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Anna Laura Pisello · Ilaria Pigliautile ·
Stephen Siu Yu Lau · Nancy M. Clark *Editors*

Building Resilient and Healthy Cities: A Guide to Environmental Sustainability and Well-being

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Editors

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Editors
Anna Laura Pisello
EAPLAB Environmental Applied Physics Lab
at CIRIAF Interuniversity research centre
on pollution and environment Mauro Felli
University of Perugia
Perugia, Italy

Department of Engineering
University of Perugia
Perugia, Italy

Stephen Siu Yu Lau
Faculty of Architecture
The University of Hong Kong
Hong Kong, China

Ilaria Pigliautile
EAPLAB Environmental Applied Physics Lab
at CIRIAF Interuniversity research centre
on pollution and environment Mauro Felli
University of Perugia
Perugia, Italy

Department of Engineering
University of Perugia
Perugia, Italy

Nancy M. Clark
Center for Hydro-generated Urbanism UF|CHU
College of Design Construction and Planning
University of Florida
Gainesville, FL, USA

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Contents

Introduction

Ilaria Pigliautile and Anna Laura Pisello

1 Healthier and Resilient Cities: Green Urbanism and Other Solutions

More than 55% of the world population already live in urbanized areas, and this percentage is expected to rise in the coming years and decades in the wake of the consolidated trend of the last century (United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022: Ten Key Messages.). Urban settlements are a clear demonstration of the humans' impact on the environment, but, while being significant contributor to climate change (Mi et al., 2019), cities are particularly vulnerable to extreme weather events and other consequences of the changing climate (Hunt & Watkiss, 2011; Zhao et al., 2018). In this view, citizens are exposed to environmental boundaries that could negatively impact on their health status generating risks for individuals according to their specific vulnerabilities (Chan et al., 2019; Song et al., 2020). There is urgency of adapting the built environment to the main effects of climate change already experienced (Yang et al., 2021), such as the always more frequent and intense occurrences of heat waves or extreme precipitation patterns causing floods (Guerreiro et al., 2018). At the same time, there is the need to improve cities liveability by limiting pollution associated with anthropogenic activities (Crippa et al., 2021).

The challenge of counteracting the urban environmental quality detriment due to climate change and natural resources depletion must be tackled accounting for both adaptation and mitigation strategies. These need to be carefully implemented by limiting conflicts or trade-offs while enhancing potential synergies (Garafakos et al., 2019). Here rises the relevance of tools availability for quantifying the foreseen effects of any urban plans or intervention in terms of reducing health risks potential associated with different level of population vulnerabilities, always in the framework of climate change. In order to reach this goal, it is fundamental to better understand the impact of possible strategies at different levels and scales. Researchers have the role of providing evidence about potential benefits achievable thanks to novel technological or even nature-based solutions so to promote virtuous practices among local authorities, practitioners, and communities.

This book collects experiences about cities and the built environment in general, worldwide and their impacts on both natural resources and human health that are strictly correlated. All the contributions are framed in the climate change context providing different perspectives on how to cope with occurring changes in order to make cities more resilient and liveable, even in critical circumstances such as the recent COVID-19 pandemic, and proposing solutions at different scales, from single building up to urban planning passing by outdoor public areas design.

The overall book content is thus structured into two parts: the first one focuses on the relation between cities and citizens, accounting for health implications of overheating and pollutants exposure of population characterized by different vulnerabilities, and looking for opportunities and inspirations coming from both nature and cultural heritage; the second part of the book focuses on urban planning for a greener and more sustainable future; here different models are proposed for different contexts always underlining the importance of locally declining the sustainability concept which undertakes the three pillars of economic vitality, social equity, and environmental protection (Purvis et al., 2019).

More specifically, the first part is entitled "Health and Environmental Resilience and Liveability in Cities" and is made by eight chapters. Chapters from 2 to 4 are associated

I. Pigliautile · A. L. Pisello (✉)
EAPLAB Environmental Applied Physics Lab at CIRIAF Interuniversity research centre on pollution and environment MauroFelli, University of Perugia, Perugia, Italy

Department of Engineering, University of Perugia, Perugia, Italy

I. Pigliautile
e-mail: ilaria.pigliautile@unipg.it

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by the theme of solid waste management (SWM) to be urgently tackled (especially in developing countries) to ensure healthy urban areas. Chapter 2 focuses on the case study of the Philippines where community participation in solid waste segregation, the process at the base of a proper SWM, was explored through surveys submitted to 100 households in a specific municipality of the country. Study results reveal the needed conditions for the active participation of local community which could be summarized into a clear alignment among regulations at different levels to be properly communicated to foster social innovation. Chapter 3 focuses on the relevance of a specific stakeholder into the SWM process: waste pickers. According to the authors, waste pickers are not properly framed into official waste management system, while their contribution demonstrated to be effective, cheaper, and sustainable. Finally, Chap. 4 combines the analysis of the solid waste issue in Nigeria to the high health risks associated with air pollution in the country. Air pollution is highly dependent on inefficient cooking systems mostly relying on biomass, while available engineering solutions for waste to energy could generate opportunities in the national energy transition, simultaneously tackling both waste management and air pollution issues. Therefore, Chaps. 5 and 6 provide solutions to increase liveability at building level taking inspiration directly from natural systems (Chap. 5) and heritage buildings (Chap. 6), while Chap. 7 proposes a method to quantify rising overheating risks in indoors through the definition of an "overheating signature". More specifically, Chap. 5 presents the design concept of multi-regulation biomimetic envelope both in theory and through an explanatory case study. Mimicking natural systems that have adapted over centuries to specific environmental conditions would allow to achieve a positive environmental impact of the built environment, according to authors, and such impact could be amplified by considering more than one natural regulation system at a time. On the other hand, Chap. 6 compares the performance of modern and heritage buildings in providing healthy conditions for people during the COVID-19 pandemic and related lockdown periods. The study in based in Egypt and highlights design strategies and features that positively affect the heritage building performance (high visual and indoor air quality, in particular) to be potentially included in future buildings design. Finally, Chap. 7 avoids focusing on buildings envelope characteristics to indeed provide a data-driven model for predicting indoor overheating risks according to internal temperature, external conditions, and occupants' behaviours. Presented application demonstrates that data-driven methods could be a valid alternative to time-consuming dynamic thermal simulations in predicting overheating risks in the climate change framework. The last two chapters of book part I analyse resiliency and liveability of the built environment by focusing on outdoors but through two different perspectives and scopes. Chapter 8 explores requirements for open public areas in order to be a safe place for children, including the autistic ones. These are particularly vulnerable groups which therefore need specific measures in space design that are generally addressed in the private sphere while are still not considered in public areas. The lack of such spaces increases their vulnerability. Concluding, Chap. 9 presents the relevance of green infrastructures for the sustainable development of cities fostering ecosystem services, increasing resiliency, and reducing local poverty. Landscape assessment via both cartography and visual inspection was thus used as a tool for critically analysing a specific region in Mexico to guide future urban plans on the need of green corridors.

The topic of Chap. 9 opens the door to the main theme of book part II entitled "Principles of Green Urbanism and the Transformation to a Greener Sustainable Environment". As the previous, also part II is made by eight chapters. Chapters 10 and 11 take a look to the relation between local communities and public green areas. More specifically, Chap. 10 discusses "greenification" of dense neighbourhood through the design of pocked parks. These are envisaged into areas that are still without buildings into dense urban environments like the capital of Albania, Tirana, that is the presented case study. The authors emphasize the relevance of urban pocket parks for improving community interaction and promoting healthy habits such as walking or cycling. On the other hand, Chap. 11 highlights the local dimension of sustainability due to spatial, ecological, and cultural specifics of each community. Therefore, the research focuses on green markets as examples of urban identity where citizens interact, exchange, and experience diversity. Given these characteristics, green markets are presented as potentially sustainable public spaces, and such hypothesis was tested in the two largest cities of Croatia (Zagreb and Split) through a quantitative research methodology. Chapters from 12 to 14 present the common topic of sustainable urban planning in four different contexts and under different emergencies and constrains. Chapter 12 describes the planning constrains related to the Vesuvian National Park (Italy) which is globally recognized for its environmental and landscape value. Here the challenge is to combine nature conservation and local development instances. The study points out fragilities and vulnerabilities of the area concluding that environmentally sustainable actions plan must address conservation of natural resources by relocating production activities and mitigating risks. Chapter 13 presents the urban development of Amman, Jordan, as the results of a lack in planning policies that did not consider refugees crisis which strongly characterize the area. Informal settlements have become part of the city, and research findings aim at supporting effective future planning policies to improve the quality of the

urban environment. Chapter 14 moves from a different crisis, the recent COVID-19 pandemic, to justify the renovate interest in the garden-city model of Howards, specifically referring to the context of Istanbul. Indeed, the garden-city model would provide healthy houses in green areas that was recognized as a plus during the pandemic and related lockdowns. How to quantify the sustainability of all these approaches to urban planning is the topic of Chap. 15. The authors of this contribution analyse the carbon footprint calculator for urban planning, a tool that was specifically developed thanks to funds from the Community of Madrid. The carbon footprint is pursued by taking into account uses and activities foreseen in future planning and the associated greenhouse gas emissions as well as changes in land use and coverage affecting soil sink capabilities. This tool has the potential of leading local authorities for the selection of the lowest carbon emissions alternative and thus for improving the overall resiliency and mitigation capability of a city. Finally, Chaps. 16 and 17 apply greening principles at building scale. More specifically, Chap. 16 deals with potential benefits achievable through the application of green roofs on buildings of the communist period in Tirana. A costs–benefits analysis was carried out. Despite green roofs are still more expensive considering the installation costs, benefits, including the reduction of CO_2 in atmosphere, the management of rainwater runoff, the reduction of noise pollution and urban heat island phenomenon, and the positive contribution to urban ecosystem, overcome costs on the long-term so that green roofs are proved to be the most cost-effective solution. Finally, Chap. 17 brings the concept of "design with nature" to present atrium with evaporative cooling as potential solution to improve liveability of Mediterranean areas. The study focused on the context of Alexandria (Egypt) and was based on CFD analysis of different configurations of the proposed solution. The analysed configuration results to be more effective in tall residential buildings increasing the effectiveness of natural-stack ventilation.

All the chapters are related to each other following the red line of the seek for more liveable cities in the framework of climate change leading to all the consequences here discussed. All the chapters contributed to the book content and the related relevant takeaways that could support scientific communities and practitioners towards the achievement of resilient and healthy cities. More specifically, takeaways could be summarized in the following: (i) the importance of addressing multiple dimensions of urban environmental quality to avoid trade-offs of implemented solutions; (ii) the need for understanding principles of human comfort and well-being in the urban areas, addressing multiple scales of analysis, to provide scalable solutions but, at the same time, the awareness that global problems always require local solutions.

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Health and Environmental Resilience and Livability in Cities

Greening the Local Solid Waste Management Through Community Participation: Unfolding the Challenges and Creating Opportunities for Development Planning

Alex M. Alazada and Dina C. Magnaye

Abstract

The local government units (LGUs) are the principal implementers of the Ecological Solid Waste Management (SWM) Act 2000 (Republic Act 9003) in the Philippines. The law requires a *barangay* (village) to handle the segregation and collection of solid waste, specifically biodegradable, compostable, and reusable wastes. The municipality or city collects the non-recyclable materials and special wastes. The study aims to assess how community participation contributes to the greening of the local SWM utilizing the theory of participation and the approaches of community participation. The survey covered 100 households from a firstclass urban municipality. Key informants were interviewed, such as the local officials and SWM stakeholders. The study revealed that community participation contributes to the greening of the local SWM given the following conditions: (a) community members are familiar, aware of, and comply with the law and ordinances; (b) households are willing to pay for SWM services; (c) local initiatives are aligned with the sustainable development goals (SDG) 1, 3, 8, 7, 11, 12, 13, and 17; (d) local SWM programs adhere to Green SWM principles that are geared toward economic, social, and environmental sustainability; and (e) local SWM programs are efficient in responding to the SWM challenges and weaknesses and address them through the strengths and opportunities of the solid waste sector. These are necessary considerations in identifying the greening strategies for local SWM and mainstreaming them in local development planning.

Keywords

Awareness level · Community participation · Solid waste management and sustainability · Participatory community approach · Planned behavior

1 Introduction

Solid wastes are unnecessary materials from household, trade, and business activities (2022 SmartRanger, 2009). These can be classified based on their sources such as ordinary house waste, commercial, institutional, industrial, and construction; according to the contents such as organic material, glass, metal, and plastic paper, among others; and based on the possible hazard such as combustibility, radiation effect, toxicity, infectious consequence, among others (Leblanc, 2020).

Biodegradable wastes have been the most significant waste composition among solid wastes in developing and developed countries (Silva, 2018). These are very common in households, offices, and backyards. These are mixed with other types of waste in landfills. Silva (2018) also indicated that biodegradable wastes occupy almost 50% of the solid waste composition and are considered the most significant contributor to global warming and climate change by emitting this environmentally harmful methane.

The critical factors in the worsening solid waste worldwide include rapid urbanization and high population growth (McAllister, 2015). The Senate Economic Planning Office (SEPO) (2017) reported that the significant concerns of SWM in the Philippines include injudicious waste disposal, irregular and inefficient waste collection, and the insufficiency of disposal facilities like material recovery facilities

A. M. Alazada
Master of Arts (Urban and Regional Planning) (Graduate Student), University of the Philippines School of Urban and Regional Planning, Quezon City, Philippines

D. C. Magnaye (✉)
University of the Philippines School of Urban and Regional Planning, Quezon City, Philippinese-mail: dcmagnaye@up.edu.ph

A. L. Pisello et al. (eds.), *Building Resilient and Healthy Cities: A Guide to Environmental Sustainability and Well-being*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-031-33863-2_2

(MRF) and landfills. Several issues concerning SWM are observed at the local level (cities, municipalities, and *barangays* or villages), including unrestrained disposal of garbage into the creeks by dwellers, non-practice of composting, littering, continuous use of plastic, and open burning of wastes. Added to these are the lack of community cooperation, participation in SWM practices, and compliance with rules and regulations (Atienza, 2008).

Greening of the local SWM becomes imperative in dealing with the SWM issues. Community participation becomes highly relevant across the hierarchy of SWM from disposal, recovery, recycling, and reuse. Elagroudy et al. (2016) emphasized that "greening in the solid waste sector will provide major benefits to societies and will significantly contribute to the indirect economic indicators in terms of employment generation, GHG emission reduction and its associated health benefits, enabling energy production, and protecting human health." This intervention is envisioned to contribute to sustaining the green economy.

The research was conducted to assess how community participation contributes to the greening of the local SWM. Specifically, the study aims to (a) examine how familiarity, awareness, and compliance of households with the SWM law and local ordinances entice community participation; (b) analyze the level of community participation in SWM implementation in terms of the willingness of the village residents to participate in SWM program; and (c) evaluate the efficiency of the implementation of the SWM law and initiatives based on the alignment of the SWM implementation with the SDG, Green SWM, and the pillars of sustainable development as well as the analysis of the strengths, weaknesses, opportunities, and challenges (SWOC) of the local SWM programs. All of these are envisioned to provide inputs to green local SWM planning.

2 Literature Review

2.1 Community Participation in Local SWM

The participatory dimension of SWM can be examined utilizing the theory and principles of community participation. Wates (2000) states that participation is "involvement in a group undertaking associated with a cause or purpose." Burns et al. (2004) indicated that community participation "concerns the engagement of individuals and communities in decisions that affect their lives…[…] improves democratic and service accountability, enhances social cohesion, adds economic value, provides opportunities to develop skills, and promotes sustainability."

According to Hamdi (1995), community participation is a "form of formal or non-formal partnership between families, community groups, government officials, and professionals to work on something." Community or citizen participation is linked by Arnstein (1969) with citizens' control of power. It is a power delegation where the formerly neglected sector exercising political and economic rights will now be mainstreamed. As Alexander (1975) stated, participation is "essentially good, for it brings the community together to be involved in crafting decisions for their good. Since the community participated in the activity promotes a sense of ownership and power among them."

Several factors influence community participation in local SWM. Knowledge is considered a factor in SWM cooperation and engagement (McAllister, 2015; Vassanadumrongdee & Kittipongvises, 2018). The study by Sudipta et al. (2016) revealed that knowledge of SWM correlates with preparedness to participate in the waste management program.

