies and documents are open and green space compliant, there is still scope for improvement when considering Malta's planning framework. In particular there is the need for strategic planning so as to improve the organisation of urban areas in terms of actively introducing urban open and green space networks. The potential for such systems to contribute to carbon sequestration, thermoregulation and mitigate soil sealing are areas which require particular improvement, with inclusivity and the hydrological function also deserving more attention. Additionally, while newly developed strategic documentations seem to be showing increased awareness in the potential contribution of urban open and green space systems, the extent to which these will be implemented and translated into actionable spatial planning policy is still to be seen.

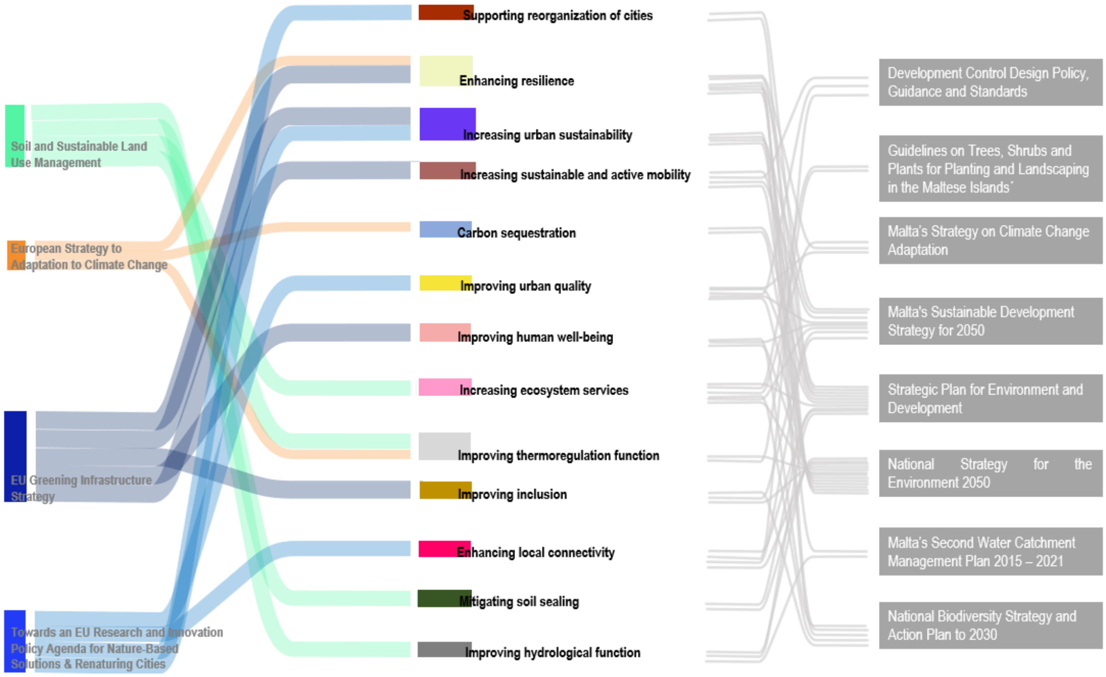

Fig.8 Positive benefits linked to the green and open spaces in cities as identified by EU strategies and Malta key urban planning documents.

One of the challenges in addressing the interlinkages between climate and energy issues and planning and design of open and green spaces could be due to the limited capacity across public sectors and policymakers, gaps in cross-sectoral knowledge and communication between planning experts and planners, as well as the shortage of human and economic resources. A systemic approach to increase the supply of urban open and green spaces is still lacking in Malta's spatial planning documents, particularly at the local and actionable scale. Policy-makers are aware that they need to address sustainability and resilience issues but they are not necessarily doing this through the strategic planning and design of urban open and green space. This represents a weakness when it comes to addressing current and long-term challenges such as climate adaptation and energy sustainability. On the other hand, as identified through local interviews and surveys, there is a growing sentiment for the appreciation and need for green open spaces from users. Inhabitants seem to understand the importance of the restoration, connectivity and multi-functionality of these spaces but these characteristics are lacking within planning documents and policy-makers approaches. So, while recent national strategies illustrate that there is clearly a growing interest in increasing the supply of urban open and green space across the various governance levels, challenges still exist in relation to socio-cultural and socio-political trends which so far do not prioritise open and green spaces in comparison to other land use functions e.g., building development and provision for vehicular movement (Scheiber, 2022). Finally, there is also the need to ensure that investment in new green open spaces appreciates the importance of the strategic planning of urban open and green spaces systems in terms of a network and the reorganisation of cities so as to ensure that the various potential benefits are capitalised on. Ultimately, this work has identified the specific areas (carbon sequestration, thermoregulation, soil sealing, inclusivity and hydrological function) in reference to the EU urban open and green space planning strategies which in the context of Malta are still lacking. Going further into how urban open and green spaces could contribute to these aspects specifically in terms of planning and policy frameworks could be the focus of future work.

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Image Sources

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Climate change-induced conflicts in Southeast Nigeria and urban food security

Implication to urban sustainability and sustainable development

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Abstract
Climate change is multifaceted and complex in its impacts on the human population across the globe. The areas of impacts include food insecurity and urban sustainability issues, which are currently ravaging the developing nations where sustainability policy frameworks are lacking or in passivity. The complex impacts of climate change on the urban population have been explored by some researchers in other regions of the world however, the nexus between climate change-induced conflicts and urban food insecurity and sustainability crises is yet to be empirically explored especially in the developing nations such as in sub-Saharan Africa. The aforementioned research and policy problem was the drive to the present study. The study which was guided by sustainability and climate change models, involved 1,658 respondents among the farming communities in southeast Nigeria using survey design and questionnaire as data gathering instrument. The study concludes that there is a cycle of anthropogenic activities among the urban population contributing to climate change, and climate change crises returning to urban population in form of food security and urban sustainability crises due to weak and passive environmental sustainability policy framework in Nigeria.

Keywords
Climate change; Food security; Environmental conflict.

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1. Introduction

In Nigeria in recent times, there has been an increase in transhumance from northern to the southern axis by the pastoralists who are majorly located in northern Nigeria; this has brought about some crises with some socioeconomic impacts on both the rural and urban populations alike (Ikezue & Ezeah, 2017; Ezemenaka & Ekumaoko, 2018; Oghuvbu & Oghuvbu, 2020). Although there has been evidence of the presence of the herders in southern Nigeria and southeast Nigeria in particular, the recent changes in the number of herders moving to the south from northern Nigeria has been raising a concern and speculations about their origin and implication to the receiving region. The influx of cattle, their herders and families has at least, unsettled the peace of the receiving communities due to herders trespasses and attendant struggle for land space with the indigenous farmers (Oli et al., 2018; Akabuiro, 2022). Following the traditional land tenure system in different parts of Nigeria, each region popularly marked by ethnic identity, do see landed properties as inheritance from lineage and communal history, which in any case, does not allow the non indigenes access to land ownership and occupation (Udoekanem et al., 2014; Ajala, 2017; Pierce, 2013; Ghebru & Okumo, 2016). As such, the presence of herders who are mainly Fulani ethnic group from the north undoubtedly triggers concern among the southern population who see the herders as intruders. There is a mutual suspicion between the herders coming mostly from northern Nigeria and the indigenous farmers in the southern axis. The herders are aggressive over land space to occupy for settlement while the sedentary farmers in the local communities are aggressive over land space for farming and as lineage/ancestral inheritance. The trespasses and conflict of interest engenders clashes, which has eventually led to the emerging trends of sudden onslaught against the host communities with monumental loss of lives, properties and farm products damage.

Owing to the glaring impacts of transhumance-related conflicts centred on the farmers and herders in sub-Saharan Africa and other parts of the globe, researchers have focused to understand the originator of the transhumance-related conflicts and the complex impacts on the urban and rural communities world over owing to its drastic effects on the United Nations Sustainable Goals 2, 11 and 12 (United Nations General Assembly, 2015). Among other factors, climate change over the years has been suspected as a culprit in the ever-growing movement of the pastoralists across Africa and sub-Saharan Africa in particular, causing some unsettlement on the side of the indigenous farmers who become vulnerable to the accompanying crises. Although the emergence of climate change crises have compelled both developed and developing nations to work out strategic land use policies to adapt into the emerging climate change issues (Zucaro & Morosini, 2018), most developing nations such as Nigeria are yet to priorities this problem. Many researchers have focused on the relationship between climate change incidents and the movement of the herders from one region to another with some findings suggesting the cause and effects relationship between climate change and transhumance activities (Serdeczny et al., 2016; Hoste & Vlassenroot, 2009; Turner & Schlecht, 2019; Musau, 2021; Connolly-Boutin & Smit, 2016; Leal et al., 2020).

According to the study by Teka et al. (2012), among the pastoralists in Eastern Tigray Ethiopia, weather activities has been found significant in their decision for seasonal movement from one region of the country to another as their local weather calendar indicates when and where drought is about to strike. Similarly, the study by (McGuirk & Nunn, 2021) equally confirmed that within the Ethiopian territory, much of the clashes between the farmers and the pastoralists have hovered around the decision of the herders to relocate because of weather challenges. According to the study by Issifu et al. (2021) among the Agogo population in Ghana who are known for pastoralist activities, the growing harsh and unpredictable weather, which is the evidence of climate change in the recent times, have forced them to move south ward in other to find pasture for their herds; this usually exposes them to conflicts and crises with the indigenous people of the south with unpleasant consequences. The study by Olaniyan, Francis and Okeke-Uzodike (2015) among the herders in Agogo Ghana who are involved in cross border transhumance activities showed that, among the herders originating from the region, the weather activities over the years have drastically affected their chances of sustainable livestock management in their original settlements, forcing them to relocate for better pasture for their livestock. This situation according to the study has resulted into countless crises with the farmers whose farms are mostly affected by these movements across border.

According to the study by Krätli and Toulmin (2020) in sub-Saharan Africa involving Mali, Ghana and Nigeria, most of the recorded and investigated transhumance-related conflicts are pointing towards the emerging issue of climate change. From the study, about 60% of the crises documented with proper investigation among some sub-Saharan African nations indicated the effects of climate change on the decision and movement of the herders towards new areas with its accompanying crises with the farming communities. From the study by Adigun (2019), evidences suggested the climate change as a culprit in the increased movement of the pastoralists from northern Nigeria towards southern Nigeria. The study concluded that with timeframe and historical changes, the increased movement of the herders towards the south from the north are undeniably connected to the recent global climate change issues. Similarly, the study by Adeniran (2020), which was carried out in northern Nigeria revealed that in the recent times, climate change impacts on the grazing areas across northern Nigeria has been affecting many herders forcing them to search for more conducive regions and areas where they can maintain their livestock.

The study by Odoh and Chilaka (2012) in the middle belt region of Nigeria [the region linking the north and southeast Nigeria] suggested that the climate change indices are biting hard on the activities of the herdsmen in northern Nigeria, forcing them to relocate southward. According to the study, the movement of the herdsmen has begun quite a long time due to the emergence of climate change crises affecting the global community. Equally, the study by Halliru (2015) among the Kano state farmers and herders showed the drastic effects on the activities of herdsmen especially, their grazing areas causing the herders to involve in a somewhat internal migration for greener pastures and grazing areas. According to the finding of the study carried out by Olagunju et al. (2021) in southern Nigeria, there are common indicators among the herdsmen activities in the region that majority of their movements have been forced by weather activities in northern Nigeria. Corroborating this study is the study by Bello and Abdullahi (2021), which showed that over the years, most of the regions in northern Nigeria mostly occupied by the herdsmen have been hit by drought, the bye-product of climate change. According to the study, drought and desert encroachment have all forced the herdsmen in most of these areas to relocate to the nearby areas or towards southern Nigeria.

While the pastoralists popularly known as nomadic or Fulani herdsmen in Nigeria are viewed as operating mostly in northern Nigeria where there has been numerous encounters between them and the farmers in the region, their appearance and encounters with the indigenous farmers in the southern axis has been relatively recent owing to the peculiar nature of the southern axis as a region with multi-ethnic outfit who mostly earn their living through subsistence and relatively commercial farming (Oke & Olawale, 2019). The emergence of the pastoralists in the southern region both with a shock and fundamentally with conflicting interests to the people of the region has eventually turned to another dimension of domestic socioeconomic crises with global magnitude. Specifically, the unsettling of the farmlands and farming activities by the movement of herdsmen in the South eastern Nigeria in particular has created the crises of food insecurity and urban food sustainability issues (Okeke, 2022; Obi et al., 2021). According to the allied body of the United Nations (Food and Agricultural Organisation), food insecurity is captured in four major dimensions such as issues affecting food production, food accessibility, food stability and food utilization (FAO, 2020). The movement and activities of the herdsmen down to southeast Nigeria sparked by climate change in the recent times have drastically affected the four dimensions of food security with enduring impacts across the region and beyond (Egodike et al., 2020; Oti et al., 2017; FAO, 2022).

From farm inputs to farm output and to the market and urban access to different foods originally produced in southeast Nigeria, there are evidences of hardships among the population of the region (Tanyi et al., 2021). Most of the farm products produced in the southeast Nigeria is either in short supplies to the host and urban communities in the region or totally supplied from other regions due to climate change triggered conflicts between the farmers and herders in the region (Obi et al., 2020; Akerjiir, 2018). Although the change in pastoralists movement towards the southeast Nigeria has been attributed to the climate change crises, which have drastically affected the nomadic activities in the northern region (Odoh & Chilaka, 2012; Oyaba & Nein, 2019), some scholars have attributed the problem to the challenges of poor governance and a smokescreen of land grabbing agenda (Christiana, 2021; Bello & Abdullahi, 2021). As a matter of fact, the southern Nigeria leadership structure under the aegis of southern governors forum have formed alliance to enact anti open grazing bill in their respective states targeting the activities and encroachment of the herdsmen and the eventual conflicts with the farmers (Aligba et al., 2020; Alonge, 2019; Jooji, 2020).

The impact of herdsmen clashes with the indigenous farmers in southeast Nigeria, which is triggered by climate change, has some wide range and long lasting magnitude and impacts. These included the urban food security and sustainability in the region; for instance, all the urban communities in southeast Nigeria receive their food supplies from the rural communities where the herdsmen-farmers clashes are taking place (Enete & Achike, 2008; Akukwe, 2020; Olumba et al., 2021). In the recent times, there has been an increase in the prices of foodstuffs in the urban communities in southeast Nigeria, especially with the recent farmers' herders clashes in the region (Ifejirika et al., 2013; Adekunle et al., 2020). The farmers and other indigenous people being destabilised due to the climate change-induced farmers-herders clashes are forced into the nearby urban communities for safety and new venture of seeking for greener pastures. For instance, in the recent conflicts between the migrant herdsmen and the indigenous farmers has eventually pushed more people into the nearby urban communities such as Enugu in Enugu state, Umuahia and Aba in Abia state, Owerri in Imo state, Abakiliki in Ebonyi state, Onitsha, Nnewi and Awka in Anambra state all within southeast Nigeria. The nexus of the urban food security and climate change-induced farmers-herders crises in southeast Nigeria points to a critical and strategic gap in the ongoing United Nations Sustainable development goals domestically in the region and internationally to the overall global agenda in ending hunger, achieving inclusiveness and sustainable food consumption in the urban communities as well as in the rural communities. The aforementioned gap in knowledge and policy option is yet to be explored by any researcher in southeast Nigeria prompting this study, which is focused on answering the following questions such as:

i. What is the relationship between observed climate change indicators and herdsmen movement from northern Nigeria towards southeast Nigeria?
ii. What is the relationship between climate change-induced conflicts and urban food insecurity in southeast Nigeria?
iii. What are the predictors of urban food insecurity originating from the rural communities in southeast Nigeria?
iv. What is the implication of climate change-induced conflicts to urban sustainability in southeast Nigeria?

2. Climate change and urban sustainability

The interrelationship between the anthropogenic activities and climate change produces the environmentally related crises, which eventually return to the same human population responsible for environmental degradations especially in the urban communities. This usually comes in a way that may not easily be fathomed except through scientific cross-examination of cause and effects analysis of factors (Heidi & Somaya, 2017; Archer & Satterthwaite, 2019). Urban sustainability, which goes beyond economic, political, social and religious perspectives and paradigms (Khalili, 2011; Jenkins, 2008) to involve behavioral disposition of the urban population, awakes in our consciousness the implication of the unseen individual and collective attitudinal disposition of the urban population towards the natural environment. Beginning from the government urbanization policies to the obtainable urbanism in the urbanized areas, there are issues of environmental negligence, which ultimately resulted to emerging environmental related crises in the developing nations. And this is connected to poor urban planning in the developing nations, where the emergence of urban areas follows no definite pattern due to population crises and poor governance.

Following the sustainability models such as the political, economic, ecological and theological models, which are invariably interwoven in the explanation of the concept of sustainability, urban sustainability is multidimensional with a bearing on the human behavioral ethics (Jenkins, 2008; Khalili, 2011). For instance, the political model, which focuses on environment and human dignity with the instances of environmental justice and civic environmentalism (Jenkins, 2008; Khalili, 2011; Childers et al., 2014), cannot be achievable in the absence of checkmated human attitudinal disposition towards the natural environment. This is also obtainable in the case of ecological, economic and theological models, which are primarily on using the returns from the natural environment for further investment opportunities, sustainability of biological diversities and ecological dignity as well as cultural transformation. All these point to the inalienable position of anthropogenic activities in the game of sustainability, especially in the urban communities where much of the present and future global populations are concentrated.

In southeast Nigeria, the urban communities are forming in rather irregular patterns without a proper and definite planning by the federal, state and local governments making it difficult for economic, political and ecological sustainability within the urban communities. For instance, the activities of the urban population in the region, which are inimical to environmental sustainability, lacked any form of supervision and documentations. This is visible in the types and forms of industrial activities as well as the crude technologies in use across the urban communities in the region (Echendu, 2020; Pona et al., 2021). These have contributed to the burden of greenhouse gasses such as carbon dioxide, chlorofluorocarbons, methane, nitrous oxide, ozone, and water vapor produced in Nigerian cities that contribute to climate change.

Climate change, which is the change in statistical distribution of the weather in at least 35 years duration, has been observed across the globe as one of the pressing challenges of the global community with daring consequences (Khalili, 2011). Climate change, which is majorly triggered by the anthropogenic activities, is roughly distributed across different human populations across the globe of which the developing nations such as Nigeria is specifically located within the nations contributing to global climate change through greenhouse gas emissions.

According to the Food and Agricultural Organisation (FAO, 2022), Nigeria contributed to about two percent of the entire global greenhouse gas emissions, which is hampering the global climate stability. Within the southeast Nigerian urban and semi urban communities, there is a cumulative of 86,694,435t, 0.48t per capita and 95.3 t/km^2 co2 intensity, which invariably points to the heavy anthropogenic activities affecting climate change from the region.

The current climate change crises rocking the entire globe have gradually began to tell on the rural and urban communities across Nigeria. One of the evidence of the emerging climate change crises impacting the urban sustainability is the emerging crises of food insecurity mostly affecting the urban communities in southeast Nigeria. Due to the absence of failed political, economic and ecological sustainability in the urban communities resulting to the heavy anthropogenic activities in the region affecting climate stability, the urban communities have invariably contributed to the unsettling of the herdsmen mainly located in northern Nigeria from their original location to new locations causing the farmers-herders crises responsible for emerging food instability in the urban communities.

In northern Nigeria, the impact of climate change has forced the herdsmen and even farmers to relocate and change strategies from their areas of occupation and the spillover of the crises has surfaced in the southeast Nigeria with some crises indicators such as food insecurity in both urban and rural communities as well as urban instabilities in southeast Nigeria.

3. Methodology

Southeast Nigeria is located at latitude N904.9199 and Longitude E8040.5166 with the landmass of approximately 41,440 km2; the region is predominantly Igbo ethnic group with about 22 million population. The population in the region is mainly Christians with some proportion of traditionalists and Muslims, while the mainstay for the population is subsistence and commercial agriculture for the rural population the urban population is mainly preoccupied with service, industrial, commercial and artisan occupations. As such, the urban population is dependent on the rural population for food sustainability.

The region is politically arranged under three-tier government of federal, state and local government levels. There are five administrative states in southeast Nigeria and approximately 97 local government areas. Among the local government areas across the five administrative states in the region, there are rural communities classified in the categories of communities, villages, wards and kindred. Within these communities there farming communities organized under cooperative societies with different farming specialties. The sample size for this study was developed from the five administrative states in the region; three states were randomly selected for the sample size through multistage sampling technique. Six senatorial districts were selected followed by 18 local councils and 54 local communities. Within the local communities, the study focused on the cooperative societies located within these communities.

A community without any form of cooperative society was replaced with another community with a presence of cooperative society. From each of the communities, one cooperative society was selected however, where there are more than one cooperative society, two or three cooperative societies were selected and on the whole, 116 cooperative societies were selected from among the 54 communities. Among the cooperative societies, there are at least 36 members for every cooperative society as the World Bank guideline for recognition and sponsorship grants for the groups has restricted for scams and irregularities through the farmers' cooperative society. For instance, the cooperative societies in the region are conditioned to have a minimum of 36 members and maximum of 45 members per cooperative society. As a matter of fact, from the documentation of the selected cooperative societies for the study, there were 4,518 registered members among the 116 cooperative societies; this made up the sample frame for the study.

The study selected 1,658 respondents for the study putting into consideration, local communities mostly affected by herdsmen-farmers conflicts in the region as well as farming communities with direct supply links to the nearby urban communities.

The study applied survey research design, using questionnaire instrument, which was designed in nominal and ordinal scales with focus on the socio-demographic information from the respondents as well as the substantive issues to the study. While the first section of the questionnaire contained the socio-demographic characteristics of the respondents, the second section contained information on the formation of farming and farming activities among the respondents such as types of farming, farming scales, farming location, climate change indices as well as encounter with the herdsmen in the area and farm settlements. The third section of the questionnaire contained information on the indices and indicators of food security and integrated rural and urban food security chain. The questionnaire instrument was validated by four experts from the faculties of the Social sciences, Education, Environmental studies and Agricultural sciences in the University of Nigeria, Nsukka. The questionnaires were shared among the study respondents for data collection with the help of research assistants recruited from the involved communities.

The collected data was analyzed using descriptive and inferential statistics such as percentages, correlation analysis and statistical models to understand the relationship of the substantive variables to the study.

According to the socio-demographic information of the respondents, 58.9% are females and 41.1% of the respondents were males showing the farming business are more of women engagement than that of men in this region of the country. By age distributions, 45.2% of the respondents are within the age range of 40-50 years, 26.7% are in the age range of 29-39 years, 13.4% are in the age range of 18-28years, 14.4% are in the age range of 51-61 years and less than one percent are in the age range of 62 years and above; this showed that the farmers in this region are relatively youths.

Spearman's rho		**Herdsmen movement towards southeast Nigeria**	**Frequency of climate change indicators**
Herdsmen movement towards southeast Nigeria	Correlation Coefficient	1.000	0.395**
	Sig. (2-tailed)	.	0.000
	N	1,658	1,658
Frequency of climate change indicators	Correlation Coefficient	0.395**	1.000
	Sig. (2-tailed)	0.000	.
	N	1,658	1,658

***. Correlation is significant at the 0.01 level (2-tailed).*

Tab.1 Frequency of climate change indicators and Herdsmen movement towards southeast Nigeria: Correlations

The above Tab.1 showed the correlation between the observed frequencies of climate change and herdsmen movement down to southeast Nigeria. The climate change indicators and there intensities were used as scale to check the frequency of change in weather activities observed by the study population; these included No observation, Rare change in sun, rain, humidity and other seasonal weather activities, Intermittent change in sun, rain, humidity and other seasonal weather activities and Extreme change in sun, rain, humidity and other seasonal weather activities. The above finding showed a positive correlation between the frequency of climate change indicators and herdsmen movement towards southeast Nigeria (rho = 0.395). Furthermore, the findings showed that about 15.6% of the herdsmen movement from northern Nigeria towards southeast Nigeria is explained by the frequency of climate change indicators as observed by the farmers in southeast region of Nigeria. As one of the goals of this study, the study sought to understand the observed relationship between climate change indicators and the movement of herdsmen from northern Nigeria towards southeast Nigeria, which has been shown from the above table that there is a positive correlation between the climate change indicators and the movement of the herdsmen from northern Nigeria towards southeast Nigeria.

Spearman's rho		**Climate change-induced conflicts**	**Urban food insecurity**
Climate change-induced conflicts	Correlation Coefficient	1.000	0.234**
	Sig. (2-tailed)	.	0.000
	N	1,658	1,658
Urban food insecurity	Correlation Coefficient	0.234**	1.000
	Sig. (2-tailed)	0.000	.
	N	1,658	1,658

***. Correlation is significant at the 0.01 level (2-tailed).*

Tab.2 Urban food insecurity and Climate change-induced conflicts Correlations

The above Tab.2 showed the correlation between climate change-induced conflicts and urban food insecurity. While climate change-induced conflicts were measured with the frequency of farmers/herders conflicts related to the movement of the herders due to climate change, urban food insecurity was measured with the frequency in decrease of the amount of food products from the rural farmers exported to the urban communities. From the finding, there is a positive correlation between climate change-induced conflicts and urban food insecurity in the region (rho = 0.234). Furthermore, the finding showed that about 54.7% of urban food insecurity in the region is explained by climate change-induced conflicts between farmers and herdsmen in the rural communities. As one of the major thrust of the study, urban food security is dependent on the rural farming activities owing to the fact that urban communities in southeast Nigeria struggle for space and do not allow for elaborate agricultural activities.

Urban food security is therefore connected to the farming activities in the region and this is facilitated through the exportation of food products from the rural communities to the nearby or even a distant urban communities. From the findings of this study, the interruption of farming activities and food transportation activities by the herdsmen/farmers clashes has invariably interrupted sustainable food security in the urban communities in the region. This can also be observed through the sudden increase in food prices around the urban communities in the region in the recent times.

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	-0.038	0.033		-1.151	0.250
Farming types	-0.141 ***	0.014	-0.151	-10.345	0.000
Open grazing	0.057 ***	0.015	0.068	3.727	0.000
Herdsmen encroachment	0.042 ***	0.011	0.044	3.705	0.000
Climate-induced conflicts	0.155 ***	0.009	0.182	16.593	0.000
Climate change indicators	0.164 ***	0.012	0.200	13.366	0.000
Increased scale of farming	-0.281 ***	0.018	-0.332	-15.308	0.000
Diminishing farming population	0.423 ***	0.039	0.499	10.918	0.000
Rural food instability	-0.228 ***	0.022	-0.227	-10.312	0.000
Rural food affordability	0.473 ***	0.020	0.500	23.815	0.000
Rural food production	0.121 **	0.043	0.137	2.778	0.006

a. Dependent Variable: Urban food insecurity

**p<0.05, ** p<0.01, *** p<0.000, R^2= (0.887), F (1288.038)*

Tab.3 Coefficients Urban food insecurity and other variables

The above Tab.3 presented a model explaining the predictors of urban food insecurity in southeast Nigeria in relationship with rural farming activities. From the model above, the explanatory power of the model is 0.887 (R2), which in translation is 78.7%. From the findings, the model explained about 78.7% of urban food insecurity in relationship with farming in the rural communities. In their order of contributions to the explanation of urban food insecurity, farming types, which was measured in the study as the ability to cultivate multiple crops, appeared to be negating urban food insecurity. This in essence indicates that the more diverse the farmers are in the rural communities, the more the reduction of urban food insecurity. Equally in the same direction, increased scale of farming appeared to be negating urban food insecurity. This is true in view of the enormous impacts of commercial agriculture in the rural communities on the urban communities. The finding showed that the larger the scale of farming by the rural farmers, the lower the incidence of urban food insecurity in southeast Nigeria.

Rural food instability is inversely a gain in urban food security; the food security crises in the rural communities such as food instability are indirectly the evidence of food exportation to the urban communities. Meanwhile, there are other variables in the model appearing as indicators of urban food insecurity originating from the rural communities. These variables included open grazing, which in this context appeared as counter weight to urban food security. In essence, the open grazing crises that have become a social problem in southeast Nigeria and other parts of the nation seems to have started telling on the overall food security in the rural communities as well as the nearby urban communities. The finding here pointed to the fact that the more the incidence of open grazing, which is responsible for other farmers-herders crises in the region, the more the likelihood of urban food insecurity. Similarly, the model showed that the more the incidence of herdsmen encroachment into the farmland, the more the likelihood of urban food insecurity.

While the problem of herdsmen encroachment into the farmland has been publicly denounced at the surface as inherently destructive, the problem has been further revealed as more complicated in this study with its positive correlation with urban food insecurity in southeast Nigeria. This also is understandable in the case of climate change-induced conflicts, which in itself is the destabilization of the farming community in the region by the herdsmen dislodged from the northern abode by climate change indicators. Nonetheless, climate change indicators as observed by the farmers appeared to be reporting on the overall food security crises both in the rural and urban communities in the region. For instance, the appearance of climate change indicators in the model pointed to a positive correlation with urban food insecurity, which in translation means, the more the frequency of climate change indicators in the region, the more likelihood of urban food insecurity. This applies to the issue of diminishing farming population in the rural communities, which is the by-product of climate change via farmers-herders clashes in the region.

4. Discussion of the findings and conclusion

The ripple effects of climate change have began to surface across the globe and this is mainly being experience in the urban communities where anthropogenic activities are highly concentrated due to high population densities compared to the rural communities especially in the developed and emerging/developing economies (Balaban & Şenol, 2015; Galderisi & Ferrara, 2012) such as in southeast Nigeria as one of the developing nations yet to give appropriate attention to climate change adaptation and mitigation strategies (Okafor et al., 2023). In southeast Nigeria in particular the industrial activities as well as other engagement of the urban population are in themselves, anthropogenic activities fuelling climate change in the long run. This is obtainable in other cities across the nation where weak and obsolete environmental policies have not measured up against climate change.

Now, the impacts of climate change have begun to return to the urban communities in rather extraneous manner. The study showed positive correlation between frequent climate change indicators and influx of herdsmen who originally occupied the northern axis of the country. Although there are pockets of evidences that herdsmen do come around the southern axis such as the southeast Nigeria, the recent influx of the group towards the region appeared to be triggered by some factors of which one of them has been identified as climate change. Specifically, the encroachments of desert in northern Nigeria as well as other unfriendly weather activities in the region are not good for the business of the herdsmen and these have started forcing the population of herdsmen in northern Nigeria towards southern Nigeria.

In southeast Nigeria from this study, the indicators of climate change have been showed positive correlation with the influx of the herdsmen in the region. The finding corroborated with the findings of the studies by (Turner & Schlecht, 2019; Opitz-Stapleton et al., 2021; Eeswaran et al., 2022) who located the recent transhumance crises in the sub-Saharan Africa as squarely connected to climate change indicators within the region. While the herdsmen are dependent on the natural resources such as land space, water, weather and other natural resources in the sub-Saharan Africa, these resources are gradually phasing off in different parts of the region such as northern Nigeria.

Within the northern Nigeria, climate change crises have engulfed both the farmers and the herdsmen alike (Ugbem, 2019; Farauta et al., 2011; Abraham & Fonta, 2018), prompting their move to safer zones such as southeast Nigeria where the crises of climate change is at least manageable for the herdsmen due to the enormous presence of water and other natural resources supportive to herdsmen business. The farmers in southeast region of Nigeria acknowledged the frequencies of climate change indicators in the region, which is measured up with the influx of herdsmen who seem to be finding relative comfort in the region compared to northern Nigeria.

One of the consequences of climate change crises pushing the herdsmen from northern Nigeria towards southeast Nigeria is the incessant conflicts between the migrant herdsmen and the indigenous farmers. The encroachment of herdsmen in southeast Nigeria has gradually reduced the food production capacity of the farmers in the region owing to the crises of insecurity in the farmsteads across the region orchestrated by the herdsmen activities in the farm settlements in the region. More importantly as it affects the urban community food sustainability, larger part of the foods consumed in the urban communities are produced in the rural communities in southeast Nigeria.

In fact, this is one of the major sustainable factors in the urban-rural interaction in the region. With the encroachment of the herdsmen in the rural communities in southeast Nigeria, the quantity of food transported to the urban communities has drastically reduced in recent times showing up in the skyrocketed food prices in the urban communities as well as the scantiness of certain food products in the urban centers in southeast Nigeria. Other studies have shown that the presence of herdsmen is usually accompanied by some level of conflicts with the indigenous farmers at least, in sub-Saharan Africa where open grazing is still the in-thing for the herdsmen (Ezemenaka & Ekumaoko, 2018; Ikezue & Ezeah, 2017; Osadebamwen, 2017; Apuke & Umar, 2020). While more than 15.6% of the movement of the herdsmen from northern Nigeria to southern Nigeria is explained by the presence of climate change indicators (rho = .395), about 54.7% of urban food insecurity in southeast Nigeria is explained by herdsmen-farmers climate change-induced conflicts (rho = .234). This confirming the earlier studies by (Sani et al., 2021; Nnaji et al., 2022; Kazzah, 2018) who confirmed the presence of herdsmen-farmers conflicts as a threat to food security in some regions.

Climate change-induced farmers-herdsmen conflicts are multifaceted and mostly bite hard to food insecurity such as food production, food availability, food accessibility and food utilization. Although this is mostly among the farmers in the rural communities, this also affects the urban population as the present study has revealed. For instance, some studies have shown that more than 60% of the foods consumed by the urban population are produced by the rural farmers especially in the developing nations such as Nigeria where the urban population are limited to commercial, industrial and service provision occupations.

In southeast Nigeria for example, the recent herdsmen-farmers conflicts have started reporting on the food prices in the urban and rural markets (SWAC/OECD, 2020; Cohen & Garrett, 2010; FAO, 2022; Owoo, 2021). This is the accumulation of the herdsmen activities in the region as they are being pushed out of northern Nigeria towards southeast Nigeria; this appears in form of unsettling the farming communities and forcing many farmers to abandon their occupation for other engagement in the nearby urban communities.

The impact of climate change-induced conflicts and crises on the urban sustainability in southeast Nigeria are multiple, anchoring on multiple factors. For instance, from the model applied to check the predicting factors to urban food insecurity in the region, some factors appeared as indicators of urban food insecurity originating from the rural communities. For instance, open grazing is one of the factors according to the findings, which is triggering urban food insecurity.

This finding affirmed other studies, which showed that open grazing is inimical to food security especially in the sub-Saharan African region (Bjornlund et al., 2022; Wudil et al., 2022; Giller, 2020). Open grazing in its manifestation is triggered by the unsettled exclusive environment of the herdsmen, which bring them to frequent confrontations with the farming communities since their cows will always feed on the available farm crops on their path of grazing. In southeast Nigeria for instance open grazing accounted for majority of the farmers-herdsmen clashes in the region due to the cows sometimes stray into the farms and in some cases the troublesome herdsmen decide to allow their cows to feed on the crops of the farmers. In any case, the open grazing crises triggers urban food crises through its destabilizing impacts on the four dimensions of food security such as food production, food availability, food accessibility and food utilization in the rural communities, which in extension affects the supply chain to the urban communities thereby triggering urban food security crises.

Climate change triggers the influx of the herdsmen into southeast geopolitical zone with its undesirable outcomes such as decreasing the farming population through climate change-induced crises, decreased farming scale as well as interrupted rural-urban food supply chain. More importantly, as implication of climate change-induced conflicts in southeast Nigeria to urban sustainability, the population being destabilized is forced into the nearby urban communities with poor infrastructures and facilities.

Since the beginning of herdsmen influx in their numbers to southeast Nigeria in 2016, most of the urban communities have swelled having more slums and over stretched settlements. This has brought about increase in crimes of all sorts, prostitution, and ballooned urban unemployment and under employment within the southeast Nigeria and beyond. Urban sustainability which is anchoring on political, environmental, economic and theological policy frameworks is altered by the influx of destabilized population in the rural communities as well as interrupted rural-urban resources flows blamed on climate change-induced conflicts in the rural communities. Evidently, climate change is being triggered by the loosed urban industrial and other anthropogenic activities and this is bringing to the table, some crises such as climate change-induced conflicts that eventually send back disturbing ripples to urban sustainability.

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Nanoparticles on electric, gas and diesel buses in mass transit buses of Bogotá Colombia

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Abstract

The concentration of traffic-related air pollutants (TRAP) within transport microenvironments has become increasingly relevant in many megacities with high population density, intense traffic, and prolonged travel times. These conditions can intensify exposure to TRAP and exacerbate public health problems. However, TRAP concentrations in these microenvironments are changing due to the introduction of cleaner technologies. In this study, we compared the concentration of nanoparticles inside diesel, gas, and electric buses during their normal operation in Bogota, Colombia. We used a miniature diffusion size classifier (DiSCmini) to measure the nanoparticles' concentrations, average particle size, and lung-deposited surface area. Our results revealed significantly lower levels of this pollutant inside electric buses. Specifically, the concentration of nanoparticles per cubic centimeter was approximately 41% and 27% lower in electric buses compared to diesel and gas buses, respectively. Additionally, the lung-deposited surface area was also lower in electric buses. However, the average particle size in electric buses was 10% and 18% smaller compared to diesel and gas buses, respectively. The results of this study give useful information for future selection processes of bus technologies for public passenger transport in cities around the world; This research provides information that can be used in technical evaluation processes that link the possible health effects on commuters and impacts the environment.

Keywords

Diesel buses; BEV electric buses; CNG compressed natural gas buses; Nanoparticles; LDSA lung deposited surface area; Mass transit system.

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1. Introduction

Urban sprawl is recognized as a significant issue, particularly due to its negative impact on environmental sustainability, economic efficiency, and social implications (Hernandez, 2012). From a technical perspective, it leads to the consumption of rural land, reliance on automobiles, and increased carbon emissions. Additionally, it results in the abandonment of inner-city locations, underutilization of urban infrastructure, and the need for new infrastructure in peripheral areas. Mobility, as defined by the Larousse dictionary, refers to the property or characteristic of being capable of movement and changing place or function. It can also be seen as a concept that encompasses the practices of people moving to engage in specific activities (Ghédira & El Kébir, 2022).

In urban environments, air pollution has become a growing concern, particularly due to evidence of significant health impacts caused by previously accepted levels of air pollutant concentrations (Zargari & Khan, 2010). Among the various microenvironments in cities, mass transit areas may expose a larger number of city dwellers to higher concentrations of traffic-related air pollutants (TRAP) (de Nazelle et al., 2017; de Nazelle et al., 2012; Gurram et al., 2019; Hoffmann, 2019; Matz et al., 2019; Morales et al., 2017; Shekarrizfard et al., 2020; Spinazzé et al., 2015). Most mass transportation systems rely on buses, which can be classified as heavy-duty vehicles. Over the past decade, Euro VI and Euro V diesel buses equipped with diesel particulate filters (DPF), Compressed Natural Gas (CNG) powered buses, and battery electric vehicles (BEV) buses have become increasingly common in mass transit systems of many cities (Kholod & Evans, 2016; Morales et al., 2018; Wang et al., 2015).

Heavy-duty vehicles significantly contribute to particulate matter emissions in many cities (Ali et al., 2019; Giechaskiel, 2018; Gireesh et al., 2021; Rodrigues et al., 2020; Winkler et al., 2018), with diesel engines being the primary emitters of ultrafine particles in urban areas (Bessagnet et al., 2022; Hudda et al., 2020; Kwon et al., 2020; Myung & Park, 2011). Natural gas vehicles may emit less soot and particulate matter by mass but potentially more particles by number (Bielaczyc et al., 2015; Chen et al., 2018; Distaso et al., 2020), which could have more significant health effects due to a larger surface area to mass ratio (Deng et al., 2019; Ohlwein et al., 2019; Schraufnagel, 2020). Although fewer studies have examined nanoparticles emitted by BEV vehicles, non-exhaust particulate matter from BEV vehicles could occasionally surpass particulate emissions from internal combustion engines (Beddows & Harrison, 2021; Liu et al., 2021; Zimakowska & Laskowski, 2022). The progressive electrification of vehicles in circulation presents a potential solution to address air pollution-related issues (Maternini et al., 2014).

In Bogotá, a city with a population of over seven million residents, the mass transit system comprised approximately 9,400 buses by 2021, utilizing various technologies. Table 1 illustrates the evolution of bus technologies, highlighting a decrease in the number of buses with standards lower than EURO V and an increase in the number of buses employing less polluting technologies (see Table 1). Furthermore, in 2021, 470 new battery electric vehicles (BEV) buses were introduced into operation, and it is anticipated that the city will have approximately 1,500 BEV buses by the end of 2022.

Significant improvements were observed in the concentrations of fine particulate matter and black carbon within Bogotá's bus rapid transit (BRT) system, a segment of the city's mass transit system. These improvements, amounting to approximately 80%, were a result of the fleet upgrade that involved the deployment of diesel EURO V buses equipped with particulate filters and EURO VI compressed natural gas (CNG) buses (Morales et al., 2022). Primarily, the older EURO II/III buses were replaced during this fleet upgrade, potentially leading to a positive effect on reducing nanoparticle exposure levels. However, the measurements conducted did not include the BEV buses that commenced operations after January 2021.

This research presents data obtained from measurements and analyzes the concentration, average size, and lung-deposited surface area of nanoparticles exposed within diesel, CNG, and BEV buses operating within the zonal component of Bogotá's mass transit system, during their regular operations. Furthermore, a comparison is made to assess variations and determine whether differences in bus technology impact commuters' exposure to nanoparticles.

Technology	2013	2015	2017	2020	2022
< Euro IV	1,338	3,148	2,703	1,824	749
Euro IV	138	983	964	972	986
Euro V	125	2,369	2,666	2,656	3,327
HYbrid		56	56	56	56
Euro VI – CNG			3	2,498	1,490
BEV			1	484	1,128

Tab.1 Bogota's mass transit fleet technology share

2. Methods and data

2.1 Study domain

The mass transit system in Bogotá comprises two components: a Bus Rapid Transit (BRT) system and a zonal component. The BRT system operates articulated and bi-articulated buses on exclusive lanes, while single-body buses are used to feed end-of-line stations on mixed traffic lanes (refer to Fig.1). The zonal component employs single-body buses and operates a mixture of diesel, compressed natural gas (CNG), hybrid (diesel-BEV), and battery electric vehicle (BEV) buses mainly on mixed traffic lanes (refer to Fig.2). In this study, our focus was on measuring exposure inside diesel, CNG, and BEV buses of the zonal component operating on the Carrera 13 route, which runs from West to East and covers the localities of Fontibón, Kennedy, Puente Aranda, Los Mártires, Antonio Nariño, and Santa Fe (refer to Fig.3). The selected buses, lines, and their respective technologies, as well as some route characteristics, are presented in Tab.2.

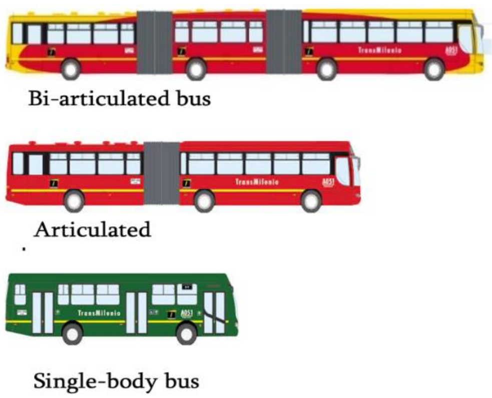

Fig.1 Buses used by the BRT component

To collect the measurements, a person carried the instruments with the inlet nozzle positioned at the breathing zone and free from obstructions. The person consistently traveled at the back between the second and third doors of the buses (refer to Fig.2). This particular area receives the highest number of users and is closer to the engines. The data were recorded every 10 seconds. The measurement days were carefully chosen to represent average operating conditions and were limited to business days. We conducted measurements outside the hours of vehicular restrictions and during typical weather conditions for the city, avoiding periods of heavy rainfall. Any days with atypical events such as protests or car-free days were excluded from the analysis.

Inside single-body buses, measurements were taken for 80 passengers across all three technologies. It was verified that the tested diesel and CNG buses had no post-treatment or filter installed to control emissions. Tab.3 provides information on the tested bus characteristics (technology, standard, brand, last oil change on km) as well as details about the measurements (date, location, and route).

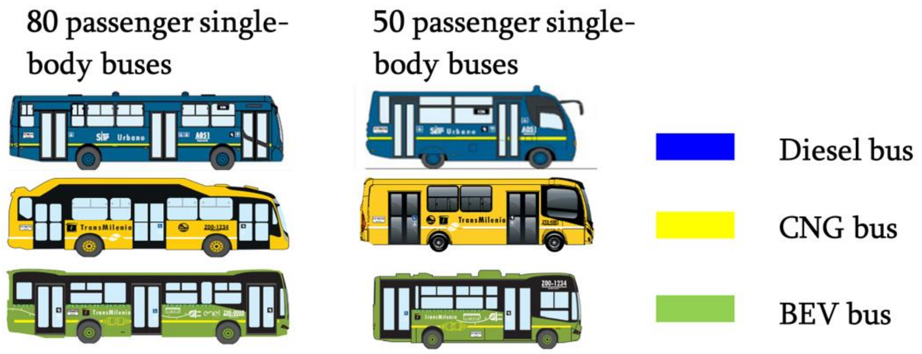

Fig.2 Buses used on the zonal component

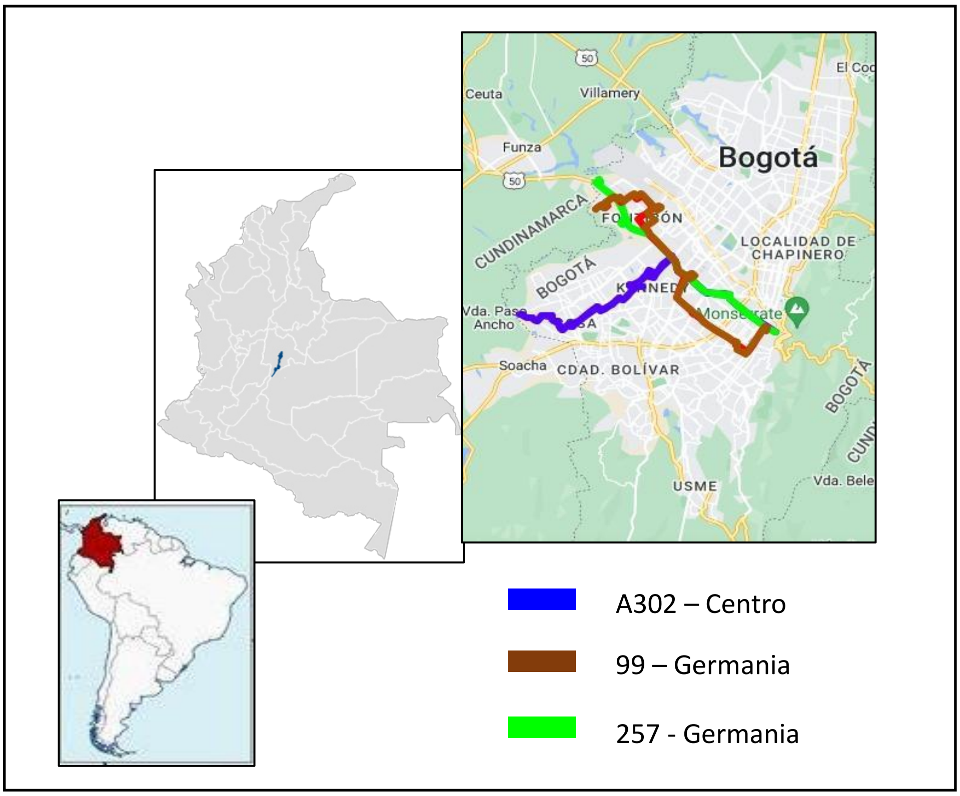

Fig.3 Selected routes in Bogotá in Colombia

Route Name	Bus Technology	Bus stops	Origin	Destination
A302 – Centro	BEV	62	Kr 123 - Cl 14 / Fontibon	AC 19 – Kr 9 / Las Nieves
99 – Germania	Gas	64	Tv 80i – Dg 89 b South / Bosa	AC 19 – Kr 4 / Las Nieves
257 - Germania	Diesel	37	Cl 17d – K135 / Fontibon	AC 19 - Kr 5 / Veracruz

Tab.2 Bus routes measured

Bus Technology	Standard	Brand	last oil change (km)	Date of monitoring	Location *	Total rides *
BEV	BEV	BYD	8.174	05/05/2021	E-W	1
BEV	BEV	BYD	7.140	13/05/2021	E-W / W-E	2
BEV	BEV	BYD	9.327	20/05/2021	E -W	1
CNG	Euro VI	Volkswagen	11.320	07/05/2021	W-E	1
CNG	Euro VI	Volkswagen	6.908	13/05/2021	E -W / W-E	2
CNG	Euro VI	Volkswagen	12.730	21/05/2021	E -W	1
Diesel	Euro VI	Volvo	4.600	20/05/2021	E -W / W-E	2
Diesel	Euro VI	Volvo	5.230	25/05/2021	E -W / W-E	2

Tab.3 Buses measured / * E: East / W: West

2.2 Instruments

We used the miniature diffusion size classifier - DiSCmini (Testo SE & Co. KGaA, Titisee-Neustadt, Germany) portable device to measure the number concentrations (# cm-3) of particles between 10 to 700 nm in size. The instrument also reports the mean nanoparticle diameter (nm), and the lung-deposited surface area (µm2.cm-3), with a frequency of 0.1 Hz.

3. Results

The measurements for BEV buses were conducted on four different dates, with three measurements in the West-to-East (W-O) direction and one measurement in the East-to-West (O-W) direction. In total, the measurements covered a duration of 177 minutes and a distance of 37.24 km. The average nanoparticle concentration was found to be 108,519.5 particles per cubic centimeter (#.cm-3), with a mean nanoparticle diameter of 35.2 nm and an average lung-deposited surface area of 191.6 µm2.cm-3.

Bus technology	BEV	CNG	DIESEL
Total records	841	929	851
Total buses	3	3	2
Total routes	4	4	4
Average nanoparticle concentration (#.cm^{-3})	109,773.0	124,075.6	175,000.5
Max Nanoparticle Concentration(#.cm^{-3})	492,263	495,730	1,247,418
Min Nanoparticle Concentration(#.cm^{-3})	13,556	18,590	14,526
Average Nanoparticle Diameter (nm)	35.2	42.7	37.6
Average Average Lung-Deposited Surface Area (μm^2. cm^{-3})	195.0	281.5	349.6

Tab.4 Summary of measurements and data

For the Diesel buses, four measurements were conducted, with two measurements in the W-O direction and two measurements in the O-W direction. The total duration of these measurements was 225 minutes, covering a distance of 47.62 km. The average nanoparticle concentration for Diesel buses was 166,558.6 #.cm-3, with a mean nanoparticle diameter of 37.2 nm and an average lung-deposited surface area of 344.31 µm2.cm-3.

Similarly, the CNG buses were measured four times, with two measurements in the W-O direction and two measurements in the O-W direction. The total duration of these measurements was 233.4 minutes, covering a distance of 51.45 km. The average nanoparticle concentration for CNG buses was 142,920.8 #.cm-3, with a mean nanoparticle diameter of 42.39 nm and an average lung-deposited surface area of 318.5 μm2.cm^{-3}.
Tab.4 presents a summary of the measurements and data obtained for each bus technology, while Fig.4 illustrates the nanoparticle concentrations for each bus technology on each route.

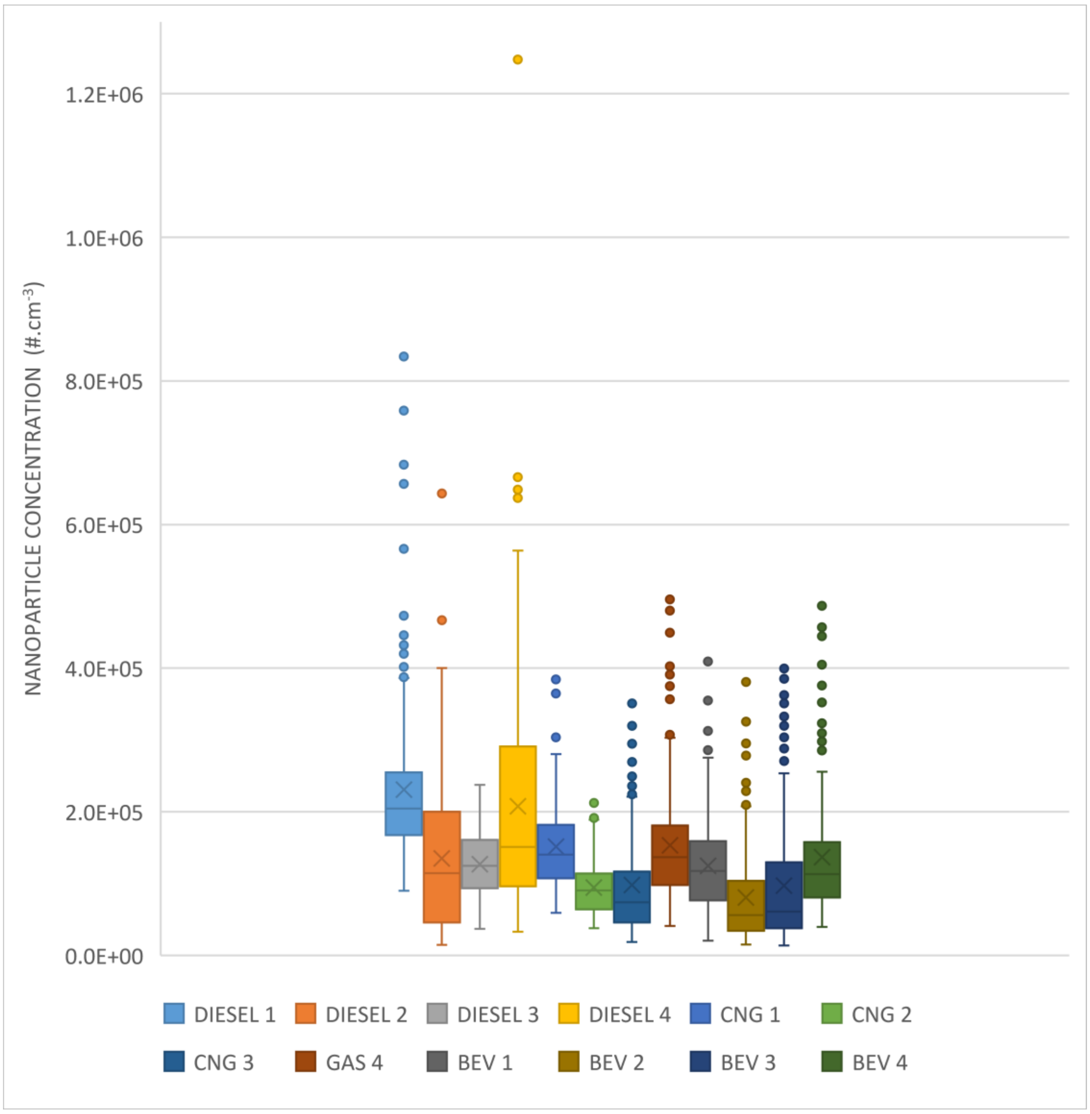

Fig.4 Nanoparticle concentrations for Diesel, Gas and electric bus technologies

Overall, these results provide important insights into the nanoparticle concentrations, nanoparticle diameter, and lung-deposited surface area associated with each bus technology.

4. Discussion

The findings of this study reveal important insights into the exposure concentrations of nanoparticles in different bus technologies. The results show that BEV buses exhibit lower nanoparticle concentrations compared to CNG and diesel buses (Tab.5). This finding is consistent with previous studies conducted in cities such as Arnhem, Netherlands, and Como, Italy, which have also reported higher UFP concentrations in diesel buses (Singh et al., 2016; Zuurbier et al., 2010). On the other hand, compressed natural gas buses and electric buses tend to have lower UFP concentrations (Ragettli et al., 2013; Morales et al., 2017; Knibbs et al., 2011).

These differences in nanoparticle concentrations can be attributed to the combustion characteristics and emissions profiles of each bus technology.

The average nanoparticle diameter was found to be greater in CNG buses compared to diesel and BEV buses (Tab.5). This observation is consistent with the understanding that different combustion processes and fuel characteristics can influence the size distribution of nanoparticles emitted by vehicles. For example, the combustion of natural gas in CNG buses can result in the production of larger nanoparticles compared to diesel combustion (Singh et al., 2016). Additionally, factors such as the engine design and emission control systems can also contribute to variations in nanoparticle size among different bus technologies.

Furthermore, the average lung-deposited surface area (LDSA) was lower in BEV buses compared to CNG and diesel buses (Tab.5). The LDSA is an important parameter that indicates the potential health impact of nanoparticles, as particles with larger surface areas have a greater potential for interaction with lung tissues. The lower LDSA observed in BEV buses suggests a potentially reduced health risk associated with nanoparticle exposure in these vehicles compared to CNG and diesel buses. However, it is important to note that other factors, such as the chemical composition and toxicity of the nanoparticles, should also be considered when assessing the health implications of nanoparticle exposure.

The findings of this study align with previous research conducted in different cities around the world. For example, studies conducted in Arnhem, Netherlands, and Como, Italy, have reported higher UFP concentrations in diesel buses compared to electric and natural gas buses (Singh et al., 2016; Zuurbier et al., 2010). Similarly, studies in Barcelona, Spain, and Beijing, China, have shown relatively low nanoparticle concentrations in electric buses (Moreno et al., 2015; Yang et al., 2021). These consistent findings across various cities indicate that the bus technology, along with other factors such as traffic conditions and urban air pollution levels, plays a significant role in determining nanoparticle exposure in public transportation systems. Also, the mode of transport, commuting route, and type of vehicles play influential roles in determining the levels of particulate matter exposure (Zuurbier et al., 2010).

It is worth noting that the relationship between nanoparticle diameter, concentration, and LDSA is complex and not directly proportional. The results of this study demonstrate that nanoparticle count and LDSA exhibit a proportional relationship across the different bus technologies (Table 6). However, the nanoparticle diameter does not follow a consistent pattern. This highlights the need for a comprehensive understanding of the factors influencing nanoparticle characteristics and their potential health effects. However, nanoparticle count and lung-deposited surface area show a proportional relationship across the different bus technologies (refer to Figg. 5-7).

Technology	**Average Nanoparticle concentration (#.cm^{-3})**	**Average particle size (nm)**	**Average lung-deposited surface area (μm^2. cm^{-3})**
BEV	108,519.4	35.2	191.6
CNG	121,904.9	42.4	273.9
Diesel	166,558.6	37.2	344.3

Tab.5 Average results per bus technology

Comparative	**Average number (#.cm^{-3})**	**Average nanoparticle diameter (nm)**	**Average lung-deposited surface area (μm^2. cm^{-3})**
BEV Vs Diesel	-41%	-10%	-48%
BEV Vs CNG	-27%	-18%	-39%

Tab.6 Comparison of the results per bus technology

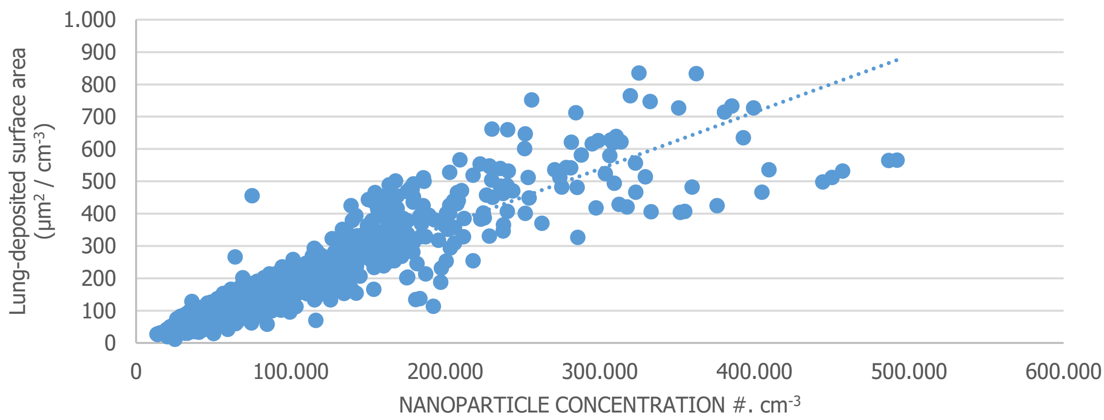

Fig.5 Nanoparticle concentration vs lung-deposited surface area in BEV buses

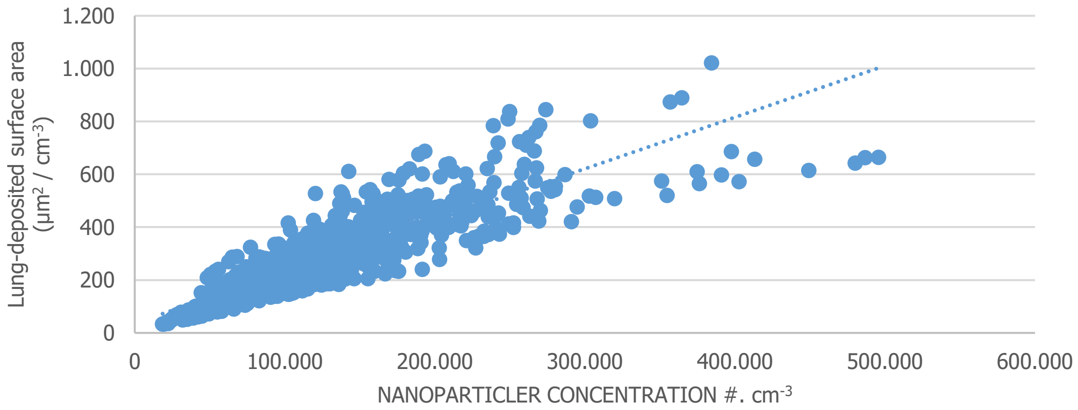

Fig.6 Nanoparticle concentration vs lung-deposited surface area in CNG buses

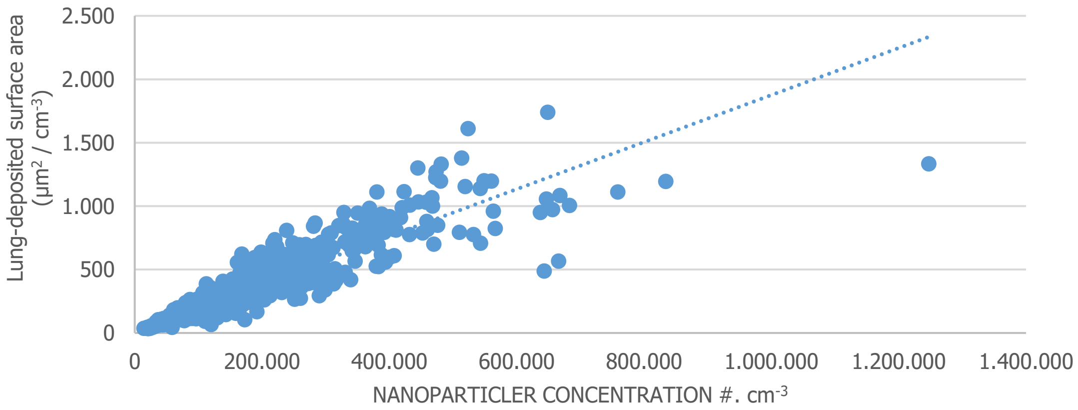

Fig.7 Nanoparticle concentration vs lung-deposited surface area in Diesel buses

The age of lubricating oil in diesel and CNG engines has been identified as a potential factor influencing nanoparticle concentrations (Singh et al., 2016). However, the results of this study did not show a clear direct proportionality between lubricating oil age and nanoparticle concentration per cubic centimeter for any of the bus technologies. This suggests that other factors, such as engine condition, maintenance practices, and driving conditions, may also contribute to the emission characteristics of nanoparticles in these buses. Further research is needed to explore the specific mechanisms and factors influencing nanoparticle emissions from different bus technologies.

While BEV buses generally exhibited lower nanoparticle concentrations on average, there were instances where the concentrations reached levels similar to CNG and diesel buses along the route. This variation can be attributed to factors beyond the bus technology itself, such as urban pollution, presence of other vehicles, and other local sources. Peaks in nanoparticle concentrations resulting from doors opening at bus stops indicate the influence of external factors on nanoparticle exposure. Similar findings have been reported in studies conducted in cities such as Barcelona and Beijing (Moreno et al., 2015; Yang et al., 2021). The "stop-start" nature of bus journeys and door openings can increase opportunities for air infiltration, even when windows are closed (Knibbs et al., 2011; Zuurbier et al., 2010). These findings emphasize the importance of considering external factors and localized conditions when assessing nanoparticle exposure in buses.

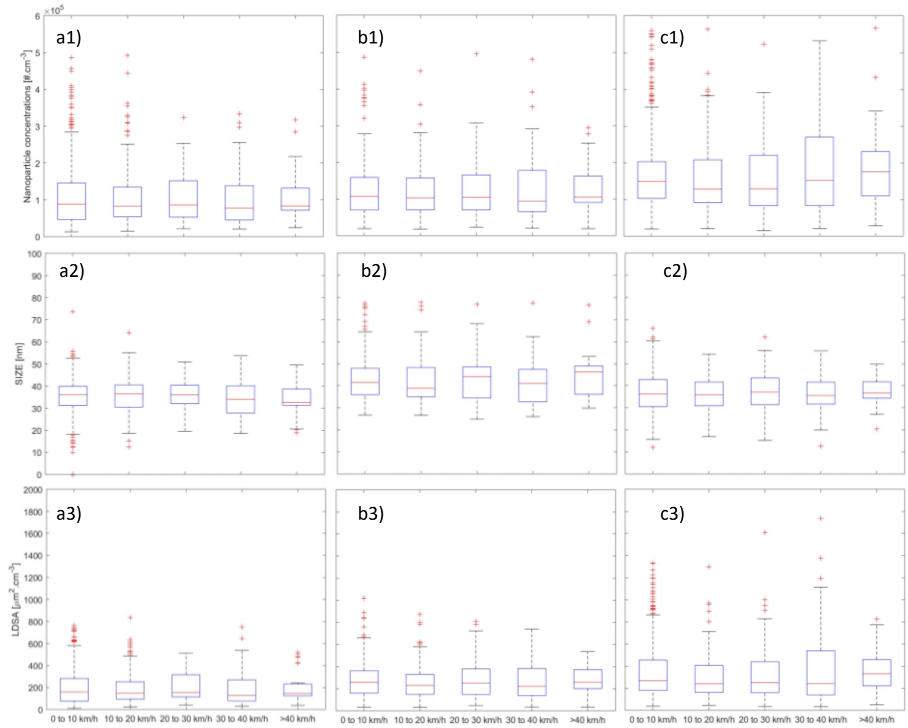

Fig.8 Nanoparticle concentration, average particle size and lung deposited surface area Vs. operating speed in a) BEV, b) CNG, and c) Diesel buses

The relationship between bus operating speed and nanoparticle characteristics was also investigated in this study (see Fig.8). Nanoparticle concentrations vs speed results indicate that there could be an optimal speed in to which less nanoparticles are emitted. Between 30 to 40 km/h there seems to be a reduction in nanoparticle concentration per cubic centimeter for BEV and CNG (Fig.ss 8 a1 and b1). For diesel buses a speed between 20 and 30 km/h seems to produce less particles (Fig.8 c1). Average particle size seems greater for CNG buses (Fig.8 b2) than for BEV or Diesel (Fig.ss 8 a2 and c2) but there is no evident dependency between size and speed. LDSA is much smaller inside BEV buses (Fig.8 c1) and between 30 to 40 km/h there seems be a reduction in LDSA for all technologies.

The particle levels in buses in this study were higher than in other cities, including Basel, Switzerland, (17 days of measurements between December 2010 and September 2011. The city, located in the Rhine valley (260 m above sea level), has about 190,000 inhabitants and has average temperatures of 3 °C – 6 °C in winter, and 21 °C–25 °C in summer. Residents primarily use public transport (52%), private car (18%), or bicycle (17%) for their daily commute to work), (Ragettli et al., 2013), Arnhem, Netherlands (capital of the province of Gelderland, located in the east of the Netherlands. Arnhem has about 150,803 inhabitants in 2014) (Singh et al., 2016) and, Beijing, China (capital of the Republic of China and one of the most populated cities in the world with 21,890,000 inhabitants in 2020, and dense traffic with more than 6 million vehicles) (Wang et al., 2022), Barcelona, Spain (Spanish city, capital of the Community of Catalonia, with a population of 1,636,732 inhabitants in 2021, is the second most populous city in Spain, measurements were made between October and November 2014 for 39 working days, with only one day with rain) (Moreno et al., 2015) the proportion of the results was only similar to studies in Milan, Italy (almost 3 million inhabitants) (Cattaneo et al., 2009) and Santiago, Chile (capital and main city of Chile, with 5,614 million inhabitants in 2017, and approximately 5.98 million registered vehicles) (Sirignano et al., 2018). The differences can result from many factors such as traffic conditions, bus technology, and urban air pollution concentration in the different cities, but also from bus ventilation (fans, air conditioning, open windows, and others). Comparisons with particle levels observed in other cities reveal variations influenced by multiple factors. The higher particle levels observed in this study compared to cities like Basel, Arnhem, Beijing, Barcelona, Milan, and Santiago can be attributed to differences in traffic conditions, bus technology, urban air pollution concentrations, and bus ventilation systems. These variations emphasize the importance of considering the specific context and local factors when assessing nanoparticle exposure levels.

5. Conclusions

This study provides valuable insights into the nanoparticle concentrations, sizes, and lung-deposited surface areas associated with different bus technologies. The findings support previous research indicating lower nanoparticle exposure in BEV buses compared to CNG and diesel buses. However, the complex relationship between nanoparticle characteristics, bus technology, and external factors highlights the need for further research to better understand and mitigate nanoparticle exposure in public transportation systems. Future studies should explore additional factors influencing nanoparticle emissions, such as engine conditions, maintenance practices, and driving conditions, to develop effective strategies for reducing particle exposure in buses. Furthermore, comprehensive assessments considering the chemical composition and toxicity of nanoparticles are necessary to fully evaluate the potential health impacts associated with nanoparticle exposure in different bus technologies. This study was the first to compare the exposure to traffic-related nanoparticles, inside three bus technologies: Diesel, CNG, and BEV, in Bogotá, a megacity in Colombia.

The concentration of nanoparticles per cubic centimeter in BEV buses is 27% and 41% lower than in CNG and diesel buses, respectively (Navarro et al., 2021). This reduction in nanoparticle exposure is significant as it can contribute to reducing the risk of health effects such as respiratory tract irritation, increased susceptibility to respiratory infections, and exacerbation of symptoms in individuals with chronic diseases. Moreover, the average diameter of nanoparticles in BEV buses is 18% and 10% lower than in CNG and diesel buses, respectively. Additionally, the average lung-deposited surface area in BEV buses is 39% and 48% lower than in CNG and diesel buses. This reduction in lung-deposited surface area is crucial as nanoparticles with smaller sizes have a greater potential for entry into the bloodstream, potentially affecting diseases related to the circulatory system (Navarro et al., 2021).

The analysis of the relationship between bus operating speed and nanoparticle characteristics shows that Diesel buses emit a greater number of particles per cubic centimeter and greater LDSA.whereas CNG buses have particles with grater average diameter. It also suggests that there could be an optimal operating speed to minimize number concentrations and LDSA for each bus technology and highlight the need for further investigation into the impact of operating speeds on nanoparticle characteristics.

In Colombia, as in many other countries, land-use regulations are often under the jurisdiction of autonomous municipalities. However, local governance tends to prioritize issues directly related to citizens' aspirations, leaving strategic concerns such as environmental considerations at the trans-municipal level outside the priority agenda (Howell-Moroney, 2008). The rapid motorization of cities has resulted in significant changes in urban conditions and the nature of inner-city areas. Traditional centralities have faced challenges, while new forms of centrality have emerged along corridors and strips around avenues and highways, concentrating various activities. This urban transformation, accompanied by sprawl and fragmentation, poses risks to environmental, economic, and social sustainability (Hernandez, 2012).