A study by Bagulong (2011) on community participation in Davao City highlighted that community participation could be measured based on five (5) indicators: SWM, materials and utilities, penalties, programs, and incentives. The implementation of the SWM program was above the minimum requirement, although not on the maximum execution level. Nevertheless, it showed that the villages properly managed the implementation of the Ecological SWM Act. Village enforcers contributed to a fair implementation or management of the law.

2.2 Greening the Local SWM

Local solid waste sector greening toward a green economy. Gaber et al. (2011) described a green economy with the presence of …[…] "public and private investments that result in improved economic returns, a healthier environment, and social development." According to them, greening any sector covers the "…process of configuring businesses and infrastructure to deliver better returns on natural, human, and economic capital investments, while at the same time reducing greenhouse gas emissions (GHG), extracting and using less natural resources, creating less waste, and reducing social disparities" (Gueye, 2010, as cited in Gaber et al., 2011). Godfrey (2014) indicated that the "waste sector, as with many sectors of the economy, is responding to the call to transition to a green economy."

The municipal solid waste (MSW) sector contributes to the local economy since it engages the workforce in labor-intensive SWM activities and requires investments in machinery and equipment for handling, transport, and processing (Gaber et al., 2011). Other economic activities in

the sector include recycling, composting, and energy production. In addition, "greening the solid waste sector" is recognized where "SWM will contribute to job creation, mitigate environmental and health impacts, and improve the whole nation's economy." (Gueye, 2010).

Greening the solid waste sector and the sustainable development goals (SDG). The greening of the solid waste sector is a means to contribute to the SDGs and green growth "through reduction of waste, conservation and efficient use of material and energy, lowering of emissions, protection of human health and creation of jobs and employment opportunities" (Elagroudy et al., 2016). Table 1 shows that greening the solid waste sector is recognized to contribute to the goals and targets of the SDGs.

The transition of the green solid waste sector to a green economy. The United Nations Environment Program (UNEP) (2010) defines a green economy as an "economy that results in improved human well-being and reduced inequalities over the long term, while not exposing future generations to significant environmental risks and ecological scarcities." With human beings at the core of the green economy, the role of engaging the community in SWM becomes a sustainable mechanism to ensure the greening of the solid waste sector.

Elagroudy et al. (2016) also emphasized that greening the waste sector also capitalizes on an SWM plan where benefits can "maximize economic, environmental, and social benefits at a reasonable cost for current and future MSW generation…." Tulebayeva et al. (2020) emphasize that a green economy involves growth in income and employment due to public and private investments in sectors such as reducing environmental risks, including waste management improvement.

Zhu et al. (2008) established the sustainable and integrated SWM (SISWM) or Green SWM. The SISWM requires the following: "a) an essential part of successful local governance; b) emphasizes stakeholder participation and involvement; c) ensures occupational health and safety; d) provides economical service delivery; e) guarantees cost recovery; f) performed in an environmentally friendly manner that minimizes resource use and maximizes resource recovery; g) contributes to job creation in the sector itself and encourages services and products in other sectors and industries, and h) helps reduce the financial pressure on governments." (Zhu et al., 2008).

The SWM sector is also believed to contribute to the green economy when it meets the requirements of the three pillars of sustainable development—social, environmental, and economic (Elagroudy et al., 2016). Table 2 presents the pillars of sustainable development and how the SWM sector can achieve these pillars.

2.3 Local SWM in the Philippines

Waste generation. The Philippines registered annual trash of 14.66 million tons (UNEP, 2010, as cited in Bagayas, 2020). The Environmental Management Bureau (EMB) projected that the annual volume of waste generated would surge to 18.05 million tons in 2020. In terms of waste composition, the National Solid Waste Management Commission (NSWMC) reported that disposed waste is dominated by biodegradable waste (52%), followed by recyclable waste (28%), and residuals (18%). The sources of biodegradable waste include wastes from yards and households' kitchens like food, among others. Recyclable

Table 1 Contribution of the solid waste sector to the SDGs

Sustainable development goal	Contribution of the solid waste sector to the SDG
No poverty (goal 1)	By achieving full and productive employment and decent work for all MSW sector workers, including women and young people
Good health and well-being (goal 3) and decent work and economic growth (goal 8)	By improving the labor conditions and working environment for workers in the MSW sector. In addition, proper waste management leads to healthy water and food, which in turn enhances the health of human beings
Affordable and clean energy (goal 7) and Sustainable cities and communities (goal 11)	By integrating the principles of sustainable development into the country's policies and programs. Greening the MSW sector will also reverse the loss of environmental resources by following the solid waste hierarchy and encouraging the concept of the three Rs: reuse, recycle, and recover
Responsible consumption and production patterns (goal 12)	By substantially reducing waste generation through prevention, reduction, recycling, and reuse
Climate action (goal 13)	By reducing GHGs in the solid waste sector and its impacts
Partnership for the goals (goal 17)	By providing international funding, new technologies, information, and communications to private and governmental sectors in developing countries

Source Elagroudy et al. (2016)

wastes, on the other hand, comprise items like metals, plastic packaging, leather, and so on.

In response to the anticipated growth in the quantity of waste generated, the Ecological SWM Act required the LGUs to formulate a local SWM plan that details the reuse, recycling, and composting of waste, with the NSWMC serving as the approving and overseeing entity in implementing SWM plans. However, since November 2020, only 62% or 1000 of the 1634 LGUs have approved 10-year SWM plans. This scenario is attributed to limited funding, space availability, and resources (Ranada, 2014). Sanitary landfills are lacking in many LGUs. This scenario poses potential environmental and human health risks due to untreated solid waste and the absence of residual waste recovery. In addition, many sanitary landfills are reaching their maximum capacity. The Ecological SWM Act of 2000 enjoins all sectors of society to participate in the successful implementation of the SWM program.

Solid waste infrastructure. The LGUs are required by the Ecological SWM Act to establish SWM facilities like MRF to process compostable and recyclable materials. As specified in Article 6, section 37 of the law, LGUs have until 2004 to convert their open dumpsites into sanitary landfills. As of 2018, only 10,730 MRF facilities in the Philippines service about 33.3% of the 42,046 *barangays* (Ranada, 2014). The gap can be explained by insufficient funds to put up an MRF. According to Ranada (2014), a functional MRF costs around half a million to be installed, coupled with the annual salaries of garbage collectors of PhP960,000 (19,200 USD).

Due to the absence of standards in establishing disposal facilities, different LGUs constructed MRFs based on their capability and requirements. Some build a combination of recycling and composting facilities, others build just a *barangay* recycling facility, and others a communal bin or market composting.

Budgetary constraints pushed some LGUs to collect fees on garbage collection. They also impose fines on violators, sell recyclables, produce composed fertilizers for sale, charge fees on special waste collection, and lease facilities to private individuals, even though transfer station is not popular in the country (Lapid, 2007).

Compliance with the SWM law. The Local Government Code (Republic Act 7160) states that "LGUs shall be primarily responsible in the implementation and enforcement of the provisions of the law within their respective jurisdictions." At the local level, the SWM law (RA 9003) states that "the *barangay* (village) handles the segregation and collection of solid waste specifically for biodegradable, compostable, and reusable wastes. The collection of non-recyclable materials and special wastes shall be the responsibility of the municipality or city."

At the *barangay* (village) level, compliance is primarily determined by strict observance of some provisions of the Ecological SWM Act and its implementing rules and regulations (IRR). Section 6 of the IRR requires *barangays* (villages) to create their SWM Committee. The *Barangay* SWM Board has the following functions and responsibilities: (a) formulate an SWM program consistent with the city/municipality plan; (b) segregate and collect biodegradable, compostable, and reusable wastes; (c) establish MRF; (d) allocate *barangay* funds; (e) look for sources of funds; (f) organize core coordinators; and (g) submit a monthly report to the city or municipality.

Table 2 Requirements of the three pillars of sustainable development for the SWM sector

Pillars of sustainable development	Basis of the SWM sector in achieving the pillars of sustainable development
Economic sustainability	• The waste sector cost effectively generates secondary material, establishes new enterprises, provides more jobs, supplies affordable carbon–neutral energy, and minimizes the amount of residual waste disposed of • Funds and investments must be directed to appropriate practices, infrastructure, equipment, and affordable services to operate and maintain over their lifetime • Wherever possible, economic investments should encourage local technologies and enterprise financing
Social sustainability	• Working conditions in the waste sector are safe and healthy for employees and the public • Employment in the green economy also needs to be concerned with other social factors such as child labor, social protection, and freedom of association
Environmental sustainability	• Resources should undergo life cycle analysis, starting with the production and manufacturing sectors, to promote the production of non-hazardous goods and materials, resulting in the least amount of waste generated • Sustainable consumption should be promoted by addressing the consumer side by implementing waste prevention strategies

Source Elagroudy et al. (2016)

3 Research Method

3.1 Research Framework

Theoretical basis. The study is anchored on the Participation Theory and the Community Participation Approaches. These guided the authors in analyzing community participation in implementing local SWM and its contribution to greening the local solid waste sector (SWS).

The Participation Theory. The participation theory builds up on the concepts and principles of community participation, which may come in different typologies and approaches depending on the type of project and the nature of the partnership between institutions and the community, government and the public, and non-government organizations (NGOs) and the people (Abrams & Kolodny, 1971). There are four approaches to community participation. These include contributions, instrumental, community empowerment, and developmental processes.

The contributions approach is defined by Preston et al. (2009) as "the type of participation which considers involvement mainly as voluntary contributions for an activity." The contributions might be in the form of devoting time to the activities of the project, and it might be in kind, resources, or monetary, or it might be in the form of sharing knowledge with a fellow community member. It is a process wherein the community as a participant of the program shall be guided or mentored by an expert or an authority on the subject activity or project. This professional mentor or leader typically comes from outside the community and will oversee the entire program and decide how the community's contributions will be put into proper perspective or use. Figure 1 shows the components of the contributions approach.

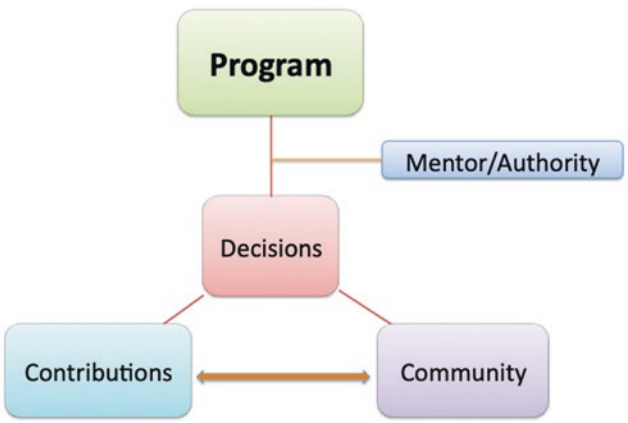

Fig. 1 Contributions participation approach (authors' construct)

Preston et al. (2009) characterized the instrumental approach where community participation is geared toward achieving results from intervention to planning and development. He viewed community empowerment as a means by which communities are empowered to solve issues and challenges. The developmental approach involves the community in the conceptualization of development and decision-making guided by the principles of social justice.

Conceptual framework. Among the four approaches to community participation, the contributions approach is adopted in assessing community participation in local SWM. In practice, a top-down contributions approach is applicable in local SWM where the community participates in waste segregation supervised by authorities or technical support in composting biodegradable waste from an expert of the national government agency. The community voluntarily devotes time for meetings, lectures, money, and resources to conduct composting activities. In this case, the contributions approach is seen as a "mentoring" type of participation by a community in a government-led action to attain a common objective.

The Participation Theory can be analyzed by looking at the various stakeholders in implementing the SWM at the local level. Figure 2 shows the key actors in the SWM implementation, including the LGUs and the village officials.

The participation of the community can be evaluated based on the provision of Section 10 of the Ecological SWM Act. It specifies that the LGUs shall be primarily responsible for the implementation and enforcement of the requirements of the act within their respective jurisdictions.

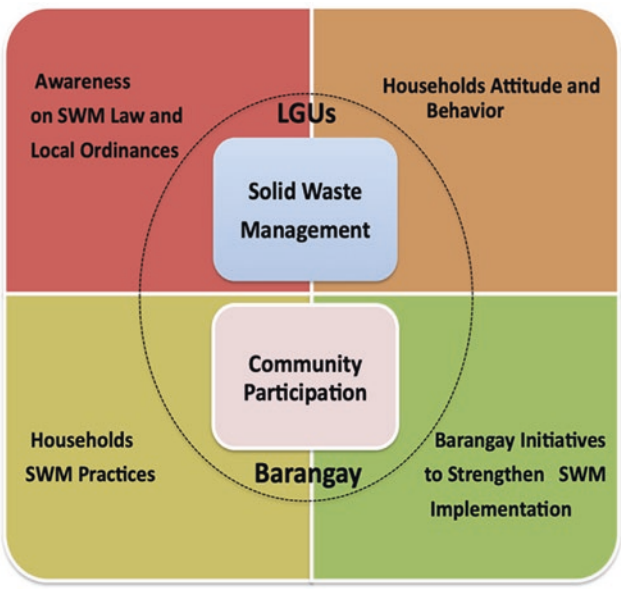

Fig. 2 Conceptual framework (authors' construct)

The assessment of community participation covers four key areas. These include knowledge and awareness of SWM law and local ordinances, households' attitude and behavior, SWM practices, and the village initiatives to strengthen the implementation of SWM.

3.2 Developed Questionnaire

There were two sets of questionnaires developed for the study. One set was for the household survey and the other for the key informant interview to include the village officials and the garbage collectors.

The first set of questionnaires was structured in the following manner: (1) socioeconomic profile of the respondents; (2) familiarity, awareness of, and compliance of the respondents with the SWM law and local ordinances; (3) willingness to participate in and pay for the services of the village's SWM program; (4) perception of the respondents on the efficiency of implementing the SWM law; and the (5) recommendation on how to improve the implementation of SWM in the village. The fourth part of the questionnaire established the alignment of the SWM implementation with the SDG, Green SWM and pillars of sustainable development, as well as the analysis of the strengths, weaknesses, opportunities, and challenges (SWOC) of the local SWM program.

The second set of questionnaires defined the perceptions of the village officers and garbage collectors on community participation in SWM implementation. Further, the questionnaire also included the recommendations of the respondents on the enhancement of SWM implementation at the village level.

3.3 Case Study

The study area is *Barangay* Tuntungin-Putho in the Municipality of Los Baños, Province of Laguna in the Philippines. Figure 3 shows the map of the study area.

The chosen study site is one of the 13 *barangays* of the Municipality of Los Baños, with a population of 9231 in 2018, as given in Table 3. The village is the fourth-largest population and is one of the three (3) *barangays* with its garbage truck used for solid waste collection. It is also one of the top performers in terms of SWM implementation in the municipality.

Based on the 2018 *Barangay* Monitoring System (BMS), the total volume of biodegradable wastes generated by the community is approximately 1795.92 kg/day, while the non-biodegradable and recyclables combined are only 630.14 kg/day. The Municipality of Los Baños has an approved 10-year SWM plan as required in Section 16 of the Ecological SWM Act.

Instrumentation. The convenience sampling method was utilized in choosing the respondents. According to Dudovskiy (2017), convenience sampling, or availability sampling (accidental sampling or grab sampling), is a manner of sampling dependent on conveniently available participants in collecting data, with no statistical probability involved in selecting the sample population.

The respondents were interviewed face to face. The critical issues in compliance with the Ecological SWM Act and local ordinances were generated from the municipality's 10-year SWM plan covering the period from 2014 to 2023. This conveys the situation in managing solid waste at the local level.

Data analysis. Based on the structure of the questionnaire, the efficiency of the implementation of the SWM law (fourth part of the first set of the questionnaire) was used to establish the alignment of the SWM implementation with the SDG as well as its SWOC. For the former, the parameters of Elagroudy et al. (2016) in greening the SWS with their contribution to the goals and targets of the SDGs were used in the analysis.

The FGD and the interview with the *barangay* officials were utilized to analyze the SWOC in the implementation of the local SWM activities. The efficiency of SWM implementation was also evaluated using the SWOC framework. This framework established the weaknesses and challenges as the basis of crafting local strategies that enable community participation in the local SWM program, as described in Table 2.