The right to an adequate environment for health and well-being necessitates the integration of sustainability variables in all processes of technological advancement. Therefore, the selection processes of bus technologies for public passenger transport in urban contexts must consider not only financial and technical factors but also analyze potential health risks to users and other stakeholders, as well as conduct environmental impact assessments (Hernandez, 2012). The alarming levels of nanoparticle exposure observed in diesel buses in this study, along with their widespread use in many megacities, highlight the urgent need for policymakers to prioritize improving bus transportation systems by transitioning from diesel to cleaner power sources.

Considering the characteristics of the population (more than 7 million inhabitants), vehicle density vehicles (more than 1,9 million additions to two-wheeled motorcycles), average travel distances, road infrastructure, and hourly demand for transport services, it is unlikely that travel times will decrease significantly in cities with similar characteristics. The observed reductions in nanoparticle concentrations with BEV buses can potentially decrease the health risks for users. This finding has important implications for public health policies and high-impact projects in major cities (Navarro et al., 2021).

Future studies should aim to confirm these results with new measurements conducted at different times of the year and under varied weather conditions. Comparative analyses should also be conducted to assess the performance of diesel, CNG, BEV, and other technologies for different types of buses, including small buses, articulated buses, and buses with more than two bodies. Additionally, research should be expanded to include private transport vehicles, taxis, trucks, and other possible applications such as delivery and last-mile transportation.

Other variables such as temperature, sound, vibrations, and external factors like doors opening, windows, and stops in areas with high pollution levels should be analyzed to gain a comprehensive understanding of nanoparticle exposure in buses. Furthermore, including the perceptions of bus users in future research would provide valuable insights into their experiences and perspectives.

The current global challenges, including climate change mitigation and reducing social inequalities, demand the integration of technological innovations into territorial contexts to foster the development of smart and sustainable cities. This requires the definition of strategies and concrete actions that support the evolution of urban and territorial systems, ultimately contributing to the achievement of the sustainable development goals (SDGs) outlined in the United Nations' 2030 agenda.

The findings of this study provide valuable information for planners, decision-makers, and investors responsible for improving transportation systems and reducing social disparities through technological advancements. The comparative data on bus technologies presented in this study can serve as a decision-support tool when selecting the appropriate bus technology to prioritize the health and well-being of users. By leveraging natural resources and energy efficiency, transportation integration can become a platform for regional development, leading to the creation of wholesome, responsible, and sustainable cities that ensure a high quality of life for all populations.

In conclusion, the measurement processes of the three bus technologies used in this study demonstrate that BEV buses exhibit a positive variation in nanoparticle exposure levels compared to CNG and diesel buses, contributing to improved health outcomes for transport system users. The findings emphasize the importance of incorporating sustainability considerations and health impact assessments into the decision-making processes surrounding bus technology selection and urban development. By aligning technological advancements with the goals of climate change mitigation and social equality, cities can pave the way for a more sustainable and resilient future.

Authors contribution

All authors contributed to the conception and design of the study. Vargas did the preparation of the material, the data collection and the analysis. The first manuscript version was written by Vargas, the initial review and corrections to the data analysis were made by Durán and Galvis. Data corrections and analysis improvements were made by Bernal and Galvis; all authors commented on earlier versions of the manuscript. All authors read and approved the final manuscript.

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Disclosure statement

The authors report there are no competing interests to declare.

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Remote sensing investigation of spatiotemporal land-use changes

A case study of Batticaloa town in Sri Lanka from 1979 to 2021

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Abstract

Rapid and haphazard urbanization has disastrous environmental and socio-economic consequences. The increase of unofficial habitation characterizes urbanization in Batticaloa town. Urban land use and cover changes require research to plan and ensure long-term growth. This study employed geographic information systems and Landsat imagery from 1979, 2000, and 2021 to look at regional and temporal variations in Batticaloa's land use cover. A support vector machine and supervised classification constructed the land use cover maps. The transition matrices produced from the classified map were further investigated to find the essential change processes for prioritizing planning, and during the 42 years investigated, built-up, including residential, commercial, and public facilities, increased in a similar vein (i.e., mangroves, paddyland, vegetation-covered areas, and shrubs). Land use cover modifications happened more quickly between 2000 and 2021 than between 1979 and 2000. The analysis found that only one land-use category, net built-up area changes, grew by 8.2%, and the average yearly change was 0.22%. By 21.9%, paddy land area substantially increased. Bare lands rose 4.45%, and thick woods fell 21.37%. These data show built-up areas frequently targeted bare terrain. This research laid the groundwork for long-term urban planning and development in Batticaloa Town.

Keywords

Land use; Land cover, Remote sensing; GIS; Urbanization.

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1. Introduction

Urbanization represents the anthropological activities influencing land use that the immense pressure from population growth has endangered. Global and regional environmental sustainability is affected by urbanization (Grimm et al., 2008). anthropogenic activities have severely threatened sustainable resource use, where urbanization has played a significant role. The United Nations (2019) predicts that by 2050, urbanization will make up 68 per cent of the world's population, a rise from 55 per cent in 2021; over 90% of this increased population will be in Asia, particularly in small and medium cities. In 2021, only 42.9 per cent of Asians lived in towns, predicted to climb to 56.5 per cent by 2050. A complete land use/land cover (LULC) analysis is required to thoroughly examine environmental change and sustainability (Manandhar et al., 2009). Anthropogenic activities such as urbanization have increased, hastening LULC changes (Gunasinghe et al., 2021). All regions' interactions are unique, but most scholars agree that specific demographic, socio-political, economic, and environmental conditions drive most LULC changes (Masek et al., 2010; Addae & Oppelt, 2019). The paper argues that a more extensive use of remote sensing, coupled with GIS analysis, can provide valuable insights and tools for enhancing land use policies. Remote sensing technologies like satellite imagery can capture detailed information about land cover, land use patterns, and changes over time. GIS analysis allows for the integrating and interpreting spatial data, enabling a better understanding of land dynamics and supporting evidence-based decision-making. Fistola (2021) said that, Through the clever adoption of new technologies, it is possible to "see" and verify the transformation of the city in advance and take socially shared decisions.

In most cases, these elements interact. Since urban regions provide better economic and social opportunities than rural areas, many people move to the cities, fueling a surge in population that depletes natural resources for settlement and livelihood (Addae & Oppelt, 2019; Mwathunga & Donaldson, 2018). Many people are drawn to cities because of their economic and social advantages over rural areas, leading to rapid population growth and over-exploitation of natural resources for city settlement and life.

Advances in remote sensing have benefited LULC change research throughout the last four decades. Using remote sensing techniques, LULC changes can be tracked over time (Yang & Lo, 2010). Despite constraints such as spatial and spectral confusion in metropolitan regions, remote sensing is an excellent data source for LULC investigations. Land-use planning and urban management in developing nations rely heavily on analyses of urban land-use changes based on Landsat photos. Landsat data can be a valuable source of information not available from other sources. South Asia has a high population density and sociocultural diversity, making it an economically developing region (Dissanayake et al., 2017). This economically expanding region can also be unstable politically (Dissanayake et al., op. cit.). Combined with land use and climate variability, these factors probably played a significant role in the LULCC in the region (Mitra & Sharma, 2010). Despite ongoing political and social instability, limited historical documents in this region often hinder these studies, which can shed light on land-use change and its consequences. Sri Lanka faces a fundamental challenge in land cover change analysis because there has never been a large-scale study of LULCC. The ones available are very confined and restricted to temporal comparisons (Mapa et al., 2002; Perera & Tsuchiya, 2009; Subasinghe et al., 2016; Suthakar & Bui, 2008; Wickramaarachchi et al., 2013).

Despite this, the country's landscape changes due to socio-economic, political, and biophysical factors. In the late 1970s, adopting an open economic policy led to significant socio-economic and political changes. Following this were many initiatives, such as the Mahaweli River Basin Development Project (1980–2018), which implemented transportation and road improvement projects and irrigation-based agricultural development (Mapa et al., 2002; Näsström & Mattsson, 2011). In addition to the civil war, Sri Lanka was also afflicted by a civil war between 1980 and 2009. The northern and eastern parts of the country were severely damaged, and for some portions of the war, the entire country was negatively affected. (Athukorala et al., 2017). This period's LULC changes records are either missing or significantly limited. In 2009, the end of the 30-year civil war sparked a flurry of construction projects around the country. This dynamic terrain's LULC changes have yet to be studied and measured.

In 1978, Sri Lanka gained its democratic government system and has been experiencing progressive urbanization ever since. The country has become one of the fastest-growing nations in South Asia. Despite that, various research has been done on LULC changes in Sri Lanka (Athukorala et al., 2017; Masakorala & Dayawansa, 2015; Partheepan & Manobavan, 2008; Perera & Tsuchiya, 2009; Subasinghe et al., 2016; Wickramaarachchi et al., 2013), In Sri Lanka, studies on urban LULC change are few and far between; as a result, the concept of urbanization is mainly based on population data. Economic and environmental planning is hampered because lacking LULC change information leads to erroneous policy decisions (Masakorala & Dayawansa, 2015). Low-income nations like Sri Lanka prioritize urgent requirements like poverty reduction above long-term goals like sustaining a robust LULC system (Masakorala & Dayawansa, 2015; Mwathunga & Donaldson, 2018).

Batticaloa, the second-largest city in eastern Sri Lanka by population, has not yet been assessed for urban LULC status. The descriptive analysis of land use and land cover changes in Batticaloa aims to provide an overview of how various factors, such as economic growth, population growth, and political government instability, have influenced the transformation of the city's land over time. By examining these factors, we can gain insights into the dynamics of land use and land cover changes in Batticaloa. One significant driver of land use and land cover changes in Batticaloa is economic growth. As the city experiences economic development, there is often an increased demand for commercial and industrial spaces. This can lead to the conversion of agricultural or natural areas into built-up environments, such as factories, offices, and shopping centres. The growth of the population in Batticaloa can have a substantial impact on land use and land cover patterns. As the number of residents increases, a greater need for residential areas and associated infrastructure like housing, schools, and healthcare facilities exists. This can lead to the conversion of agricultural land or natural habitats into residential zones. Population growth may also drive the expansion of commercial and recreational spaces to meet the needs of the growing population, potentially resulting in the transformation of undeveloped land. Political government instability can also contribute to land use and land cover changes in Batticaloa. Uncertain political environments may lead to changes in land ownership, policy shifts, or infrastructure development project disruptions. These factors can influence land use patterns as investments and development activities may be delayed or redirected. Moreover, political instability may result in conflicts or displacements that can affect land cover, particularly in terms of land abandonment, informal settlements, or changes in land use due to security concerns. By integrating and analyzing these data sources, researchers can generate a comprehensive understanding of the land use and land cover changes in Batticaloa, attributing them to economic growth, population growth, and political government instability. This descriptive analysis can provide valuable insights for urban planning, resource management, and decision-making processes in the city and its surrounding region.

In addition, there is a need for more empirical evidence documenting changes in urban LULC across time. Therefore, this study aims to examine the evolution of Batticaloa's urban LULC from 1979 to 2021 using Landsat data to promote sustainable urban development. 1979 was selected as a starting year since Sri Lanka changed its democratic governing structure. The field verification is scheduled for 2021, so the end year was chosen for comparison, and 2000 was used for comparison as an interim year. The primary objectives of this study are as follows:

- to mitigate the adverse environmental and socio-economic impacts associated with rapid and unplanned urbanization;
- to analyze the patterns of urban land use and cover changes in Batticaloa town, with specific emphasis on the growth of unofficial habitation;

- to compare and assess the modifications in land use cover between two distinct time periods, namely 1979-2000 and 2000-2021, to determine the change rate;
- to investigate the transition matrices generated from the classified maps, aiming to identify the significant processes of change. These findings will aid in prioritizing planning efforts.

A study has been done to determine how urbanization has influenced LULC in Batticaloa Town from 1979 to 2021. Because of the following three reasons this study is important: Firstly, it shows anthropological progressions in municipal landscapes and their relations; Secondly, the generated data can help manage the increasing pressure of anthropological activities and municipal development on the city area; and lastly, the findings can be used to identifying future land uses and setting policy priorities in support of inclusive and equitable urban development. This initiative will benefit Batticaloa Town residents as well as the environment.

2. Literature Review

The phrase 'land usage' typically refers to the alterations made to the earth's surface as a result of an increase in human activity. The term "land cover" refers to the physical manifestation of the earth's surface, water distribution, soil, plant, and urban area layout. The use of land and land cover are two independent ideas, yet they are connected. Land cover and land use variation information is vital in domestic, local, and general administration and planning. Due to a lack of knowledge of land use and land cover differences, the planning and organization of environmental initiatives and activities are frequently disrupted (Fahad et al., 2020).

According to Fahad et al. (2020), changes and variations in the land cover occur gradually, but occasionally they can occur rapidly and unexpectedly due to human activities. As a result of the destruction of a region's nature and vegetation, land use and land cover changes may affect the ecosystem. Variations in land cover and land use are among the most significant human activities altering hydrology. Remote sensing has advantages for mapping land cover and land use and analyzing essential changes. The primary benefit of remote sensing systems is the capacity for repeated coverage, which is required for global investigations of change detection. Remote sensing can detect changes in land cover and land use and monitor the consequences of human and natural activity. Among the most significant advantages of remote sensing are cost and time savings. Land cover and land use products are utilized for global mapping, identification modification, and landscape design. Image classification using remote sensing combines image processing and image classification algorithms (2020).

Given the importance of land surface cover and use and their changes associated with urbanization, satellite remote sensing can play an important role in providing relevant baseline geospatial information on land use land cover (LCLU) and its historical change delineation, as well as the surface temperature field during satellite overpasses. The Landsat series of satellite sensors, specifically the Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) have been indispensable image data sources. Visible/infrared data from satellites such as Landsat can be interpreted to provide quantitative parameterizations of land cover and usage and thermal images of areas of interest (Zhang & Sun, 2019).

According to Zhang and Sun (2019), the spatial resolution of Landsat image data (30 m in the visible/infrared and 60–120 m in the thermal infrared parts of the spectrum) is insufficient to resolve the intricate details of the majority of urban areas, posing one of the most significant obstacles to interpreting Landsat image data. Consequently, most image pixels contain contributions from diverse surface covers, such as artificial impervious surfaces such as roads and building roofs, as well as herbaceous and forest plants. Numerous spectral un-mixing techniques to extract fractional components, such as V-I-S and endmember analyses (e.g. Powell et al., 2007) and percentage estimates of impervious surface and forest cover, have been developed in the past to address the 30-metre resolution limitation problem (Guindon et al., 2004).

According to international data, by 2050, the global urban population will increase by up to 68 per cent. The United Nations (UN) forecasts that Asian and African nations will urbanize more rapidly than nations on other continents (United Nations, 2018). Rapid urbanization will bring severe environmental and socio-economic challenges in the future, including land degradation, the loss of urban ecosystem services, urban heat islands, air pollution, flooding, health, urban poverty, crime and violence, and traffic congestion (Son et al., 2017). Industrialization and urbanization are very important determinants of the rate of agricultural land conversion into non - agricultural uses (Olaniyi et al., 2021). Consequently, sustainable urban development has emerged as a topic of interest for research in a diverse range of academic disciplines, including geography, engineering, economics, politics, and sociology. Despite the many advantages of urbanization, sustainable urban development is seen as a method for preventing, lessening, and minimizing the negative consequences of urbanization on the environment and the socio-economic system (i.e. social and economic improvement of living conditions). So, understanding the spatial-temporal diversity of urbanization patterns will make it easier to undertake sustainable urban planning in developing nations.

Many researchers have focused on urbanization patterns during the preceding two decades. Quantitative studies of urbanization have improved, even though there is a lack of spatial data to work with. This is especially true in the developing nations of Asia and Africa. These developing nations can overcome their restrictions by utilizing the data gathered from remote sensing and the techniques provided by the geographic information system (GIS) (Ndzabandzaba, 2015). For data extraction, remote sensing can utilize various geographical and temporal resolutions. This allows for collecting information on land use and cover, the ground surface temperature, population density, and energy consumption. The patterns of urbanization may be analysed using GIS techniques, as can the patterns of urbanization in the future. Consequently, the relationship between urbanization and sustainable urban development has emerged as a primary concern in constructing sustainable cities at all levels, including local, regional, and worldwide (Murayama et al., 2021).

3. Data and Methods

3.1 Description of the Study Area

Batticaloa city is located between 7°42'02"N and 7°43'60"N, and 81°40'62"E and 81°42'60"E. The Batticaloa lagoon surrounds it on three sides. It has a total size of 75.09 square kilometres. Batticaloa Town has a dry climate with hot summers, with a mean minimum and maximum of 30.7oC and 37oC, respectively. Monsoon winds provide rain to the region from November through February. Between 1900 and 2006, annual rainfall averaged 1645 mm. (Partheepan & Manobavan, 2009). A "sandwich pattern" of ethnic populations exists in Batticaloa, with 91 per cent Tamils, 5 per cent Muslims, 0.14 per cent Sinhalese, and 3.86 per cent others. (Department of Census and Statistics 2022). Batticaloa was a small town in Sri Lanka in 1979, with 52,452 residents; by 2021, Batticaloa had grown to 93,058 (Department of Census and Statistics, 2020). It has a population density of 1,938 persons per square kilometre, accounting for about 16 per cent of the district's population. (Partheepan & Manobavan, 2009).

Approximately 4311.87 hectares of the land area of Batticaloa city are devoted to the different purposes of residential, agricultural, commercial, wetlands, water bodies, scrub, and others (Fig.1). Due to the lack of sewage infrastructure in many unauthorized/regularized communities, sewage is discharged into these bodies of water, although they were built to transport rainwater (Partheepan & Manobavan, 2008). Because of its outstanding tertiary operations, Batticaloa is a vibrant regional development centre in the eastern province (Agriculture, fishing, and trade services). Due to its main historical growth factors, the town experienced a quick urbanization process.

Due to ongoing development initiatives, Batticaloa City's infrastructure facilities will improve, but urban planners and other key development officials still need to plan these initiatives. The area is highly prone to arbitrarily constructed development, which impacts the sustainability of land use. Since 1979, rapid population growth has altered the authorities have not considered the completed pattern for sustainability. Because this area is the central urban hub accessible to all amenities in Sri Lanka's Eastern Province, migration from other parts of the district and the Eastern province increased to the Batticaloa city region because of the effects of the 30 years of the Civil War.

However, assessing whether the Batticaloa land use would accept this population expansion long-term necessitates a full grasp of the population's socio-economic characteristics and specific features of urban planning and the urban environment. Batticaloa's agricultural land and forest resources have suffered due to rapid population growth and low economic living conditions. According to Partheepan et al. (2016), demographic pressures contribute to greater competition for land, agricultural, and commercial areas. They claim that the demand for land to construct settlement infrastructure and other services increases as the population develops.

Fig.1 Study area - Batticaloa Town in Eastern Sri Lanka

3.2 Remote Sensing Data

In the present study, Landsat Thematic Mapper (LTM) and Operational Land Imager (OLI) data were used to obtain a 16-day repetition cycle with 30 m spatial resolution (Willis, 2015). To get cloud-free Landsat photographs for the research region shown in Tab.1, the US Geological Survey Earth Explorer, https://earthexplorer.usgs.gov/, was used (US Geological Survey, 2016). The acquisition quality of these photos was outstanding. The data were collected during the dry season between May and October best to distinguish the spectral signature of different land cover types.

Satellite type	Sensor type	Spatial resolution (metre)	Acquisition date	Source
Landsat 5	TM	30	17 September 1979	USGS: United States Geological Survey
Landsat 5	TM	30	4 August 2000	USGS: United States Geological Survey
Landsat 8	OLI	30	19 September 2021	USGS: United States Geological Survey

Tab.1 Details of Landsat data to analyse the LULCC in Batticaloa town by using Landsat data

3.3 Image Processing

These Landsat images were an L1T product topographically, geometrically, and systematically corrected. ArcGIS 10.3 software clipped the research region onto the Landsat image (ESRI, Redland, CA, USA) as a vector file. Before image classification, the preliminary image categorization was improved using ENVI 5.2 software to make radiometric and atmospheric corrections (Harris Geospatial, Broomfield, CA, USA)(Traore et al., 2018).

ID	LULC Classes	Description of Classes
1	Bare land	Non-occupied/open landmasses with little or marginal vegetation
2	Built-up area	All types of urban construction sites: residential, commercial, industrial, public buildings, roads network, and other similar facilities.
3	Dense Vegetation	Forest area, /fruit orchards, tree-covered areas, and temporary/permanent highland croplands.
4	Paddy & Shrubs	Paddy fields, grassland, shrubs, and other idle lands along the lagoon.
5	Marshy land	Mangrove land, Wetlands, Swamps
6	Water	Open water, lagoon, tanks, and ponds exist.

Tab.2 An overview of LULC classes

As shown in Tab.2, the support vector machine (SVM) classifier was used with the supervised classification scheme in ArcGIS 10 software (ESRI, Redland, CA, USA) to create four primary LULC classes.
The classes were adapted from (Anderson et al., 1976) with slight changes to fit the research topic. Comparing false-colour composites from Landsat 5TM and Landsat 8TM using spectral bands 5, 4, 3, 2, and 1 were used to construct each LULC class's training samples (see Fig.2). A cross-tabulation matrix for LULC changes was created. During the December 2021 study region field visit, Google Earth archival photos and ground control points were consulted when assembling the training samples.

(a) (b) (c)

Fig.2 Classified LULC maps for Batticaloa town in (a) 1979, (b) 2000 and (c) 2021

4. Results

4.1 Land Use/Land Cover Change Detection and Classification

Post-classification comparisons of bi-temporal maps were used to detect LULC changes. In this study, Landsat data from 1979, 2000, and 2021 to derive spatial and temporal patterns of LULC classes for the first period (1979-2000), the second period (2000-2021), and the overall period (1979-2021).

Batticaloa's urban LULC has altered dramatically during the last 42 years. The dense vegetation around water bodies (lagoons) was the most common terrain type in the study area. There were 27.79 per cent water bodies (lagoon), 24.82 per cent lush vegetation, 15.67 per cent bare land, and 15.60 per cent built-up area in 1979. The most notable changes are an increase in a built-up area and a depletion of greenery. From 1979 to 2021, the built-up area grew at an annual rate of 8.2 per cent. The built-up class grew slower at 3.65 per cent per year during the first era (1979–2000) than at approximately 4.55 per cent per year during the second era (2000–2021). The growing built-up area of Batticaloa Town is a sign of urbanisation. During the study period, vegetation land declined by 0.52 per cent yearly. The first era (1979–2000) saw a high annual rate of 0.82 per cent, followed by a meagre 0.24 per cent in the second decade (2000–2021).

Land use Land cover class	1979		2000		2021	
	User's accuracy (%)	Producer's accuracy (%)	User's accuracy (%)	Producer's accuracy (%)	User's accuracy (%)	Producer's accuracy (%)
Bare Land	100	86	91	96	88	91
Dense Vegetation	74	100	100	85	90	95
Paddy / Shrubs	72	98	98	86	96	93
Marshy land	70	100	100	89	95	92
Disturbed /Built-up Area	77	99	88	82	81	86
Lagoon/water bodies	100	100	100	98	100	100
Overall accuracy (%)		88.6		86.7		87.9
Kappa Coefficient		0.79		0.77		0.75

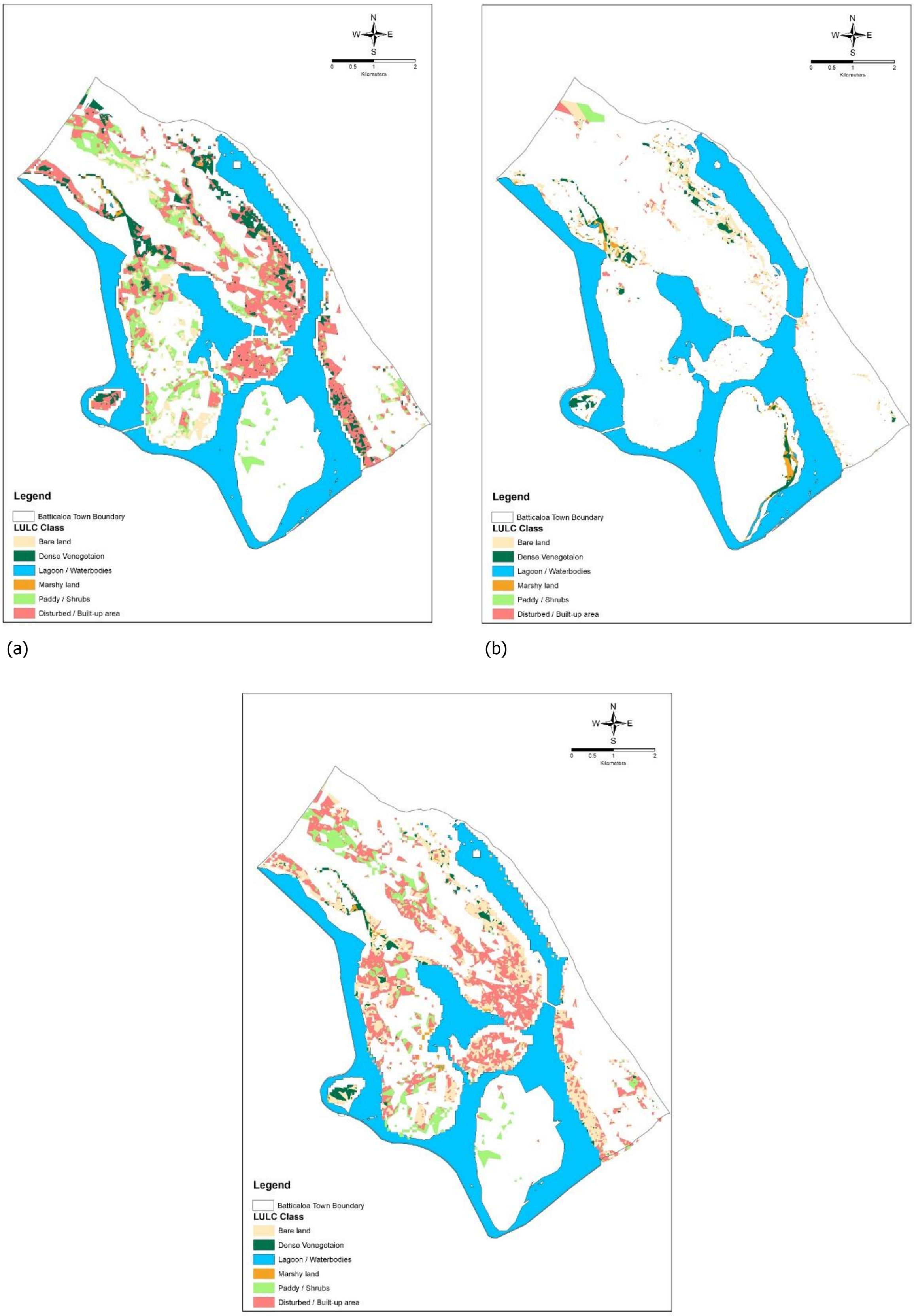
Tab.3 Accuracy assessment for 1979, 2000 and 2021 classified maps of Batticaloa Town

4.2 Land Use/Land Cover Change Detection and Classification

Tab.3 presents the accuracy assessment findings for LULC maps classified in 1979, 2000, and 2021. The total accuracy of the 1979, 2000, and 2021 images was 88.6, 86.7, and 87.9%, at least 85 per cent above the minimum standard set by the USGS. Therefore, after classification, the findings can be used as a data source for comparisons and further analysis. Strong agreement existed between the categorized map and the reference data, as indicated by the Kappa coefficients of 0.79, 0.77, and 0.75, respectively (Alo & Pontius, 2008).

4.3 Detection of post-classification changes

As a result of analyzing the classified maps for the first and second periods (1979-2000 and 2000-2021, respectively) and the total period (1979-2021), the transition matrix is presented in Tab.4. Tab.4a shows that approximately 59.21 per cent of the landscape changed from one type to another during the first period (1979–2000), but Tab.4b shows that about 47.27 per cent of the landscape changed during the second period (2000–2021), confirming that changes were faster in the early era.



(a) (b)

(c)

Fig.3 Land use changes: conversion of Dense vegetation to other land classes (a) 1979, (b) 2000 and (c) 2021

Tab.5 provides the outcomes of computing gains, losses, total change, swap, and net change from the matrices as a benchmark for better understanding the transition budget. These calculations depict the interaction of the LULC classes in the terrain. According to Tab.5, shrubs/paddy land and vegetation classes have undergone a swapping type of alteration in this study.

For example, 5.76 and 16.39 per cent of the total modifications in the Paddy/shrub class were made in the first and second periods. Similarly, about 24.82 % and 12.94% of the overall change in vegetation class-switched places at the relevant periods. In addition, dense vegetation has been significantly changed around Batticaloa town and is geographically illustrated in Fig.3.

The simultaneous reforestation and deforestation actions in the environment may be to blame for the switching tendencies between paddyland/shrubs land and vegetation classes. For the first and second research intervals, the built-up type accounted for 15.67% and 18.63% of overall change in the class, respectively. The built-up area has been constantly expanded, as visualised in Fig.4.

The built-up type accounted for 15.67 per cent and 18.63 per cent of changes in the class, respectively, during the first decade.

Based on Tab.3, commission and omission errors are equal to the sum of the user and producer accuracy. Determining whether classification errors were responsible for the losses and swap proportions for the built-up class is impossible. Due to Landsat's 30 m spatial resolution and edge effects and the issues of spectrum confusion in the urban context, certain misclassifications may occur (Bhatta, 2009; Congalton & Green, 2008; Herold et al., 2005; Yang & Lo, 2010).

Moreover, the built-up areas occupied the highest proportion of the total area between 1979 and 2000, around 17%. Agriculture land gained around 21%, a smaller percentage than before 2000, and it lost considerably to the built-up areas. This change is partly attributed to more people moving into the study area from elsewhere in the district due to the civil war.

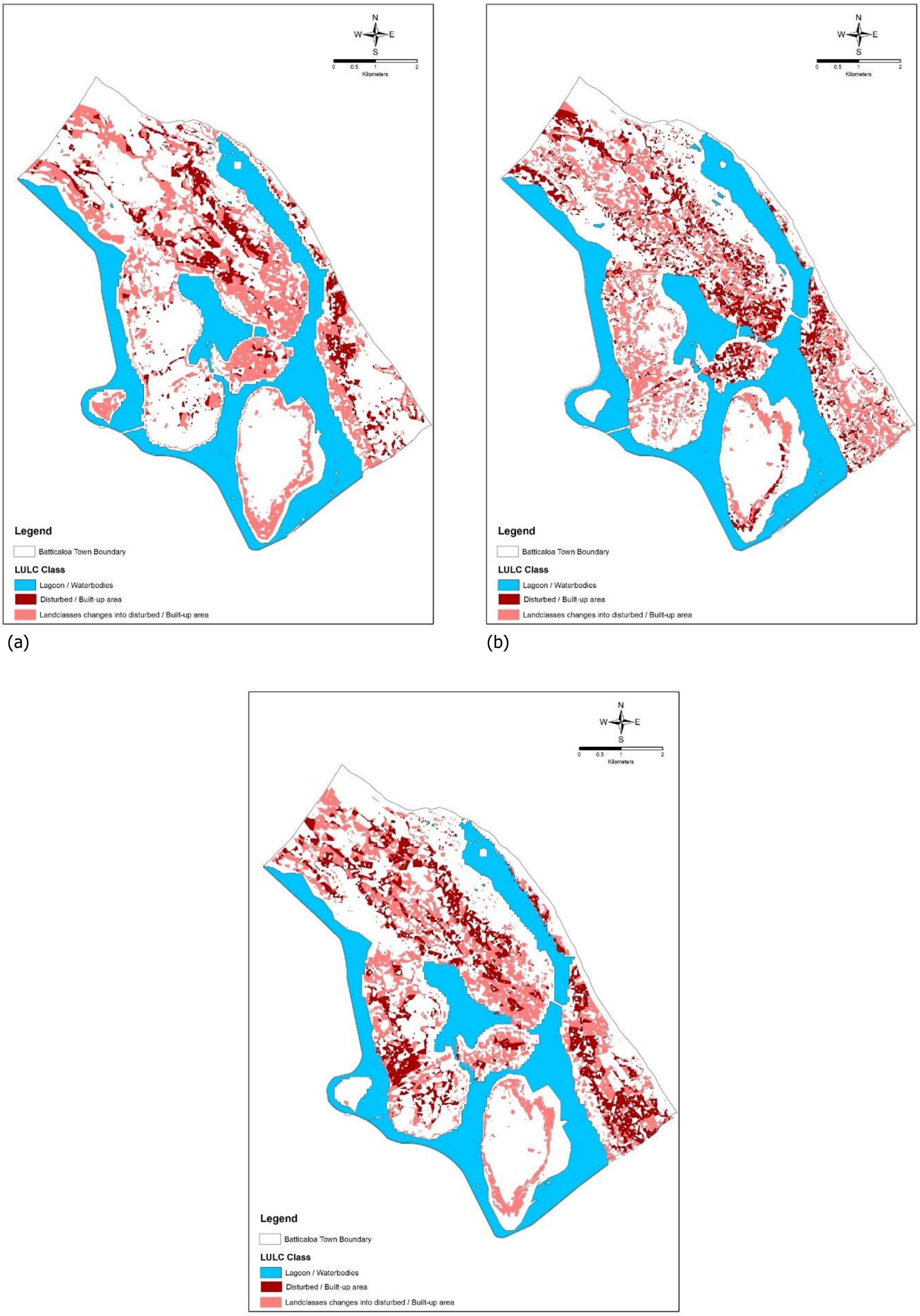
According to Fig.4, the urban expansion gradually increased from 1979 to 2021, changing approximately 1200 hectares. There was a small gain of about 17 per cent hectares from 1979 to 2000. After that, the urban expansion increased by more than 700 hectares between 2001 and 2006. In the decade between 2000 and 2021, there was a dramatic increase of around 700 hectares.

Similarly, 24.82 per cent and 12.94 per cent of vegetation class-switched sites changed during the relevant periods. Simultaneously environmental reforestation and deforestation efforts may explain this.

Switch between paddyland/shrubs land and vegetation classes. Additionally, shrubland/paddy land expansion is focused on vegetation and avoids densely populated areas, as illustrated in Fig.4. This procedure has reduced the vegetation cover in the research area, and agriculture has declined over time (Fig.4), possibly due to the tsunami effect in 2004, when seawater inundated agricultural grounds.

The standard of living has been dramatically improved through the construction of large houses and single-family homes during this time.

They had changed their lifestyle through modernization, and tiny houses and apartments needed to show the standard of living. There has been a noticeable impact on agricultural land and the rest categories. For example, parts of the town's suburban areas now lack agricultural land because of built-up areas (Fig.5). Similarly, between 2000-2021 the land use categories, such as agricultural and bare land, decreased to 14.19% and 12.58%, respectively.



(a) (b) (c)

Fig.4 Land-use changes: land classes conversion to the built-up area / disturbed land (a) 1979, (b) 2000 and (c) 2021.

Fig.5 Land use changes: land classes conversion to shrubs/ paddy land (a) 1979, (b) 2000 and (c) 2021

(a) 1979-2000

		2000: Bare Land	Dense Vegetation	Water bodies	Marshy land	Shrubs/Paddy	Built-up Area	Total	Losses
1979	Bare Land	0.75	1.32	0.11	1.10	5.94	2.88	12.09	11.33
	Dense Vegetation	2.24	3.37	0.00	0.28	6.31	11.16	23.36	20.00
	Water bodies	0.00	0.01	24.92	0.61	0.00	0.05	25.59	0.67
	Marshy land	0.05	1.29	1.94	2.98	1.39	2.23	9.90	6.91
	Shrubs/Paddy	3.93	0.48	0.00	0.04	2.42	1.59	8.46	6.03
	Built-up Area	6.23	0.40	0.01	0.08	7.54	6.35	20.60	14.25
	Total	13.20	6.87	26.98	5.09	23.61	24.25	100.00	
	Gains	12.45	3.50	2.06	2.10	21.19	17.90		

(b) 2000 - 2021

		2021: Bare Land	Dense Vegetation	Water bodies	Marshy land	Shrubs/Paddy	Built-up Area	Total	Losses
2000	Bare Land	0.61	0.00	0.00	0.22	7.20	5.15	13.20	12.58
	Dense Vegetation	3.57	1.23	0.12	0.96	0.30	0.68	6.85	5.63
	Water bodies	0.00	0.00	26.64	0.32	0.00	0.00	26.97	0.33
	Marshy land	0.49	0.27	1.14	3.08	0.02	0.09	5.09	2.01
	Shrubs/Paddy	2.59	0.05	0.01	0.39	9.44	11.16	23.63	14.19
	Built-up Area	9.23	0.44	0.08	1.50	1.29	11.73	24.27	12.53
	Total	16.49	1.99	28.00	6.46	18.24	28.82	100.00	
	Gains	15.88	0.76	1.36	3.39	8.80	17.08		

(c) 1979 - 2021

		2021: Bare Land	Dense Vegetation	Water bodies	Marshy land	Shrubs/Paddy	Built-up Area	Total	Losses
1979	Bare Land	2.18	0.38	0.19	1.38	5.14	2.81	12.08	9.90
	Dense Vegetation	8.25	0.98	0.01	0.30	3.61	10.21	23.36	22.37
	Water bodies	0.02	0.00	25.20	0.33	0.01	0.00	25.58	0.37
	Marshy land	0.84	0.53	2.55	4.23	0.67	1.08	9.89	5.66
	Shrubs/Paddy	1.23	0.00	0.02	0.11	3.56	3.57	8.49	4.93
	Built-up Area	4.01	0.08	0.02	0.12	5.22	11.13	20.59	9.45
	Total	16.53	1.99	27.99	6.46	18.22	28.80	99.98	
	Gains	14.35	1.00	2.79	2.23	14.66	17.67		

Tab.4 The percentages represent the land use/land cover (LULC) transition matrix

(a) 1979-2000

LULC Class	Persistence	Gain	loss	Total Change	Swap	Net change
Bare Land	0.75	12.45	11.33	23.78	22.67	1.11
Dense Vegetation	3.37	3.50	20.00	23.49	7.00	-16.50
Water bodies	24.92	2.06	0.67	2.74	1.35	1.39
Marshy land	2.98	2.10	6.91	9.02	4.20	-4.81
Shrubs/Paddy	2.42	21.19	6.03	27.22	12.07	15.16
Built-up Area	6.35	17.90	14.25	32.16	28.51	3.65
Total	40.79	59.21	59.21	59.21	37.90	21.31

(b) 2000-2021

LULC Class	Persistence	Gain	loss	Total Change	Swap	Net change
Bare Land	0.61	15.88	12.58	28.46	25.16	3.3
Dense Vegetation	1.23	0.76	5.63	6.39	1.52	-4.87
Water bodies	26.64	1.36	0.33	1.69	0.66	1.03
Marshy land	3.08	3.39	2.01	5.4	4.02	1.38
Shrubs / Paddy	9.44	8.8	14.19	22.99	17.6	-5.39
Built-up Area	11.73	17.08	12.53	29.61	25.06	4.55
Total	52.73	47.27	47.27	47.27	37.01	10.26

(c) 1979-2021

LULC Class	Persistence	Gain	loss	Total Change	Swap	Net change
Bare Land	2.18	14.35	9.9	24.25	19.8	4.45
Dense Vegetation	0.98	1	22.37	23.37	2	-21.37
Water bodies	25.2	2.79	0.37	3.16	0.74	2.42
Marshy land	4.23	2.23	5.66	7.89	4.46	-3.43
Shrubs/Paddy	3.56	14.66	4.93	19.59	9.86	9.73
Built-up Area	11.13	17.67	9.47	27.14	18.94	8.2
Total	47.28	52.7	52.7	52.7	41.06	11.64

Tab.5 Land use and land cover changes (LULCC) summarised in percentage

5. Discussion

While many studies have demonstrated that remote sensing with geographic information technologies is an effective tool for detecting and mapping land use/cover change, few have conducted spatial and explanatory analyses. Anderson et al., 1976 suggest this is the most common method to detect changes., and it has been used successfully in several types of research, including (Briones & Sepúlveda-Varas, 2016; Hansen & Loveland, 2012; Jensen et al., 2007; Jiménez et al., 2018; Manandhar et al., 2009; Mawenda, 2020; Mwathunga & Donaldson, 2018; Ouedraogo et al., 2011; Shoyama & Braimoh, 2011; Yuan, 2007).

In Batticaloa town, substantial changes in all types of land use/cover occurred between 1979 and 2021, which can be attributed to the ethnic conflict. However, other factors contribute to these changes, including large-scale population displacements, military actions such as setting up high-security zones, the economic embargo, inadequate transportation and market facilities, and large-scale logging (Sarvananthan, 2009). The result of population displacement, high-security zones, and economic blockades has resulted in the loss of agricultural land within the city limits, primarily cultivated land. Despite the encroachment of built-up areas on previously dense forest areas, most changes occurred on shrubland. Over the past 42 years, Batticaloa town has seen increased anthropogenic-induced urban landscape changes. The expansion of the built-up area, which moved from 3.65% initially to over 4.55% in the later period, by an average annual change of 0.22%, supported this. The quick fall rates for vegetation and bare land are a source of environmental worry.

In another sense, due to its land consumption ratio, Batticaloa Town's urban expansion is becoming more comprehensive rather than compact. By integrating neighborhoods tightly and providing quick access to socio-economic services, this type of expansion harms the city's environmental sustainability and social interaction. Increased impervious surface area, reduced groundwater recharge, and increased solar radiation reflected in space worsen urban heat islands and floods (Sundarakumar et al., 2012). As a result, urban development is in jeopardy, and better management is required to ensure a more sustainable future.

Changing vegetation (flora, mangroves) contributes to a decrease in green space, negatively impacting ecosystem services such as water purification, flood mitigation, noise abatement, and urban cooling (Vargo et al., 2013). It also damages soil (Estoque & Murayama, 2013), resulting in areas that have been abandoned. Humans benefit from ecosystems that do not pertain to material possessions, such as spiritual enrichment, cognitive growth, introspection, recreation, aesthetic experiences, and their role in maintaining knowledge systems, social interactions, and aesthetic standards.

Environmental factors, demographics, and economic development influence Batticaloa town's land use/cover dynamic. As a result of Batticaloa's increased political and strategic importance as a development target after 2010, the city's infrastructure and urban areas have undergone substantial transformations, as has the region's land use pattern.

Finally, the shrinking of undeveloped regions places tremendous pressure on suitable properties for development. In unplanned settlements such as wetlands and lagoon buffer zones in Batticaloa town, climate change and climate variability have increased the frequency and intensity of floods in recent years (Konrad, 2003) (Partheepan et al., 2005a). These rigorous techniques suggest that the expansion of built-up regions is concentrated on bare ground, avoiding vegetated areas. Lands that cannot be developed, such as wetlands and buffer zones around the lagoon, can be found in most vegetated regions. Nevertheless, the post-war period following 2009 was politically stable, resulting in measurable growth in LULC changes, especially in built-up areas. In Batticaloa, 60% of the land area belongs to the private sector, so infrastructure investments drive the majority of change (Mapa et al., 2002).

Between 1979 and 2000, paddyland decreased due to deforestation and paddy land converted into built-up areas. The eastern and western parts of the Batticaloa district have different economic conditions. As a result of employment opportunities in the coastal belt, including Batticaloa town, there was a mass migration from west to east, and unproductive paddylands and shrubs were abandoned due to a labour shortage in agriculture in our study area. Rapid urban sprawl has been causing a significant loss of dense forests from 2000 to 2021, which has attracted the government's attention. In 2000 and onward, home garden acreage was barely over paddy lands, and it appears to be expanding with the rise in homesteads.

Similarly, cultivated lands in Batticaloa rose by 41.9 per cent from 2000 to 2005 due to the country's current peace process. Anthropogenic activities such as the exploitation of timber for fuel, the destruction of mangroves, and poor land management could explain this loss (Grogan et al., 2015; Lindström et al., 2012; Mahanama et al., n.d.; Partheepan et al., 2005b; Rathnayake et al., 2020; *Sri Lanka - Land Use Land Cover LULC (Change) Mapping - Datasets - Water data*, n.d.). Due to the transition and the terrible economic crisis, people began to overexploit the vegetative resources to sustain their livelihoods.

LULC changes during 2000-2021 concentrated in the Batticaloa town area. The aftermath of the civil war was attributable to open economic reforms, agricultural land expansion, population redistribution, and infrastructure upgrades, which had a significant impact after 2009 (Athukorala et al., 2017).

In this scenario, the underlying belief is that by relying heavily on technical analysis, which emphasizes objective data and scientific methods, a more effective and efficient approach to land use governance can be achieved. This aligns with the positivist philosophy that emphasizes the primacy of empirical evidence and the application of scientific principles in understanding and solving societal issues.

6. Conclusions

This study underscores the results obtained through the analysis of urban land use in Batticaloa from 1979 to 2021. The findings reveal a concerning trend of increasing built-up areas and bare land at the expense of vegetation and marshy areas. This transition from dense vegetation to barren land, and then to built-up areas, signifies inefficiencies in the city's approach to urban growth. These results provide important insights for policymakers and planners, emphasizing the need for prioritizing sustainable urban development in Batticaloa. Based on the study's findings, several recommendations emerge. The government should expedite the allocation of suitable land for development while curbing illegal expansion in high-risk areas. It is also crucial for planning bodies at the local authority, municipal, regional, and national levels to regularly assess physical plans and promptly provide serviced land. To mitigate the observed loss of vegetation cover, it is suggested to identify and conserve essential vegetation patches from human impact. Citizens can play a role by protecting vegetation on bare lands and other reserves in Batticaloa, allowing for natural regeneration.

Furthermore, the study highlights the strain on Batticaloa town's natural equilibrium over the four decades of population growth. The mapping of changes and disturbances in land use can serve as a valuable tool for landowners, non-governmental organizations (NGOs), and policymakers to protect environmentally fragile areas from further damage. This information can guide efforts to preserve and conserve the natural environment of Batticaloa. In addition to the specific findings on land use changes in Batticaloa, this study also proposes a time-series remote sensing analytical tool-chain for mapping land use and land cover change (LULCC) in highly dynamic tropical environments. This tool-chain aims to address the information gap caused by political instability and limited access to cloud-free images. By employing remote sensing techniques, policymakers and researchers can gain valuable insights into land use dynamics and make informed decisions for sustainable urban development. The research outcomes provide a significant contribution to the field of sustainable urbanization by highlighting the land use changes in Batticaloa and the need for sustainable development practices. The study emphasizes the importance of considering social equity, economic growth, and governance in comprehensive evaluations of urban sustainability. By integrating these dimensions and addressing the identified challenges, policymakers and planners can work towards creating a more sustainable and resilient future for Batticaloa and similar urban areas.

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Image Sources

All images are by the Authors.

Fig.1: Study area—Batticaloa Town in Eastern Sri Lanka;

Fig.2: Classified LULC maps for Batticaloa town in (a) 1979, (b) 2000 and (c) 2021;

Fig.3: Land use changes: conversion of Dense vegetation to other land classes (a) 1979, (b) 2000 and (c) 2021;

Fig.4: Land-use changes: land classes conversion to the built-up area / disturbed land (a) 1979, (b) 2000 and (c) 2021;

Fig.5: Land use changes: land classes conversion to shrubs/ paddy land (a) 1979, (b) 2000 and (c) 2021.

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A platform to optimize urban deliveries with e-vans

Dealing with vehicles range and batteries recharge

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Abstract

The paper reports the results of a research targeted to develop a Decision Support System (DSS) for planning and operation of urban deliveries carried out with electric vans.

The research was included within the 2019-21 Research Program for the Electric System, coordinated by the Italian Ministry for the Ecological Transition, and has been performed by ENEA, the Italian Agency for Energy, New Technologies and Sustainable Development, and "La Sapienza" University of Rome.

The new DSS is based on meta-heuristics algorithms capable to manage a generic set of goods to be delivered by means of a generic fleet of electric vans, with the objective of minimizing the overall cost of the daily operation. The algorithm considers all the physical constraints, including vehicles batteries capacity. It is assumed that fast recharges can be performed during the delivery tours.

For the real-time operation, a monitoring system of the vehicle fleet, road network and recharge stations is assumed, based on IoT technologies, in order to detect possible unexpected events and manage them in the best way, according to the available resources time by time.

The paper describes the DSS general architecture, the optimization algorithms and the recovery procedures and shows results for two testbeds.

Keywords

Urban deliveries; Electric vans; Decision support system.

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1. Introduction

The paper describes the results of a three years research carried out within the 2019-21 Research Program for the Electric System, coordinated by the Italian Ministry for the Ecological Transition (formerly by the Italian Ministry of the Economic Development). The research has been performed jointly by ENEA, the Italian Agency for Energy, New Technologies and Sustainable Development, and "La Sapienza" University of Rome.
The research goal consists in a software tool aimed at optimizing, day by day, the delivery tours within an urban network, when transport is carried out with Battery Electric Vans (BEVs). The software is designed to manage supply and demand data of urban deliveries in order to make the logistic process more efficient, reducing both operational costs and energy and environmental impacts, but also allowing a better management of public and private facilities such as vehicles unloading areas and charging stations for electric vans. In this sense the tool is targeted not only to logistic operators but also to local public administrators.
The vehicles routing optimization for goods delivering is a topic of vast operational interest, just thinking of the thousands of deliveries that are handled every day in the context of e-commerce. Systems of optimization and management of delivery operation are already adopted by many commercial carriers involved in the deliveries of goods (Logistica Management, 2019; Iveco, 2020; Nissan, 2020; Ford, 2020; Paganoni, 2020; Zuccotti & Konstantinopoulou, 2010).
However, the use of electric vehicles is a relatively recent topic of research. When considering electric traction, the usual constraints related to vehicle routing problems, like time-windows at delivery points or vehicles load capacity, need to be taken into account jointly with the vehicles range limits linked to its battery energy capacity. This means that the daily vehicles activity program must also consider the possibility to perform suitable electric recharges during the delivery tours, using the recharge infrastructure spread in the urban area, either public or private. This leads to an increase in computational criticalities, which has been faced during the research.
Apart from this planning functionalities, the project was directed to manage, during vehicle operation, the most common unforeseen events, deriving, for instance, from anomalous traffic conditions or battery defaults, that can require real-time changes to the original schedule, rising new routes and / or recharging operations. From this perspective, the information to be acquired in real time both from the vehicles and the territory in which they operate is crucial.
In recent years, the development of the Information Technologies opened new horizons in the management of Transport and Mobility. Big amounts of data on demand behavior as well as infrastructures and vehicles status can be continuously acquired from the field much easier than in the past. At the same time, communication among users, administrators and operators can take place widely and fast, allowing both off-line analyses and on-line interventions that were unimaginable just few decades ago. In this framework, many sectoral studies and researches have focused on the design of modern decision support platforms for local administrators and stakeholders, aimed at identifying, through analytical processes, policies and actions to facilitate the transition to a more efficient planning and management. This is part of a more general attempt to reinvent cities to optimize energy consumption, and quality of life (Gargiuo et al., 2022; Staricco & Brovarone, 2016; Del Ponte, 2021; Gonzalez-Feliu & Morana, 2010; Carrese et al., 2021).
In this paper we propose an application of IoT specifically focused on urban delivery electric fleets management. A monitoring system capable to collect data from in-motion electric vehicles, unloading and recharge facilities and transfer them to a Control Center has been designed and tested. For the objectives of the research, this information must be updated at regular and short intervals, in order to allow the algorithms residing on the platform, in case of unexpected events, to rearrange the remaining vehicles tasks, taking into account new operation conditions as well as physical and commercial constraints.
The following figure illustrates the functions to support the urban distribution of goods and the expected results for the two categories of users of the platform.

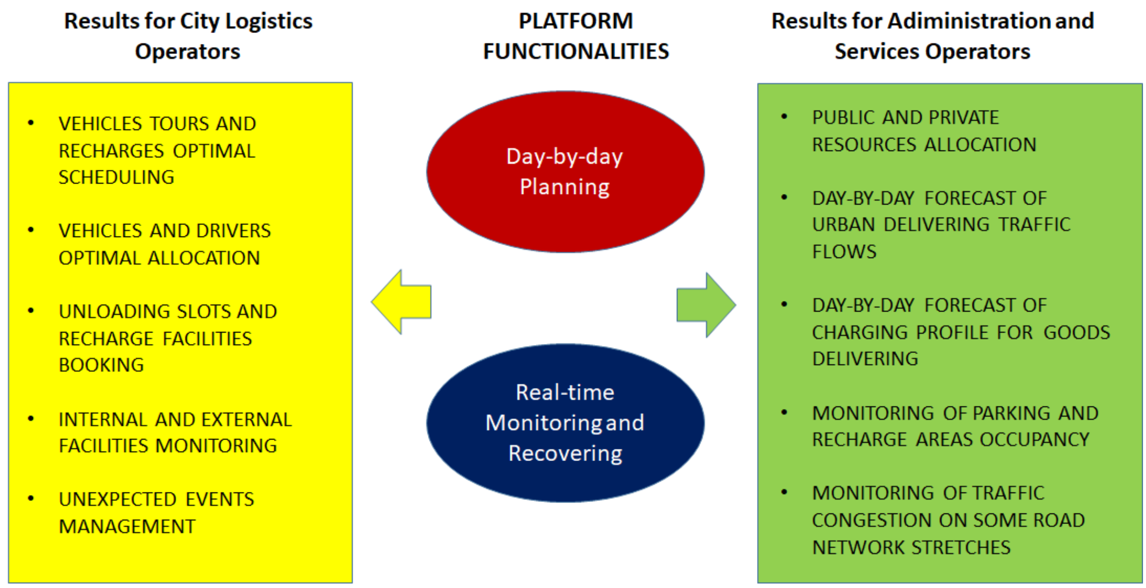

Fig.1 Functionalities of the platform for planning and operation of urban deliveries with batteries electric vans

2. State of Art of technologies

Urban areas are the hub of last mile deliveries, which to date represent the least efficient link in the entire logistics chain in terms of generating costs and negative externalities. According to recent estimates, last mile deliveries account for up to 40% of the total cost of the supply chain (Capgemini Research Institute, 2018) and are responsible for 30% of CO2 emissions and about 20% of traffic. About 80% of deliveries take place in the urban areas, 20-25% of them, in terms of travelled kms, concerns outgoing goods, 40-50% are for incoming goods, the remainder relates to goods with both origin and destination within the urban perimeter (Struttura Tecnica di Missione del MIMS, 2022). In the absence of ad hoc interventions, the number of light commercial vehicles for urban delivery of goods will increase by 36% by 2030 (WEF, 2020).

The renewal of fleets with clean or low-emission vehicles represents an indispensable opportunity towards a substantial reduction in urban negative emissions (GHG, air pollution, noise). Operators and builders consider various sustainable transport solutions, such as cargo bikes (which might contribute to the reduction of road congestion and the risk of accidents) and electric vans. The former, characterized by modest costs, are severely limited in terms of range and load capacity; electric vans on the other hand have higher costs of investment, also for the re-charging equipment.

In Italy, the light commercial vehicles market in the first semester of 2022 was of 86.700 units (ANFIA, 2022), decreasing by 11.6% compared to the same period of 2021, due to economic uncertainty. The national van market remains dominated by IC engines and, although in the past few years the sales of electric vans are increasing, in 2021 remaining limited to 2% as for purely electrics and to 7% as for the hybrid ones.

Fig.2 shows the technology split of vans in Italy in 2021, when the national LCV fleet counted about 4.34 million units, 23% of which were Euro 6. BEVs represent only 0.24% while the hybrids 0.43%.

Industrial policies are presently strongly influenced by increasingly stringent environmental regulations, as well as by energetic concerns, so that the electric gamma is rapidly enlarging. In 2022, some automakers even sell only electric van models.

Currently, battery packs guarantee an average of 100-200 km daily mileage, with an energy capacity ranging from 37 up to 70 kWh. Batteries can generally be recharged either with an AC wall-box, requiring several hours, and therefore suitable for an overnight charging, or with more powerful DC charging stations that allows for shorter charging times.

The rise of e-commerce is influencing the evolution of urban logistics so much that the use of goods transport vehicles of limited size and load capacity, such as bicycles and tricycles, drones and robots, have been introduced to carry out small deliveries within narrow areas such as urban ones. In an even more innovative scenario, the 3D printing directly at the buyer's premises can become a widespread mode of goods delivery, making it possible to virtualize freight transport on a par with what teleworking and teleservices are doing with passenger mobility.

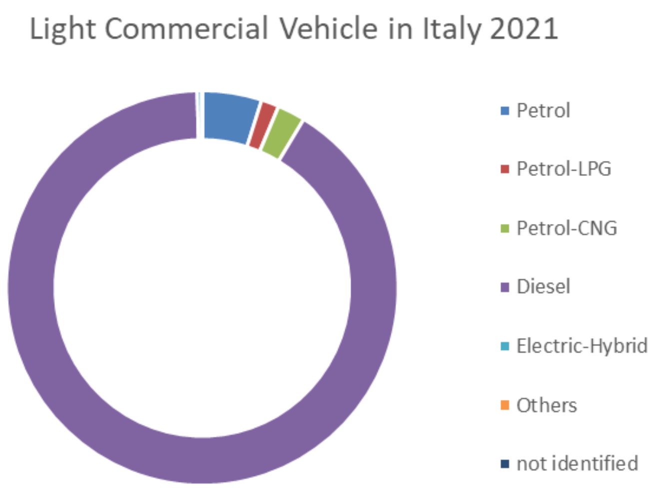

Fig.2 Light Commercial Vehicle fleet in Italy by technology, 2021 (%) – Data source ANFIA

The modern cargo bicycles, even trikes (tricycles), can be electrified and modular, this facilitates the carrying out of deliveries and, considering that e-bikes have already been successfully utilised for providing postal deliveries, it can be said that the two / three wheels are back in vogue again. Velove's Armadillo, for example, is used by numerous delivery operators, including DHL, DB Schenker, Deutsche Post, DPD, Hermes and Swiss Post. Centaur Cargo has developed a modular cargo bike for Royal PostNL and AN Post while Coolblue and Truck Trike partner with Urban Arrow and a Portland-based company is working with UPS

Cargo bicycles might also be used in other services, in addition to the distribution of small packages, such as the Cyclo Plombier, a hydraulic company that travels around Paris on cargo bikes. This allows operators to carry all of their work tools, eliminating the costs of fuel, parking, repairs and all the associated stress.

In Groningen, non-electric trikes were present long before "Mobility-As-A-Service" or "sharing economy" were coined. These very distinctive trikes have become a city institution, rent for half a day at a cost of 12 euros, still not competitive for the delivery of goods, compared to the prices charged by traditional couriers.

Numerous companies are developing drone delivery services for small loads, including Matternet (2 kg for 20 km), ZipLine (1.8 kg for 80 km), Flirtey. The DPDgroup subsidiary of the French group La Poste recently opened its second commercial line to deliver packages at medium altitude, using a drone capable of carrying 2 kg up to 15 km. The Swiss Post teamed up with Matternet to provide medical supplies, although they stopped after two incidents. Alphabet (Google's parent company) and Amazon have received clearance from the US Federal Aviation Administration to operate their drones and have started delivering via their subsidiaries, with PrimeAir (2.5kg over 25km) and Wing Aviation (2.5 kg over 25 km).

According to the European Energy Agency (EEA, 2019), in urban area bikes and e-vans can operate better than drones. In any case, all the studies recognise that the environmental benefit of using drones is limited to a small segment of the market (i.e. last mile deliveries to a single or a few recipients with a low payload).

Several players are also evaluating pilot studies for the use of autonomous electric vehicles for last mile delivery, among these: Nuro is planning to build a special vehicle that, for the first time, can keep a speed of 40 km / h. The start-up has already made several food deliveries. Two other operators are Gatik and Udelv, the former intends to specialize in the "middle mile" delivery from warehouses to stores, and has pioneered its solution with Walmart, while the latter has made test deliveries to retail stores. Amazon also aims at autonomous driving with Aurora Innovation; the company is developing a complete software package and hardware components, to allow autonomous vehicles at level 4. More recently, Amazon has also collaborated with the start-up Embark autonomous trucking company to test autonomous driving in the United States attempting to tackle the "middle mile".

In China, Alibaba is testing low-speed (15 km/h) driverless delivery robots and sidewalk delivery robots, these are smaller vehicles with the aim of allowing deliveries in areas where other types of vehicles, more traditional, are not allowed (e.g. pedestrian streets, campuses) and short deliveries in dense urban centres. This initiative is the focus for a number of start-up, including Dispatch, Marble, Robby, Starship or Kiwi Campus. These little robots are also an integral part of Amazon's multimodal delivery strategy. The company also developed its own delivery robot, a small six-wheeled electric vehicle, and tested it on a new service called Scout. Likewise, FedEx developed Roxo, a four-wheeled robot with the ability to climb a few stairs and aim for same-day delivery, and PostMates was authorised to test their vehicle on the San Francisco sidewalks.

The Ez-Pro solution proposed by Renault consists of a fleet of autonomous electric capsules, capable of transporting up to 2 tons of goods and coordinated by a leading vehicle, on which the "messenger of the future" travels, a single operator whose function it is no longer that of driving the vehicle, but of supervising the route and delivery of goods.

Both vehicle and telematics innovation can be of great importance in the re-thinking logistics systems for last mile distribution and freight transport more generally; as the connection of things (Internet of Things – IoT) grows, the possibilities of managing processes in a more informed and efficient way grow and the overview of telematic solutions aimed at last-mile services is already very wide.

Pending the marketing of autonomous vehicles, connected vehicles are already a reality: complex systems consisting of a set of Electronic Control Units (ECU) connected to each other. The technologies underlying these systems are protocols that allow different types of communication: vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-everything (V2X). The "connected vehicles" therefore process a lot of information: from technical data on the condition of the vehicle or related to its use (speed, seat occupancy or maintenance status), to those on the road surface and weather conditions, or on the presence of pedestrians or other vehicles; or information relating to the location, owner or user. Some advanced features could allow the processing of biometric data, both for the authentication of the driver or user of the vehicle and for the monitoring of some of its psychophysiological parameters.

These strategies will save energy, better divide the work between the various carriers and offer a higher quality service, creating the conditions for the cost-effectiveness of last-mile delivery.

3. Theoretical hints

Researchers and practitioners have been studying the Vehicle Routing Problem (VRP) for more than 60 years (Dantzig & Ramser, 1959). It has been now declined in the problem of designing least-cost delivery routes from a depot to a set of geographically scattered customers, subject to side constraints. With the introduction of Electric Vehicles (EVs) for urban freight transport, the limited driving range represents a significant additional constraint, also due to the large time difference between refueling and recharging. Therefore, in literature, many works are addressing the Electric Vehicle Routing Problem (E-VRP), each considering different constraints and approximations.

E-VRP's goal is to design low-cost BEV (Battery Electric Vehicles) routes in order to serve a number of customers taking into account the usual constraints: vehicle load capacity, customer location and time windows, working hours, fleet size and characteristics, time-dependent travel time; moreover, vehicles range limits and re-charging possibilities must be considered, either schematically or more realistically. In a review from Erdelic & Carić (2019) 80 articles regarding E-VRP have been analyzed to determine the frequency of appearance of variants and constraints, including those specific for electric vehicles, as shown in Fig.3.

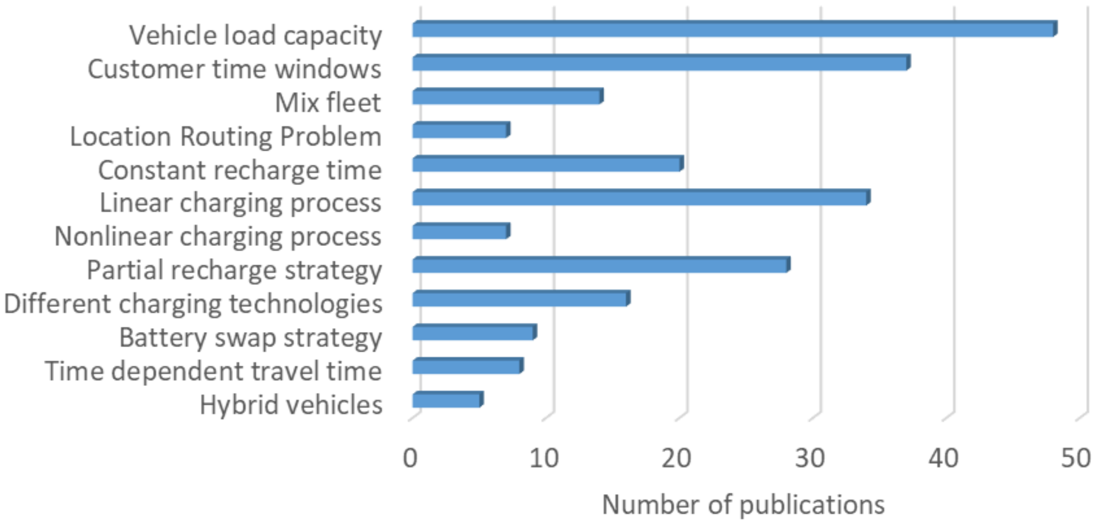

Fig.3 Frequency of Variants and Constraints in EVRP papers

The figure highlights that, as for recharging time, a linear process is considered, rather than a fixed or, on the opposite, non-linear one.

Numerous resolution procedures have been proposed to solve the VRP, and many of them, with appropriate adaptations, are also applicable to solve the problem of vehicle routing with electric vehicles (E-VRP). For small-size problems, several exact procedures have been proposed, but since this is an NP-hard problem with a large number of deliveries to be made in real scenarios, most of the procedures used in practice are heuristics, metaheuristics or hybrid combinations.

Heuristics are generally classifiable in two main families: Constructive Heuristics and Local Search Algorithms. The former iteratively inserts customers to the available routes, constructing solutions in what is commonly defined a "greedy" way, that cannot be reversed afterwards. At each step of the algorithm, an unserved customer is added to the route, along with its position in the route, according to the objective function. Two pioneering contributions are the savings method (Clarke & Wright, 1964) and the sweep algorithm (Gillett & Miller, 1974). On the other hand, Local Search algorithms, or Improvement Heuristics, start from a feasible solution and iteratively try to improve it by exploring the current solution in its neighbourhood, by applying perturbation moves. When it is not possible to find an improvement of the solution in its neighbourhood, a local optimum is reached and the search stops.

Metaheuristics, more complex frameworks of heuristics, are employed to allow the algorithm to escape from these local optima to find a better solution. Population metaheuristics are based on the definition of a population of individuals, which represent possible solutions of the VRP and go through the process of evolution. Many applications to E-VRP can be found in literature, including genetic algorithms, ant colony and particle swarm optimization. Otherwise, metaheuristics can be neighbourhood-oriented, directly addressing the problem of falling into repetition patterns, since by allowing a decrease of the objective function the risk of going back to the previous current solution must be prevented. Among this last family, the Simulated Annealing (SA) algorithm modifies the local search algorithm by introducing a randomized criterion for the selection of the new point in the current neighbourhood and for accepting the next step of the local heuristic. It is inspired by the physical cooling process of glass materials, controlling the search process through a parameter that is called temperature. The basic idea of the algorithm is to allow significant worsening of the value of the objective function in the initial stages of execution, to avoid being trapped in local optimum far from the global optimum. After a sufficient number of iterations, the algorithm is supposed to reach a part of the solution space close to the global optimum: at that point the temperature is decreased to refine the search.

For a detailed explanation of the heuristics and algorithms for vehicle routing problems the readers are referred to the works of Erdelić & Carić (2019) and Vidal et al. (2013).

4. Solution approach

As already stated, this work is aimed at developing a procedure to optimize, both in planning and operation phases, the tours for delivering goods within an urban network, when transport is carried out only with Battery Electric Vans (BEVs), by a unique carrier, from a unique sorting center.

The electric fleet can be heterogeneous, composed by vehicles of various load capacity, range and operational unit costs. Deliveries are linked to a set of delivery points, each of them characterized by a double time window within the fleet operation hours. A set of fast recharge stations is available across the delivering area, to be used if the battery State of Charge (SOC) goes under a certain lower threshold (20% of battery capacity), and a constant recharge time of 30 minutes for any considered type of vehicle.

The procedure is composed of four modules, two of which working off-line, before vehicles operation is started. A first algorithm allocates the deliveries to a subset of vehicles, optimizing the overall delivery time and cost, by matching vehicles load capacity and deliveries time-windows. A second algorithm determines the position of the vehicles on the graph and estimates energy consumption, verifying if and when the battery energy is almost down; in such a case, one (or multiple) recharge(s) is(are) inserted along the vehicle route, selecting the more suitable recharge station(s) among those available. Both these modules work without particular pressing from the time processing point of view. In fact, generally, goods to be delivered in a certain day are known at least the evening before so that more than few hours are available to search for the best solution. This is a crucial factor to set out the optimization methodology to be adopted. In our case a metaheuristic algorithm has been chosen, in the family of Simulated Annealing. The objective function minimizes the number of vehicles used, the total mileage and the total travel time, while penalizing time-window violations.

The other two codes work in real-time, during vehicles operation, in case of anomalies respect to the original schedule. The 'Recovery' code manages any default of battery State of Charge, suggesting additional or alternative recharges to those scheduled. Finally, the 'Update' code manages vehicle delays, not necessarily leading to an alert on the remaining battery range.

The flow diagram presented in Fig.4 illustrates the whole software procedure, starting from the acquisition of the characteristics of the road network, which must be schematized with an appropriately graph. The data of the specific case study are then acquired, relating to the composition and characteristics of the electric fleet as well as the attributes of the goods to be delivered, in terms of quantity, delivery points and related time constraints. In this phase, information relating to the charging infrastructure located in the area and the consumption functions of the electric vans are also collected. On the basis of these data, the two modules responsible for the off-line planning of delivery tours (Optimization and Simulation) return a sub-optimal solution. This solution is defined in terms of allocation of the goods to the vehicles, timing of the deliveries and possible recharge, as well as road routes from one delivery/recharge point to another. In addition, the vehicles positions and battery SOCs are provided at time intervals of 10 seconds.

The modules for the recovery of anomalies are launched only in a phase in which the vehicles have already begun their tours and only if, through data acquisitions from the field, there is an excessive misalignment with respect to the planned tour. This misalignment can be due to the battery's state of charge, too low than expected, or the vehicle's position, too far back. In the absence of a real monitoring system, which would have involved costly instrumentation of a real fleet and a real territory, the vehicle anomalies to test the recovery procedures are simulated randomly.

Planning and recovery codes were developed in Matlab and made available as executables compiled for the Linux operating system, while the accessory procedures for creating the work environment and the input files were developed in Python language.

The entire procedure (Fig.4) was planned and implemented in order to avoid any operator intervention once the suite has been launched. The whole procedure has been integrated in eMU, a multifunctional web-based platform developed in ENEA in order to ease the diffusion of electric mobility in urban areas.