The following focal areas of the Contributions Approach were used for the SWOC analysis of implementing the local SWM:

- *Provision of time*. The community devotes time to attending meetings, seminars, and other related activities.
- *Provision of resources*. The community allocates funds/equipment for the program.
- *Provision of community-based knowledge*. The community member shares expertise/skills to fulfill a task for the program.

4 Results

4.1 Sample Composition

In this study, the sample respondents were generated from 1846 households following the BMS. The survey covered 100 respondents through convenience sampling, with 15 from the six *puroks* (districts) and the *barangay* officials representing the rest. Based on the authors' knowledge of the type of neighborhood in the study area, the chosen

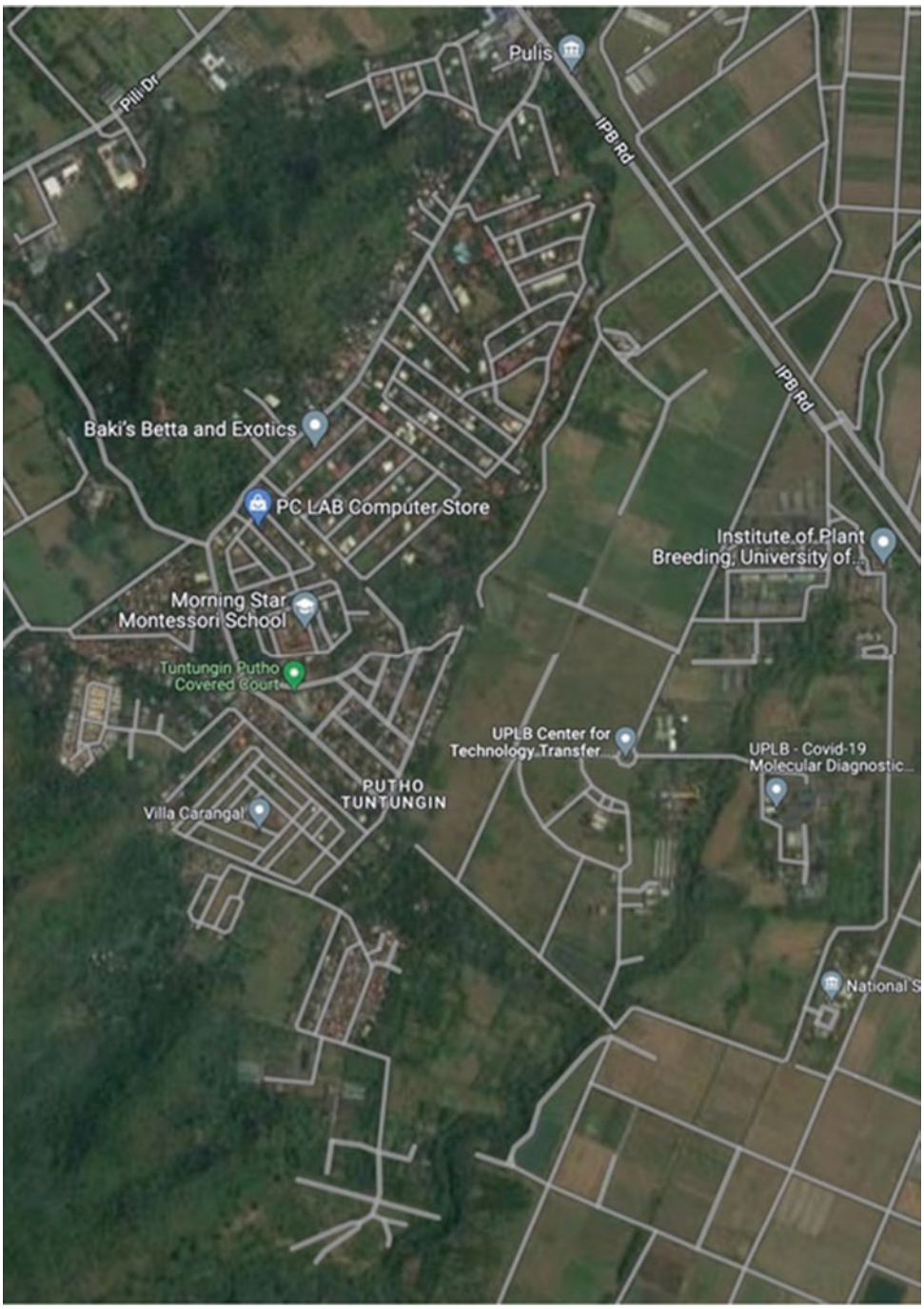

Fig. 3 Map of the study area

samples are believed to represent the total population, given the similarities in their traits. They are all part of the SWM initiatives of the village. The breakdown of the respondents is presented in Table 4.

4.2 Socioeconomic Profile of the Respondents

Most respondents are women (69%), and predominantly (78%) are married, as presented in Fig. 4. Notable age ranges between 45 to 54 years old (36%) and 55 to 64 years old (27%). A significant number (20%) belong to 35–44 years old. Around 11% of the respondents have ages ranging from 22 to 34.

In terms of education, more than half (52%) of the respondents are high school graduates. There are also college graduates at second (15%) and fourth (17%) year levels. Around 11% are elementary graduates.

Figure 5 presents that approximately 20% of the women are unemployed and serve as housewives. Others employed

Table 3 Total population and number of households by *purok* (ward), *Barangay* Tuntungin-Putho, 2018

Purok	Male	Female	Total population	Total households	Percent of total
1	835	864	1699	340	18
2	521	574	1095	219	12
3	851	827	1678	336	18
4	651	714	1365	273	15
5	1074	1101	2175	435	24
6	608	611	1219	244	13
Total	4540	4691	9231	1846	100

Source of basic data Barangay Monitoring System, 2018

Table 4 Sample composition is breakdown of respondents for the household survey

Purok	Male	Female	Total respondents
1	3	16	19
2	6	9	15
3	9	8	17
4	2	14	16
5	2	14	16
6	9	8	17
Total	31	69	100

are the variety store owners at 12%, while 10% are drivers and government employees. Other occupations stand at 6% and below.

Most respondents (80%) have a monthly income of PhP40,000 (800 USD) and below. The average income of the respondents was recorded at approximately PhP15,000 (300 USD) a month. This represented an annual per capita income of around PhP180,000 (3600 USD), which is below the 2012 per capita poverty threshold for the CALABARZON Region, equal to PhP229,644 (5593 USD) or PhP19,137 (383 USD) per month. It should be noted that more than half (52%) of the respondents finished high school and are generally considered low-income earners. A meager 4.0% belong to the PhP40,000–PhP50,000 (800–1000 USD) income bracket, while 3% have income between PhP100,000 (2000 USD) and PhP249,999 (5000 USD). The remaining 13% preferred not to answer the question.

Around 19% of the respondents have spouses who are not working, and the majority are housewives. Private employees came at third with 14%, household helpers turned up at 10%, followed by drivers and business owners with 7%. This denotes a variety of occupations of the respondents. However, the occupations are not high-paying jobs which can be attributed to the relatively low educational attainment of more than half (52%) of the respondents.

About 75% of the spouses have income below PhP40,000 (800 USD). A meager proportion (1–2%) have income ranging from PhP40,000 (800 USD) to PhP50,999

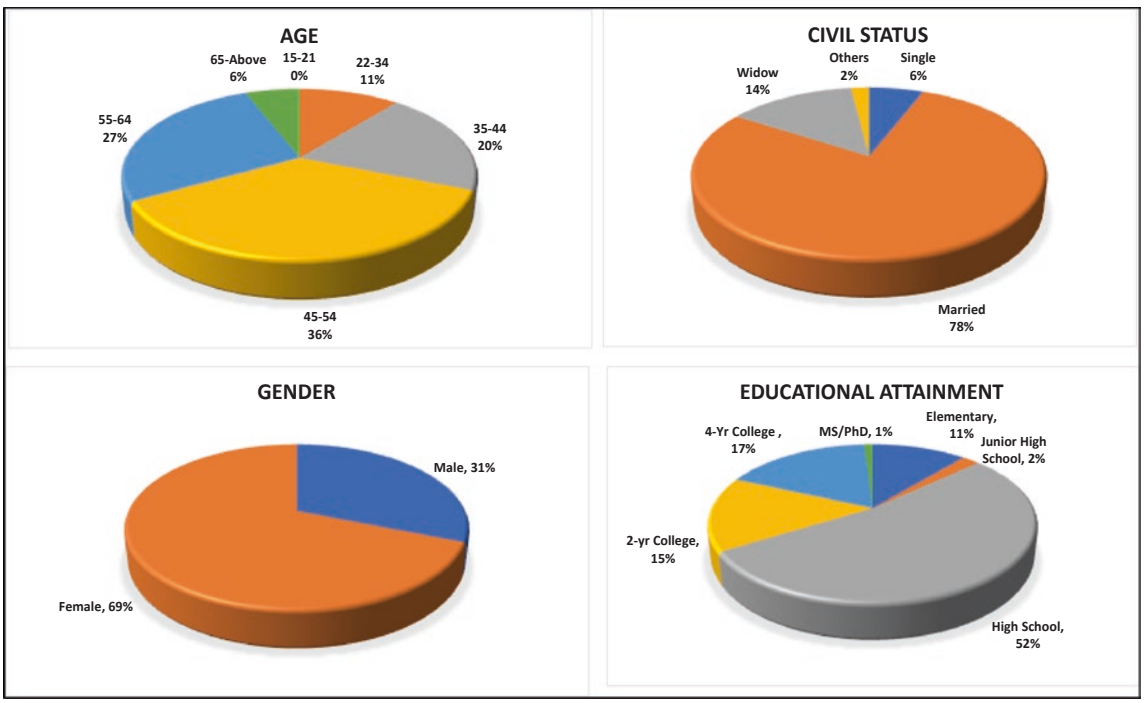

Fig. 4 Profile of the respondents

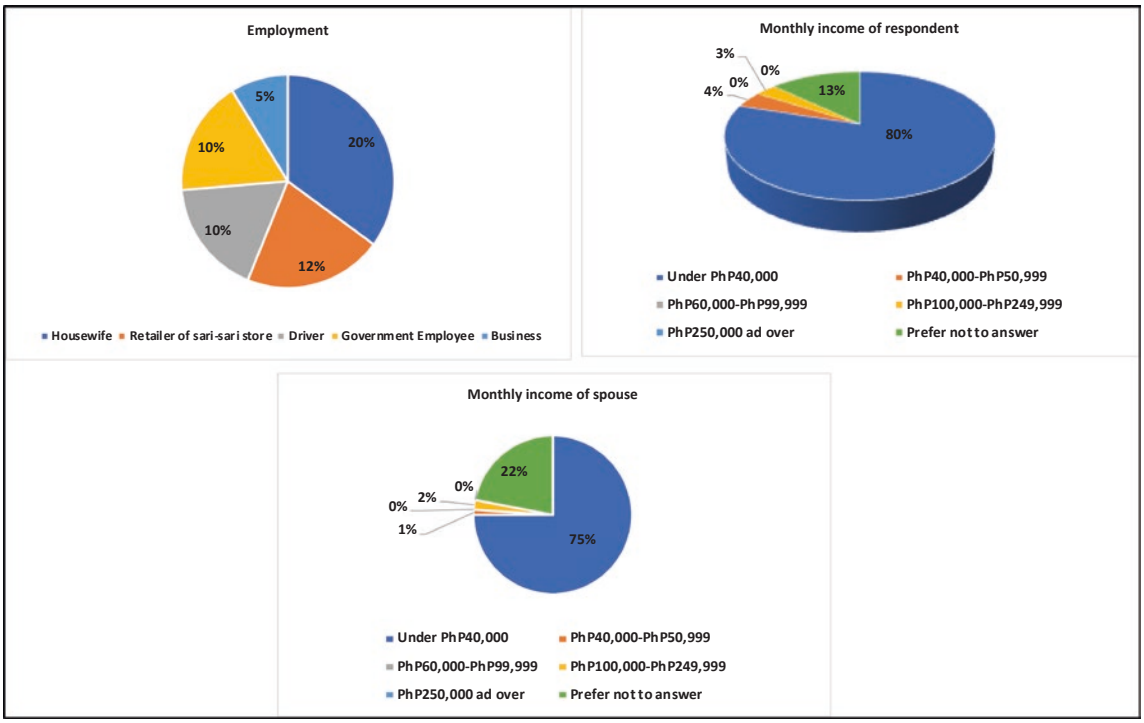

Fig. 5 Employment and income of respondents and spouses

(1020 USD) and from PhP100,000 (2000 USD) to PhP249,999 (5000 USD). The observed low income of the respondents can be partly attributed to the low educational attainment of half of the respondents.

4.3 Familiarity, Awareness of, and Compliance with SWM Law and Local Ordinances

Awareness of the Ecological SWM Act (RA 9003). In the household survey, Fig. 6 indicated that 61% of the respondents are highly aware of the Ecological SWM Act. This is followed by respondents who are moderately familiar with 25%, 8.0% are slightly aware, and 4.0% are somewhat aware. The respondents who are unaware of the law stand at only 2.0%.

Most respondents aged 45–64 are aware of the law, and most are female. Aminrad et al. (2011) indicated that the older respondents and women were seen to have higher abstract knowledge and were considered more active participants of the SWM program.

Almost the same figures were observed in the awareness of the local ordinance on SWM. The extremely aware respondents remain at 61% of the total respondents. A little difference was observed in the moderately aware at 21% of the respondents; the somewhat aware and slightly aware reached 3.0% and 7.0%, respectively. About 8.0% of the respondents are unaware of the local ordinance.

Awareness of the law (Clean Air Act or RA 8749) against garbage burning. A large proportion (96%) of the respondents are unaware of the supporting law (Clean Air Act) to the Ecological SWM Act, as described in Fig. 7. The former refers to the prohibition on the open burning of garbage. Nevertheless, all respondents recognized that it harms the environment and human health. Some others avoid burning waste to shun the complaint of their neighbors. The remaining respondents (4%) practice the open burning of dry leaves to shoo off dengue-causing mosquitoes. Practically, the awareness level of the supporting law is 100% since the burning of leaves is exempted in RA 8749.

According to 73% of the respondents, the primary reason for households' avoidance of the burning of garbage is the awareness of its negative impact on the environment and health as exhibited in Fig. 8. The second reason for not burning trash is the penalty for violating the law, as indicated by 37% of the respondents. Similarly, around 3% of the households do not burn their garbage because of complaints from neighbors.