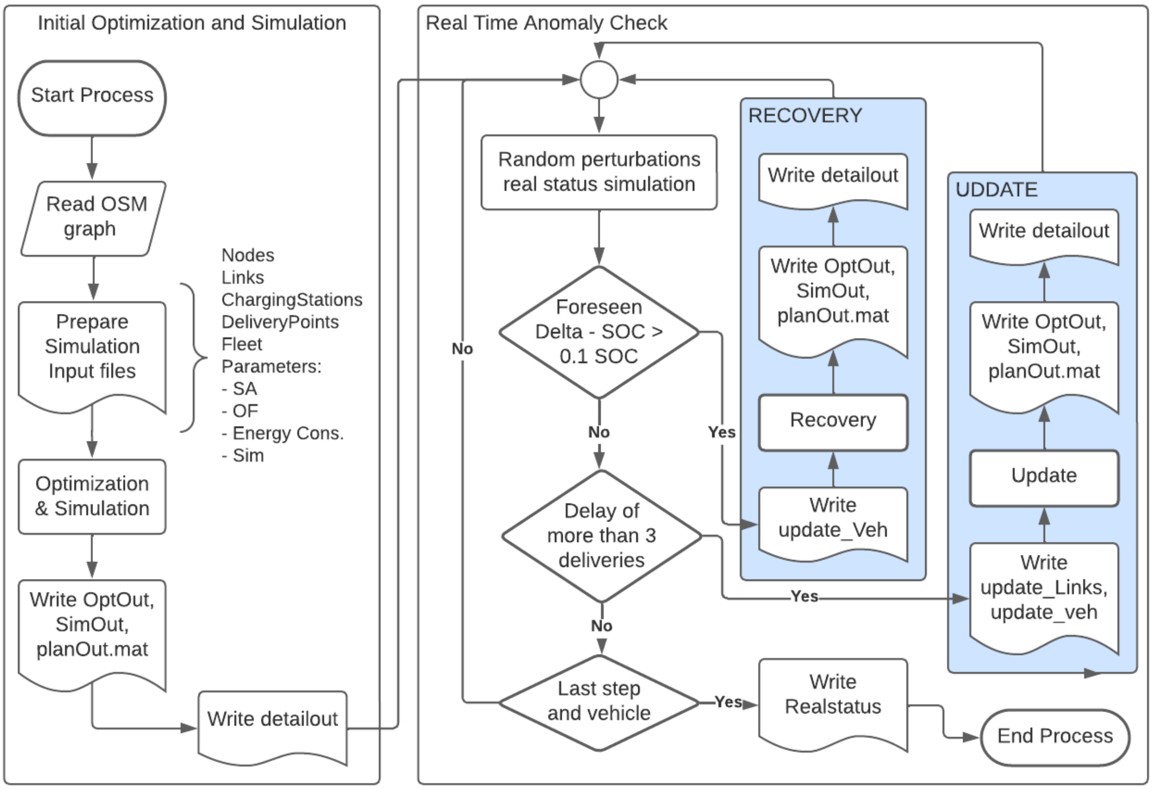

Fig.4 Optimal planning and real-time operation procedures

5. Algorithms for optimal scheduling

The vehicle routing problem (VRP) is a complex optimization problem that is typically classified as an NP-hard problem (Hashemi-Amiri et al., 2023). This means that finding the optimal solution to a VRP may require an exhaustive search of all possible solutions, which is computationally infeasible for large-scale problems. To address this challenge, various algorithms and optimization techniques have been developed to find near-optimal solutions within a reasonable amount of time.

These include heuristics, metaheuristics, and mathematical programming methods such as linear programming, mixed-integer programming, and dynamic programming (Rahmanifar etal., 2023). In this work, the proposed routing problem is solved with the use of a Simulated Annealing algorithm , which searches for the most efficient lap itinerary. SA is utilized by many scholars to solve different optimization problems and specifically, this algorithm is among one the most preferred used algorithms to address VRP (Colombaroni et al., 2020). The algorithm works according to the cooling physics process which is also called the annealing process. This is the procedure of low energy-state crystallization of molecular metal arrangements by slowing down of the temperature after being subjected to high heat (Kirkpatrick & Swendsen, 1985). The optimization process takes place as follows:

- an initial solution (S1) is created (see below);
- the solution is perturbed;
- the cost of the new solution is evaluated;
- a probabilistic function compares the cost of the new and previous solutions and decides which one to keep;

- the procedure of perturbation, evaluation and comparison is iterated for L times;
- the parameter of the probabilistic function (temperature) is decreased and the best solution of the L iterations is chosen to restart in the next cycle;

This process continues until the temperature drops below a final temperature value, and the found solution is the result of the optimization. This process is explained in Fig.5.

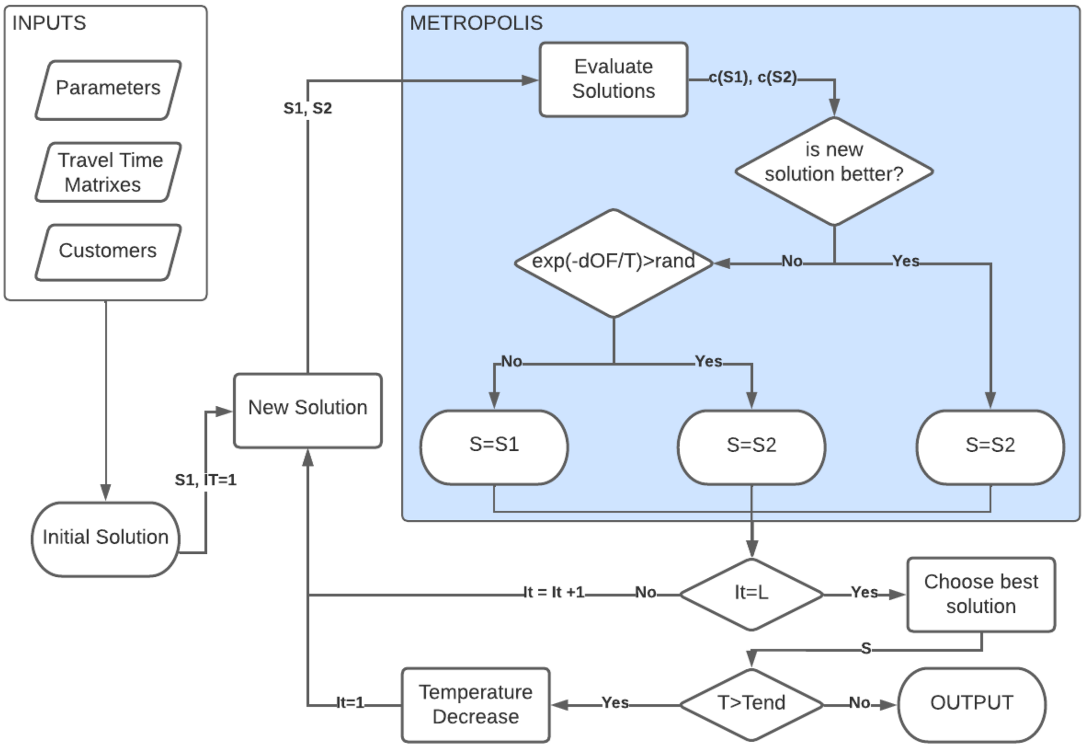

Fig.5 Optimization procedure with Simulated Annealing algorithm

The initial solution (S1) is created starting at the depot, and selecting the closest delivery point. The second delivery is determined by searching for the delivery point closest to the first one, and iteratively for the following deliveries. Time windows are not considered since they are used as a soft constraint. Once the distance of the tour overcomes the driving range of the vehicle, the itinerary of that vehicle is terminated adding a stop at the depot. The procedure of assigning deliveries to vehicles starts again with the remaining deliveries using the following available vehicle.

The perturbation of the solution can follow three different strategies: Swap, where two deliveries are randomly selected and their order is switched, Reversion, where a random set of successive deliveries is selected and their order is reversed, or Insertion, where two deliveries are selected and the first one is moved right after the second one.

The new solution is then evaluated determining its associated cost and it is verified that no autonomy or load constraints are exceeded. The cost is calculated through a linear combination of travelled distance, travel time and number of vehicles, in addition to the time windows violation penalties. The weights used to define the objective function are:

- operating cost of the vehicle per km travelled (oc);
- hourly operating cost (including driver cost - tc);
- additional cost for each vehicle used (use and depreciation - vc);
- additional cost for every time window violation (wc).

The Objective Function is therefore defined as:

$$OF = oc * dist + tc * time + vc * n\_veh + wc * tw\_violation \quad (1)$$

Where dist is the distance run in km, time is the time required to run the distance in seconds, n_veh is the number of vehicles used for the deliveries and tw_violation is the total time of the time window violations.
The "Metropolis" function then compares the current solution (S1) with the new one (S2) according to the values of the objective function and the current value of the temperature parameter. The choice is not deterministic, but is subject to a probabilistic assessment: the new solution can be accepted even though the cost is higher than the previous solution. If the analyzed itinerary is the best choice, the new solution is automatically accepted, but if the value of the objective function is lower than that of the previous solution, the solution can still be approved with a probability expressed as a function of the difference between the two values. The new solution is accepted if:

$$e^{(-\frac{\Delta OF}{T})} > p \quad (2)$$

Where *ΔOF* is the difference between the objective function of the two solutions, T is the temperature, and p is a real number extracted from a uniform distribution in the interval [0,1].

6. Monitoring and recovery procedure: the Recovery and Update processes

When considering electric vehicles, additional issues related to vehicle battery and charging stations defaults may occur in addition to the ordinary problematics related to traffic or mishaps at delivery destinations. This causes an increase of possible critical events, in particular associated to the need to suddenly include a charging event within the planned trip. Our system is designed to face such operational issues in real time. This is performed by two distinct procedures that are activated depending on the kind of problem the vehicle is dealing with. The Recovery procedure is activated in case of an unexpected discharge of the vehicle battery, while the Update process handles any delay of the vehicle, recomputing the optimal path and adding or rescheduling new recharging stops if required.
The recovery function allows to consider the need of sending a vehicle to a charging station, which was not initially foreseen in the plan, in case the power reserve is not sufficient to complete the round of deliveries due to unpredicted events that have reduced the charge compared to planning. The module calculates the current position of the vehicle and, from that position, selects the closest charging station. The schedule is then updated according to the new itinerary.
The update function offers the possibility to re-optimize the order of the remaining deliveries of a vehicle if during the monitoring operations a significant deviation of the travel times or the position of the vehicle with respect to the planning is received from the platform. The characteristics of the road network and the performance of the routes can undergo changes during daily operations. As a result, the travel time of electric vehicles may vary and it is reasonable to re-optimize the remaining part of the journey in case of significant changes in travel times. Also, the current position of the vehicle itself may be different from the plan and in this case a re-optimization for the rest of the lap may be required.
Both Recovery and Update modules act during the operational phase of the whole process. Once the Optimization module has identified a good vehicle routing, including the required stops at charging stations, all involved vehicles start their trip following the planned routes, being continuously monitored in real time.
In fact, the real vehicles operation is always affected by a misalignment respect to the planned one, due to unavoidable approximation of theoretical values (trip time, energy consumption, battery capacity) and unexpected events (traffic conditions, time waste, technical defaults, …). Thus, a proper recovery procedure must be capable to tolerate a certain amount of error, up to not overtake physical or operational constraints, such as vehicles battery capacity or deliveries time windows. In our system Recovery and Update procedure

are launched when either real battery State of Charge or real vehicle position differ from the planned ones more than pre-specified threshold values.

The following Fig.6 shows a schematic example of route rearrangement when a "battery alarm" is acquired by the monitoring system from a vehicle during its delivering operation: the nearest available recharging point is immediately identified and a new recharge is inserted in the tour before next deliveries. Possible recharges previously planned are automatically deleted and other recharges are planned to permit the end of the tour, if necessary. No changes in the deliveries sequence are provided but only recharge rescheduling.

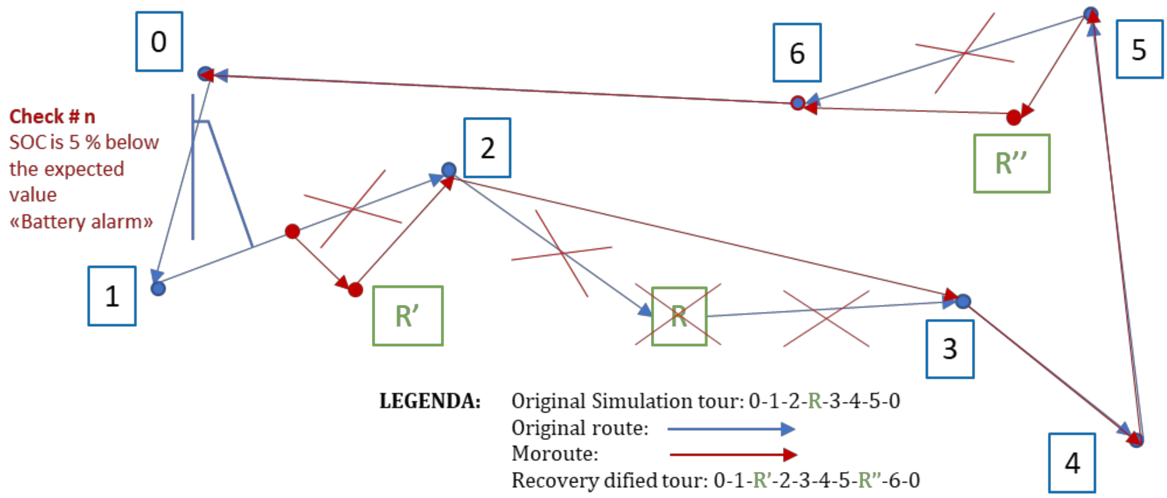

Fig.6 Recovery rationale

Vice versa, when a delay is registered respect to the schedule, a total rearrangement of the remaining deliveries is carried out, taking into account both destinations time-windows and remaining vehicle range, as well as available recharge opportunities, as schematically shown in the subsequent Fig.7.

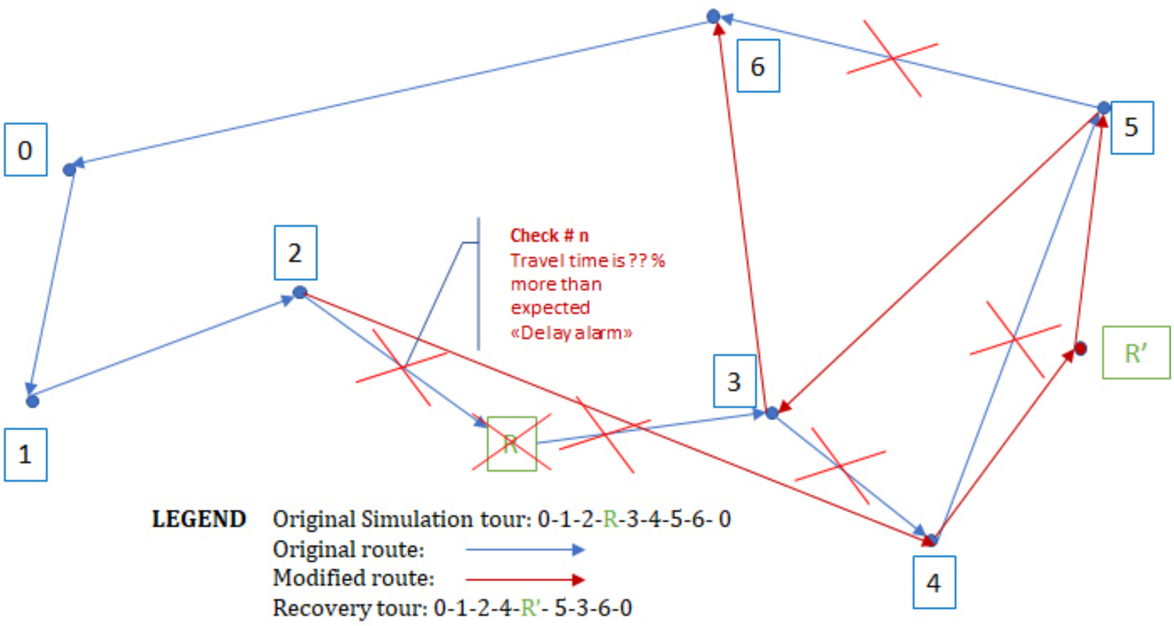

Fig.7 Update rationale

The check frequency has been set to 10 seconds. This requires to simulate the battery charge and vehicle position along the planned tour with a very high time resolution, at least less than 10 seconds, in order to determine expected values when a check respect to real conditions is carried out.

Periodically the distance between the real status and the planned status of the vehicle is computed for a set of parameters and compared with predetermined thresholds. If the distance between one of the considered parameters becomes larger than the corresponding threshold, the system automatically generates the files containing the required information to start a recovery or update for the vehicle. These processes can be repeated several times during the day in order to correct the path and the delivery process as many times as required by the forcing of the external conditions. Moreover, the recovery or update processes are run only for one vehicle per time, in order to allow to modify only the required paths and deliveries, without disturbing the other vehicles, on schedule at the time of launching, and therefore optimizing the time of recovery and update for each vehicle.

The system is built to acquire information from sensors onboard of vehicles. Yet, in our study the real status of the vehicles is simulated by adding a set of random perturbations to the planned delivery trips: every 10 seconds a delay of 10 seconds and an 0.01 kWh increase in battery discharge is randomly added with 20% probability to the actual status of the vehicle. Contrary to the real case, when both increments and decrements in the delay are possible, in this configuration only a monotonic increase is allowed, in order to test the system under an over-realistic stress.

Separate checks are carried on for discharge and delay in deliveries, in order to activate separate recovery processes. Battery status is checked every 5 minutes. Both absolute SOC value and deviation from expected discharge are monitored, in order to avoid unnecessary recharges when a vehicle is about to conclude its delivery trip. The chosen thresholds, that can be changed by the operator, imply to send a vehicle to a recharging station if its SOC is lower than 20% of its total capacity and if at the same time its value is 5% lower respect to the foreseen one. This is handled by the Recovery process, described above. In particular the Recovery resets all future planned recharging stops and plans an immediate new recharge as well as any other further recharge required up to the end of the delivery trip.

The second check is related to the Update process, and in particular to the delay of the vehicle respect to the expected position and performed deliveries. If the difference between the expected and performed deliveries at the time of check is larger than 3 (operator chosen parameter), the Update process is launched. As described in the case of the Recovery process, also in the Update process the planned path is reset and is recomputed in order to optimize the remaining deliveries by considering the updated status of traffic, using real time velocities associated to the arcs of the graph. Moreover, if required, new stops for recharging are planned up to the end of the delivery tour.

7. The monitoring system

In order to allow for the comparison between planned and real status of critical variables, a monitoring system from the field has been designed and partially tested, as described hereby.

7.1 Getting vehicle data

An embedded system has been developed, which is able to interface with the CAN BUS of the vehicle and transmit the collected data to a remote controller for subsequent processing.

The information of interest of the vehicle concerns the instantaneous position and speed and the state of charge (SoC) of the battery. The issue of capturing data from a moving vehicle in real time has been addressed in the past to pursue a variety of goals. Often, for example, the primary objective has been to study vehicle emissions and fuel consumption. Over time, different technologies aimed at capturing real-time data from the vehicle have been developed.

In any case, to achieve this goal it is necessary that an "Onboard Unit" (OBD), a tool aimed at data acquisition, is installed on the vehicle. It is therefore necessary to identify a so-called embedded system, able to connect to the standard OBD port of the vehicle, to acquire the data of interest, process them and transmit them to a monitoring and remote control platform (Fig.8).

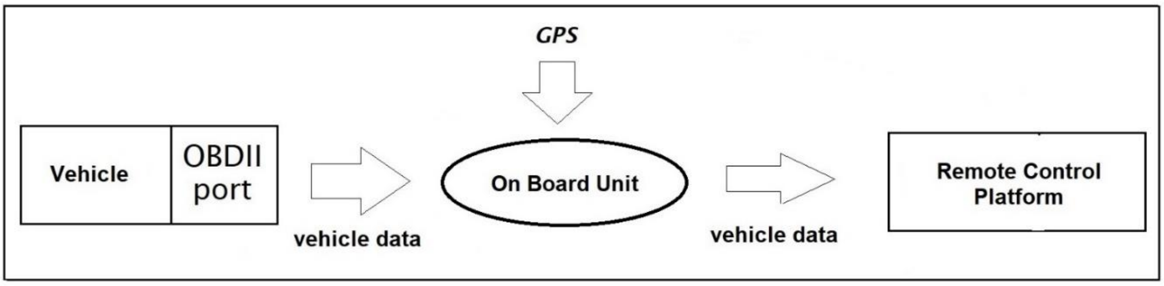

Fig.8 On-board unit information exchange

The system embedded on board the vehicle is complex, composed of several units, each with specific and well-defined tasks (Fig.9). To connect to the standard OBD port, capture the information and interpret it correctly, we used a CAN USB interface device.
It is able to read the messages exchanged on the CAN BUS of the vehicle and interpret them thanks to the use of special APIs usually written in a widespread programming language, such as C or Python. For this purpose, it is equipped with a DB9 serial port to connect to the vehicle's OBD port, and a USB output port to connect to the control device. The control device we used is a Raspberry PI 4 with a Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz processor, and 8GB LPDDR4-3200 SDRAM. The Raspberry PI device is equipped with the native Raspbian operating system based on the Debian Linux distribution. The acquisition software developed by ENEA Researchers and based on the API provided by the CAN USB device has been installed over the Raspbian operating system.

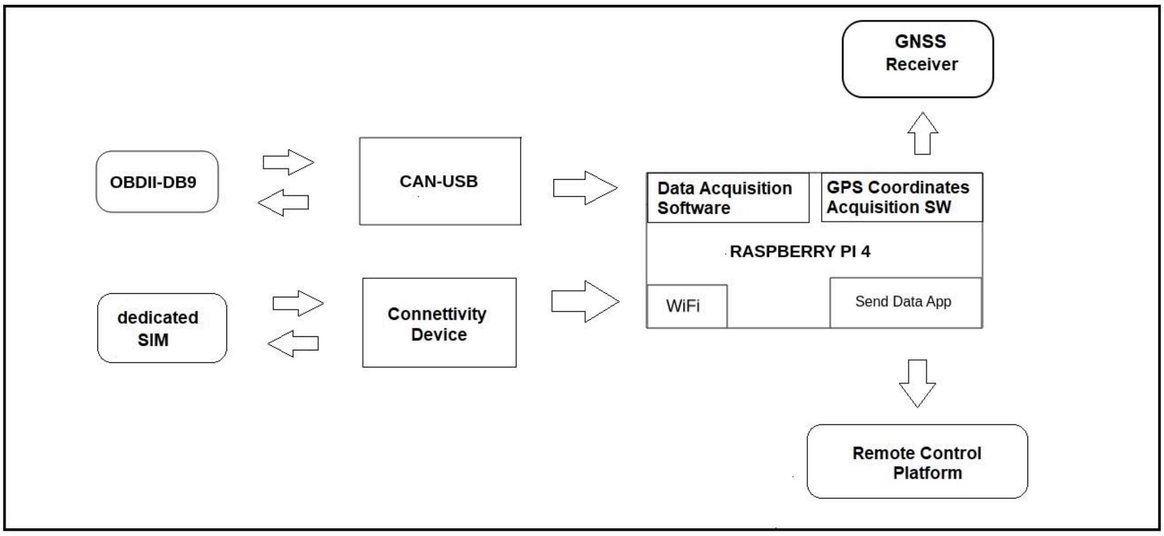

Fig.9 On-board unit architecture

These three processes are activated at regular intervals in time, to be synchronized with each other. The main process that manages the timing and synchronization of all other processes is the Scheduler process, based on the Linux crontab daemon on the Raspberry PI.
The scheduler, at fixed time intervals, activates the three other processes, with a delay from each other, so that the results of the processing can be collected and packaged in the form useful for transmission, and sent to the remote controller for further processing.
In the following Tab.1 the most relevant data that can be acquired from the vehicle are shown.

Field	Unit/format	Description
Data	YYYYMMDD	Date
Ora	hhmmss	Time
SoC	%	Battery State of Charge
motorRPM	rpm	Motor Angular rate
battA	A	Battery Charge Electric Current
battV	V	Battery Charge Voltage
AvBattery	W	Available Battery Power
Vvehicle	m/s	Vehicle Speed
qcComm	A	Quick Charge Electric Current
qcVoltage	V	Quick Charge Voltage
chargeRem	minute	Time to get battery fully charged

Tab.1 Data acquired from vehicles

7.2 Getting surrounding information

Since electric vehicles often have a limited range, to real-time optimize travels in the urban area, it is necessary to acquire the location of charging stations, in order to identify the unoccupied and available ones, closest to the vehicle when the battery needs to be recharged.

This information must be sent to the remote-control platform and must also be updated at regular intervals, in order to have a constant full knowledge of the (mapped) location of available charging stations, to be used when needed.

To acquire the free/busy status from the charging station, local magnetic field sensors are installed on the ground. The sensor measures the change in the Earth's natural (ambient) magnetic field caused by the presence of vehicles or other ferromagnetic objects close to it.

The information about the free/busy status of the charging station is sent by the sensor to a Local Gateway, which is able to communicate with the Remote Control Platform (Fig.10). At regular intervals during the day, the Remote Controller interrogates the Local Gateway to get information about all monitored charging seats, as listed above:

- position, expressed in terms of latitude and longitude coordinates;
- date and time of the detection;
- binary information about the occupation or not of the parking space.

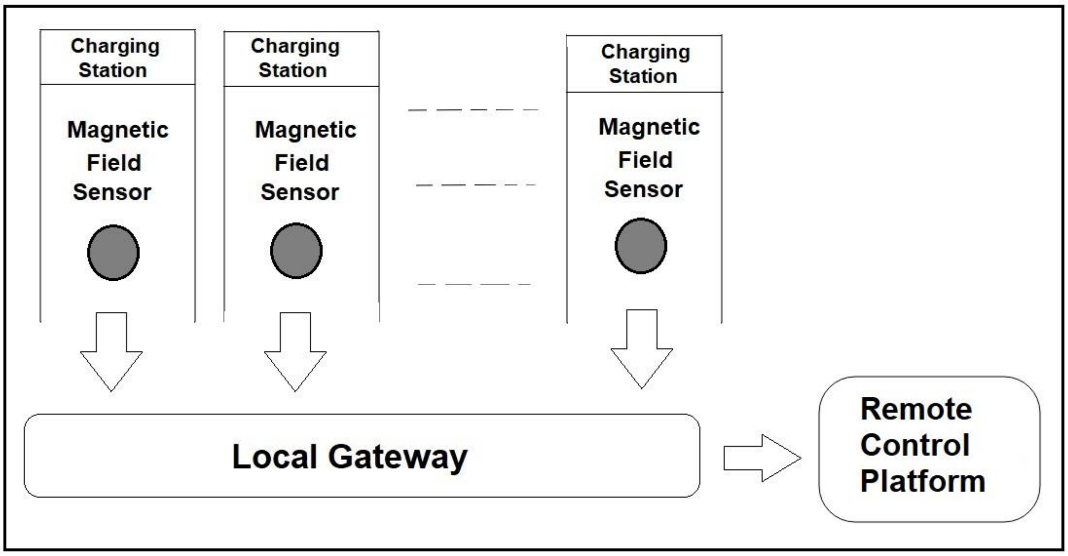

Fig.10 Architecture for acquisition of information from recharge and unloading stalls

8. The test case

Performance and effectiveness of the proposed system have been verified by implementing two real size testbeds containing 209 delivery points through the city of Rome, as shown in the Fig.11.

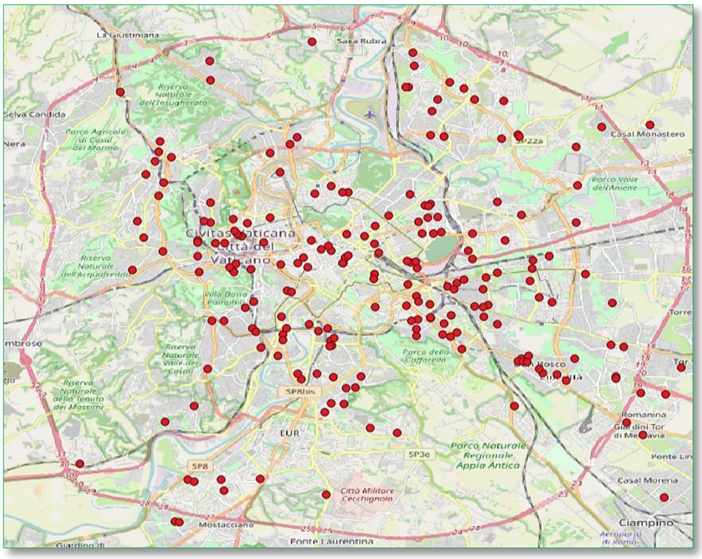

Fig.11 Testbeds' delivery points map

The differences between testbeds are related to the demand for each delivery point and the time-windows scattering, so that the second case results more challenging than the first one, as schematically reported in Tab.2.

Test #	N° of Delivery Points	Time Windows ranges [minutes from 00:00]	Total Demand [kg]	Total fleet capacity [kg]	Numbers of vehicles
1	209	(480-780), (520-780)	12,370	18,400	10
2	209	(480-780), (520-780) (500-650), (550-750)	18,362	18,400	10

Tab.2 Main testbeds' characteristics

The available vehicle fleet is the same for the two testbeds: two mini vans (450 kg capacity), two medium vans (1,100 kg capacity) and six small trucks (2,550 kg capacity).

A set of KPI has then been chosen in order to evaluate the quality of optimization performed in the two cases. Results are shown in Tab.3.

Performance Indicator	#1	#2
Total distance Traveled by all vehicles	610.3 km	1,137.4 km
Total time traveled by all vehicles	717.6 min	1,288 min
Objective function value	1,789.3	2,701.1
Capacity violation	0	0
Earliness	0	0
Tardiness	0	0
Travel constraint violation	0	0
Unit energy consumption	31.6 Wh/kg	29.7 Wh/kg
Number of used vehicles	7	10
Number of recharging by all vehicles	4	5
Running Time	274.3 seconds	271.4 seconds

Tab.3 Overall performance indicators of planning results

Results show that an increasing number of vehicles is needed as the demand gets larger, with consequent larger total travel times and distances.
Algorithm running times are similar since they mainly depend on the optimization parameters and not on demand characteristics such as time windows or total demand. For test #1, where seven vehicles are used for deliveries, four of which with scheduled recharges during their trips, vehicles performance indicators are reported in Tab.4.

#vehicle	DISTANCE TRAVELED TO LAST DELIVERY (KM)	TIME TRAVELED (MIN)	CAPACITY (KG)	UTILIZED CAPACITY (KG)	NUMBER OF DELIVERIES	CONSUMED ENERGY (KWH)	NUMBER OF RECHARGING
1654	64.93382	647.4999	1,100	826	13	18.78975	0
5381	101.9029	817.1348	2,550	2,264	38	64.38861	1
2843	89.43698	748.6876	2,550	1,777	29	53.44788	1
8464	76.37869	775.3624	2,550	1,772	30	43.4429	1
6184	125.9067	774.0042	2,550	1,500	29	71.56418	1
6185	66.24281	745.3154	2,550	2,162	37	42.2879	0
6188	72.68141	755.093	2,550	2,069	33	46.00743	0

Tab.4 Detail performance indicators of #1 testbed' planning results

A recovery procedure has been launched, when the real battery SOC of vehicle #2843 detected by the monitoring system was lower than expected, not allowing to perform all the remaining deliveries before the scheduled recharge.
With the information on the current position of the vehicle, the last delivery point and the battery state of charge, the Recovery function found the nearest recharging station and, after adding this charging point to the trip, updated the tour for the remaining deliveries.
The strings in Tab.4 represent the sequence of delivery and recharge points of the tour based on the result of the planning (P) and after the application of a Recovery (R). The points indicated with code zero (highlighted in red) within the tour represent the charging station. Delivery points in green represent the last delivery before applying the recovery procedure. The original recharge provided by the end of the planned tour is replaced with an earlier one and a second recharge is inserted at the very end of the updated tour, after all deliveries are carried out.

P	28	99	41	51	61	61	28	81	-	94	71	34	66	93	49	51	55	100	72	24	30	66	51	91	57	77	0	25	48	90	83	-
R	28	99	41	51	61	61	28	81	0	94	71	34	66	93	49	51	55	100	72	24	30	66	51	91	57	77	-	25	48	90	83	0

Tab.5 Vehicle #2483 Original (P) and updated (R) sequence of delivery and recharge points

The following figures show the rendering of original and updated tours by the User Graphic Interface of the ENEA platform that integrates the Optimal Deliveries modules described in this paper. Original tours are plotted with a semi-transparent line while the updated ones are marked with bold lines. Large part of the new paths is often over imposed to the old ones.
In Fig.12 an example of a Recovery result is shown on map. The process is activated just after the delivery at point 11 has been carried out, so that the vehicle is diverted toward the closest recharging station. The vehicle is then sent back on the original path in order to restart the delivery sequence from delivery number 12.

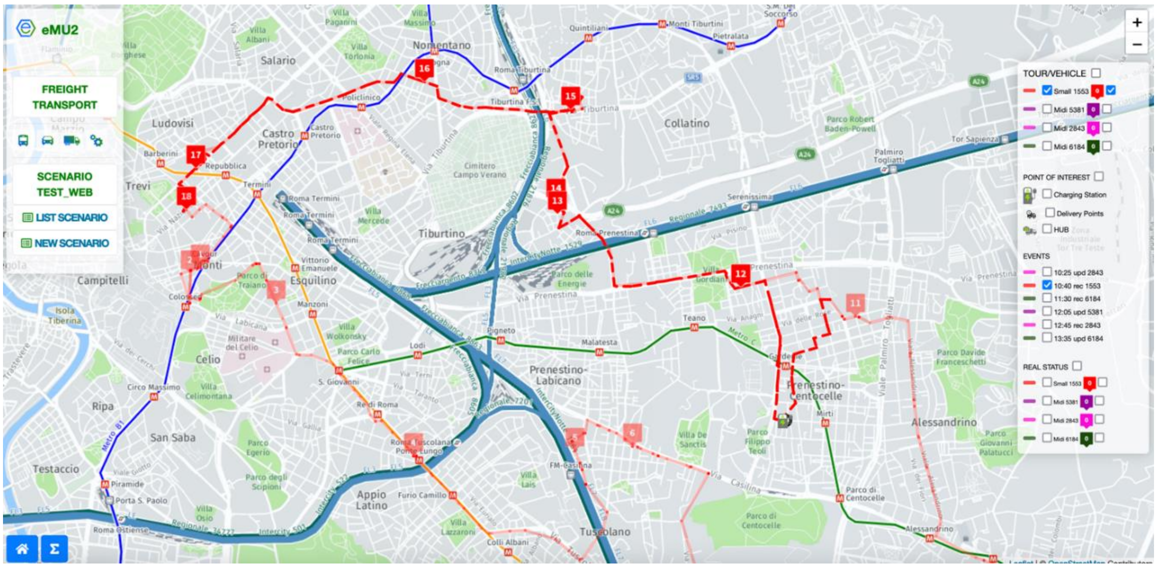

Fig.12 Graphical rendering of a Recovery' results, when a default in battery SOC is detected

In Fig.13 an example of Update is shown for another vehicle. The Update starts from the delivery number 18, due to an excess of delay respect to scheduled time; the path is deeply modified due to the updated speeds associated to the arcs of the graph.

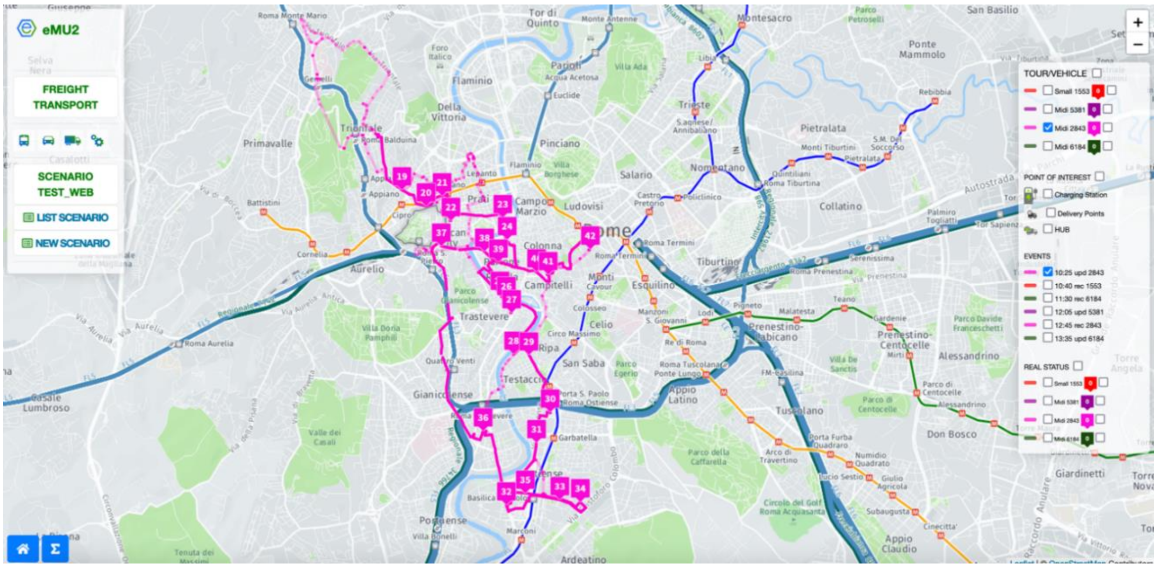

Fig.13 Graphical rendering of an Update' results, when a default in battery SOC is detected

9. Remarks

This paper proposes a general methodology to optimize BEVs operation in city logistics, taking into account possible recharge needs. Energy refuels are considered since the off-line delivery planning, adding a new complexity to the classic VRP with Time-Windows. Moreover the research proposes the possibility of activating a recovery process if unexpected events, such as battery defaults or delays due to traffic congestion or other inconveniences occur, to be monitored on-field. The performance of the proposed tool has been investigated by implementing two real-size tests consisting of a large number of delivery points and vehicles. Through the tests, different performance indicators of the initial optimization procedure have been calculated, showing a good level of results, as well as of the real-time rearrangement, both in case of additional recharge needs and delays, corresponding to the expected results.

The system is aimed at building an integrated facility to plan and handle deliveries using electric vehicles, including online monitoring of each vehicle status and of the available charging stations. All available information is handled by a central monitoring station, capable to prepare the initial planning, receive information from the field, and react to unexpected events, in order to rearrange the delivery plan to correctly fulfill the complete delivery plan.

More work needs to be performed in order to integrate the system with real acquisition of the traffic status, needed for a better evaluation of the update processes. Though, the described platform can be a good candidate for both delivery operators and city administrations. The formers to better plan and handle delivery schedules with the additional constraints related to electric vehicles and their limited autonomy, the latter in order to better handle three crucial urban mobility factors: a) freight vehicles flows integration into ordinary traffic; b) early detection of traffic anomalies through floating fleets which can operate as additional traffic sensors , c) freight vehicles parking slot and recharging infrastructure design and their real time optimal handling, Administrators functionalities require to operate the proposed platform at an upper centralized level, collecting data from single last-mile operators and, possibly, if commercial agreements are dealt, to set up public-private infrastructures such as Urban Distribution Centers allowing an even more coordinated last-mile handling.

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Image Sources

Fig.1: ENEA, Italian Agency for New technologies, Energy and sustainable development, 2022;

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Fig.12: ENEA Italian Agency for New technologies, Energy and sustainable development, 2022;

Fig.13: ENEA Italian Agency for New technologies, Energy and sustainable development, 2022.

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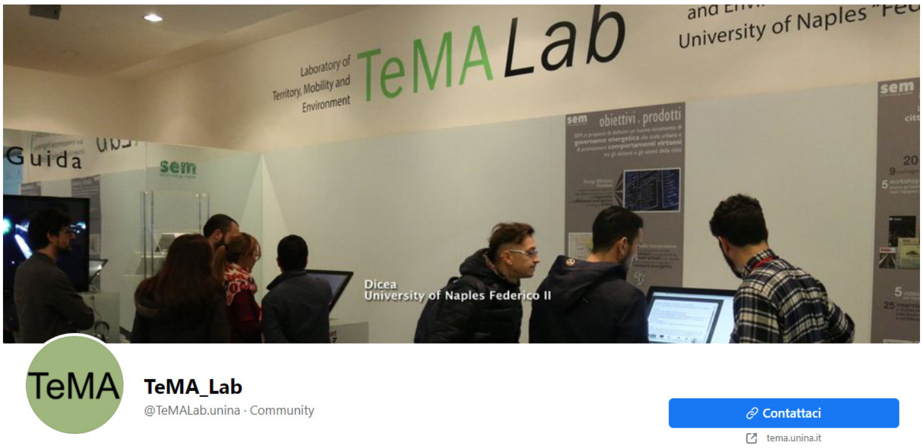

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Evaluation of sustainability of university campuses

The evaluation of Bursa Uludag University Görükle Campus according to UI GreenMetric World University Ranking

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Abstract
In this study, a total of six categories belonging to the International GreenMetric (UI GreenMetric) index by applying observational and physical analyses to Bursa Uludag University (BUU) Görükle Campus; structure and infrastructure (15%), energy and climate change (21%), waste (18%), water (10%), transportation (18%) and education (18%) and 51 evaluation criteria that define these categories. As a result of the evaluation, the university's estimated UI GreenMetric score for 2021 was calculated. As a result of the calculations, the estimated total success of BUU Görükle Campus was determined as 5,775. The highest success rate was obtained from the Education and Research (ED) (97.22%) category, while the lowest success rate was obtained from the Energy and Climate Change (EC) (39.29%) category.

Keywords
Sustainability; Green Campus; UI GreenMetric University Ranking.

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1. Introduction

One of the main concerns of generations living in the 21st century is called sustainable development. The pursuit of sustainable development has become a priority for both public and private organizations that aim to promote social, environmental and economic development without compromising the well-being of future generations. Reducing social inequalities and improving conditions, mitigating and adapting to climate change, and protecting cultural and natural heritage are some of the critical challenges organizations must focus on when creating wealth for communities that can thrive over time (Franco, 2022). Today, governments, research centers and local communities play a key role in promoting sustainability, which leads to increased commitment and work to identify the most impactful and harmful factors on the environment while disseminating education for sustainable development. The use of sustainability indicators has become a common methodology as a tool for reporting on the state of the economy or the state of the environment, clarifying goals and setting priorities, evaluating policy performance and monitoring progress towards sustainable development (Spadora et al., 2022). For this, attitudes and policies in social, economic and environmental fields need to be implemented not only in people's daily lives but also by institutions (Faga Iglecias Lemos et al., 2018).

Universities have been conceptualized as 'small cities' in their pursuit of sustainability due to their size and the impact of campus activities on the environment and society (Alshuwaikhat & Abubakar, 2008; Lauder et al., 2015). Planning and designing a new campus that responds to needs such as accommodation, work, rest and transportation is almost no different from planning and designing a city (Düzenli et al., 2017). For this reason, a university campus, besides being a natural part of the city ecosystem that plays a role in environmental sustainability, has the responsibility of directing the society to a sustainable future for a sustainable world (Abdurrahman, 2003; Hakim & Endangsih, 2021; Altun & Zencirkıran, 2021).

The importance of the role of universities in the development of sustainable development, which plays a key role in the development of society and the ecosystem, has been widely accepted. For this reason, ensuring campus sustainability has become a global concern for universities (Ak, 2022). The world's leading universities are taking steps to combat climate change by reducing their carbon footprints and thus managing their sustainability. Today, universities all over the world want to set an example with their environmentalist approaches and sustainable activities as well as their academic achievements. At this point, many systems have emerged that evaluate universities through sustainability approaches (Altun & Zencirkıran, 2021). The most widely accepted among these is the UI GreenMetric World University Ranking System, created by the University of Indonesia in 2010 and considered the first step towards a global ranking of the sustainable behaviour of universities (Grindsted, 2011). As a result of ranking the system campuses according to their sustainable approaches, online survey results are provided about the current conditions and policies regarding the green campus. The purpose of the system; is by drawing the attention of university leaders and stakeholders to combating global climate change, saving energy and water, recycling and green transportation, it is ensured that more importance is given to these issues in universities. As a result, it is expected that the importance given to behavioral change and environmental sustainability in universities will increase, along with solutions to economic and social problems related to sustainability. Identifying leading universities in this regard will guide other universities (Anonymous, 2022a).

In line with the sustainability goals, it is important to fully understand the current situation of the campus and to make the feasibility to plan the next step. To promote sustainable campus development, issues arising during development should be analyzed and possible approaches and action plans explored accordingly (Tan et al., 2014). This study, it is aimed to shed light on the progress of green campus development to understand the current situation of all initiatives to run a campus that covers sustainability in all its aspects and the upgrade of the campus to a green campus. In this direction, BUU Görükle Campus was evaluated according to the GreenMetric and the findings were interpreted with a critical perspective.

2. Material and Method

2.1 Research area

The main material of the study consists of BUU Görükle Campus and UI GreenMetric World Universities Ranking Guide and UI GreenMetric Measurement System criteria and indicators in the guide.
BUU Görükle Campus is located in the Marmara Region of Turkey, in the west of Bursa province. Located in an urban area, the campus lies between 40°13'26" latitude and 28°52'14" longitude and is 18 km from the city centre (Fig.1). The area of the campus is 14.26 km². In the 2021-2022 academic year, the total population of BUU Görükle Campus is 55065 (51,196 students, 2,074 academic and 1,795 administrative staff) (Altun, 2022).

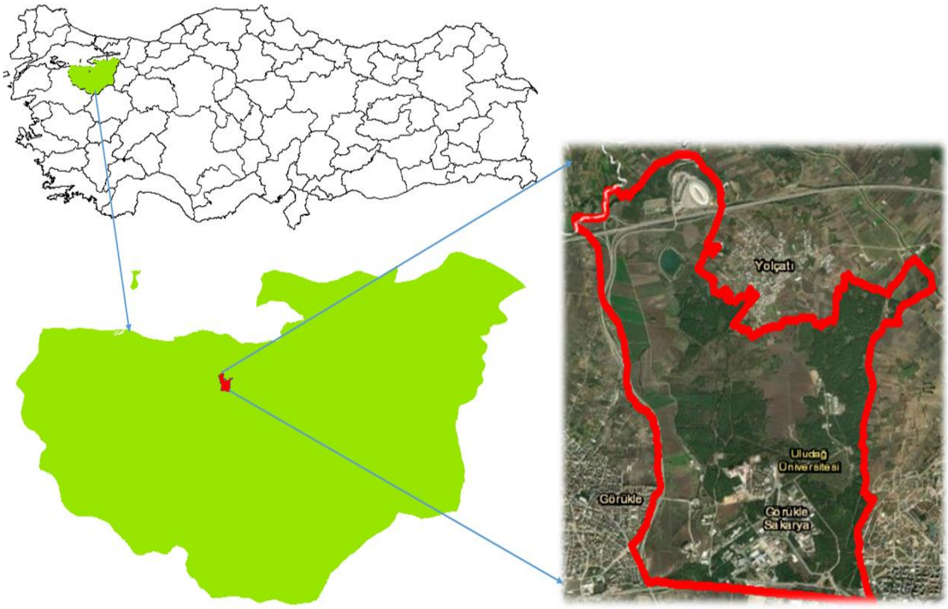

Fig.1 Location of the research area

2.2 UI GreenMetric World Universities Ranking

In the UI GreenMetric index, which offers universities from all over the world an online survey where they can evaluate their current situation and policies regarding sustainability and compare the results with other universities, 6 categories in total are Structure and Infrastructure (15%), Energy and Climate Change (21%), Waste (18%), Water (10%), Transport (18%) and Education (18%) (Tab.1), and 51 assessment criteria define these categories (see Supplementary Tab.) (Anonymous, 2022b).

	Category	Number of evaluation criteria	Maximum points (nr)	Maximum points (%)
1	Setting and infrastructure (SI)	11	1,500	15
2	Energy and climate change (EC)	10	2,100	21
3	Waste (WS)	6	1,800	18
4	Water (WR)	5	1,000	10
5	Transportation (TR)	8	1,800	18
6	Education and research (ED)	11	1,800	18
	Total			100

Tab.1 Categories and their weights used in the GreenMetric ranking

2.3 Method

This study covers the evaluation of BUU Görükle Campus by taking as reference the UI GreenMetric 2021 guide and the criteria/indicators in the guide (Tab.1).
Stages of work:

- providing information and documents from BUU management;
- collecting literary, visual, geographical, environmental and digital data related to the study area;
- field studies and measurements of BUU Görükle Campus;
- analyzing the data obtained in the ArcGIS program and obtaining estimated results based on the analyzes made (in case the requested data cannot be obtained or is not available on the campus, it is evaluated by writing 0 in the score section);
- developing proposals within the scope of sustainable/green campus planning.

3. Results

According to the calculations, the total score obtained by Bursa Uludag University Görükle Campus from the IU GreenMetric Word University ranking is 5775. The distribution of the total score according to the categories is given in Table 2.

Category	Maximum Points	Score	Success percentage
Setting and infrastructure (SI)	1,500	1,050	70.00
Energy and climate change (EC)	2,100	825	39.29
Waste (WS)	1,800	975	54.17
Water (WR)	1,000	400	40.00
Transportation (TR)	1,800	775	43.06
Education and research (ED)	1,800	1,750	97.22
Total score	10,000	5,775	57.75

Tab.2 Percentage of success of BUU Görükle Campus according to criteria and parameters

3.1 Setting and infrastructure (SI)

The ratio of the scores obtained by each of the criteria belonging to this category to the maximum score is as follows. The full score was obtained from 27.3% and 0 points were 27.3% of the criteria in this category (Supplementary Tab.1, Fig.2).

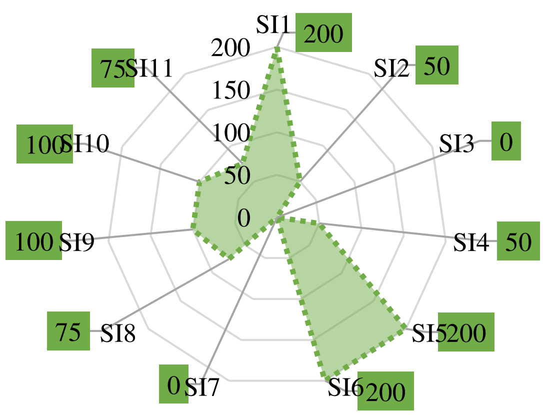

Fig.2 Ratio of the score obtained in the building and infrastructure category to the maximum score

In order to evaluate the criteria of the building and infrastructure category, a map of the land use of the campus was created (Fig.3). The areal values of the campus land uses are given in Table 3 and the proportional distributions of the land uses are given in Figure 4.

Land Use Classes	Area (km^2)	Land Use Classes	Area (km^2)
Green space	6,24	Parking lot	0,08
Farmland	2,61	Roads	1,79
Bare lands	1,94	Pond	0,04
Residential area	1,28	Other	0,28

Tab.3 The amount of land use classes of BUU Görükle Campus

When the land uses were classified, it was seen that 43.73% of the existing areas in the campus belong to green areas (forest-woodland-garden and landscape areas), followed by agricultural lands and bare lands (Tab.3, Fig.4).

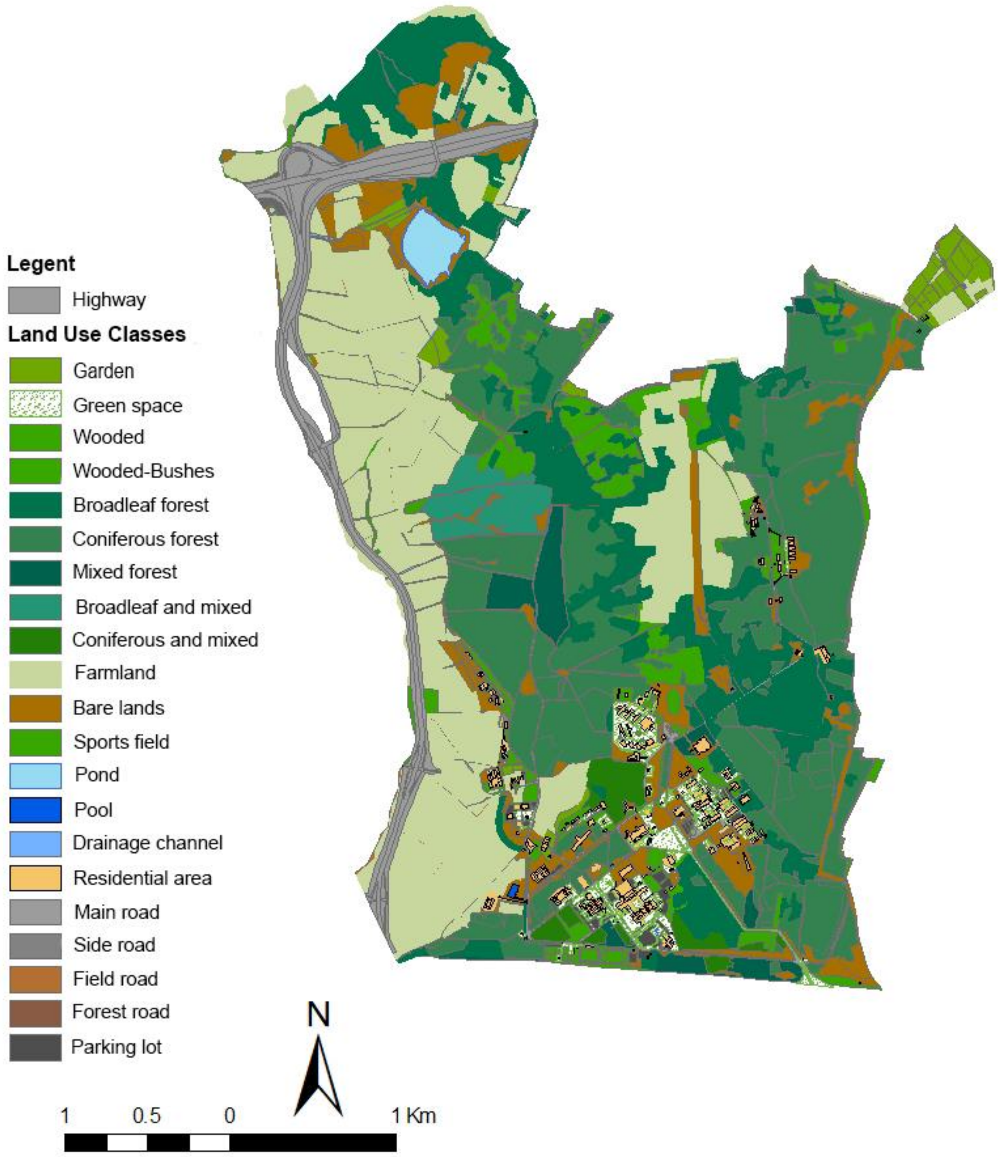

Fig.3 The land use map of BUU Görükle Campus

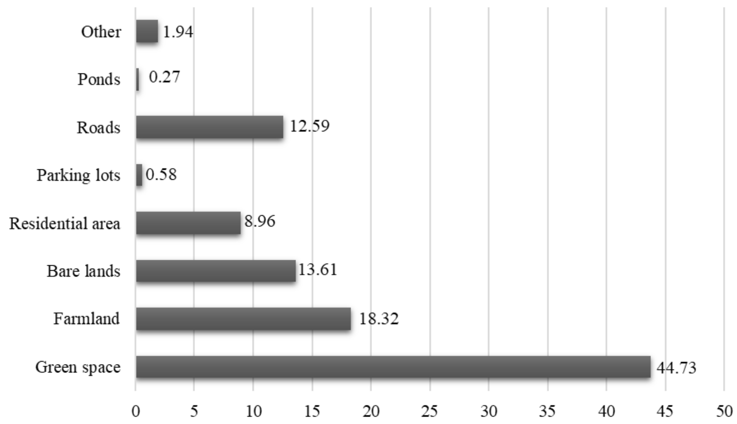

Fig.4 Distribution of land uses of BUU Görükle Campus (%)

The buildings on the campus constitute 8.96% of the total land (Fig.4). The buildings are used for educational purposes at a high rate of 31.57% (Fig.5).

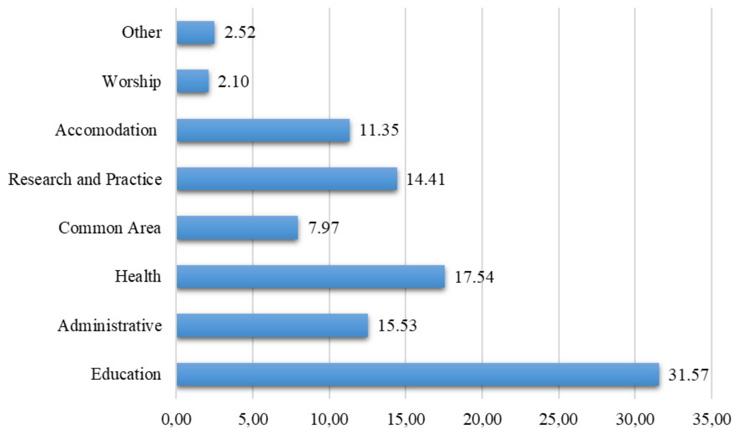

Fig.5 Proportional distribution of buildings in BUU Görükle Campus residential areas (%)

91.04% of BUU Görükle campus land consists of open spaces. 43.73% of these open areas are green spaces. 69.80% of the open green areas within the campus borders are forests, 22.33% of them are wooded areas, and only 7.87% of the open green areas are anthropogenic landscape areas (Tab.4, Fig.6).

Green Space Classes	Area (km^2)
Forest	4.4
Wooded	1.4
Anthropogenic green spaces	0.5

Tab.4 The amount of green areas in BUU Görükle Campus

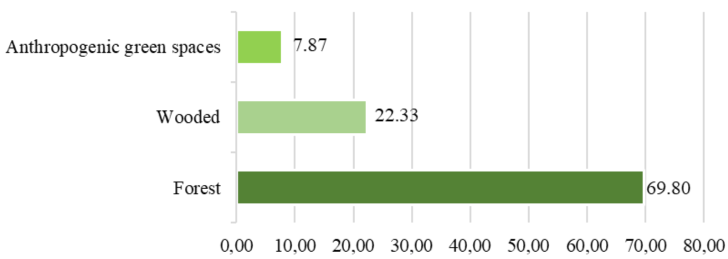

Fig.6 Distribution of green areas in BUU Görükle Campus (%)

3.2 Energy and climate change (EC)

The ratio of the scores obtained by each of the criteria belonging to the EC category of the campus (to the maximum score is as follows. While 0 points were obtained from 20% of the criteria in this category, no full scores were obtained from none of the criteria is remarkable (Supplementary Tab.1, Fig.7).

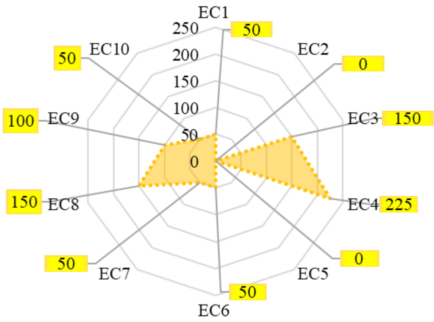

Fig.7 Ratio of the score obtained in EC category to the maximum score

The total energy used in BUU Görükle Campus for purposes such as lighting, heating, cooling, and operation of university laboratories in the last 12 months is 20,959,942,640 kWh. In 2020, the highest energy consumption on the campus was realized in July, August and September. Again in 2020, the ratio of total electricity use within the campus to the total campus population is 380,640,02 kWh.

3.3 Waste (WS)

The ratio of the scores obtained by each of the criteria belonging to the WS category of the campus to the maximum score is as follows. The full score couldn't be obtained from any of these categories. The full score was obtained from 20% of these categories and 0 points were obtained from 40% of them (Supplementary Tab.1, Fig.8).

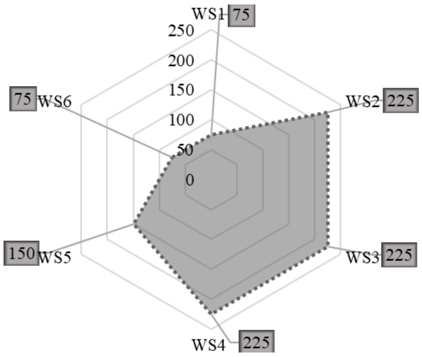

Fig.8 Ratio of the score obtained in the WS category to the maximum score

The wastes generated and recycled within BUU Görükle Campus are recorded and the recycling amount is systematically entered into the nationwide waste monitoring system. There are recycling bins in the buildings on the campus. In this way, organic wastes and recyclable materials (plastic, paper, glass, aluminium, etc.) are separated and sent for recycling. Organic wastes are collected in separate containers. The collected wastes are sent to the landfill by Bursa Metropolitan Municipality. Construction wastes generated on the campus are collected by the district municipality and sent to the Inert Waste Storage area. Waste batteries are collected separately in special containers. The collected batteries are sent to the Exitcom Recycling centre. Toxic wastes produced in BUU Görükle Campus are collected in laboratories within the campus, and when a certain amount of toxic waste is collected, the contracted waste management company is called to collect the waste.

It is connected to the sewerage system of the Western Wastewater Treatment Plant, for which Bursa Water and Sewerage Administration (BUSKİ) is responsible for the sewer line management of BUU Görükle Campus. The campus' wastewater line is connected to the sewage system of the city's Western Wastewater Treatment Plant. The treated wastewater is discharged into the Marmara Sea. However, there is no recycling program for the wastewater produced by the university (Anonymous, 2022c).

3.4 Water (WR)

The ratio of the scores of each of the criteria belonging to the WR category of the campus to the maximum score is as follows. The full score was obtained from 20% of these criteria and 0 points were obtained from %40 of them (Supplementary Tab.1, Fig.9).

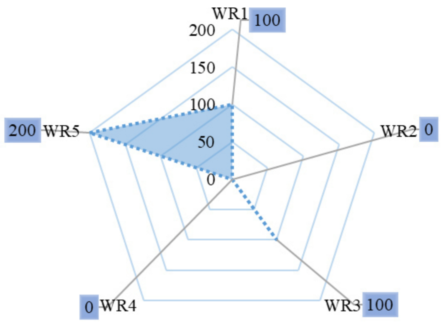

Fig.9 Ratio of the score obtained in the WR category to the maximum score

Yolçatı (Göbelye) pond, which has a maximum operating volume of 645,000 m^3 and an asset volume of 630,000 m^3, is located within the borders of BUU Görükle campus and the water of the pond is used for irrigation of agricultural lands in the campus.

3.5 Transportation (TR)

The ratio of the scores obtained by each of the criteria belonging to the TR category of the campus to the maximum score is as follows. It is remarkable not to get a full score from any of the criteria while getting 0 points from 12,5% of the criteria in this category (Supplementary Tab.1, Fig.10).

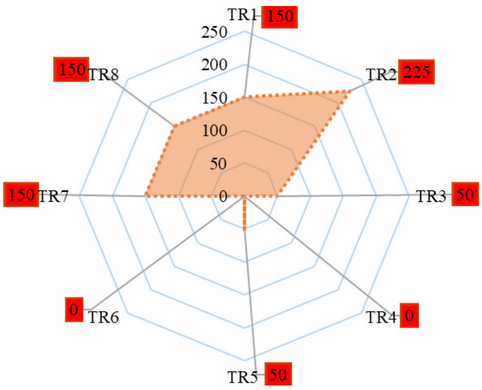

Fig.10 Ratio of the score obtained in the TR category to the maximum score

Users providing access to the campus are permanent users (students, academics and administrative staff) and temporary users (service personnel working in university enterprises, patients coming to BUU Medical Faculty Hospital and patient relatives). The average value of the number of vehicles and motorcycles entering BUU Görükle Campus daily was obtained from the camera images taken by BUU security centre. As a result of the examination of the camera images taken from the Görükle Campus security centre, it has been determined that the average number of vehicles entering the campus per day is 5329, and the number of engines is 151. The ratio of the total number of vehicles to the total campus population is 0.10. There are 46 shuttle vehicles operated by the university administration to reduce private vehicles on campus, bus stops that allow transportation to many points of the city, as well as metro lines and campus shuttles.

A carbon footprint calculation based on transportation was made in BUU Görükle Campus. The total carbon footprint (CO^2 emissions in metric tons in the last 12 months) at BUU Görükle Campus is 19561.57 metric tons. The ratio of the total carbon footprint produced on the campus to the total campus population (metric tons per capita) is 0.36 metric tons.

3.6 Education and research (ED)

The ratio of the scores of each of the criteria belonging to the ED category of the campus to the maximum score is as follows. The full score was obtained from 9.1% of the criteria in this category, and 0 points were obtained from none of the categories (Supplementary Tab.1, Fig.11).

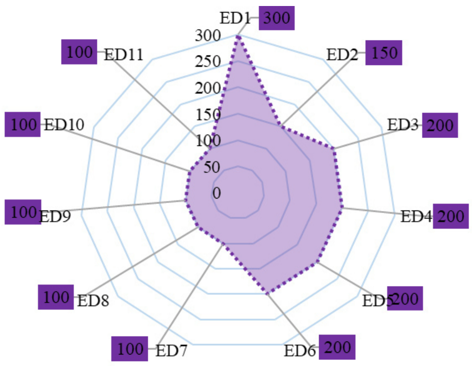

Fig.11 Ratio of the score obtained in the ED category to the maximum score

4. Discussion and conclusion

Based on the evaluation of 6 categories of UI GreenMetric standards, the estimated score obtained from the research results regarding the evaluation of the Bursa Uludag University Görükle Campus sustainable campus concept was 5775 (Tab.2). According to the sustainability report published by BUU sustainability office for the first time in 2021, the 2021 success score of BUU Görükle Campus is 6475 (Anonymous, 2023a). It is seen that there is a 500-point difference between the results obtained in this study and the official results announced by the university. With the data containing the results of our evaluations, it was seen that the differences occurred mostly in the SI and TR categories (Fig.12). This difference can be explained as the inaccessibility of data because this study is a master's thesis and necessarily covers a certain period, some data were not included in the web page user interface during the period (including the pandemic period). The main reason for this difficulty is that some of the literary, visual, geographical, environmental and digital data cannot be shared with individuals within the framework of some legal regulations in our country.

Evaluating the success rates of the campus in each category separately and examining the sustainable practices of universities with high success scores in the GreenMetric rankings will contribute to the sustainability vision of the university.

The total green space of the campus can meet the green space needs of the campus population. In this way, 70% success was achieved in the SI category (Tab.2). To increase the success score obtained in this category, the water permeable area surface and the amount of planted area on the campus should be increased (Supplementary Tab.1). For example, the University of Connecticut, called the USA Tree Campus, has achieved high success in the SI category, thanks to its Tree Care Plan that provides a safe and sustainable campus environment. The purpose of the University of Connecticut Tree Care Plan; making the most suitable species selection for the campus, promote species diversity in the tree population, protect valuable trees during construction works, appropriately replace trees that are lost due to disease and death, track tree planting and removal processes in the GIS environment, and campus residents respecting trees and provides value (Anonymous, 2023b).

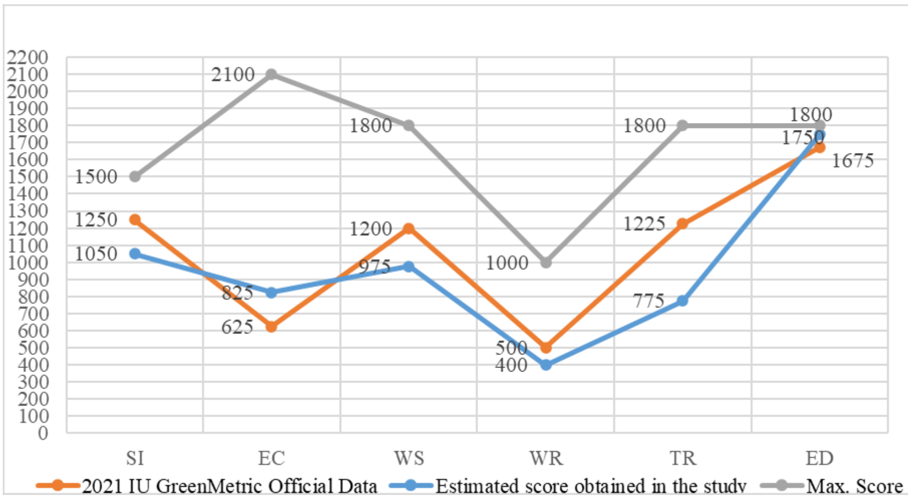

Fig.12. Comparison of the estimated score obtained in the study and the official score of the BUU 2021 IU GreenMetric to the maximum score

54%, 43% and 40% success was achieved in waste, transportation and water categories, respectively (Tab.2). This rate indicates that success below the average was achieved in the aforementioned categories. Establishing a comprehensive recycling program for university wastes in the waste category and adopting innovative solutions, especially for the disposal of sewage waste will increase the score obtained in this category (Tab.2). For example, at Nottingham Trend University, trash cans and signage markings are placed almost everywhere on campus to maximize access to recycling. In addition, with the "Pack for Good" project, 19,467 bags of clothing were donated by students in Nottingham during 2021/22, thus removing 155.5 tons of items from the landfill, saving 917,712 kg of carbon emissions and collecting 272,104 pounds for the British Heart Foundation (Morrell, 2022). Another example of waste management is the University of California wastewater treatment plant. Approximately 1.2 million gallons of wastewater are produced every day on the 5,300-acre campus. With a sanitary sewer collection system, the wastewater discharged from all campus facilities or spilt into the sewer is transported to the treatment plant for processing, where it is made available for use in animal shelters. This innovative sustainable practice helps the campus reduce its waste and carbon footprint while saving approximately $50,000 per year in costs (Anonymous, 2023c).

Reducing the use of vehicles on the campus and expanding the ring service, bicycle use and pedestrian transportation will ensure higher scores in this category. The main deficiencies are the widespread use of vehicles on the campus, the ring service, the use of bicycles and the lack of pedestrian transportation. In this sense, the Almabike Project carried out at the University of Bologna is a good example of popularizing the use of bicycles on campuses. Within the scope of the project, smart bicycles were designed to be given to students free of charge and 600 units were produced in the first place. In case of unauthorized use of bicycles with GPS technology, both movement and stopping stages are tracked through a push-mail system that alarms. In addition, a new public bicycle path was opened in partnership with the university and the municipality to promote the use of bicycles between the campus and the city, and 500 new parking spaces were provided in the city. Following the end of the project, it was determined that the use of bicycles on campus increased from 11% to 24% (Battistini et al., 2022; Anonymous, 2023d).

In the water category, zero points were obtained in both categories due to the absence of a recycling program for the wastewater produced on the campus and the absence of a treatment system (Supplementary Tab.1).

This situation shows that a project should be carried out to recycle the wastewater produced in the campus. An online water treatment facility at the University of Connecticut is a case study in this regard. The facility draws wastewater with a chlorine contact tank and processes the water with membrane microfiltration and ultraviolet light (UV) disinfection. The recovered water is transferred to a finished water storage tank and then pumped for distribution after chlorination. The treated water corresponds to 20% of the drinking water demand on the campus (Anonymous, 2023e).

The lowest achievement in the campus was achieved on the energy category with 39% (Tab.2). It is seen that the lack of attention to the use of renewable energy on the campus, the fact that the smart building application has not been implemented yet and the use of energy-efficient devices in the existing buildings has not been widespread, negatively affecting the sustainability of the campus. Wageningen University is producing the Akifer Thermal Energy Storage system project, which uses the green electricity produced on campus for the heating and cooling of the buildings and greenhouses on the campus. Aquifer Thermal Energy Storage is a sustainable energy source in which heat and cold are stored using a heat exchanger (counter-current device) in a sand pack carrying water 90 meters deep in the ground. This system, it is aimed to cool the buildings with underground water coming from cold wells in summer and to heat them in winter by pumping the groundwater with a heat pump over the same heat exchanger. The project, it aims to save more than 1 hm^3 of natural gas per year (Anonymous, 2023f).

The highest achievement in the campus was achieved in the education category (97%) (Tab.2). In 2020-2022, it achieved the highest success in the ED category at BUU Görükle Campus. This is due to the fact that the ratio of the number of sustainability-related courses to the total number of courses is 25.24%, and the total number of sustainability-related activities is more than 182 (eg. conferences, workshops, awareness raising, hands-on training etc.), the number of scientific publications on sustainability is 5900, and the average research fund of the last 3 years allocated to sustainability research is 934,000 dollars (Anonymous, 2022d).