Generally, compliance with the SWM law and ordinance is high (61%). Only a few do not comply since they do not want to be blamed by their neighbors who complained of the unfavorable smell of burned garbage. The *barangay*

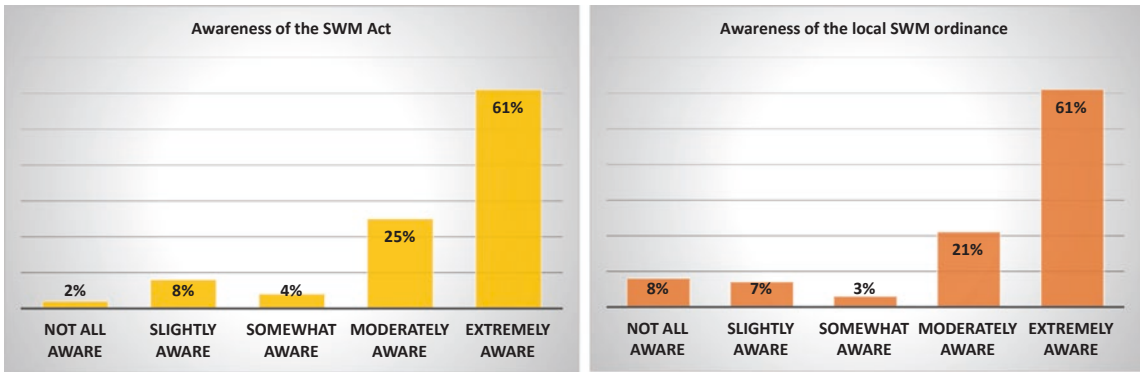

Fig. 6 Awareness of the SWM Act, local SWM ordinance, and garbage burning

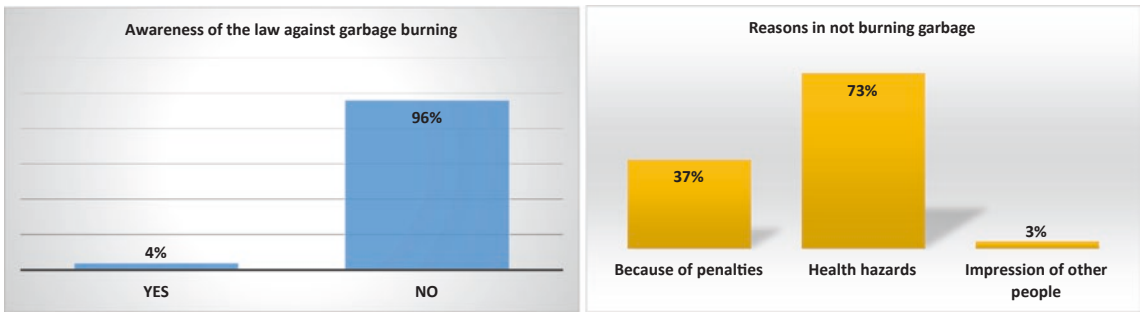

Fig. 7 Awareness of the law on the burning of garbage

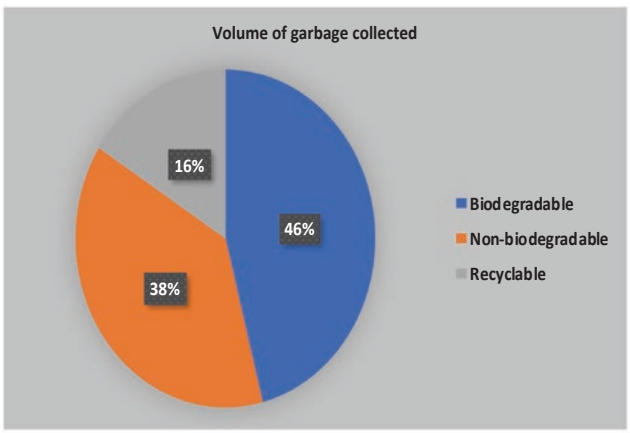

Fig. 8 Volume of garbage collected

officials believed that the residents were aware of the health hazards caused by the burning of waste.

A reasonably high (52%) proportion of the respondents are high school graduates. They already possess relatively high comprehension levels. The second (17%) group is composed of those who finished a 4-year course in college, while the third group (15%) represents those who completed two-year college. These clusters demonstrated better grasp or comprehension levels of the law. Based on Sudipta et al. (2016), the well-off and educated class are more willing to participate than those in the lower educated and poor classification.

Community participation in the implementation of the local SWM. The households perceived that their awareness of the law and the ordinances motivated them to reduce the volume of biodegradable waste generation further. Figure 8 illustrates that the household survey indicated that the volume of biodegradable waste generated, equal to 46%, is higher than that of non-biodegradable waste collected at 38% (Fig. 8). As perceived by the households, participation in the SWM initiatives like waste composting significantly reduced waste.

Awareness of likely consequences of behavior toward SWM implementation is recognized as a dominant factor in community participation. All the respondents avoided throwing their garbage anywhere (littering). They knew that it would cause environmental hazards, clog canals, and contribute to flooding. Others mentioned that mishandling of garbage contributes to an unclean environment, serves as eyesores, and causes infectious diseases.

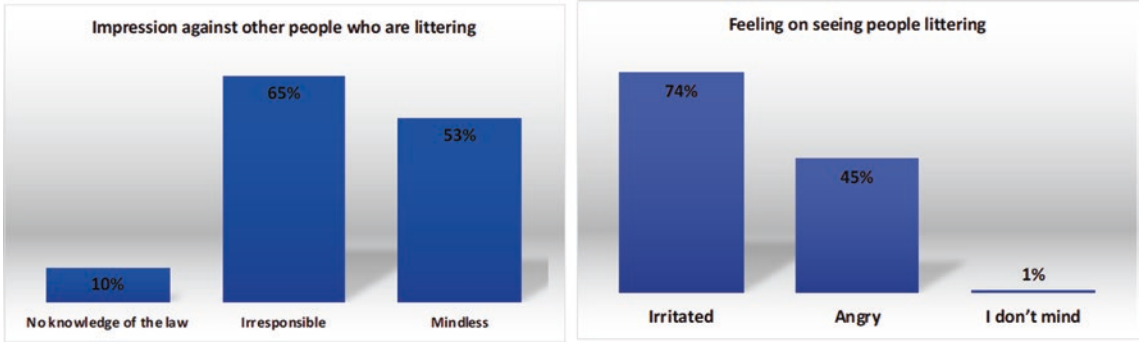

Fig. 9 Impressions on the attitude and behavior of others on SWM

Impressions on the attitude and behavior of others on SWM. Around 65% of the respondents recognized people dumping or throwing waste anywhere as senseless. More than half (53%) tagged them as not cautious, and the remaining 10% are treated as ignorant of the law, as shown in Fig. 9. These results substantiated the Theory of Planned Behavior (TPB) in implementing the SWM law and ordinances. The TPB asserted that the likely consequence of behavior influences an individual's behavior. When the respondents saw people who were littering, they felt irritated (74%) and angry (45%). A meager 1.0% just ignored this unpleasant behavior of other people.

Interest in voluntarily complying with the law. Figure 10 presents that around 55% of the respondents are dubious that residents will willingly follow the law without strict implementation of the ordinances. About half (45%) of the respondents thought otherwise, as long as there is good information and education campaign (IEC). This is evidence that compliance with the SWM law and ordinances will be challenging without strict implementation of the law and pertinent information and dissemination campaigns by the LGU.

4.4 Level of Community Participation in SWM Implementation

Other factors influenced community participation in local SWM. These include community acceptance of the strict implementation of waste segregation and community perception of the payment of garbage collection fees to ensure participation.

Community acceptance of the strict implementation of waste segregation. A great majority (99%) of the respondents strongly agree (58%) and agree (41%) with the strict implementation of waste segregation in every *purok*, as exhibited in Fig. 11. A meager 1.0% is still undecided on the matter. The survey generally contradicted the belief of the *barangay* officials that strict implementation of SWM ordinances will weaken their chances of being re-elected in future local elections.

Willingness to pay for SWM services. A large percentage (83%) of the respondents are also willing to participate in local SWM, including the payment of garbage collection

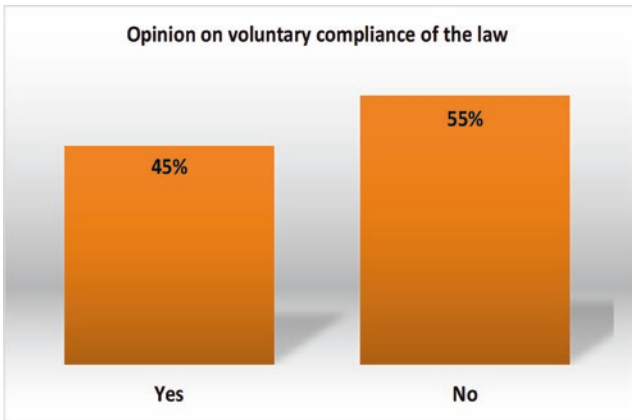

Fig. 10 Impressions on the attitude and behavior on compliance with the Ecological SWM Act

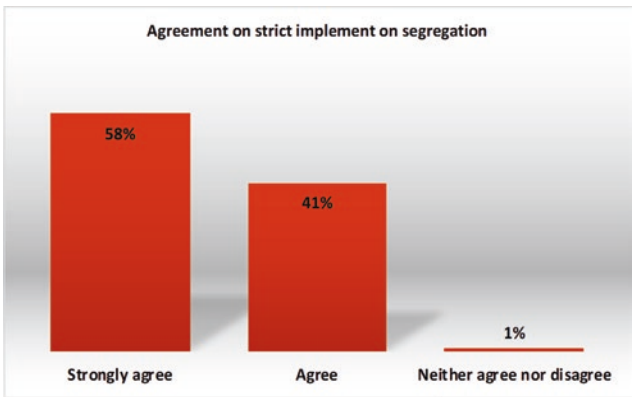

Fig. 11 Perception of strict implementation of waste segregation

fees, as presented in Fig. 12. The suggested amount of garbage collection fees ranges from PhP5.00 to PhP20.00 (0.10–4.0 USD) with a higher proportion for PhP5.00 (0.10 USD) (37%) and PhP10.00 (5.0 USD) (29%). However, 14% of the respondents are unwilling to pay garbage collection fees since they already pay income taxes. They believe that garbage collection is part of the local government's responsibility.

4.5 Efficiency of Implementing the SWM Law and Initiatives to Trigger Community Participation

The efficiency of implementing the SWM law and initiatives is analyzed based on the alignment of the SWM implementation with the SDG, Green SWM, and pillars of sustainable development, and the analysis of the SWOC of the local SWM programs.

Efficiency of local SWM based on alignment with SDG, Green SWM, and pillars of sustainable development. The efficiency of implementing the local SWM law and initiatives establishes the greening of the local SWM. Three key areas were assessed on this matter: (a) contribution of community participation in local SWM initiatives to the achievement of the SDGs; (b) alignment of the local SWM initiatives with the SISWM or Green SWM; and the (c) contribution of the local SWM to the green economy based on the pillars of sustainable development.

Contribution of community participation to local SWM initiatives for the achievement of SDGs. As emphasized by Elagroudy et al. (2016), the greening of the solid waste sector has to contribute to the attainment of the SDG (Goals 1, 3, 8, 7, 11, 12, 13, and 17). The assessment of the contribution of the Ecological SWM Act and the local SWM initiatives to achieving the SDG based on the interview with the households is summarized in Table 5.

Alignment of the local SWM initiatives with the SISWM or Green SWM: Emphasis on community participation. Zhu et al. (2008) underscored eight requisites for a SISWM or Green SWM. The analysis of the community participation in local SWM revealed that seven of the eight requisites are demonstrated in the local SWM initiatives of the village, as presented in Table 6.

Contribution of the local SWM to the green economy based on the pillars of sustainable development. Elagroudy et al. (2016) indicated that the "SWM sector would contribute to the green economy if….[…]….. it satisfies the social, environmental and economic sustainability." Table 7 demonstrates how the local SWM initiatives of the *barangay* are in harmony with the pillars of sustainable development to achieve a green economy.

Efficiency based on SWOC analysis of community participation. The SWOC analysis unfolded the focal areas of development planning of the community. The weaknesses and challenges are the triggers for the *puroks* (district) to implement and monitor the local SWM plan. The strengths and opportunities must be translated into actionable measures and resources that can be utilized by the community in addressing the constraints and challenges of local SWM. Table 8 presents the SWOC analysis on the implementation of the local SWM.

4.6 Initiatives of Local Officials on SWM for Community Participation

Information, education, and communication campaign. Information dissemination on SWM implementation is one of the initiatives of the community officials in the form of information, education, and communication (IEC) activities. More than half (51%) of the respondents shared that they received flyers and observed tarpaulin banners on the SWM programs of the local government, as presented in

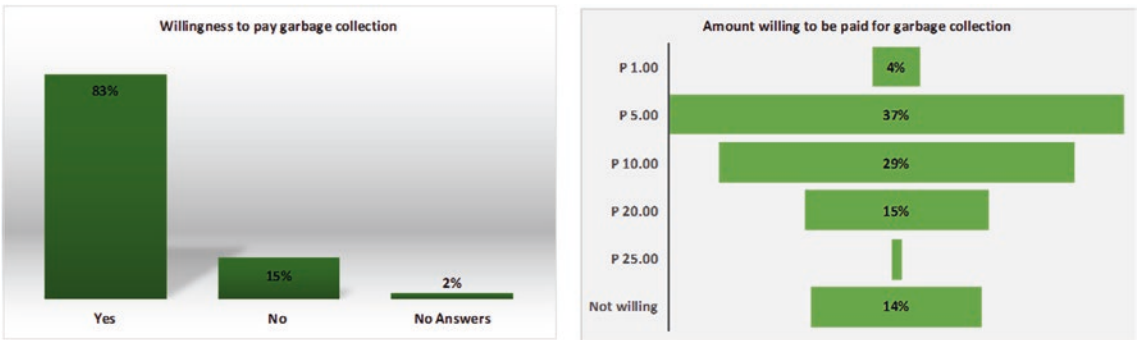

Fig. 12 Willingness to participate in SWM

Table 5 Contribution of the ecological SWM Act and the local initiatives in achieving SDG

Sustainable development goal[a]	Contribution of the solid waste sector to the SDG (Elagroudy et al., 2016)	Community participation in Ecological SWM Act and local SWM initiatives that are aligned with the achievement of the SDGs based on the household survey and key informant interviews
No poverty (goal 1)	By achieving full and productive employment and decent work for all MSW sector workers, including women and young people	• The *barangay* engages in livelihood development using recycled materials for artificial flowers, bags, and decorative stuff • Residents make handcrafted bags from paper trash and other scrap materials, marketed under the project, "*Bags for Life*" • Employment opportunities are expanded since the demand for the bags is increasing with orders from nearby municipalities and provinces and from "*balikbayans*" (a Filipino returning to the country after visiting another country) • Expansion of livelihood products to include native bags • The *barangay* explores using recycled/scrap materials in making chandeliers and flowers for aesthetics • The MRF in the village is an opportunity to create livelihood and employment • Mothers in the village make bags, plastic flower beads, and accessories from plastic bottles and scrap papers and sell them (Cardenas, 2018)
Good health and well-being (goal 3) and decent work and economic growth (goal 8)	By improving the labor conditions and working environment for workers in the MSW sector. In addition, proper waste management leads to healthy water and food, which in turn enhances the health of human beings	• Local officials strive to achieve a zero-waste disposal community • The *barangay* and the households minimize waste generation and disposal • Local officials voluntarily provide an additional amount for garbage collectors from personal funds
Affordable and clean energy (goal 7) and Sustainable cities and communities (goal 11)	By integrating the principles of sustainable development into the country's policies and programs. Greening the MSW sector will also reverse the loss of environmental resources by following the solid waste hierarchy and encouraging the concept of the three Rs: reuse, recycle, and recover	• Biodegradable wastes are turned into vermicompost, which is combined with eco-blocks for landscaping • Task force development of the village regularly gathers the waste materials in the community and sorts them based on three classifications of waste: recyclable, biodegradable, and non-biodegradable • Biodegradable materials are used to fertilize the plants
Responsible consumption and production patterns (goal 12)	By substantially reducing waste generation through prevention, reduction, recycling, and reuse	• Local officials promote using eco-blocks (eco-bricks) made from cleaned plastic bottles filled with non-biodegradable wastes. These are used in landscaping initiatives
Climate action (goal 13)	By taking actions to reduce GHGs in the solid waste sector and its impacts	• The *barangay* plans to produce biogas from kitchen waste. Biogas is a "renewable source of energy..[..].. which can reduce GHG emission" (Tanigawa, 2017)
Partnership for the goals (goal 17)	By providing international funding, new technologies, and information, and communications to private and governmental sectors in developing countries	• *Barangay* conducts the Green Gardening Project to influence the youth to plant vegetables and properly manage waste disposal. This involves a partnership between the Los Banos Gender and Development (GAD) Office (Cardenas, 2018), which provided the seeds for gardening such as squash, taro, bitter gourd, horseradish, eggplant, and gourd

(continued)

Table 6 Green SWM requisites that demonstrated community participation in local SWM initiatives of the case study village

Requisites of Green SWM	Community participation in the ecological SWM Act and local SWM initiatives and alignment with the requisites of Green SWM based on household surveys and key informant interviews
An essential part of successful local governance	• A majority (75%) of the respondents generally assessed that the SWM implementation strategies of the *barangay* are effective • The *barangay* is targeting zero-waste disposal • The local officials have initiated several programs and projects to strengthen awareness of solid waste reduction and conversion
Emphasizes stakeholder participation and involvement	• A majority (99%) of the interviewed respondents strongly agree (58%) and agree (41%) with the strict implementation of waste segregation • Participation of the community in local SWM was influenced by awareness and knowledge of the law and by the *barangay's i*nformation dissemination and implementation initiatives • High awareness level was viewed as one of the factors in the participation of the community in the implementation of the SWM law, specifically on segregating wastes
Emphasizes occupational health and safety	• There is a plan to provide protective gear (mask, gloves, boots) and equipment to garbage collectors
Provides economic service delivery	• Waste management is translated to income and food generation, where the community engages in livelihood opportunities to make and sell waste products (bags, flower beads, and accessories, among others) • Waste is turned to vermicompost for vegetable gardening
Guarantees cost recovery	• The *barangay* makes native bags, artificial flowers, and decorative stuff for sale • The *barangay* introduces the "*Barangay Plastic sa Bote Program*," wherein plastic trash will be put inside an empty 1.5-L bottle to be used as "eco-blocks"
Performed in an environment-friendly manner that minimizes resource use and maximizes resource recovery	• Production of compost fertilizers from biodegradable waste • Implementation of "disposal of segregated garbage at the *barangay* designated place, on designated day and time only"
It helps reduce the financial pressure on governments	• Local officials voluntarily provide an additional amount for garbage collectors from personal funds due to the limited budget of the LGU to compensate the garbage collectors

Table 7 Alignment of the SWM initiatives of the village with the pillars of sustainable development

Pillars of sustainable development (Elagroudy et al., 2016)	Community participation in the case study area that reflects the achievement of the pillars of sustainable development in local SWM
Economic sustainability	• The local SWM creates livelihood opportunities that enable the community residents to realize income and engage in food production
Social sustainability	• Personal protective equipment will be provided to waste handlers/collectors to avoid potential exposure to health hazards • Women and youth participate in making recyclable products such as bags, artificial flowers, and native bags, among others • Attendance by all *barangay* officials and a few community members in seminars carried out by the Municipal Environment and Natural Resources Office (MENRO) on SWM implementation
Environmental sustainability	• The *barangay* has a plan to produce biogas from kitchen waste • The *barangay* produces compost fertilizers derived from biodegradable waste • The households produce vegetable seedlings utilizing compost fertilizers • Implementation of "no segregation, no collection" policy in some areas of the *barangay,* such as the *Gawad Kalinga* housing project and subdivisions • The *barangay* regularly reminds households found to be habitually not properly segregating their wastes

Fig. 13. Close to half (49%) provided a negative response. This can be partially construed as a weakness of the LGU in its IEC campaign on SWM. In the 10-year SWM Plan, the municipality is responsible for conducting the IEC of the program with the *barangay* as the critical partner. Thus, it can be deduced that success in implementing SWM at the *barangay* level heavily relies on the municipality's leadership in terms of the IEC program and project implementation.