It is seen that BUU Görükle Campus, which was included in the ranking from 335th place in 2021 with 6475 points, achieved a total of 6740 points in 2022, but took 357th place in the ranking (Anonymous, 2023a; Anonymous, 2023g). This result shows that the sustainable activities carried out on the campus lag behind other world universities. To increase the success achieved, this report needs to be renewed every year and further enriched with various activities and practices. To increase sustainability success of the university and to improve its place in the ranking, the activities planned by the university administration and announced on the web page of the university's sustainability office are as follows (Anonymous, 2022e; Anonymous 2022f; Anonymous 2023h):

- regulation of campus traffic: regulation of traffic signs, renewal of road lines, orderly and safe parking rows, control of on-campus vehicle speeds;
- in-campus lighting: determining the dark spots on the campus and using lighting elements that benefit from renewable energy sources at these points;
- security of forest areas: taking smart security measures in cooperation with the University Police Department at the entrance and exit of the campus forests;
- hazard notification: developing and executing applications that can be used by both students and staff to detect dangerous situations that may occur on campus;
- making a functional map of the campus: creating an interactive map where the features of the campus are accessible from different aspects (security, waste management, energy management, etc.);
- waste management: converting collected electronic wastes into economic value in partnership with Akademi Çevre, Vodafone and BalkanTürksiad, creation of computer and coding classes with the income obtained;

- rainwater harvesting: to use the rainwater to meet the cleaning and irrigation needs of the campus, operations such as connecting the rainwater gutters created on the roof surfaces to the common system and accumulating the collected rainwater in underground tanks.

In addition to the goals that BUU Görükle Campus plans to achieve in order to reach the highest level that can be achieved in terms of energy, water consumption, construction, waste, food and beverage and mobility, and to increase its UI GreenMetric score; equipping the constructed buildings with a sustainable air conditioning system, generating the energy to be used in the buildings with solar panels, using smart devices for lighting and benefiting from renewable energy sources, transforming all kinds of waste produced in the campus into economic value, providing a healthy lifestyle for the residents of the campus with sustainably produced food , keeping food waste to a minimum and reusing organic waste as compost, establishing a sustainable mobility program that supports transportation by public transport, electric vehicles and bicycles, and protecting the campus with its diverse plant and pest communities in mind, and transforming it into a living laboratory where students and researchers work can be cited as examples of activities that should be evaluated.

Supplementary

No	CRITERIA	Point	Weighting
1	**Setting and Infrastructure (SI)**		**15%**
SI1	The ratio of open space area to total area	200*	200
SI2	Total area on campus covered in forest vegetation	100*	50
SI3	Total area on campus covered in planted vegetation	200*	0
SI4	Total area on campus for water absorption besides the forest and planted vegetation	100*	50
SI5	The total open space area divided by total campus population	200*	200
SI6	Percentage of university budget for sustainability efforts	200	200
SI7	Percentage of operation and maintenance activities of building during Covid-19 pandemic	100*	0
SI8	Campus facilities for disabled, special needs and or maternity care	100*	75
SI9	Security and safety facilities	100*	100
SI10	Health infrastructure facilities for students, academics and administrative staff's wellbeing	100*	100
SI11	Conservation: plant, animal and wildlife, genetic resources for food and agriculture secured in either medium or long-term conservation facilities	100*	75
Total		1500	1050
2	**Energy and Climate Change (EC)**		**21%**
EC1	Energy efficient appliances usage	200	50
EC2	Smart building implementation	300	0
EC3	Number of renewable energy sources on campus	300	150
EC4	Total electricity usage divided by total campus' population (kWh per person)	300	225
EC5	The ratio of renewable energy production divided by total energy usage per year	200	0
EC6	Elements of green building implementation as reflected in all construction and renovation policies	200*	50
EC7	Greenhouse gas emission reduction program	200	50
EC8	Total carbon footprint divided by total campus' population (metric tons per person)	200*	150
EC9	Number of innovative program(s) during covid-19 pandemic	100*	100
EC10	Impactful university program(s) on climate change	100*	50
Total		2100	825

3	**Waste (WS)**		**18%**
WS1	Recycling program for university's waste	300	75
WS2	Program to reduce the use of paper and plastic on campus	300	225
WS3	Organic waste treatment	300	225
WS4	Inorganic waste treatment	300	225
WS5	Toxic waste treatment	300	150
WS6	Sewage disposal	300	75
Total		1800	975

4	**Water (WR)**		**10%**
WR1	Water conservation program & implementation	200*	100
WR2	Water recycling program implementation	200*	0
WR3	Water efficient appliances usage	200	100
WR4	Consumption of treated water	200	0
WR5	Percentage of additional handwashing and sanitation facilities during Covid-19 pandemic	200*	200
Total		1000	400

5	**Transportation (TR)**		**18%**
TR1	The total number of vehicles (cars and motorcycles) divided by total campus' population	200	150
TR2	Shuttle services	300	225
TR3	Zero Emission Vehicles (ZEV) policy on campus	200	50
TR4	The total number of Zero Emission Vehicles (ZEV) divided by total campus population	200	0
TR5	Ratio of ground parking area to total campus' area	200	50
TR6	Program to limit or decrease the parking area on campus for the last 3 years (from 2018 to 2020)	200	0
TR7	Number of initiatives to decrease private vehicles on campus	200	150
TR8	Pedestrian path on campus	300	150
Total		1800	775

6	**Education and Research (ED)**		**18%**
ED1	The ratio of sustainability courses to total courses/subjects	300	300
ED2	The ratio of sustainability research funding to total research funding	200*	150
ED3	Number of scholarly publications on sustainability	200*	200
ED4	Number of events related to sustainability	200*	200
ED5	Number of student organizations related to sustainability	200*	200
ED6	University-run sustainability website	200	200
ED7	Sustainability report	100	100
ED8	Number of cultural activities on campus	100*	100
ED9	Number of university program(s) to cope with Covid-19 pandemic	100*	100
ED10	Number of sustainability community services project organized and/or involving students	100*	100
ED11	Number of sustainability-related startups	100*	100
Total		1800	1750

Supplementary Tab.1 The scores of BUU Görükle Campus from each of the IU GreenMetric criteria. Symbol (*) indicates new ratings introduced in 2021 (Altun, 2021).

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REVIEW NOTES

The quality of the offer that the magazine has set as a priority since its foundation has given increasingly encouraging results, first with the recognition by readers and, subsequently, by the institutional bodies responsible for the quality of research in Italy. The recent inclusion of TeMA in the list of reviews of A class represents a milestone to start from. The Review Pages section, since the first issue of TeMA in 2007, has played a substantial role in the general balance of the review, both as an expression of constant updating and as a permanent observatory on emerging issues relating to the relationships between urban planning, mobility and the environment. Starting from the issue of August 2020, the Review Pages will have the new form of Review Notes. They will become short scientific articles, which, while maintaining the function of a reasoned review, will deepen relevant issues in the context of the scientific debate on the recent challenges of the cities, territories and environment. The Review Notes will contain critical thoughts congruent with the topic of the review. The guidelines for these considerations will be: centrality and interest in the scientific debate; advancements and innovativeness of topics; significant gaps resulting from the analysis of the state of the art; recent evidence stemming from the scientific debate; perspectives and potential developments. The Review Notes will consist of five sections, edited by the following researchers:

- Carmen Guida for the section Urban Practices;
- Federica Gaglione for the section Town Planning International Rules and Legislation Overview;
- Annunziata D'Amico for the section Urban Planning Literature Review;
- Sabrina Sgambati for the section NextGenerationEU and urban development;
- Nicola Guida for the section Methods, tools and data for the city energy governance.

Researchers can identify a specific and personal topic to deepen in more than one issue, becoming self-contained scientific articles. Articles are subjected to the usual submission process required by the statement of TeMA journal. The Editorial Staff provides a specific quality control of the articles.

UNIVERSITY OF BRESCIA

CeSCAM

Living and Walking in Cities

NEW CHALLENGES FOR SUSTAINABLE URBAN MOBILITY

XXVI International Conference LWC 2023,
6-7-8 September 2023, Brescia (Italy)

The **LWC International Conference** traditionally deals with the topics of urban mobility and quality of life in urban areas, with a specific focus on vulnerable road users. The LWC Conference allows researchers, experts, administrators, and practitioners to gather and discuss about policy issues, best practices, and research findings from different perspectives.

The European Sustainable & Smart Mobility Strategy sets targets to be achieved by 2050 to reduce pollutant emissions from mobility and make the transport system more efficient and resilient. 75% of European population live in urban areas. The 3rd flagship action of this strategy therefore focuses specifically on those areas, which are considered fundamental to the environmental transition process of the transport system. In those areas mobility achieves its greatest variety, intermodality and conflict. The XXVI LWC Conference therefore focuses on defining the **new challenges for sustainable urban mobility**.

The topic will be addressed through a fourfold perspective. From the perspective of **transport systems and pedestrian mobility** it will range from the observation of waiting spaces to policies, going through the paradigms of accessibility and what mobility means in an era of emergencies. From the perspective of **urban planning**, the changes necessary to achieve a more active and sustainable urban mobility will be observed through the social and temporal implications. From the perspective of **public transport and new technologies** that can influence it, the relevance of the use of data, economic and ethical issues and the change in mobility paradigms that can be translated through the concept of MaaS will be observed. From the perspective of **urban safe mobility**, the observation of risk will be declined from the general analysis of infrastructures to the specific case of pedestrianism, not neglecting the broader theme of accidentality and going so far as to decline the theme in the socio-psychological sphere through the analysis of user behaviour.

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REVIEW NOTES – Urban practices

City vs Energy consumptions: Energy Communities in Italy

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Abstract

Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always remaining in the groove of rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of continuously updating emerging topics concerning relationships between urban planning, mobility and environment, through a collection of short scientific papers written by young researchers. The Review Notes are made of four parts. Each section examines a specific aspect of the broader information storage within the main interests of TeMA Journal. In particular, the Urban Practices section aims at producing, analyzing and reporting data on recent and relevant policies in the urban domain.

This contribution aims at delving into the Energy Community paradigm and its application into the Italian context. The concept of energy communities has gained significant attention and recognition in both the European and Italian contexts. These communities are based on the idea of decentralizing energy production and fostering local participation in the transition to renewable energy sources. Since only recently the legislative panorama provided a set of limits and opportunities to the implementation of energy communities, this note is dedicated to some of the most interesting spontaneous experiences recently born in Italy, to highlight their strengths and weaknesses.

Keywords

Energy crisis; New technologies; Urban energy.

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1. Introduction

Urban planning plays a crucial role in addressing the pressing issue of energy consumption and efficiency in cities. With the increasing impact of climate change-related events and the ongoing energy crisis, it is imperative for urban planners to incorporate concrete solutions to mitigate risks and promote sustainability (Papa et al., 2014; Fasolino et al., 2020). One key aspect of sustainable urban planning is the integration of renewable energy sources (Al-Thani et al., 2022; Derkenbaeva et al. 2022).

On this issue, the potential impacts of energy communities are gaining much more interest, not only in the scientific panorama, but also in international agendas and research-and-development departments of industrial companies.

Energy communities (also known as Renewable Energy Communities – REC) are collective initiatives that enable individuals, businesses, and local organizations to participate in the production, consumption, and management of energy resources, primarily focusing on renewable energy. These communities aim to decentralize energy production, foster local self-sufficiency, and empower community members to actively engage in the clean energy transition. By prioritizing renewable energy sources, energy communities contribute to mitigating climate change and reducing environmental impact. They help decrease greenhouse gas emissions, air pollution, and reliance on non-renewable resources (Pilogallo et al., 2019; Shirgir et al., 2019). The localized energy production and reduced transmission losses also improve overall energy system efficiency (Papa et al., 2016; Gargiulo et al., 2023).

More generally, thanks to the promotion of active involvement and decision-making by local stakeholders, energy communities encourage citizens, businesses, and local authorities to come together and collectively own, develop, and manage renewable energy projects. This participatory approach enhances energy democracy, giving individuals a say in shaping their local energy systems. Moreover, they prioritize the production of energy from renewable sources, such as solar, wind, hydro, and biomass. They often install renewable energy systems within their community, ranging from solar panels on rooftops to small wind turbines or community-owned solar farms. This localized generation reduces dependence on centralized fossil fuel-based power plants and contributes to carbon emissions reduction. Energy communities are designed for self-consumption and energy sharing: they prioritize the use of locally produces energy, meaning that community members consume the renewable energy produced within the community, reducing reliance on grid electricity. Excess energy is usually shared within the community or fed back into the grid, enabling energy sharing and supporting the overall energy transition. Form the energy efficiency side, communities promote measures to reduce energy consumption. They often implement energy-saving technologies, such as smart meters, energy management systems, and building retrofits. Furthermore, communities can adopt demand-response mechanisms, adjusting energy consumption patterns based on supply and demand dynamics, to optimize energy usage and reduce peak loads. For what concerns economic and social benefits, energy communities offer various advantages (Ceglia et al., 2022; Lode et al., 2022).

Locally generated energy contributes to job creation, stimulates local economies, and retains energy spending within the community. Community members may experience reduced energy costs through group purchasing or benefit from financial incentives for renewable energy production. Energy communities also foster social cohesion, knowledge sharing, and community resilience. In order to be effective, energy communities need a widespread technological support: they often adopt smart grid technologies, energy storage systems, and flexible demand management solutions. This enables better integration of intermittent renewable sources, optimizes energy distribution, and enhances grid resilience.

The most interesting aspect of energy communities is their potential to foster social innovation and community empowerment beyond the energy sector.

Energy communities have the power to transcend their primary focus on renewable energy and become catalysts for broader community development. By involving citizens, businesses, and local organizations in decision-making and project implementation, energy communities can create a sense of ownership and empowerment among participants. This engagement can extend to other areas such as sustainable transportation, waste management, local food production, and environmental conservation. Energy communities can thus become drivers of holistic, sustainable development within their communities, promoting a deeper connection to the environment and fostering a sense of pride and resilience.

For example, an energy community may initiate projects like community gardens, eco-tourism initiatives, or educational programs on sustainable practices. By expanding their scope beyond energy, these communities can address multiple social and environmental challenges, leading to improved quality of life, enhanced social cohesion, and a stronger sense of community identity. This holistic approach not only strengthens the overall impact of energy communities but also opens doors for collaboration with other local stakeholders, including educational institutions, non-profit organizations, and local governments. Together, they can create a more sustainable and thriving community while inspiring others to adopt similar initiatives.

In summary, energy communities have the potential to go beyond their energy-focused objectives and act as platforms for social innovation and holistic community development. By empowering individuals and fostering collaboration, these communities can bring about transformative change and inspire sustainable practices beyond the energy sector.

Although energy communities represent undoubtedly an opportunity to boost green energy transition, the regulatory framework for the implementation of these solutions is still weak and lacks operational guidance to incentivise transformations. For the Italian context, the Milleproroghe Decree of 2019, which brought RECs to Italy, opened the door to the concept of collective self-consumption. Initially, the scope of sharing was that of the secondary electrical substation in line with the principle of physical proximity. In other words, community members had to live in the same building or use the same premises. Furthermore, the maximum total power of the renewable plant was 200 kilowatts, so only small installations were allowed.

The subsequent Legislative Decree 199 of 2021 went beyond this regulation: the option to go up to 1 megawatt of power for each individual plant was introduced, thereby reaching energy capacities comparable to those of industrial power plants. At the same time, the scope of sharing shifted to the primary electrical substation: as a result, it became possible to share energy between neighbourhoods, individual citizens, or even small neighbouring municipalities. So, nowadays, community members no longer have to live in the same building to share energy, nor do they have to be in neighbouring buildings. Indeed, the basic idea behind the adjustments to the regulations is to encourage the active involvement of citizens so that the energy sharing system becomes increasingly efficient. For more information, the "Town Planning International Rules and Legislation" section of this issue's Review Notes delves into the developing regulatory framework of energy communities and districts.

Only more recently has the single text been approved, which regulates the modalities for enhancing diffuse self-consumption, with clear indications and procedural simplifications. The expected outcome of these regulatory innovations is the exponential increase of RECs in Italy: a study by the Politecnico di Milano (Electricity Market Report) estimates that by 2025 Italian energy communities will number around 40,000 and will involve around 1.2 million households, 200,000 offices and 10,000 SMEs (Small and Medium-sized Enterprises).

In spite of the innovations introduced by legislation, a number of virtuous energy communities have emerged in Italy in recent years, which have quickly become best practices.

The first urban planning practice analysed in this contribution is from a working-class neighbourhood on the outskirts of Naples, Italy. This experience is one of the first developed energy communities in Italy and it was selected for this Review Notes section due to its several social benefits.

The second urban planning practice comes from Emilia Romagna Region. This case-study was selected because it promotes the installation of a wide range of technologies (rather that only solar plants) to generate and distribute renewable energy among the community.

By drawing on the experiences and practices of urban energy communities, we can better understand the unique challenges and opportunities of implementing energy communities in urban settings. This knowledge can inform the development of effective policies, strategies, and approaches for creating sustainable, resilient, and inclusive urban energy systems.

Comunità Energetica e Solidate di Napoli Est

San Giovanni a Teduccio is a working-class neighborhood on the outskirts of Naples, Italy. Once an industrial center, today it's home to abandoned factories that sit in ruins by the sea. But the rooftop of a former orphanage points to new beginnings for the community. There, the sun shines onto the deep blue surface of 166 solar panels that provide low-cost, clean energy to 20 neighboring families, placing San Giovanni at the helm of an equitable energy transition. San Giovanni, which launched in 2021, is one of at least 35 renewable energy communities across Italy, according to Legambiente Campania, a leading environmental nonprofit that helped create the entity and install the panels. The project is part of a national effort to get households, businesses and local authorities to jointly generate and distribute energy from renewable sources. Proponents say it's a model not just for transitioning economies away from fossil fuels, but also for lifting people out of poverty.

The project required an investment of about 100,000 euro, financed by the Fondazione con il Sud, promoted by Legambiente and the local community, starting with the fundamental role of the Fondazione Famiglia di Maria and the 40 families with social disadvantages involved in the energy community, who will enjoy the benefits of this new energy system. A project that will also see the families involved in a path of awareness-raising and greater awareness of energy issues, in order to make the benefits of the community more efficient.

Serving the energy community is a 53 kW photovoltaic system built on the roof of the Family of Mary Foundation, capable of producing about 65,000 kWh/y of electricity, partly consumed by the structure itself and partly shared with the 40 families involved. It is also estimated to be able to generate real savings, in terms of less electricity consumed by all REC members, of around 300 thousand euro in 25 years.

GreenVulcano

GreenVulcano is an energy community initiative based in the Emilia-Romagna region of Italy. It focuses on the development of local renewable energy projects, aiming to foster sustainable energy production, community engagement, and economic growth. GreenVulcano operates as a cooperative, actively involving farmers, landowners, and local businesses in the production and distribution of clean energy. The initiative emphasizes collaboration and synergy among different actors within the community. By leveraging local resources and expertise, GreenVulcano seeks to create a sustainable and resilient energy system. It aims to reduce dependence on non-renewable energy sources, lower carbon emissions, and promote environmental sustainability.

The renewable energy projects developed by GreenVulcano include wind farms and biogas plants. Wind farms harness the power of wind to generate electricity, while biogas plants utilize organic waste materials to produce biogas for electricity and heat generation. These projects contribute to the local energy supply, decrease reliance on fossil fuels, and support the transition to a cleaner and more sustainable energy mix. Additionally, GreenVulcano fosters economic development and job creation within the community. By engaging local businesses and farmers, it promotes a circular economy approach, maximizing the utilization of local resources and supporting local entrepreneurship.

The initiative aims to strengthen the local economy and retain energy spending within the community. GreenVulcano serves as an example of how energy communities can drive the renewable energy transition at the local level. It showcases the potential for collaboration, innovation, and collective action to achieve sustainable development goals. By empowering community members and promoting renewable energy projects, GreenVulcano contributes to the social, economic, and environmental well-being of the Emilia-Romagna region.

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REVIEW NOTE – Town Planning International Rules and Legislation

Policies and practices to transition towards Renewable Energy Communities in Positive Energy Districts

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Abstract

Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always following a rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is a continuous update about emerging topics concerning relationships among urban planning, mobility, and environment, thanks to a collection of short scientific papers written by young researchers. The Review Notes are made up of five parts. Each section examines a specific aspect of the broader information storage within the main interests of the TeMA Journal. In particular: the Town Planning International Rules and Legislation. Positive Energy Districts has entered the scientific and policy arena to accelerate urban transitions in Europe, however their implementation remains challenging in planning processes. The PED incorporates socio-economic, technological, environmental, political, and institutional challenges that need to be addressed simultaneously as part of a holistic urban strategy. The theme of PEDs finds its first application implications in renewable energy communities on a local scale. This review focuses its attention on Renewable Energy Directive Recast which also provides for financial support for the production and self-consumption of electricity from renewable sources and on the Italian legislation on renewable energy communities governed by the Milleproroghe decree.

Keywords

Urban sustainability; Positive Energy Districts (PED); climate neutrality; Renewable Energy Community.

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1. Energy districts and communities

The concept of Positive Energy Districts (PED) has recently emerged in the scientific and political debate to facilitate the energy transition and contribute to climate neutrality through the reduction of consumption and the efficiency of urban areas (Xiaomin & Chuanglin, 2023). Climate change and energy poverty are urgent concerns for urban systems and require increasingly sustainable yet reliable forms of organization (Hoang & Nguyen, 2021).
The data published by OIPE for 2020 report, for example, that Italy has 2.1 million households in energy poverty, or 11% of the population (just over 6 million people) according to Eurostat. On the other hand, Europe has set highly ambitious goals such as the 40% reduction in greenhouse gas emissions by 2030 compared to 1990, the achievement of the target of 32% penetration of renewable energy sources (RES) in energy consumption and the 32.5% reduction in consumption as a goal for energy efficiency, placing local consumers at the center and as the main protagonists of the energy transition. According to Urban Europe (JPI, 2020), each PED should find its optimal balance between three main components: the energy efficiency of the infrastructure, the local production of renewable energy and the energy flexibility within the district. Instead, to date in the scientific debate it is difficult to find an unambiguous definition of PED, leaving open the field of existence of the various integrations in planning processes (Koutra et al., 2022).
The transformation of the energy system within urban systems incorporates socio-economic, technological, environmental, political, and institutional challenges that need to be addressed concurrently and simultaneously as part of a holistic urban strategy (Gargiulo & Papa, 2021). The idea of PEDs does not appear to be entirely new and derives from studies such as (Net) Zero Energy Buildings, Energy Positive Neighborhoods, Energy Neutral Districts and Positive Energy Blocks (Brozovsky et al., 2021; Bossi et al., 2020). The common goal of these academic works is to propose methodologies for design, energy modeling and simulations of different scenarios as well as the dissemination of good practices aimed at meeting the energy needs from low-cost renewable sources at different scales from that of building to that of the neighborhood or district in accordance with the environmental sustainability standards to which cities today are called to respond (Gouveia et al., 2021; SET-Plan, 2018). In particular, the studies of Sartori et al., (2012); Omrany et al., (2022) aim to favor the high efficiency of buildings from renewable sources capable of generating electricity, or other energy vectors to compensate for the energy needs of users. Studies such as Monti et al. (2016); Ala-Juusela et al. (2014); they deal with studying how an area can generate more electricity and how much it consumes to identify Energy Positive Neighborhoods (EPN) areas. The authors investigate key defining characteristics of future energy systems that include the growing penetration of low-carbon electricity generation, electric heating, and transportation.
Finally, district-scale studies are still few, the PED concept has gained more attention in policy-oriented works. Some authors consider that the concept of PED is similar Energy Neutral District considering this new term ill-defined and with an ambiguous connotation (Hedman et al., 2021). First, "positive energy" refers to an energy surplus where (renewable) energy production exceeds consumption over a certain amount of time. Second, "district" refers to a larger area of the city, which is larger than a city block or neighborhood. According to Lindholm et al. (2021) three types of PED can be identified: autonomous, dynamic, and virtual. The difference between these different types is their ability to interact with energy networks, consumers, and producers outside their geographical boundaries. The autonomous PED refers to a district where the energy needs are covered by renewable energy that is generated internally and energy imports are not allowed. Dynamic and virtual PEDs are instead flexible in their interaction, go beyond geographical boundaries and are based on renewable energy systems and energy storage. Although PEDs may be a promising and compelling concept to accelerate decarbonization and urban transitions in Europe (Bruck et al., 2022; Pilogallo et al., 2019), however their implementation remains challenging with multiple limitations and at the same time partially

developed analyzes mainly focused on solutions and technological projects as well as the legislative body is still fragmented.

It remains remarkable that after many years' attention is paid to the issue of energy in urban areas at the district level but with limited results due to its complexity. Today, the theme of PEDs finds its first application implications in those territorial contexts where experiences of renewable energy communities have been introduced which, thanks to the association between citizens, commercial activities, local public administrations, and small/medium enterprises undertake to exchange and consume energy from renewable sources on a local scale (De Vidovich et al., 2023).

A recent study published in the scientific *journal Nature* surveyed energy communities in 29 European countries, including 26 EU member states. In the EU countries there are 9252 energy communities, although we can see large disparities between the member countries: more than half of these communities are in Germany, which has 4848 energy communities, with the other states of the Union following like the Italy with 198 up to countries such as Bulgaria, Malta, Romania, and Hungary which have just one. The key aspect of renewable energy communities continues to be the relationship with the territory to understand which the best ways are to make this relationship functional and mutually beneficial (Grignani et al., 2021). It is therefore necessary to know the specific characteristics of the territorial context in question and the resources and infrastructures it offers. The territory is not only the physical "support" for the construction of small/large-scale energy production and distribution plants with the aim of minimizing costs and maximizing efficiency.

The purpose of the energy communities is the inclusion in the territory and the satisfaction of the energy needs that it presents with a "distributive" objective within the local community (Atutxa et al., 2020). Private and public actors, cooperatives, foundations represent important models for the creation of local support towards energy communities such as the participation of experts with certain technical skills to allow energy innovation for the construction of new plants and new techniques. A further issue for the success of Energy Communities is social acceptability, which depends on several factors, including equity in the distribution of benefits and level of decision-making participation of the different stakeholders. In this direction, this review focuses its attention on the Renewable Energy Directive Recast, also known as RED II, which among the various regulations also provides for financial support for the production and self-consumption of electricity from renewable sources and on the Italian legislation on community renewable energy regulated by Milleproroghe Decree 162/2019 (converted with Law no. 8/2020 of 28 February 2020).

Renewable Energy Directive Recast (REDII)

In recent years, the European Commission has played a leading role on the issue of energy. Most of the legislative acts are contained in the Clean Energy Package which redesign the energy sector through measures for energy efficiency, renewable sources, the energy market structure. Legislative Decree 199/2021 (REDII) represents a significant leap in the promotion of renewable energy by defining the tools, mechanisms, incentives, and institutional framework for achieving the objectives of increasing the share of energy from renewable sources by 2030. Furthermore, it provides the provisions for the implementation of the measures of the National Recovery and Resilience Plan PNRR. The expected target in terms of installation of renewable sources is at least 70 GW of new power by 2030, of which at least 40 GW of photovoltaic and over 12 GW of wind. Another 3 GW should come from biogas (1.5 GW), hydroelectric; geothermal (0.2 GW) and other minor sources for 0.8 GW (solar thermodynamic, etc). The REDII is also an important step because it allows the Government to continue the bureaucratic simplifications already started with the Simplification Decree to make up for the significant delay accumulated in the transition towards the 2030 objectives and to unblock investments and to install the 70 GW of new renewable plants envisaged by the Green Deal. In detail, the document is based on two main guidelines. The first, on an aid scheme for the support, throughout the country, of renewable energy communities and individual and collective self-consumption configurations aimed at pursuing the decarbonization objectives by 2030; the second governs the conditions and methods for granting and disbursing

operating aid for the promotion of renewable energy communities and individual and collective self-consumption configurations.
The decree provides for incentives for renewable source plants through: (i) systems of individual remote self-consumption of renewable energy: systems that provide for the remote self-consumption of renewable electricity by a single end customer, without resorting to a direct line, i.e. using the existing distribution network to connect production sites and consumption sites; (ii) collective self-consumption systems from renewable sources: systems created by groups of self-consumers acting collectively; (iii) renewable energy communities: systems built by customers. The renewable energy communities constitute the first step forward because they encourage the sharing of the energy produced, however raising the power threshold of the plants to 1 MW (previously 200 KW), expanding the community to users (production and consumption) connected under the same primary substation (currently the secondary substation was envisaged) overcoming the constraint that required community participants to belong to the same medium voltage substation and opening up existing renewable plants to enter the community, provided they are not beneficiaries of other forms of incentive and for a total power not exceeding 30% of the total. The increase in plant power to 1 MW will therefore make it possible to build larger plants, potentially able to meet the needs of communities and no longer just a few families. The effectiveness of the promotion mechanism can be assessed when the value of the recognized tariff is known. The funding can be both a tariff incentive and a non-refundable grant. With regard to the tariff incentive, specifically, the share of energy shared within the CACER (Self-consumption configurations for sharing renewable energy) through the portion of the distribution network underlying the same primary substation is entitled to a incentive rate in the form of a premium rate. The tariff is paid by the Energy Services Manager GSE, which is the body managing the measure and which will be able to preliminarily verify the eligibility of the interested parties to guarantee the concrete possibility of accessing the benefits of the measure. As regards the non-repayable contribution of the PNRR matrix only in small municipalities, the measure that allows the disbursement of non-repayable contributions of up to 40% of the investment will only be up to the energy communities created in municipalities with less than 5,000.

Energy Communities in Italy

The implementation of the European directive RED 2 was acquired in Italy in the Milleproroghe decree. In Italy the first experiences of Renewable Energy Communities are recorded around the 2000s, mainly in the North. Only in recent years, however, has it increased its attention and has made users aware of the principles of self-consumption and environmental sustainability. In turn, the Renewable Energy Communities are mentioned for the first time by the Italian Energy Strategy in 2017 and, subsequently, by the National Energy and Climate Plan in 2018. Then in 2018, the Piedmont Region approved a law on Energy Communities, which is It being mainly a declaration of intent, even if it was politically relevant, being the first legislative initiative explicitly dedicated to the Energy Community sector. In detail, article 42 bis allows for the establishment, on an experimental basis, of collective self-consumption, which can be activated by families and other subjects who are in the same building or condominium. Compared to RED II, the Milleproroghe decree provides for and establishes a system of continuous monitoring and growth of self-consumption configurations, detectable from the monitoring activity, and from the evolution of the overall requirement of the various components. For these purposes, the regulatory authority for energy, networks, and the environment (ARERA) can make use of the companies of the Energy Services Manager (GSE) Spa group. Furthermore, it identifies ways to encourage the direct participation of municipalities and public administrations in the community's renewable energy. The decree provides that the incentive rate is paid for a maximum period of use and is modulated between the different configurations eligible for incentives to guarantee the profitability of the investments. Furthermore, the mechanism is implemented considering the overall balance of bill charges and the need not increase trend costs with respect to those of the mechanisms in force. Finally, a single adjustment is envisaged, consisting of the refund including the share of shared energy, and the incentive tariff. Renewable energy communities within positive energy districts constitute an innovative model for which energy needs are met locally, autonomously and in a shared way. Starting from 2020, the legislation has been defined in a more accurate way making possible the formal establishment of the Renewable Energy Communities in our country but there are still gaps in the implementation in the planning processes such as experimental analyzes in relation to the physical and functional organization of urban systems. Finally, the CER allows us to make a cultural leap where everyone shares something to make it available to others, users and their behavior are a key element. The social benefit becomes the engine — in motion — of the community which, through the energy vector, produces and realizes the common good.

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REVIEW NOTES – Urban planning literature review

New frontiers for sustainable mobility: MaaS (Mobility as a Service)

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Abstract

Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always remaining in the groove of rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of continuously updating emerging topics concerning relationships between urban planning, mobility and environment, through a collection of short scientific papers written by young researchers. The Review Notes are made of four parts. Each section examines a specific aspect of the broader information storage within the main interests of TeMA Journal.
In particular, the Urban planning literature review section presents recent books and journals on selected topics and issues within the global scientific panorama.
This contribution aims at delving into the issue of sustainable urban mobility through a new mobility paradigm represented by MaaS (Mobility as a Service). Effective and sustainable management of urban transportation activities and services plays an important role within the city to reduce environmental impacts and improve the quality of life for citizens. For the second issue of TeMA Journal, volume n.16, this Review Notes section offers a literature overview on the main aspects of MaaS and its impact on the urban mobility system. It analyzes the potential sustainability benefits of using MaaS in the urban context by citing some interesting and significant journals and books which delved into the topic.

Keywords

MaaS; Mobility as a Service; Urban mobility.

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1. Introduction

United Nations in The Report on the Sustainable Development Goals 2022 states that "Today, more than half the world's population live in cities. By 2050, an estimated 7 out of 10 people will likely live in urban areas. Cities are drivers of economic growth and contribute more than 80 per cent of global GDP. However, they also account for more than 70 per cent of global greenhouse gas emissions. If well-planned and managed, urban development can be sustainable and can generate inclusive prosperity" (UN, 2022).

The evolutionary process of urban phenomena is also connected to the growing demand for mobility and thus traffic flows. The Global Mobility Report 2017 (Sustainable Mobility for All, 2017) mobility will progressively grow with more and more people and goods moving through cities and around the world. By 2030, annual passenger traffic will reach over 80 trillion passenger-kilometres, a 50 percent increase from 2015; in addition, the number of vehicles on the road will reach 1.2 billion, double compared to the current total.

However, fulfilling growing demands for mobility has the potential to contribute to environmental degradation and increase air pollution levels in cities as well as amplify the effects of climate change. Therefore, urban mobility has a considerable impact on sustainability and quality of life in cities.

Although mobility offers many benefits to users, we cannot ignore the costs it entails for our society: greenhouse gas emissions, air, soil and water pollution, as well as road accidents, congestion of traffic and the loss of biodiversity. All of these factors have a significant impact on our health and well-being. (EU, 2021). The fuels used for transport generate over 50% of the nitrogen oxides emitted globally which, added to the particulate matter, together constitute a significant threat to human health, especially in urban areas. (Fenu, 2021; World Energy Investment, 2017; Watts et al., 2019).

To promote the growth of ecological consciousness and stimulate a new perspective in the way the world is designed, it is necessary to adopt principles, values and processes that include additional issues to traditional ones, such as the environmental, social and economic impact of proposed solutions (Spadaro I. et al., 2022; Beatly, 2015). Only through conscious and responsible planning can we create a sustainable future for everyone.

The study of sustainability in combination with urbanization has led to the concept of the sustainable city which has become of interest in multiple sectors including research, education, policy making and business (Höjer & Wangel, 2015).

Sustainable transportation and mobility are critical to realizing the promise of the 2030 Agenda for Sustainable Development, particularly to achieve the vision of the city by 2030 proposed by Goal 11: "Make cities and human settlements inclusive, safe, resilient and sustainable" (UN, 2015).

In recent years, automobile-centered policy has caused an increase in negative externalities in the urban environment, so a change of course is underway, and developments in digitization and technology are helping in this process. The shift from car ownership to shared mobility and the transition of combustion engines to electric are just some of the concrete examples of this evolutionary process in urban mobility.

Just as in the past the mass introduction of the automobile changed people's way of life, new technologies are transforming the traditional idea of mobility into the new concept of "smart mobility" (Tirachini, 2020; Docherty et al., 2018). Clean mobility and soft mobility, combined with greater accessibility and the ability to obtain real-time information, provide savings in time, economic and environmental costs and make the transport system "smart" and efficient (Pellicelli G. et al., 2022; Niglio & Comitale, 2015). Autonomous vehicles and sharing services are among the innovations in the transport field that can be linked to the concept of "as a service", describing a new paradigm in which mobility is no longer based on private vehicle ownership but rather accessible on demand (Wong Y. Z. et al., 2020).

The panorama of urban mobility is rapidly evolving and citizens are gradually being offered multiple solutions, this has the consequence that it may not be easy for the user to choose the best way to travel (UITP, 2019).

The double challenges of multimodality and decarbonisation have led to the spread and integration of traditional and new mobility services such as public transport, ride-sharing, car-sharing, bike-sharing, scooter-sharing, taxi, car rental, ride-hailing ed so on. In the urban transport sector, the digital revolution and the ambition to significantly reduce traffic congestion and pollution through the integration of mobility services has led to the emergence of the MaaS (Mobility as a Service).