A majority (75%) of the respondents generally assessed that the SWM implementation strategies of the *barangay* are effective. At the same time, 25% remarked on the strategy's ineffectiveness since there are still residents in the community who do not diligently follow proper waste

Table 8 SWOC analysis of the implementation of the local SWM

Provision of time *(The community devotes time to meetings, seminars, and other related activities)*	
Strengths • Frequent visits/meetings between the local environment office (MENRO) and the *barangay* council on the implementation of SWM activities • There is time allocation for an effective garbage collection of five times a week • Participation of the *barangay* in the first *Fiesta ng Kalikasan* (Environment Feast) conducted by the LGU • Attendance of *barangay* officials and community members in the LGU-led training/seminar on (a) livelihood projects, (b) composting, and (c) SWM implementation • Participation by the *barangay* officials in the LGU-led IEC for the different schools in the *barangay* • Participation of the different community sectors (senior citizens, women, *barangay* athletes, and youth) in the flower-making project using recycled materials from trash • Participation of the community members in a *barangay*-led gardening project utilizing compost materials from garbage • Participation of the community in the *Barangay Plastic sa Bote* Project	*Weaknesses* • Non-promulgation of a *barangay* ordinance on SWM • There were times that garbage was not collected due to a defective dump truck • Not all households were reached by information dissemination on SWM • The hectic work schedules of some *barangay* officials prevented them from attending the SWM IEC activities of the *barangay* • The majority of the residents have no time to participate in *barangay*-initiated SWM programs and projects • Non-cooperation of some residents in segregation and proper disposal of garbage • Non-participation of some residents/establishments in the "no plastic" policy of the LGU
Opportunities • Presence of external support from the municipality for the maintenance of dump truck • Availability of external technical support from the private entities in conducting livelihood training for residents • Presence of external support (equipment) from institutions around the area	*Challenges* • Absence of external support to enhance compliance with waste segregation • Lack of external support to conduct composting at the community level
Voluntary provision of resources *(The community allocates funds/equipment for the program)*	
Strengths • *Barangay* allots resources for an effective garbage collection system five times a week • *Barangay* allocates resources to train some residents in livelihood projects • Residents allot money to buy sacks for their garbage • Residents in subdivisions pay voluntary monthly dues as their token to the *barangay* for the collection of their garbage • Some residents provide financial support or token to garbage collectors to alleviate their meager salaries	*Weaknesses* • Irregular and insufficient provision of protective paraphernalia to garbage collectors • Non-provision of training in waste handling for garbage collectors as required by the law • Non-allocation of resources by some residents in buying sacks makes their garbage vulnerable to stray dogs • Irregular receipts of assistance from the LGU
Opportunities • Provision of monetary/materials support by other institutions to the *barangay* • Allocation of funds by the LGU as assistance in the repair and maintenance of the b*arangay* dump truck • Offering by the LGU for a 50/50 sharing to purchasing another dump truck for the use of the *barangay*	*Challenges* • Irregular receipts of assistance from supporting institutions • Irregular/insufficient support from the LGU
Provisions of community-based knowledge *(The community member shares knowledge/skills to fulfill a task for the program)*	
Strengths • Some skilled residents assist in the construction of the *barangay* MRF facility • The *barangay* captain shares knowledge of gardening and composting activities of the *barangay*	*Weaknesses* • Scarcity of volunteer residents in carrying out *barangay* programs and projects on SWM
Opportunities • Availability of private individuals from institutions that conducts livelihood projects for the *barangay* to enhance community-based livelihood skills	*Challenges* • The inadequate number of external experts who can share skills and knowledge on SWM

segregation. To address this, the *barangay* officials need to assign *barangay tanod* (enforcers) who will monitor waste segregation during garbage collection.

The survey revealed that 52% of the respondents had observed *barangay* officials who went around their areas to disseminate information on appropriate segregation. Around 48% of the surveyed households did not witness the mentioned activity. Aside from distributing information materials, the *barangay* officials either conducted house-to-house visits or adopted a public announcement (PA) system to remind the residents about proper segregation. Generally, this *barangay* activity is an effective alternative

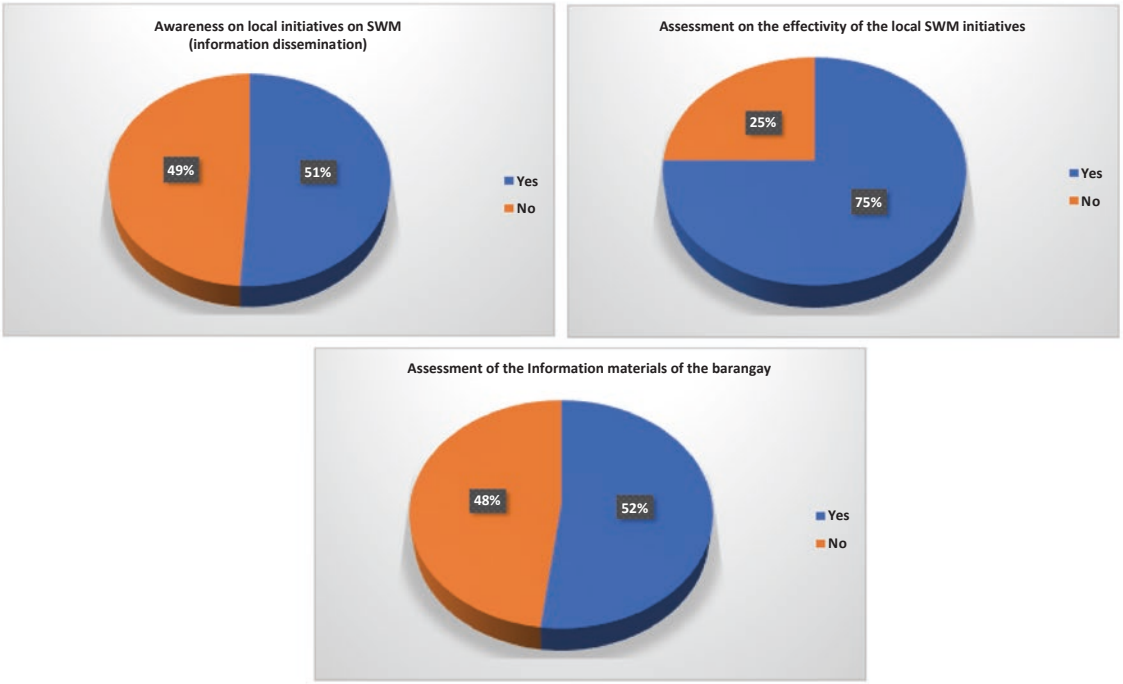

Fig. 13 Awareness of local SWM initiatives of the local officials and assessment of their effectivity

to the distribution of tarpaulin and flyers, which is believed to be a very effective means of information dissemination. Some *barangay* officials also suggested that tarps should be placed in strategic areas of the community to enhance information dissemination.

Local officials' assessment of community participation in SWM implementation. The local officials believed that community participation in SWM reflects the residents' adherence to the waste disposal schedule, placement of the garbage at the designated pickup points, and segregation of biodegradable and non-biodegradable wastes. Community participation is also evident when community residents practice composting waste in their backyard.

Local SWM initiatives to entice community participation in the implementation of the SWM. The SWM strategies of *barangay* Tuntungin-Putho are a component of the 10-year SWM plan of the municipality of Los Baños, Laguna. The plan covers 2014–2023 as approved by the NSWMC on September 30, 2014.

In the local SWM Plan, the *barangay* must address the SWM issues in its programs and activities. Measures such as the imposition of garbage collection fees were covered in the plan to reduce expenditures on solid waste collection and handling. There should be a house-to-house garbage collection during the daytime and imposition of the policy on the "no segregation, no collection" system. The plan also emphasized that the *barangay* should ensure that the households comply with the segregation policy even if garbage is collected at night.

Local SWM strategies. The interview with the *barangay* captain and his council implied that several SWM programs and projects had been initiated to strengthen the awareness and participation of the residents in solid waste reduction, reuse, and recycling. He enumerated the following measures:

- Engage in livelihood projects that utilized recyclable waste in making artificial flowers, bags, decorative stuff, and rags
- Produce compost fertilizers from biodegradable waste
- Produce vegetable seedlings using compost fertilizers and distribute them to interested residents who are into backyard gardening
- Introduce the *"Barangay Plastic sa Bote Program*," wherein plastic trash is placed inside an empty 1.5-L bottle to be used as "eco-blocks." Eco-blocks are used in constructing display booths during the celebration of the Bañamos Festival every September.

In terms of proper waste disposal and segregation, the *barangay* captain and his council spearheaded the following activities:

- Implementation of the disposal of segregated garbage at the designated place and prescribed schedule
- Implementation of "no segregation, no collection" policy in some areas of the *barangay,* such as in housing projects and subdivisions
- Continuous information dissemination on proper segregation by talking personally with households who are found to be habitually not following proper waste segregation.

Information dissemination. The IEC is done by the local environment office (MENRO) with the assistance of the *barangay*. The IEC covers recycling, reduction at source, and composting. The MENRO handles the non-biodegradable and residuals to be brought to the municipal MRF and eventually to the sanitary landfill.

5 Conclusions

The study generally revealed that community participation contributes to the greening of the local SWM given the following scenarios: (a) the households have a high level of familiarity, awareness of, and compliance with the law and ordinances, which motivated them to reduce the volume of waste generated and participate in SWM initiatives; (b) households are willing to pay for SWM services such as garbage collection in recognition of the importance of proper waste management in ensuring human health and protecting the environment, and (c) efficiency of implementing the SWM law and initiatives. In terms of efficiency, the study demonstrated the following: (a) the local SWM generally contributed to the achievement of SDG 1, 3, 8, 7, 11, 12, 13, and 17; (b) satisfied most of the requisites of SISWM or Green SWM, and demonstrated harmony with the pillars of sustainable development (social, environmental, and economic) to achieve a green economy; and (c) the SWOC provide opportunities to translate weaknesses and challenges to strategies for local SWM. Thus, community participation should be centric on local SWM development planning to attain a zero-waste community, promote green jobs in the SWS, and provide incentives to communities that generate these jobs.

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The Role of Waste Pickers in Solid Waste Management for Sustainability in Developing Cities

Baker Sekubwa

Abstract

The management of solid waste is a great challenge for many city authorities in developing countries, and this can be greatly attributed to the increasing generation of waste, a burden of enormous costs, associated with management, the knowledge gap on factors affecting different stages in the management of waste, and the affiliation of stakeholders for this paper waste pickers' roles and functions. The great literature of work was compiled to draw and analyze the different roles pivoted by waste pickers and the waste picking activity wherein naturing their function in the management of solid waste in developing cities with a purpose of attaining sustainable development. The objective of this research is to justify the position and role of waste pickers as major stakeholders in solid waste management and their function in the sustainability of the environment in developing cities. The possible outcomes of this research are to improve solid waste management through cheaper alternatives such as waste picking and also help in the planning and policy-making processes to ensure proper implementation of waste management systems in developing cities for the attainment of sustainable development.

Keywords

Solid waste management (SWM) · Waste pickers · Sustainable development and developing countries · Stakeholders · Urbanization and environment · Waste picking · The environmental role of waste pickers in urban economies and sustainability

B. Sekubwa (✉)
Faculty of Global Environmental Studies, Sophia University, Tokyo, Japan
e-mail: C2095750@eagle.sophia.ac.jp

1 Introduction

While analyzing several systems, engineered systems were initiated to consolidate SWM agencies in the 1960s. Marshall and Farahbakhsh (2013) further stated that the collection and removal process dominates (SWM) in developing countries; however, urbanization, inequalities, and socioeconomic aspects policy regulations have contributed greatly toward complicating SWM in developing countries and cities.

According to SDG 11 (n.d.), ensuring sustainable waste services, valuing waste workers, and prioritizing their job security are crucial for SWM in developing cities toward the achievement of green cities, and it is through these conditions that the state of urban waste management systems whether poor or failed are the indicators of inhabitants, suffering in bad living conditions resulting into the formation of informal employments in such communities and neighborhoods such as informal waste picking. Although its widely known that millions of people worldwide earn their livelihoods from recycling and reusing waste items (Waste Pickers | WIEGO, n.d.), finding the relevant statistical data is a barrier, while waste pickers are mobile and momentarily their population fluctuates. However, waste pickers deliberately avoid researchers for fear of information disclosure of their activities which may sometimes amount to arrests since the sector is informal.

Impressive are the numbers on recycling (Recyclers: From Waste Pickers to Global Agents of Sustainable Development | Human Development Reports, n.d.), from the millions of tons of recycled materials and the new products on the market, millions in profits and savings for businesses, treasury, and livelihoods. However, recyclers are still working informally, and very little or less of the profits are generated to reach the pockets of these workers.

Furthermore, regardless of the conditioning, waste is still a paradise for millions of families, and in this case, the waste pickers are provided with food and shelter through

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the collection of waste materials sold for recycling an informal activity with a great potential of uplifting several communities socially, economically, and environmental calls for more attention toward policy and regulations securing the activity in order to formalize and achieve green urbanism in developing cities through solid waste management.

1.1 Urbanization and Environment

Developing countries and the world are predicted to experience a massive increase in population over the twenty-first century (Sustainability et al., 2020). With a remarkable half of the world's population now living in cities (Brunn et al., 2020), the unprecedented number of human settlements from rural to urban only mounts and exerts more pressure on natural resources. According to Al-Zu'bi and Radovic (2018), making cities and human settlements is major to inclusive, safe, and resilient in the post-2015 goals. Further validating the adaptive capacity and adaptation of climate impact related hazards, and associated risks, the cities would have to inhibit a greater role while developing natural resource planning and management also an impactful government structure.

The United Nations Sustainable Development Goal (Goal 11, n.d.)[1] stated that by 2050, two-thirds of humanity which is 6.5 billion will be urban, and contrary to sustainable development cannot be achieved through the inappropriate distribution of urban spaces. The rising growth of cities has been reflected by the rapid increase in population and migration leading to the establishment of megacities especially in the developing world thus resulting in slums as a characteristic feature of urban life.

On the other hand, engaging in dialogue has to be open within a diverse range of concepts with meaningful applications. According to World Commission on Environment and Development, WCED, 1987[2] stated that 'Environment is where we live and development is what we all do in attempting to improve the lot within the abode'. For this case, environment is the green and development is urbanism, and amidst all the controversy both factors have to coexist than uneven dependence. This validated the optimal changes of the world enormously within the aspects of social, economic, and environmental. Despite the exponential growth mainly driven by globalization, communication, transport, and technology, urbanization has doubled the toll on the environment resulting in unsustainable trends of green dependency birthing environmental degradation, and solid waste open dumping has developed as a characteristic of developing cities later on negatively affecting the ecosystems and biodiversity.

1.2 Waste Picking in the City

The exponential increase in urbanization has resulted in unprecedented amounts of recyclable waste materials in urban centers (Singh & Chokhandre, 2015). Furthermore, waste pickers factor a critical though unrecognizable role in solid waste management. This type of activity is a major source of income for the growing numbers of urban poor regardless of skill. According to the WIEGO-Waste-Pickers-Position-Paper.Pdf (n.d.) stated before the adoption of the concept of a green economy waste pickers offered a positive and social environmental impact on their communities regardless of the informal economy, the concept was highly recognized as a form of green urbanism.

The Waste Pickers | WIEGO (n.d.) addressed that waste pickers provide reusable materials to several enterprises and that over three-quarters of waste pickers in the IEMS sell their products to the formal sector. In Kampala according to KCCA (Komakech et al., 2014), over 28,000 tons of waste were collected and delivered to the Kiteezi dumping site. This totaled 40% of the initial waste and over 60% of waste went uncollected and normally dumped in unauthorized vicinities, hence calling for health and environmental problems. In countries like South Africa, the Department of Trade and Industries (Taiwo & Venter, 2017) suggested a potential job-creating opportunity for the 27.6% that is unemployed through the collection of recyclables.

Municipalities take on the responsibilities for waste management, while the work of the waste pickers is described as informal and unproductive toward the collection and recycling (Huysman, 1994) withholding its potential as an alternative source of financial generation for low-income earners.

However, WIEGO-Waste-Pickers-Position-Paper.Pdf (n.d.) recommends that waste pickers gaining control as legitimate workers should be supported without underestimation of their existence for purposes of long-term contributions wherein strengthening their organization's path of economic and social dignity thence better working conditions, earnings for the waste pickers as well as a sound resource recovery suitable for sustainable development (Fig. 1).

[1] United Nations Sustainable Development Goal 11, 2015. Sustainable Cities and Communities.

[2] Our Common Future, The World Commission on Environment and Development 1987.

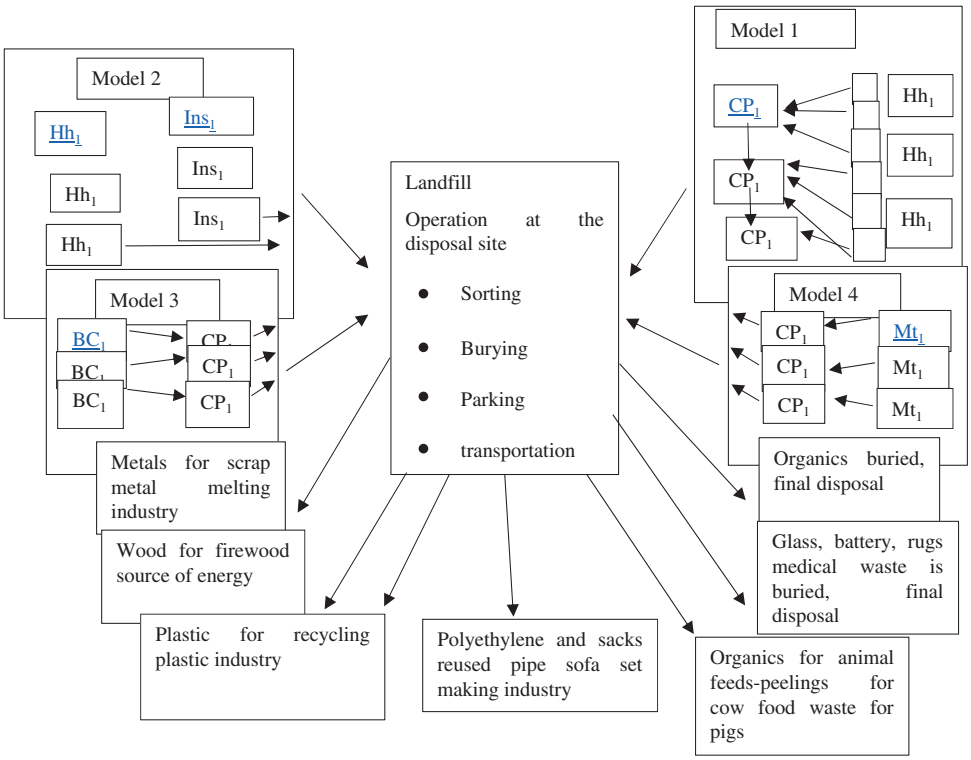

Fig. 1 Multi-model waste management supply chain in Kampala City: CP, collection point; Hh, household; Mt, market; Ins, institution; Bc, business centers (Kinobe et al., 2015). https://doi.org/10.1016/j.wasman.2015.04.012

2 Environmental Role of Waste Pickers in Urban Economies and Sustainability

Recent studies indicate that over 1.5 million new jobs created in landfills, and incinerators for recycling and reuse in the United States of America, whereas the European Union predicts over 400,000 job creations in Europe through the implementation of recycling policies (WIEGO-Waste-Pickers-Position-Paper.Pdf, n.d.), the role for waste pickers in the communities is still under-appreciated; however in cities without any household a collection or municipal recycling systems, waste pickers address a twenty-first-century challenge as important actors towards the increment of quantity in solid waste (Dias, 2006), and accordingly, below are some of the environmental roles of waste pickers aligned to urban economies and sustainability.

Dias (2006) validated that informal waste pickers are direct contributors to the life span of landfills by limiting the volume of materials dumped and also providing input in the recycling market as key economic actors. This can be further witnessed in several developing cities as a result like in Mumbai (India) as stated (Huysman, 1994) where groups of unemployed mothers form coalitions bestowing on improving their living conditions and as a result operate waste picking activities while selling off the materials to recycling companies as an economic benefit and environmentally contributing to the cleansing of the city through limiting waste disposal while contributing to sustainable development.

According to Waste Pickers | WIEGO (n.d.), waste pickers contribute to the general cleanliness of the city and its beautiful design. A significant quantity of materials from waste to streams is diverted by waste pickers. It should be known that waste pickers discovered over 20% of waste materials in cities of countries Brazil, Colombia, and India. In accordance from Brazil's national statistical system recorded that about 229,000 people were working as waste pickers conducting and responsible for recycling over 92% of aluminum and 80% of cardboard in 2008. This clearly points out the environmental role and duty of waste pickers in all communities and a momentum factor toward the attainment of sustainable cities and the concept of green urbanism are one of the drivers of sustainable development.

2.1 Organization of Waste Pickers and the Inclusion of Public Policies

The enormous contribution of cities towards global warming and natural resource depletion coupled with environmental change and resource depletion, (Campos & Hall, 2013) verified the emphasis on sustainable urban governance which is crucial for the contemporary urban spaces and their wider economical footprint. Furthermore, while

examining issues of waste management, tensions between policy discourse and ecological modernization coupled with the local narratives begin to surface. Organizing waste in any community is there to see for everyone while affluent citizens see trash, and waste pickers can see reusable and recyclable items (Borch & Kornberger, 2015).

As a strategy for how dispossessed communities can create their own common ground, Borch and Kornberger (2015) championed the appropriation of their own resources coupled with the reduction of environmental footprint in several developing countries through picking, cleaning, dissembling, storing, and transporting as acts toward achieving sustainable development goals, but society still disapproves of the appropriateness of the waste pickers in cities. In various developing cities, Waste Pickers | WIEGO (n.d.) according to a study that was carried out on 80,000 active waste pickers were responsible for three million tons of recycled waste which calls for a much stronger case for the inclusion of public policies drawing the relevance of their activities in the community and the concept of green urbanism.

According to WIEGO-Waste-Pickers-Position-Paper.Pdf (n.d.), one of the most labor-intensive models of waste management is recycling, and the cheapest navigators enforcing the recycling process through the collection are the waste pickers which are also one of the fastest ways to reduce greenhouse gas emissions. Furthermore, reducing one ton of CO_2 emissions through recycling is 30% lesser than the application of wind power; however, waste pickers are far more vulnerable to dramatic exploitation through price fluctuations that are endowed due to a lack of functional policies backing up the existence of waste pickers.

With the introduction of the United Nations SDG 17[3] on the partnership for goals, through the core of strengthening means of implementation and revitalizing the global partnership for sustainable development, collective and collaborative policy-making for all sorts of employment should be a great bargain in the case for waste picking as a sector with enormous potential in both economic and environmental sustainability.

2.2 Planning and Practicing Alternatives for Solid Waste Management

As discussed earlier on in this paper, waste picking accounts for enormous social, economic, and environmental contributions to the cities. This points to the value of alternative solid waste management models, planning, and practices in building more inclusive cities which can enable and accommodate a diversity of livelihoods driving sustainable development.

According to Dias (2006), the conventional views of waste management have been highly regarded as monofunctional and attributed to the fact of solely relying exclusively on advanced capital-intensive technologies excluding traditional and customary practices that are cheap and flexible such as waste picking.

According to Marello and Helwege (2018) through channels of participation for joint implementation and planning solid waste management promotes universal access. This can be realized through several technologies and processes discussed as forms of impacting the livelihoods of the urban poor with the manifestation of informal sectors, and waste pickers can be contracted as the service provider in their respective communities, thence lubricating the sustainable practices of solid waste management for green and urbanism of cities.

The rights of waste pickers should be echoed through and by the appropriate legal frameworks in order to access waste without any form of underrecognition. As Dias (2006) lamented on a process that would facilitate waste picking to move up the chain of recycling, furthermore, improving the good quality of waste management across several cities and promoting inclusivity among their inhabitants. Such an act would initiate unprecedented models of planning and practice of solid waste.

However, due to the current trends toward the increase in urban population, Marshall and Farahbakhsh (2013) stressed that solid waste management has become an increasing issue of global concern. With such statements, the developing world and cities should focus on cheap and sustainable means for greening their communities as possible alternatives to solid waste management as a result of modern technological deficiencies, wherein waste picking could bridge the technological gap thus facilitating sustainable development.

3 Conclusion

Due to the increasing volume of waste in most developing cities, Guerrero et al. (2013) stated that the management of solid waste fosters challenges in cities. Most of the burden posed through several stages of waste management emerge as a result of a higher budget cost associated with enabling waste management. The stakeholders command great responsibility in the implementation of solid waste management practices.

The separation of waste for recycling is critically lacking imperatively imposing public concern towards the proper management of waste for the purposes of sustainable

[3] United Nation Sustainable Development Goal 17, 2015. Partnership for Goals.

development. Chiee (n.d.) elaborated on the causes of open and illegal dumping fostering the creation of a dire state, while citing minimal disposal of recyclable materials in the waste composition.

With these concerns, the role of waste pickers should be recognized as major stakeholders within the boundaries of waste management because of their contribution to socio-economic and environmental activities. Waste picking has great potential (Waste Pickers | WIEGO, n.d.) with a magnitude of employing large sums of the population and still recognized as an informal sector, and for this case, waste picking should be formalized in developing countries for it is the cheapest mobile model to recycling due to the deficiency in the technological gap and finance which are major drivers towards the attainment of sustainable, clean, and green cities, wherein enabling sustainable development.

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Air Pollution and Solid Waste: Promoting Green and Resilient Recovery in Nigeria

Cyril J. Effiong, Ejikeme Kanu, Surindar Dhesi, Irina Kuznetsova, Saad Mahmoud, Raya Al-Dadah and Andrew N. Aziz

Abstract

Air pollution has posed a serious health challenge for both developed and developing countries. Through the Paris agreement, countries have developed actions toward net zero carbon emissions. However, developing countries are being confronted with other environmental challenges which seem to make the path to green recovery unrealizable. This scoping literature review examines air pollution and solid waste issues in Nigeria with the view of promoting green and resilient recovery. The review reveals that, there is high dependence on biomass for cooking, and cooking smoke has exposed more than 120 million people to health risks linked to respiratory tract infection, lung cancer, cardiovascular disease, coughing, eye irritation, etc. More so, rapid population growth and the continuous reliance on forest wood for cooking have not only resulted in environmental degradation and deforestation of forest reserves but have increased the challenge of air pollution. Furthermore, solid waste management remains intractable in most Nigerian cities despite the efforts of various state governments. Government policy on solid waste management seems not to be comprehensive as often the contribution of the informal sector, which is the most active player in waste collection, disposal, and recycling is excluded. While it is worrisome that solid waste volumes outweigh the capacity of urban managers with obvious implications on well-being, there are greater opportunities for waste to energy solutions. Nevertheless, available disposal strategies lack the technological capacity to explore engineering solutions for waste management. Therefore, there is a need to promote green recovery through engineering solutions which will ensure the transition to a climate compatible environment that is inclusive, safe, resilient, and sustainable.

Keywords

Pollution · Nigeria · Solid waste · Green recovery · Sustainable development

1 Introduction

Household air pollution and waste management are the major challenges confronting both developed and developing nations of the world with implications for human health and well-being (Puthumana et al., 2021). The poor management of waste can become an environmental threat that is detrimental to healthy living. The rate of urbanization is increasing waste management challenges especially in middle- and low-income countries. The relationship between improper solid waste disposal and air pollution can result in human disease, death, airborne contaminants, and other related hazards (Kupchik & Franz, 2012). As reported in "ambient (outdoor) air pollution" (2022), more than 50% of deaths worldwide are attributed to air pollution with a link to an increase in lung and cardiovascular disease. Exposure to particulate matter (PM2.5) caused about 2.9 million premature deaths globally, and the continuing carbon emissions will increase the risks to children and elderly in our society. More so, Ozoh et al. (2018) reported that more than 4.3 million people annually are reported as dying from household air pollution globally, and most are reported in low middle-income countries, with women and children

C. J. Effiong (✉) · E. Kanu · S. Dhesi · I. Kuznetsova
Department of Geography and Environmental Science, University of Birmingham, Birmingham, UK
e-mail: cxe921@student.bham.ac.uk; cyrileffiong@uniuyo.edu.ng

S. Mahmoud · R. Al-Dadah · A. N. Aziz
Department of Mechanical Engineering, University of Birmingham, Birmingham, UK

A. L. Pisello et al. (eds.), *Building Resilient and Healthy Cities: A Guide to Environmental Sustainability and Well-being*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-031-33863-2_4

mostly affected. Studies have documented cooking practices in Western countries compared with developing counties and reveal that indoor air pollution is responsible for over 80% of deaths in middle- and low-income countries compared to their Western counterparts at over 55%, and the major activity that triggers indoor air pollution is frying and grilling (Hanif, 2018; Megbowon et al., 2018; Ofori et al., 2018). The lower percentage recorded in developed countries could be attributed to the adoption of clean energy for cooking, unlike in low and middle-income countries where there is high reliance on the use of firewood, sawdust, and animal dung for cooking which generate significant indoor air pollution (Jung & Huxham, 2018).

The WHO (2016) estimates that 79,000 deaths occur annually associated with indoor air pollution in Nigeria. Also, about 42 million tons of waste are generated annually in Nigeria, and it is causing huge environmental, health and social problems, and loss of resources for the country (Ike et al., 2018). Furthermore, as urbanization increases, solid waste generation also increases implying greater challenges of solid waste management in many cities of the world. Solid waste management is a critical component in urban governance, which is the reason it is considered by governments as an essential social service. However, waste management in some areas seems to be beyond the capacity of urban mangers as they lack the requisite technology to deal with the rising waste generation associated with the rate of urbanization (Nnorom & Odeyingbo, 2020).