In the academic world, the acronym MaaS was born only recently and the first application of Mobility as a service dates back to 2016, in Finland, with the launch of the "WHIM" app. MaaS, a consequence of the digital revolution, has become an element of discussion in the urban transport sector (CERRE, 2021).

A first consensual definition among public and private organisations was provided in 2017 by the White Paper of the MaaS Alliance in which MaaS is defined as "the integration of various forms of transport services into a single mobility service, accessible on demand. For the user, MaaS offers added value using a single application to provide access to mobility, with a single payment channel instead of multiple ticketing and payment operations" (MaaS Alliance, 2017).

Mobility as a Service enables customers to meet and manage all their mobility needs on demand, according to their specific requirements. The service is based on the seamless integration of all the different modes of public and commercial transport and is provided to the user through a single digital channel (web site or app). MaaS allows multimodal travel choices, from planning, booking to payment and eventual route modification. MaaS also ensures that relevant authorities to collect data and information on demand and travel behavior that can be used to improve mobility services and plan infrastructure investments (EMTA, 2019).

MaaS requires a business system in which different groups of actors interact and collaborate: there are the platform owners (e.g., third parties, transportation service providers, authorities), on the demand side there are the users requesting the mobility services, and from the supply side the transportation service providers (public or private).

The MaaS model sees the involvement of multiple actors who can cooperate to enable the operation of the service and improve its efficiency, including local authorities, payment clearing companies, telecommunications and data management (Jittrapirom P. et al., 2017).

From the user's perspective, MaaS provides more personalized mobility options and services to meet the individual needs of users, offering on-demand, flexible, and affordable services that can push the user toward moving away from private car use, making more conscious, multimodal and sustainable mobility choices.

MaaS is a user-centric system so it takes into account the user's general preferences such as speed, convenience, comfort, costs, presence of luggage, without neglecting the special accessibility needs of some fragile users (ERTICO, 2019).

From the transport operator's point of view, MaaS offers its travelers a wide range of mobility services that can attract a wider portion of the market and users. "It is clear that any business actor in the MaaS ecosystem will pursue the goal to grow his business" (UITP, 2019).

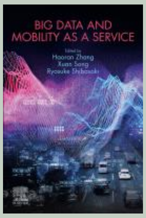
From a city authority's point of view, MaaS can become a tool to improve the livability of urban environments: by offering more efficient and coordinated mobility services, to reduce the volume of car traffic, noise and air pollution, to solve the parking problem and to also revise street and urban space design in a way to promote active mobility and intermodal mobility.

Sustainable, innovative and integrated mobility becomes a priority for authorities who want to promote a transition towards cities with a good quality of life. It is estimated that 74% of Europeans live and move in cities every day, and urban mobility i accounts for 40% of total CO_2 emissions in the transport sector (Spadaro I. et al., 2022, Diez J.M. et al., 2018). The environmental and social component of sustainability must be a priority objective of MaaS, including equity and accessibility as essential elements (Nykanen, 2017).

Although some examples of MaaS exist and a few pilot projects have been conducted with generally positive results, so far progress and large-scale implementation are rather slow. As a result, little empirical evidence remains on whether or not MaaS meets expectations (Karlsson, 2020). The reasons for the limited deployment of MaaS can be attributed to various reasons including legislative gaps, difficulty in coordinating multiple actors, infrastructure gap between different urban areas, data sharing, lack of funding, business models and so on.

In conclusion, MaaS is a new global concept of mobility which involves the integration of multiple public and private transport services accessible through a single digital channel. This new mobility paradigm offers services aimed at meeting user needs while at the same time enabling the promotion of political and social goals, such as sustainability and accessibility. The use of MaaS in the urban context can bring numerous benefits, including better organization of mobility services and optimization of the design and distribution of urban space. Promoting the implementation of MaaS pilot projects is a valuable tool for increasing the efficiency of services and assessing their impact on the environment and socioeconomic contexts. The experiments can thus provide important guidance to relevant authorities on mobility management choices, facilitating the adoption of MaaS in the future as a means of shifting to more sustainable modes of transportation for a more livable urban system.

Big Data and Mobility as a Service



Authors/Editors: Haoran Zhang, Xuan Song & Ryosuke Shibasaki
Publisher: Elsevier
Publication year: 2022
ISBN code: 978-0-323-90169-7

"Big Data and Mobility as a Service" explores MaaS platforms that can be adaptable to the ever-evolving mobility environment. It looks at multi-mode urban crowd data to assess urban mobility characteristics, their shared transportation potential, and their performance conditions and constraints.

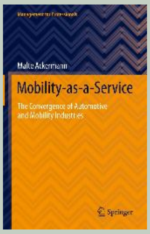
The book analyzes the roles of multimodality, travel behavior, urban mobility dynamics and participation. Combined with insights on using big data to analyze market and policy decisions. Big data-driven MaaS development is an emerging area both in academic and industrial aspects. Though several research studies and technical reports are available, a clear link to understand big data in MaaS appears vague and fragmented. This book aims to fill this gap by systematically summarizing the knowledge in this field. Collectively, the knowledge in this book is of immense significance for stakeholders in MaaS and those planning to enter the industry, such as researchers, engineers, operators, company administrators, and policymakers in related fields, to comprehensively understand current technology infrastructure knowledge structures and limitations.

Automated Vehicles and MaaS: Removing the Barriers

Authors/Editors: Bob Williams
Publisher: John Wiley & Sons
Publication year: 2021
ISBN code: 9781119765349

"Automated Vehicles and MaaS: Removing the Barriers" is a topical overview of the issues facing automated driving systems and Mobility as a Service, identifies the obstacles to implementation and offers potential solutions. Written in a clear and accessible style, this timely volume summarizes recent research studies, describes the evolution of automated driving systems and MaaS, identifies the barriers to their widespread adoption, and proposes potential solutions to overcome and remove these barriers. The text focuses on the claims, realities, politics, new organizational roles, and implementation problems associated with CAVs and MaaS—providing industry professionals, policymakers, planners, administrators, and investors with a clear understanding of the issues facing the introduction of automated driving systems and MaaS. The book is an essential resource for transport providers, vehicle manufacturers, urban and transport planners, students of transportation, vehicle technology, and urban planning, and transport policy and strategy managers, advisors, and reviewers. computing techniques.

Mobility-as-a-Service
The Convergence of Automotive and Mobility Industries



Editor: Malte Ackermann
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Pubblication year: 2021
ISBN code: 978-3-030-75589-8

"Mobility-as-a-Service" analyzes MaaS (Mobility-as-a-Service) from an automotive industry viewpoint, considering the context of business, social, political and generational changes affecting the future of the sector and mobility. In addition, strategic tips are provided that are indispensable for the automotive industry.
The advent of mobility-as-a-service and the disruption of the automotive industry are both overlapping and fuelled by the same developments and thus raise a very fundamental question: are we at peak car? Based on the author's extensive field research, academic study, and professional experience, this book explores this very question as well as the underlying social, economic, generational, and regulatory changes that lead to a new mobility regime. Through rich descriptions of established OEMs and mobility start-ups, it discusses the current forms of mobility and the promise of autonomous technology. It further explores the strategic dimension of these developments so as to navigate and succeed within the disruptive and ever-changing environment of mobility services.

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REVIEW NOTES – Urban development and NextGenerationEU

The interventions of the Italian Recovery and Resilience Plan: sustainable development

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Abstract

Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always following a rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of a continuous updating of emerging topics concerning relationships among urban planning, mobility and environment, through a collection of short scientific papers. The Review Notes are made of five parts. Each section examines a specific aspect of the broader information storage within the main interests of TeMA Journal.
This section of the Review Notes deals with the new frontiers of urban development through the lenses of the European program NextGenerationEU.
In particular, this contribution deals with the topic of sustainable development in urban environments, analysing it in the frame of the Italian National Recovery and Resilience Plan. The paper takes into account the recent PNRR strategies, projects, and initiatives that intervene in multiple sectors - such as the environment, energy, and infrastructures - to promote sustainable development. It provides an overview of the proposed projects and interventions in different urban areas.

Keywords

Sustainable development; NextGenerationEU; Urban development.

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1. Sustainable development in cities

The 1987 Brundtland Commission Report provided one of the first globally recognized definitions of sustainable development, defining it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). Albeit the numerous topic updates that occurred since the 1990s (such as the 1992 Earth Summit in Rio de Janeiro, the 1997 Kyoto Protocol, the 2015 Paris Agreement, and the United Nations Climate Change Conferences) this definition is still very contextual (Kwatra et al., 2020). The recent energy crisis, along with the COVID-19 emergency, has, indeed, imposed new challenges for sustainable development (Mukarram, 2020), undermining the availability and equal distribution of resources for future generations and communities.

In this context, due to the increasing urbanization and its economic, social, and environmental consequences, cities have settled their role as main actors in accelerating the transition towards sustainable development models (Guida & Natale, 2021). Currently, more than half of the global population lives in urban areas and the phenomenon is going to accelerate in the coming decades (UN, 2022). In this scenario, hurried and inadequately structured urban development gives rise to numerous obstacles to sustainable development, comprising shortage of affordable housing, inadequate transportation and essential services, hazardous levels of air pollution, as well as vulnerability to climate change and natural calamities that involve not only urban areas but also neighboring territories (Campbell, 1996; Krähmer, 2021). Covid-19, in the first instance (Lai et al., 2020), and the Ukrainian-Russian war implications, in the second (Cutini et al., 2023), have further stressed this situation, emphasizing the issues deriving from relying on non-renewable resources, like environmental pressures, unsustainable production patterns, let alone inequalities and poverty (da Costa et al., 2023).

The bright side is that numerous advantages can result from the implementation of sustainable solutions in urban areas, both directly and indirectly. Several studies have demonstrated that making cities more sustainable can effectively mitigate adverse environmental, social, and economic conditions, improve citizens' quality of life, and increase attractiveness and territorial competitiveness (Sgambati et al., 2022; Fan et al., 2023). The implementation of sustainable development strategies in cities can minimize energy consumption, waste production, and the use of unsustainable energy sources (Galderisi et al., 2016). This may bring the reduction of air pollution, the preservation of ecosystems, and the mitigation of climate change consequences (Pillogallo et al., 2019; Lai et al., 2021). Furthermore, sustainable development strategies contribute to creating healthier and safer living environments, guaranteeing different population categories equitable and just services. Regarding equity, implementing sustainable measures means ensuring equal access to resources and opportunities for all residents and guaranteeing that level of accessibility to future generations (Davidson, 2010). Sustainable urban development aims at reducing disparities in income, education, healthcare, and access to essential services.

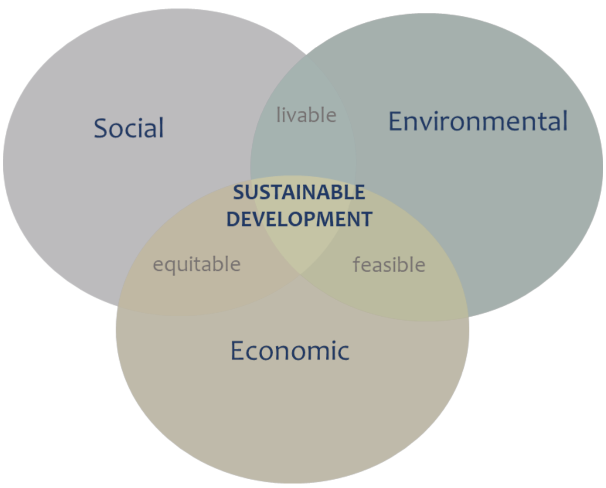


Fig.1 Dimensions of sustainable development

Governing urban transformations towards more sustainable standards helps in creating well-designed, compact, and walkable cities with efficient infrastructures and improved connectivity (Papa et al., 2016). In brief, sustainable development in cities aims to strike a balance between economic growth, social well-being, and environmental protection (Fig.1), leading to more resilient, inclusive, just, and livable urban environments (Duran et al., 2015).

1.1 SDG11 - Sustainable Cities and Societies

In 2015 the United Nations adopted the 2030 Agenda for Sustainable Development comprising 17 Sustainable Development Goals (SDGs) (UN, 2015) to achieve by 2030. SDGs are a call to action to reduce disparities, protect the environment, and end poverty, covering a range of issues and involving several subjects and entities.

Particularly, SDG 11 is dedicated to building more sustainable communities and societies in cities, making human settlements inclusive, safe, and resilient, and promoting sustainability in cities either in the social, economic, and environmental spheres. It is structured in 7 targets that afford different urban challenges, namely:

- Target 11.1 deals with the quality of living: this target aims at making cities pleasant, safe, and adequate environments where to live, ensuring diffused well-being - regardless of population classes - and reducing the proportion of the urban population living in slums;
- Target 11.2 concerns public transport: this target aims to provide safe and equitable access to public transport systems for the population living in cities, improving road safety, expanding public transport supply, and focusing on the most vulnerable groups, such as the elderly, persons with disability and children;
- Target 11.3 deals with inclusive and sustainable urbanization: given the unprecedented urbanization that has characterized numerous urban areas over the past decades, this target aims at limiting uncontrolled urban sprawl, and creating integrating and cutting-edge urban communities;
- Target 11.4 deals with the protection of natural and cultural heritage to preserve cities' identity and history and their natural resources;
- Target 11.5 concerns the response to natural disasters: it aims at reducing exposure and vulnerability of urban areas to natural disasters, focusing, in particular, on poor and vulnerable people;
- Target 11.6 regards environmental pollution and waste: it aims at reducing the environmental impact of cities, paying attention to air quality and waste management;
- Target 11.7 deals with accessibility to green and public spaces: this target aims at enhancing access to services, public spaces, and retail facilities to different segments of the population;

In summary, according to Agenda 2030, fostering sustainable development in cities can generate added value on multiple levels, such as quality of life, production and economy, mobility, environment, governance, safety, as well as competitiveness. Given the recent changes that have disrupted the state of equilibrium preceding the pandemic, cities need to tackle these issues to achieve sustainable development objectives (Cirianni et al., 2022).

2. Sustainable development in the NGEU program and the Italian PNRR

The 2020 pandemic as well as the 2022 Russian-Ukrainian crisis are spurring countries and territories to reconsider their sustainable development pathway. In Europe, the Next Generation EU program was adopted in 2021 by the European Commission to respond to Covid-19 and relaunch the development of member states (EC, 2021). It is a temporary €750 billion financial instrument designed to stimulate a 'sustainable, even, inclusive and equitable recovery', aimed at revitalizing economies, laying the foundations for a more digital-friendly, greener, and inclusive Europe, and facing unforeseen needs and challenges. Among the objectives of the Next Generation EU, there is the transition to a resource-efficient economic model not relying on resource consumption for economic growth. The program aims at making European countries greener and more resilient, and, inherently, more sustainable (Gargiulo et al., 2022). The transition to a sustainable and circular economy is going to enhance the European GDP by an additional 0.5% by 2030, creating about 700,000 new jobs (EC, 2020). For this reason, national governments in the EU have allocated substantial resources from recovery programs to the green transition, in particular to the refurbishing and energy upgrading of buildings, sustainable mobility, and the use of renewable energy sources. Furthermore, other sectors of investment are health, mobility infrastructures, and social inclusion and cohesion, all aspects that can be traced back to the three-fold concept of sustainability (either environmental, social, or economic).

In the case of Italy, one of the main objectives of the National Recovery and Resilience Plan (Governo Italiano, 2021) is to promote sustainable and resilient development of territories. This entails implementing measures that enhance environmental preservation, decrease the release of greenhouse gases, and enhance the overall well-being of residents. Specifically, the green transition is one of the main pillars of covering a total budget of €59.47 billion, along with infrastructures for sustainable mobility (€25.40 billion), inclusion and cohesion (€19.81 billion), and health (€15.63 billion) (Openpolis, 2021). The distribution of funds highlights that sustainability is one of the guiding principles of the Italian NRRP. Tab.1 displays the sectors of investment of the plan - for which territorial entities have a key role in the implementation - assigned to the three components of sustainable development, namely environmental, social, and economic.

Sustainability dimension	**NRRP Pillar**	**NRRP sectors of investment**
Environmental	Ecological transition	Land protection
		Renewable energy
		Circular economy
	Infrastructure	Railways
		Built heritage
		Public transport services
		Infrastructures for soft mobility
Social	Health	Territorial healthcare services
		Hospitals
	Social Inclusion and cohesion	Social infrastructures
	Education	Right to study
		Education infrastructures
Economic	Jobs and business	Competitiveness and innovation
		Employment
		Agriculture
	Digitalization	Digital enterprises

Tab.1 The NRRP sectors of investment articulated per dimensions of sustainable development (Source: Author)

It can be concluded that the Italian NRRP can contribute to sustainable development in cities in different ways:

- by the promotion of energy efficiency: cities can receive funding to retrofit existing buildings, install more efficient heating and cooling systems, implement smart energy management technologies, and introduce renewable energy sources. This reduces the environmental impact and improves the quality of life of citizens;
- by fostering sustainability of the transport system: the NRRP aims to invest in sustainable mobility, e.g. by improving and expanding public transport infrastructure, promoting the use of low-emission vehicles,

or promoting cycling and electric vehicles. This helps to reduce air pollution and traffic, improving air quality and urban livability;

- by promoting urban requalification: through the NRRP, cities can receive funding for the regeneration of degraded or underused areas, the rehabilitation of abandoned or unused buildings, the creation of urban parks and green spaces, and the promotion of sustainable building solutions. This enables to improve the quality of urban spaces and social fabric, as well as create new job opportunities;
- by boosting digital transition: the plan envisages a strong digitization component for cities. This includes the development of digital public services, the implementation of new smart technologies for waste management, lighting, irrigation, security as well as the management of urban services. Digital innovation can improve the efficiency, safety, and quality of urban services, contributing to overall urban sustainability.

To conclude, through these measures and investments, the NRRP aims to foster the construction of sustainable and resilient cities, geared towards increasing environmental protection, reducing greenhouse gas emissions, and improving the quality of life of citizens.

In the following tables, there is reported a selection of strategies, plans, and projects that can be contextualized in this frame, namely interventions concerning sustainable development and financed by the plan.

Urban and suburban forestation in metropolitan areas

Biodiversity conservation has a key role in achieving the goals of the Paris Agreement and the 2030 Agenda because it gives an important contribution to carbon sequestration and carbon storage and adaptation to climate change, which, on the other hand, is one of the causes of biodiversity loss, with a strong negative impact on many ecosystem services on which cities' livelihoods and well-being depend. Compared to this overall background, one of the most important biodiversity issues addressed by international and regional strategies and Italian initiatives is the conservation of forests, which is fundamental for ensuring the survival of plants, animals, and other organisms, and for the maintenance of fundamental ecosystem services including biomass production, carbon storage, regulation of the water cycle and various bio-geochemical components, soil protection, and cultural services, with a significant impact on the natural and urban environment. A significant part of the forestry theme is forestation in urban, peri-urban, and suburban areas, particularly in large metropolitan areas. It is one of the most economical and affordable nature-based solutions to improve the environmental performance, resilience, and climate adaptation of cities. The Urban and Suburban Forestation Plan represents a tool that allows all metropolitan cities to follow a common methodology, based on solid scientific references, to identify and plant the right tree in the right place (Conzonato & Sforzini, 2022).

This investment is part of the Mission 2 of the NRRP on Ecological Transition and the implementing subject is the Ministry of Environment and Energy Security. The objective is to plant more than 6.6 million trees in urban forests, namely those forested areas neighboring the 14 Italian metropolitan areas (Bari, Bologna, Cagliari, Catania, Florence, Genoa, Messina, Milan, Naples, Palermo, Reggio Calabria, Rome, Turin, and Venice), identifying native, certified species. The ultimate aim is to protect land and water resources and safeguard air quality and biodiversity, as well as improve the quality of life and well-being of citizens. The identification of the areas for reforestation must meet many requirements such as being on public land, being consistent with the urban-territorial, environmental, and landscape planning regulations, and envisaging a 5-year cultivation plan for maintenance.

Redevelopment of Taverna del Ferro and Vele di Scampia settlements in Naples

These two integrated plans, promoted in Naples within the NRRP mission M5 "Inclusion and Cohesion" and the component "Social infrastructures", aim at redeveloping two degraded settlements of Naples suburban areas, specifically the 'Taverna del Ferro' area (in the eastern part of the city, specifically the district of San Giovanni a Teduccio) and the complex 'Vele di Scampia' (in the northern suburbs), both identified as vulnerable areas of the Neapolitan territory. Both the interventions provide for the demolition of the existing complexes – built between the 70s' and the 80s' - and the construction of new housing infrastructures with facilities, a linear urban park for San Giovanni, and an eco-district for Scampia. The interventions concern two areas currently characterized by a diffuse state of degradation, marginalization, poverty, and inadequate environmental quality.

The objective of the interventions is the redevelopment of the two settlements, aiming at improving the quality of residential spaces, and energy efficiency, along with rethinking the relationship between the built environment and public space.

The main lines of actions of the plans, that can be traced back to sustainable development, are:

- maintenance for the eco-sustainable reuse and re-functionalization of large areas and related existing public building structures for purposes of public interest;
- improvement of a large degraded urban area, for regeneration and economic revitalization, through the appropriate integration of secondary facilities serving residential units;
- upgrading of buildings' energy efficiency and demolition of the remainder for the construction of new residential buildings with the n-ZEB building performance requirement and eco-districts;
- creating a renovated balance between built-up areas and green areas.

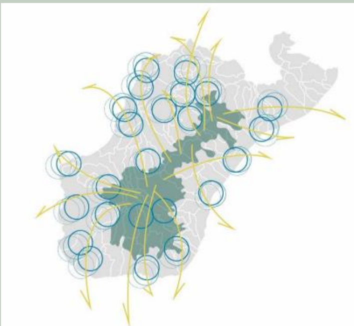
Thus, it may be deduced that these projects deal with all the components of sustainable development, taking into consideration social aspects, economic revitalization, as well as "green" objectives at the same time, dealing with the availability of existing resources. Furthermore, the Integrated Plans provide forms of participation and social innovation, empower social services and enhance ecosystem services. The expected results in the field of sustainability concern, first, the mitigation of climate change's negative effects; second, re-functionalization and adaptation of residential buildings to standards of sustainability and social justice; third, the creation of micro-models of sustainable economies and communities; finally the two interventions are thought to be the trigger for the regeneration of entire districts.

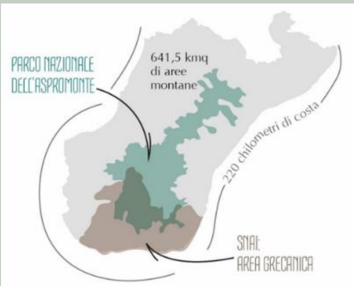
Come_IN, City of Milan

Come_IN is an integrated urban plan promoted by the city of Milan aiming at increasing inclusion in the metropolitan area through interventions of urban regeneration, with particular attention to population classes living in marginal conditions. The municipalities embedded in the metropolitan area of Milan are called upon to propose interventions of regeneration aiming at mending urban and suburban fabric, bridging infrastructure deficits, and improving access to services.

The primary objective of the investment is to rehabilitate spaces and buildings in a state of decay with the introduction of new services and the improvement of accessibility and intermodality of existing infrastructures. This objective will also be pursued by promoting social and entrepreneurial participation processes, in order to involve communities in social, cultural, and economic activities with special attention to environmental aspects. The interventions financed through this plan fall into four strands: i) recovery interventions for aggregative and social purposes of sports facilities located in the consolidated fabric of the city; ii) redevelopment projects of local or metropolitan parks and internal bicycle and pedestrian routes; iii) redevelopment of historic buildings and monastic complexes and allocation of the relative spaces for institutional and cultural events; iv) creation of spaces for social and cultural activities and activation of support functions for collective and associative life. Therefore, this plan can be seen as closer to the social sphere of sustainable development.

Reggio Calabria integrated Plan "Aspromonte in Città – A green, sustainable, inclusive and smart city"





With this integrated plan, the Metropolitan City of Reggio Calabria intends to concretely start the sustainable development transition process, aiming for the creation of a green, sustainable, inclusive, and smart city. The focus of the plan is the National Park of Aspromonte, which intends to be the core of the metropolitan area to be connected to the coast and all the urban centers disseminated in the territory. The plan emphasizes the role of designed green urban areas to fill the distributional and qualitative gaps of public and green spaces within the densest inhabited areas and to favor environmental recovery and protection. The project is characterized by many areas of interventions, namely the re-functionalization and reuse of public areas and buildings, the improvement of urban decorum, the enhancement of social services, the promotion of cultural and sports activities, the improvement of the sustainable transport system, and energy efficiency.

The interventions proposed by the plan derived from the elaboration of criteria and principles aimed at promoting sustainable development and operating on different and integrated territorial scales. Among the projects embedded within the plan, there is an integrated intervention for sustainable mobility within the entire metropolitan area. Furthermore, the city promotes the functionalization of existing public buildings to be destined for metropolitan services. The intervention "BiodiverCity" consists of a system of actions aimed at strengthening the transition process towards green and sustainable cities. It envisages the creation of a permanent laboratory for the coordination and direction of project activities, experimentation, and research on the transition towards green, sustainable, inclusive, and smart cities. The project "RI.CO.PO" intends to strengthen ecological corridors and link the territory to the sea, with the overcoming of architectural barriers and the improvement of pedestrian and cycling mobility. Another project regards the redevelopment and recovery of disused areas, urban sites, and industrial artifacts in the urban area of Villa San Giovanni-Campo Calabro,

for social and environmental purposes. It is linked to the requalification of the park "Parco dei Cardi" which proposes the recovery of a dismissed industry, giving value to the historical and environmental value of the park. Finally, many interventions intend to make Reggio Calabria a smart city, by creating platforms to support policy-makers in monitoring the interventions and making the right choices for future development.
These are just some of the proposed projects that aim at improving urban quality, enhancing social, environmental, and economic fabric, empowering social and cultural services, and increasing the environmental performance of the city. All in all, these objectives might be framed in the vision of sustainable development, involving different areas of interventions, such as urban regeneration, reuse of public buildings and spaces, and digitalization of public services.

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REVIEW NOTES – Methods, tools and data for the city energy governance

Energy transition: pinning down the gaps between theory and practice

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Abstract

Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always remaining in the groove of rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of continuously updating emerging topics concerning relationships between urban planning, mobility and environment, through a collection of short scientific papers written by young researchers. The Review Notes are made of five parts. Each section examines a specific aspect of the broader information storage within the main interests of TeMA Journal.
In particular, the Methods, tools and data for the city energy governance section focuses on the challenges that urban energy planning commonly faces, providing food for thought to readers and fellow researchers. This contribution aims at examining these challenges and the solutions proposed in the scientific literature. For the second issue of TeMA Journal volume no. 16, this section is dedicated at identifying the gaps between the theoretical scientific progress and their actual practical implementation.

Keywords

Urban Energy Planning; Energy transition; Spatial energy planning.

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1. Introduction

Cities are increasingly recognized as crucial actors in the global energy transition (Grubler et al., 2012). Hosting almost two-thirds of the world inhabitants and generating more than 80% of global GDP, their dense populations and concentrated economic activities account for about 75% of the global energy use and between 50% and 60% of greenhouse gas (GHG) emissions (World Bank, 2023). As urban areas continue to grow, their impact on energy demand, GHG emissions, and resource depletion will become even more pronounced. At the same time, cities have the potential to lead the way towards a sustainable, low-carbon, and resilient future and are expected to play a pivotal role in the energy transition (Pilogallo et al., 2019).

Starting from the first studies on the relationship between energy systems and urban characteristics, spurred by the oil crisis of the 1970s (De Pascali & Bagaini, 2018), researchers have gradually shifted their focus from the building to the urban scale (Zanon & Verones, 2012), recognising the opportunities and the positive long-term impacts that a broader perspective offers (Ko, 2013). However, this can hardly be achieved by simply applying traditional planning strategies and tools, whose limitations have been widely recognised by the scientific community for many years, requiring the formulation of new comprehensive and holistic approaches (de Almeida Collaço et al., 2019). In this sense, several methods and tools have been developed in the last decades to properly assess and manage cities' energy use (Gargiulo & Russo, 2017), giving rise to a number of conceptual frameworks, such as Integrated Spatial and Energy Planning (Stoeglehner et al., 2016) and Integrated Energy Planning (Gholami et al., 2020), among others. Since cities are dynamically complex systems (Gargiulo & Papa, 2021), their study, from an energy point of view, needs to take into account many different features that are closely interrelated, as illustrated in the following scheme (Russo, 2017).

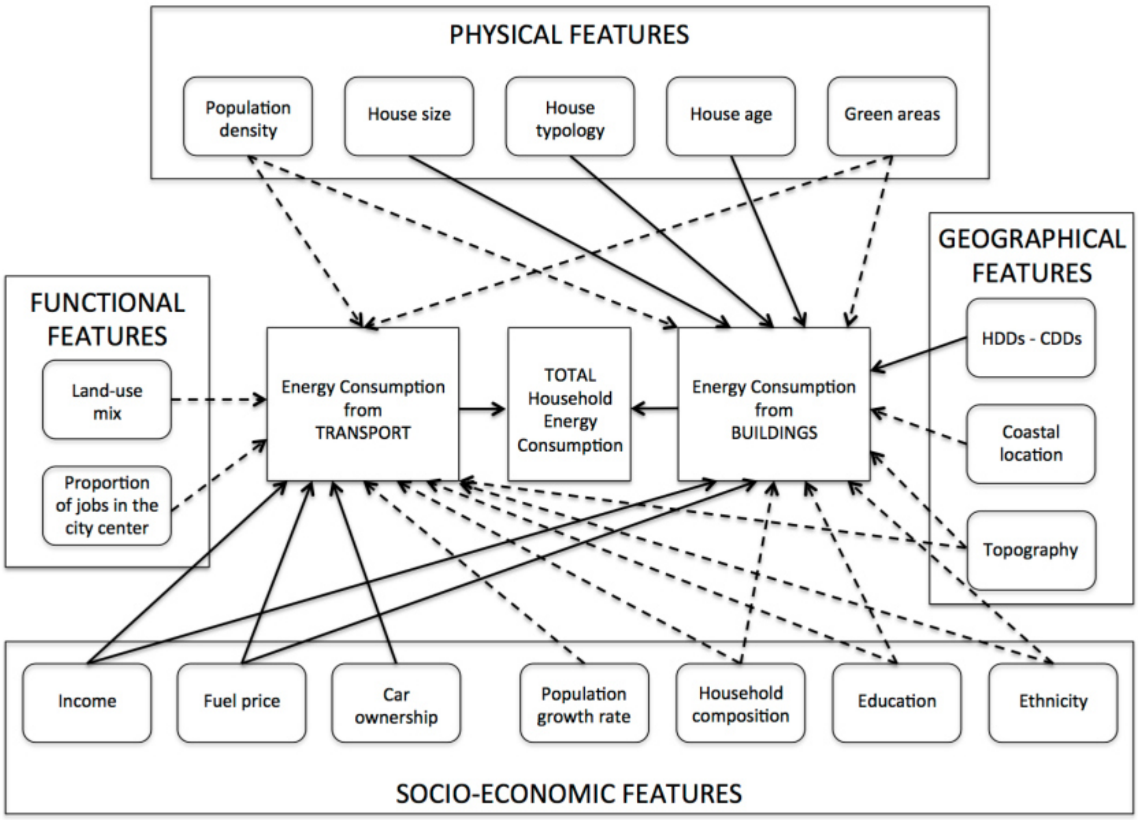

Fig.1 Key relationships between urban features and energy consumption (Russo, 2017)

Despite significant scientific progress, coordinated strategies between urban planning and energy planning are still not a widely established practice. Their effective implementation is hampered by several obstacles, which together constitute a "wicked" problem, characterised by multiplicity, heterogeneity, and uncertainty (Cajot et al., 2017).

Major factors limiting the transition from theory to practice in city energy governance include:

- *Policy and regulatory barriers:* existing policies and regulations in some regions may not be aligned with the goals of integrated urban energy planning, creating barriers to the adoption of sustainable energy practices. To address this, policy makers should review and update existing regulations to support the integration of renewable energy sources and energy efficiency measures. The introduction of new policy instruments, such as feed-in tariffs and tax incentives, can encourage stakeholders to adopt innovative energy technologies. Establishing clear and supportive policies that prioritise energy efficiency and renewable energy will provide a framework for sustainable urban development.
- *Institutional inertia:* established practices and organisational structures can be resistant to change. Overcoming this challenge requires strong leadership and the promotion of a culture of innovation. Leaders need to communicate the benefits of sustainable energy practices and create cross-departmental collaboration to promote a holistic approach to energy planning. Training and capacity building programmes should be provided to employees to enhance their skills and understanding of sustainable energy practices.
- *Funding and financial constraints*: the adoption of new strategies and tools for integrated urban energy planning may require significant upfront investments, leading to hesitancy among stakeholders to commit resources. To address this challenge, cities can explore innovative financing mechanisms, such as public-private partnerships and green bonds, to secure funding for sustainable energy projects. Developing business cases that demonstrate the long-term economic benefits, including cost savings and increased resilience, can further encourage stakeholders to invest in sustainable energy initiatives. Advocating for national and international funding opportunities will also support energy transition projects in cities.
- *Lack of awareness and capacity*: in smaller municipalities and less developed regions, stakeholders may be unaware of the benefits and possibilities offered by integrated urban energy planning. To overcome this challenge, cities can conduct awareness campaigns and educational programs to inform stakeholders about the advantages of sustainable energy practices. Technical assistance and support should be provided to help build capacity for energy planning in these regions. Partnerships with research institutions, universities, and industry experts can also be fostered to access technical expertise and knowledge.
- *Data availability and quality*: the lack of robust and accurate data poses a challenge to successful urban energy planning. To address this, cities can invest in data collection and management systems to ensure that reliable and up-to-date energy data is available for planning and decision-making. Collaboration with utility companies, research institutions, and data providers will allow access to relevant and accurate energy data. Utilizing advanced data analytics and modelling tools will enable cities to analyse energy trends, identify opportunities for efficiency improvements, and forecast future energy demand.
- *Stakeholder engagement challenges*: integrated urban energy planning involves multiple stakeholders with diverse interests and priorities, making effective stakeholder engagement critical. To address this challenge, cities can establish a participatory and inclusive approach to urban energy planning, involving all relevant stakeholders in the decision-making process. Regular workshops, public consultations, and focus groups can be organized to gather input from the public and key stakeholders. Clear communication strategies should be developed to convey the benefits of integrated urban energy planning and address concerns or conflicts among stakeholders.
- *Long planning cycles*: urban planning and infrastructure projects often have long planning and implementation cycles, which can slow down the integration of new strategies and technologies. To

overcome this challenge, cities can streamline planning processes and decision-making to expedite the integration of sustainable energy strategies. Developing flexible and adaptable energy plans will allow cities to accommodate changes and advancements in technology over time. Collaboration between different levels of government will ensure coordinated efforts and reduce bureaucratic delays.

- *Technology and market maturity*: the availability and maturity of certain technologies and markets can impact their adoption in urban energy planning. To address this, cities can encourage research and development in emerging renewable energy technologies to accelerate competitiveness. Implementing pilot projects will demonstrate the feasibility and benefits of new technologies, gaining stakeholder confidence and encouraging broader adoption. Collaborating with industry leaders and stakeholders will help identify barriers to technology adoption and work towards solutions.
- *Political will and leadership*: the commitment of political leaders is crucial in overcoming barriers to integrated urban energy planning. Advocating for sustainable energy initiatives at all levels of government and engaging with political leaders will gain their support for sustainable energy projects. Demonstrating the potential political and public support for sustainable energy solutions through public campaigns and opinion polls will strengthen the case for action. Establishing clear energy goals and targets that align with broader environmental and social objectives will create a compelling vision for sustainable urban development.

Tackling all these different issues is not an easy task but progress is being made in many regions, and successful examples are increasingly appearing across the world (Guida, 2022). By combining coordinated solutions and tailoring them to specific urban contexts, cities can pave the way for effective integrated urban energy planning, leading to more sustainable, resilient, and low-carbon urban energy systems. As awareness of the importance of sustainable and resilient urban energy systems grows, and as success stories and best practices become more widely known, the adoption of these strategies and tools is expected to gain momentum in the future.

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