Nigeria has witnessed an increase in industrial development, and this is contributing to environmental degradation and air pollution. According to "carbon brief profile (Nigeria)" (2022), the Niger Delta Region has been severely hit by oil spillage which affects livelihoods and rivers in the region; it will take an estimated $1bn over an extended 30-year period to clean up the area. More so, pollution in the region is threatening public health as a result of contamination of water bodies. The findings of carbon profile reports are consistent with other medical and epidemiological reports, evidencing the risk of people exposed to hydrocarbons and its resultant effect on health and well-being. More so, environmental challenges associated with air pollution and solid waste management are drawing the attention of many stakeholders. For example, waste collection in many Nigerian cities is irregular, and improperly sited open waste dumps deface the aesthetic quality of cities impacting public health by releasing unpleasant odors, encouraging pests, disease, and pollution of water sources (Obazi, 2015; Singh et al., 1995).

The capacity of the formal waste management sector is limited and heavily challenged in many ways (Ike et al., 2018). Studies have shown that air pollution can lead to serious health conditions, linked to respiratory tract infection, lung cancer, cardiovascular disease, coughing eye irritation, irregular heartbeats, etc. (Agbo et al., 2020). The major causes of these ailments are the air pollutants such as carbon dioxide (CO_2), particulate matter (PM), and nitrogen oxide (NO) (Jelili et al., 2020). Nigeria is a signatory to the Paris agreement to reduce greenhouse gas emissions by 20% by the year 2030 when compared to business-as-usual levels, and this will be achieved through increasing the use of solar energy and ending gas flaring. However, limited progress has been made to reduce carbon emissions (Carbonprofile, 2022). The distribution of solar across the country is still very low, and the electricity supply is erratic in most parts of the country especially in rural communities. According to a National Bureau of Statistics report, (2021) more than 40.1% of Nigerians live below the poverty line, which makes many households rely on firewood for cooking and thus contributing emissions. Furthermore, the high reliance on firewood contributes significantly to the rate of deforestation and thus makes Nigeria to loss more than 90% of its forest reserved (Owolabi, 2019). Considering the above narrative, this work examines air pollution and solid waste management in Nigeria with a view of promoting green recovery through engineering solutions which will ensure the transition to a climate compatible environment that is inclusive, safe, resilient, and sustainable.

2 Methodology

A systematic literature review was undertaken in order to synthesize and critically appraise issues associated with indoor air pollution and waste in Nigeria. In order to minimize bias, criteria were established focusing on articles that address air pollution and waste management in Nigeria. In total, 40 articles were reviewed initially. Therefore, Kitchenham et al. (2009) assertion that systematic review is based on a clear search, research question, and a proper data extraction process was utilized. This guided the choice of 15 articles for detailed analysis on issues around waste composition, cooking energy choice, and forms of carbon gas emission in Nigeria. The aim was to compare waste generation across different cities in Nigeria and consider the relationship of waste management to air pollution. Furthermore, the choice of cooking energy and the reason for reliance on particular energy source were addressed.

3 Literature Review

Waste generation is recognized as one of the most pressing environmental challenges faced by the world today. However, approaches including green supply chain management, lean/sustainable manufacturing, waste reduction

techniques, green integration, and other proper management of wastes have been identified for dealing with the problem of waste generation across the globe (Fercoq et al., 2016). Many studies acknowledge the contribution of the informal sector in waste recycling management (Manhart et al., 2011), and the benefits of the informal waste management sector are reported to include economic growth, litter control, resources conservation (Ezeah et al., 2013), inclusive development, and sustainable waste management (Mbah et al., 2019). However, developing and implementing strategies for inclusive management of waste remains key for the success of this sector and overall waste management in Nigeria. For example, in the work of Ogwueleka (2009), it was observed that common constraints faced by environmental agencies include insufficient finance, inadequate institutional framework, inadequate information on the quantity and composition of waste, weak environmental laws, and inappropriate technology.

An example of the outcome of poor waste management is shown in Fig. 1 which suggests that solid waste management in Nigeria is characterized by inefficient collection, insufficient coverage of the collection system, and improper disposal. Techniques such as those that use crude dismantling and backyard recycling techniques, uncontrolled open burning of cables to recover copper wire, and E-waste disposal at dumpsites are currently being used in the sector (Nnorom & Odeyingbo, 2020). These are not sufficient and cannot deliver optimal environmental, economic, social, and energy benefits to the Nigerian economy that is in dire need of achieving energy sufficiency (Ayodele et al., 2018).

In regard to the quantification of the zonal outputs of waste, Ayodele et al. (2018) found that plastic is the most prominent recyclable waste in all the cities in the South-East, South-South and all the Northern parts of Nigeria. However, paper is the most available recyclable material in the waste stream of the cities in the South-West. The study by Ayodele et al. (2018) also revealed that a total of 89.99 tons (1046.43 GWh) of energy could be saved per year by recycling the recyclable waste materials rather than producing new products from virgin materials. The saving in electricity could provide electrical power for about 9.8 million people based on available statistics of average electricity generation of 29,697,360.1 MWh and per capita electricity consumption of 107 kWh in Nigeria. Furthermore, a total of 11.71 million USD economic benefits could be realized, which is equivalent to round 16,562 jobs annually. The environmental assessment result indicates that a total of 307.364 k tons CO_2eq of GHG emission reduction could be achieved annually.

Table 1 shows the percentage of waste composition in urban and rural areas on Nigeria. The result reveals that urban areas generate more waste than the rural areas especially food waste; and the percentage of waste composition covers plastic, food waste, garbage, paper, and leaves with plastics becoming more dominant in urban area.

Table 2 shows the waste generation estimates for various cities from previous studies based on the 2006 national population census for Nigeria. It has been estimated that the waste generation per capita for Nigeria is about 0.49 kg per person per day (Ugwuh, 2009). From the daily waste

Fig. 1 Overflow of waste in a waste bin in Lagos adapted from www.guardian.ng

Table 1 Percentage composition of wastes in the urban versus rural areas of Nigeria

Waste category (percentage)	Arinola and Arinola (1995)		Babatunde et al. (2013)		Owamah et al. (2015)	Ejiroghene et al. (2017)	Ugwu et al. (2020)
	Rural	Urban	Rural	Urban	Suburban	Urban	Urban
Nylon	3.8	34.8	14	12	7	10.23	
Plastics			5	4			34.29
Food waste	31.6	34.5			32		32.36
Garbage/organic			59	65	77	75	
Paper	8.2	15.4	7	14	6	6.3	14.05
Leaves	40.3	8.9					
Metal	0.7		6.5	2	1	2.5	1.67
Rags/textile	5.0				1		2.69
Ashes	7.6				1	2	
Glass	0.3		3.4	1	3	3.5	0.97
Dust	0.3						

Table 2 Waste generation across major cities in Nigeria

City	Population	Per capita waste generation (kg/ppd)	Organic wastes component (%)	Combustible wastes component (%)	Daily waste generation estimate (kg)
Lagos	9,123,200	0.63	68	21	5,747,616
Kano	3,519,500	0.56	43	50	1,970,920
Benin	1,051,600	0.43	78.7	13.1	452,188
Onitsha	1,001,000	0.53	30.7	53.9	530,530
Ile-ife	313,400	0.46	77.9	12.6	144,164
Akure	369,700	0.54	59.5	16.2	199,638
Ado-Ekiti	523,300	0.71	60.4	25.7	371,543
Abeokuta	698,100	0.6	57.8	34.9	418,860
Ibadan	3,670,400	0.71	64.9	24.1	2,605,984
Makurdi	249,000	0.54	49.2	17.3	134,460
Abuja	565,100	0.57	56.4	36.4	322,107
Maiduguri	971,700	0.25	25.8	29.5	242,925
Nsukka	100,700	0.44	56	34.7	44,308
Port Harcourt	1,190,600	0.6	39.4	29.9	714,360
Ilorin	756,400	0.43	38.3	26	325,252

Source Adapted from Abila (2014) and Yusuf (2019)

generation estimate, it can be deduced that the total waste generated is a resource mine for the recovery of materials and energy.

4 Indoor Air Pollution in Nigeria

In Nigeria, household air pollution from cooking practices is very common. Studies have shown that more than 100 million households depend on wood as a source of energy for cooking (ICEED, 2021). This rather showcases the low level of awareness and lack of attractiveness of alternative options on the effect of indoor air pollution. The lack of an affordable and stable electricity supply is a major reason why the household choice of energy is commonly kerosene or firewood (Hanif, 2018). Air pollution impacted the health of many people, especially women who are particularly affected by cooking practices. As reported by The International Centre for Energy, Environment, and Development (ICEED, 2021), more than 93,000 Nigerians

die annually from cooking smoke which is majorly from firewood. This figure invariably means that more than 45,000 women and children will die in the next 5 years if an alternative cooking method is not provided. This further supports the assertion made by Jelili et al. (2020) that over 98,000 Nigerian women die annually from using firewood, and this may continue to rise to put more women and children at risk if actions are not taken to avert the lingering crisis. Studies have shown that Nigerians rely on firewood, kerosene, and gas as household cooking fuels (Megbowon et al., 2018). While firewood remains the dominant use, Danlami (2019), kerosene and gas are alternated among educated households living in cities. Studies have shown that over 98% of Nigerians cook with kerosene, especially in urban areas which amounts to about 30 million people (Lam et al., 2013). According to the National Bureau of Statistics, more than 40.1% of Nigerians are poor, which means that four people out of ten people in Nigeria are unable to afford 137,430 naira per year. This implies that over 82.9 million Nigerians are living below the national standard. When substantiated with cooking practice among households in Nigeria, the result is skewed to the use of firewood which shows that many homes are unable to afford the price of kerosene and/or Liquefied Petroleum Gas (LPG) for cooking. Furthermore, according to the World Bank report (2018), the government spent over 300 billion naira on subsidizing kerosene yet the resource is unavailable to households in the country, and when seen, it is at a high cost beyond the affordability of most households. Kerosene devices may emit very large amounts of fine particulates, carbon monoxide (CO), nitric oxides (NOx), and sulfur dioxide (SO_2), and evidence abounds that the use of kerosene for cooking exposes households to risks of diseases such as asthma, tuberculosis, heart attack, lung disease, and cancer (Amakiri & Owen, 2009). For example, the work of Ozoh et al. (2018) examining cooking fuel in Lagos revealed that like elsewhere in the country, many households in Lagos rely on firewood, kerosene, and LPG for cooking. However, the level of education and cost influence the choice of LPG and kerosene, and although more than 90% were willing to switch, they raised the concerns of safety and cost as a factor impeding their usage. Also, Ozoh's et al. study (2018) examining factors associated with household choice of kerosene or Liquefied Petroleum Gas (LPG) in Lagos revealed that there was a small number of households (1.1%) using LPG in Lagos when compared with firewood and kerosene. Although non-users of LPG always raise issues of cost and safety as reasons for not choosing LPG as a cooking fuel, the most important aspect is that they are willing to adopt clean energy in cooking and they are aware of the effect of household air pollution. Also, misinformation and belief systems of households about LPG are hindering some from adopting LPG as cooking energy, rather they accept the exposure and health risk from the use of firewood because of their inability to afford clean cooking energy. Although the type of emission in indoor air pollution is attributed to the type of fuel stove used, studies have confirmed that the use of LPG reduces the concentration of pollutants in domestic kitchens (Bisu et al., 2016; Giwa et al., 2019), which is the reason World Bank, World Health Organization, and United Nations have advocated for the wider use of cooking stoves using LPG.

Figure 2 shows the trend of cooking energy in Nigeria with households adopting firewood as the most preferred cooking choice, followed by kerosene and lastly LPG. Firewood is preferred because it is easily available and affordable to many Nigerian households. As shown in Fig. 1, this further supports that Nigeria is the highest consumer of fire wood in Africa. In the work of Gbadabo and Okonkwo (2009), it was found that Nigeria is consuming 262,783 tonnes of fuel wood compared with 7210 tonnes for South Africa and 35,313 tonnes for Thailand. More worrisome is the fact that dependency on fuelwood is rising every year and increasing the rate of deforestation in Nigeria. Also, the World Bank (2018) confirms that more than 80% of Nigerian households depend on biomass as a cooking choice because of availability and easy

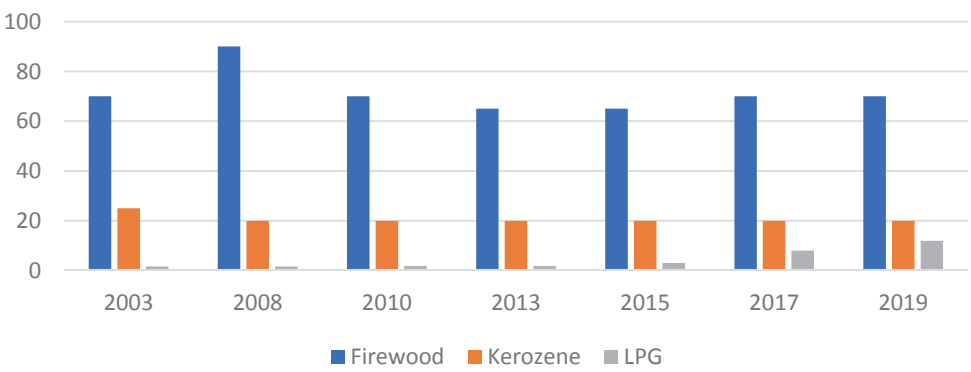

Fig. 2 Trend of cooking energy in Nigeria, adapted from Agbo et al. (2020)

accessibility in many rural communities. The increase in LPG between 2017 and 2019 could be as a result of awareness of the need to change cooking fuel. However, the usage increased mainly in urban areas in Nigeria.

5 Relationship Between Solid Waste and Air Pollution

The relationship between waste and air pollution has significance for human well-being. Kumar (2021) traced the significant role of air pollution in human diseases with emphasis on cardiovascular disease. Studies have shown that the burden of air pollution is associated with one million premature deaths especially in middle- and low-income countries. Activity such as indiscriminate burning of municipal solid waste contributes 29% fine particulate matter (PM2.5) and is a major contributor to air pollution which can result in death. This is a serious concern to public health managers in areas where open combustion practices are often prevalent such as in highly populated neighborhoods in metropolitan areas (Kodros et al., 2016). Consequently, this activity poses serious threats to human well-being and contributes to its emissions. Also, it has been reported that smoke from burning of solid waste is a leading contributor of respiratory and cardiovascular diseases with an estimate of 4.2 million premature deaths worldwide (WHO, 2014). Furthermore, an estimate from the Global Burden of Disease study reported that smoke from open solid waste combustion caused 270,000 premature adult deaths annually. It has also been reported that smoke generated from open combustion may negatively affect lung function and birth outcome (Gumede & Savage, 2017).

The composition of smoke and particulate matter is multifarious and diverse when compared with emissions from other sources of air pollution such as smoke from exhaust pipe traffic emitted, smoke, and biomass fuel combustion (Das et al., 2018). On the other hand, municipal waste consists of hazardous materials from electronic waste and consumer products which could be detrimental to human health. Therefore, clean air can reduce the effect of air pollution on human well-being as adequate waste management can also reduce hazards to health and the environment.

It has been advocated that industries promote the use of clean technology which could reduce smokestack emissions and lower the fine particulate matter (PM2.5) in the environment. To a large extent, good management practices such as developing technology to capture emitted methane gas can improve the quality of air and translate to good living conditions of the populace.

6 The Contribution of Greenhouse Gas Emission in Nigeria

6.1 Access to Electricity

Energy in Nigeria is a very important fulcrum that supports other sectors of development spanning social, economic, and industrial development (Moniz et al., 2011). The major fuel for generation of Nigerian electricity is natural gas. However, previous findings as reported by Ukaegbu (1999) show that the energy situation in Nigeria ranging from processing, preservation, development, utilization to administration is undoubtedly poor. The country has extensive capacity of oil, gas, and solar resources with the possibility of generating 12,522 MW of electric power from the current plants but in reality, just about 4000 MW, which is not adequate for a country of around 215 million population and with a total of 923,768 km^2 (Sambo et al., 2010). It is worrisome that the consequence of environmental challenge as the result of human activities is contributing to environmental degradation, burning of fossil fuel, ozone depletion, greenhouse gases emission, and climate change (Khan et al., 2014). For example, during electricity generation, gases trap heat radiating from the earth's surface, and there is a corresponding effect in the increase of surface temperature (Odewale & Sonibare, 2017).

The current state of the country's underdevelopment is traceable to poor energy provision which cripples the growth and development of the economy. Nigeria has a population of 215 million people but not every household has access to electricity (Bisu et al., 2016). For example, in the year 2020, Nigeria net electricity generation was 2815 billion kilowatt per hour as given in Table 3 but has continually dropped in generation over the years.

According to National Bureau of Statistics report (2020), 87 million people lack access to electricity which implies that one in three persons lack access to electricity; and only 40% of rural areas are connected to national grid with 90% of rural areas having unreliable or no electricity. In the report of African Development Bank, the per capita consumption of electricity in Nigeria is 48% (149 kWh) and when compared with other African countries like Ghana (72% and 344 kWh person), Cote d'Ivoire (59.5% and 212 kWh/person), Senegal (56% and 187 kWh/person) makes the situation challenging. The most concerning aspect is that renewable energy makes up only a very small portion (0.35%) of energy source in Nigeria, thereby increasing the failure of socioeconomic activities (Hansen, 2021). Furthermore, the lack of access to electricity increases the use of poor energy sources among households

Table 3 Electricity generation in Nigeria

	ENG		TFFENG		HNG		BWENG		OENG	
Year	Value (BKWH)	Change %	Value (BKWH)	Change %	Value (BKWH)	Change %	Value (BKWH)	Change %	Value (BKWH)	Change %
2018	34.45	5.06	28.00	11.71	6.39	− 16.64	0.03	1.84	0.03	7.14
2017	32.79	2.46	25.07	4.96	7.67	− 4.96	0.03	0.00	0.03	0.00
2016	32.01	3.90	23.88	− 4.83	8.07	42.48	0.03	13.64	0.03	3.70
2015	30.81	0.64	25.10	− 0.70	5.66	7.01	0.02	0.00	0.03	12.50
2014	30.61	11.48	25.27	14.13	5.29	0.38	0.02	15.79	0.02	9.09
2013	27.46	0.57	22.14	2.21	5.27	− 5.87	0.02	26.67	0.02	0.00
2012	27.30	6.15	21.66	8.96	5.60	− 3.81	0.02	0.00	0.02	4.76
2011	25.72	3.35	19.88	7.11	5.82	− 7.70	0.02	0.00	0.02	
2010	24.89	32.18	18.56	29.51	6.31	40.72	0.02	15.38	0.00	
2009	18.83	− 6.52	14.33	− 0.92	4.48	− 20.83	0.01	0.00	0.00	
2008	20.14	− 8.12	14.47	− 8.13	5.66	− 8.13	0.01	0.00	0.00	
2007	21.92		15.57		6.17		0.01		0.00	

Source https://knoema.com/atlas/Nigeria/topics/Energy/Electricity/Electricity-net-generation
BKWH billion kilowatts hour; *ENG* electricity net generation; *TFFENG* total fossil fuels electricity net generation; *HNG* hydroelectricity net generation; *BWENG* biomass and waste electricity net generation; *OENG* others electricity net generation

in Nigeria. Studies have shown that Nigeria consumes half the firewood and charcoal produce and consume each year by China, India, Indonesia, and Brazil which amount to more than 80 million cubic meters (43.4×109 kg) of fuel wood used annually for cooking and domestic uses (Sambo, 2005). Policy makers will need to facilitate innovative ways of resolving the energy crisis in Nigeria. Conversion of waste to energy could be an option to generate clean energy for households, especially when considering the high volume of waste generated annually in the country. According to an estimation made by Somorin et al. (2017), electricity generation potential for the different states in Nigeria varies between 31 and 205 MW. Hence, the country's annual electricity generation potential from municipal solid waste is estimated to be 26,744 GWh/year, with 89% of the states having sufficient generation capacity at minimum regulatory electricity generation requirement of 50 MW. As Nigerian population continues to grow with implications on waste generation per capita, about 40 million tons of waste were envisaged to be generated in 2020 with potentials of 3000 MW of energy (Atta et al., 2016). Therefore, with the massive volume of solid wastes generated across the country, if properly managed, instead of being source of pollution and health hazards, municipal waste can be source of reliable and affordable energy (Abila, 2014).

6.2 Food, Agriculture, and Land Use

Agriculture contributes significantly to the Nigerian economy. Prior to the discovery of oil in Nigeria in 1956, agriculture was the main source of revenue for the country. According to the National Bureau of Statistics report, (2019), agriculture contributed 21.91% GDP across other sectors in 2019, when compared with 27.38% from industry and 49.73% from the service sector. This means that agriculture continues to make a significant contribution to the development of the Nigerian economy.

However, the conveyance of human activities and natural resources is increasing the risk of environmental stress, thereby making farmers and river-dependent communities more vulnerable to climate change (Antwi-Agyei et al., 2012). Farming systems are having an impact on the landscape, and exploitation of resources has rendered ecosystems more vulnerable to climate change. For example, forest over-harvesting has the impact of causing local environmental harm which can reduce an ecosystems resistance to climate change and potentially compound the severity of climate change itself by releasing stored carbon into the atmosphere (Hansen & Hoffman, 2011). More so, forest over-harvesting can lead to the extinction of several plant and animal species; changes in hydrology can result in shortage of water for farming and fishing which may result in food shortages (Thomas et al., 2004). Climate change is also fuelling the risk of conflict among Fulani herdsmen and farmers in the south as drought causes them to migrate to the south in search of greener fields for rearing animals. Over-exploitation of forest is increasing the rate of deforestation. Studies have revealed that there has been a reduction in forested land area in Nigeria by 5% since 1999 because of increase in population; between the year 2000 and 2005, Nigeria has lost 55.7% of forest, and between 2010

and 2019, the country lost *86,700 ha* tropical forest due to deforestation (FAO, 2020). It is imperative that we reduce the pressure on ecosystems and on land through sustainable agricultural practices and the use of less damaging cooking fuels.

6.3 Industry

Industrial development has grown extensively in Nigeria within the last decades as investors take advantage of its high population. Studies have shown that the industrial sector has grown by 7% annually with the oil industry being the biggest driver of change between 2004 and 2014; and more recently, manufacturing and service industries have contributed immensely to the growth of the Nigerian economy. According to Chete et al. (2011), more than half of the GDP is accounted for by the primary sector with agriculture and oil sector playing a leading role in driving the economy of the country. Between 2011 and 2012, the oil and gas sector contributed 14.8 and 13.8% to GDP which means that 95% of export earnings and 85% of government revenue are from the oil and gas sector.

However, industrial development in Nigeria has unleashed undesirable consequences to livelihoods and natural resources, especially in oil producing states (Thornton, 2010). Many industries operating in Nigeria lack the strategies to manage waste generated, while others are contributing to pollution through the use of power generating engines. Oil and gas production is a major contributor to carbon and methane emission in Nigeria, and this has resulted in environmental changes which affect individual rates of growth, survival, reproduction, and thus population substitution rates. For example, approximately 200 km^2 of wetland was affected in the Delta state as a result of dredging and coastal erosion which caused destruction of livelihoods, farmland, and properties worth millions of naira (Abam, 2001). Therefore, the challenge before decision makers is how to improve industrial processes and to support materials produced to meet environmental standards. More so, it is important that we think on how industries can convert waste to energy to the benefit of Nigerians especially in rural communities and with low incomes.

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6.6 Transportation

Road transportation remains the major contributor of air pollution in Nigeria with many cities using old vehicles for public transportation. The use of old vehicles contributes to particulate matters (PM2.5) which is harmful to health. Globally, it has been reported that more than 2.9 million people die prematurely because of exposure to harmful air (WHO, 2016). Studies have shown that exposure to ambient PM2.5 is responsible for heart and respiratory diseases, mortality and morbidity covering health challenges like chronic bronchitis, weight loss, hospital admission, lower respiratory infection in children, etc. (WHO, 2016; Cai et al., 2018).

Nigeria is not an exception to the high death rates because of exposure to particulate matter; especially in large commercial cities like Lagos, Kano, Port Harcourt, Enugu, and Asaba. Table 4 shows the comparison of death rate with other African countries and reveals the apparent higher death rate from PM 2.5 especially in commercial cities. See Table 4.

Table 4 PM2.5 and deaths due to air pollution

City	PM2.5 $\mu g/m^3$ evel	Death due to air pollution	Death/100,000 people
Dakar (Senegal)	21	270	25
Cotonou (Benin)	32	200	32
Lome (Togo)	32	490	31
Abidjan (Côte d'Ivoire)	32	1500	35
Lagos (Nigeria)	68	11,200	46
Cairo (Egypt)	76	12,600	73

Source WHO (2016)

Although there is no operational air quality monitoring station in the country to quantify the contributions of each source of air pollutant, road transportation is identified as a key pollutant because of high vehicle density. More so, public transportation in Nigeria uses old emission control technology primarily because government in most states of the federation does not own their own transport services for public but rather encourages private individuals to operate intra/inter-transport service while government regulates. There is extensive use of old cars as shown in Fig. 3 for public transportation which contributes highly to air pollution; also, the high sulfur content in diesel and gasoline fuel contributes to emission of harmful gases. See Fig. 3 which shows the state of buses used for public transportation in

Fig. 3 Cost of air pollution in Lagos, adapted from www.worldbank.org

the city of Lagos, Nigeria. There are limited alternative transportation options which lead to a reliance on road transportation, whereas rail transportation does not cover and connect all the major cities in Nigeria, the cost of traveling using air transportation remains relatively high for an average Nigerian, and air transportation also brings environmental challenges. It is clear that policy makers must facilitate changes to vehicles, infrastructures, and operations to reduce transportation emissions and protect public health.

7 Conclusion

This paper reveals that environmental problems associated with indoor air pollution and waste generation in Nigeria are primarily as a result of poverty and urbanization. It is disheartening that more than 40.1% of Nigerians are living below the poverty line and more importantly rely on highly polluting energy for cooking. In most households, it is difficult to access clean cooking energy, as such they rely on firewood harvesting for cooking and livelihoods. Furthermore, the characteristic of informal settlements, which is associated with uncontrolled housing development, poor facilities, and poor waste management, is contributing to poor environmental quality and hitherto the poor state of well-being. Unsustainable harvesting of forest wood and reliance on firewood for cooking has resulted in environmental degradation and deforestation of forest reserves. Currently, Nigeria has lost more than 95% of its forest reserves due to urban growth deforestation and continuous reliance on firewood for cooking, with other drivers of deforestation, infrastructure development, and land use change (Owolabi, 2019). Urgent actions are needed to protect and harness in the face of changing climate and the realities of emerging technology.

8 Recommendations

Having established the environmental challenges associated with air pollution and solid waste management in Nigeria, it is clear that urban mangers and policy makers must prioritize actions to ensure that Nigerian cities are not overtaken by ecological problems. There is a need to develop a recovery plan to ensure that technology is applied to manage waste and reduce carbon and other harmful emissions. The following recommendations are proposed to manage the environmental challenges and make Nigerian cities safer, healthier, and more sustainable.

Waste to Energy

Waste to energy is the process of converting non-recyclable and reusable materials into heat and electricity using technology. The achievement of energy sufficiency can be said to be one of the major challenges faced by Nigeria which is hindering its growth and economic development. Hence, generation of energy from waste materials can be harnessed to grow the economy and bring sustainable development to the country with other environmental benefits. The estimation of the total waste generated in Nigeria can be deduced from the study by Ezeudu et al. (2020) which projected that at the total urban population of 199 million, the waste generation from cities in Nigeria will be 125,473 tonnes per day (TPD). In as much as there is advocacy for the reduction of waste materials to achieve greener planet, the reuse of waste materials in terms of energy generation and other functions such as construction are encouraged for sustainable development in Nigeria. Therefore, Nigeria needs technologies that will convert waste to electricity for low-income members of the population. Especially as it has been established that waste to energy is a major contributor to net zero carbon emissions, as it may have the capacity to avoid methane gas production while aiding the production of more electricity from each ton of waste. This should be pursued vigorously, and the process should be well coordinated to ensure inclusive waste management strategies that will integrate the roles of the informal sector into the broader waste management strategies of Nigeria. The technology that processes waste to energy is shown in Fig. 4 irrespective of the form of waste, but the potential to convert to other form of energy like heat, power, or fuel (WEC, 2013). In the work of Muis et al. (2010), he optimized cost efficiency by advocating for the feasible economic solution which includes incineration of admixture of wastes, anaerobic digestion of organic waste, and gasification of part of the refuse derived fuel.

Adopt Economic Stimulus Plan

The Nigerian Government should consider economic stimulus plans that will support the de-carbonization and adoption of clean energy which can create good models for innovation and sustainable growth. For example, subsidizing the production of solar energy can reduce cost and increase demand, thereby reducing gas emissions. The world was severely impacted with COVID-19 and hopes for strong, sustainable international policy to recover from the virus. Before the pandemic, the world was battling

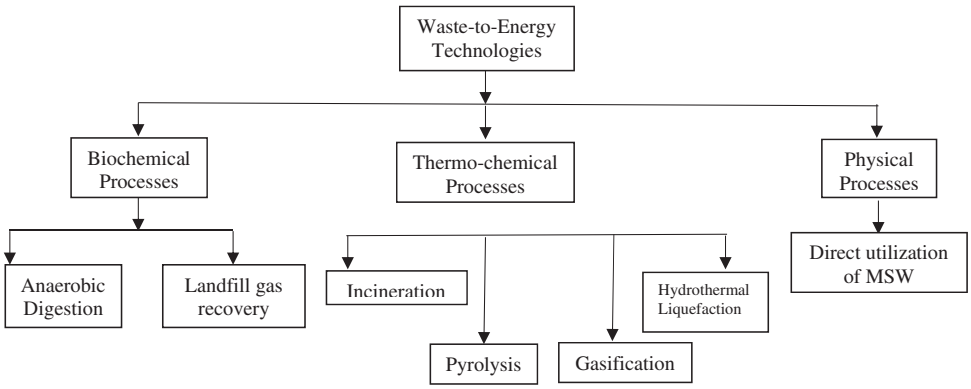

Fig. 4 Process chart of WtE technologies (Asinyetogha & Ibiye, 2016)

with climate change, which manifested in many forms like wildfire, storm, flood, and drought. Nigeria was not an exception from this catastrophe which makes the recovery process essential. As demonstrated by the UN Report, green recovery programs can reduce emission by 25% by the year 2030. It is pertinent that Nigeria should make green infrastructure investment a key component of green recovery, as investment in green infrastructure has the ability to create multiple jobs for young people and achieve the net zero carbon emission target in the future, while also reducing the poverty gap in the country and also protecting the health of women and others in the home environment.

Support Clean Technologies

Government should encourage the production of affordable clean energy stoves that reduce carbon emissions for households, as this will discourage the use of firewood as cooking choice in Nigerian homes. More so, they should consider technology that utilizes waste products as a source of affordable and cleaner fuel for cooking.

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Generating a Design Concept of a Multi-regulation Biomimetic Envelope as an Approach to Improving Comfort Conditions of the Built Environment

Nada Hossameldin Kamel, Nagwan Shehata and Eman AlAkaby

Abstract

In line with the current world circumstances and global strategies for year 2030, which focus on the improvement of energy efficiency and the enhancement of human health and well-being, and based on the proven contribution of buildings to global warming and climate change due to their greenhouse gas (GHG) emissions, built environments need, not only to overcome the negative impact on the environment in the future, but also to achieve an overall positive environmental impact. This can be achieved by mimicking the strategies of natural systems that are critically distinct from many man-made systems in their reliance on homeostasis, rather than energy or non-renewable sources. In spite of the research and efforts that have been carried out over the past decade to develop reliable biomimetic methodologies and envelopes, only a few have dealt with the multi-regulation of environmental aspects. While living systems in nature do not address every environmental aspect individually, but rather are unique in their ability to regulate number of them simultaneously. Proceeding from that, this paper comes to test the hypothesis that in the existence of a coherent biomimetic methodology, generating a design concept of a multi-regulation biomimetic envelope is possible. For that purpose, following the *BioGen* methodology, this research studied specific natural systems, such as human lungs, termite mounds, prairie dogs' burrows, veins in human legs, zebra, elephant, and Mescal Cactus plant, to analyze their control strategies of air, heat, and water and then implemented these strategies in the design of an outdoor pavilion's envelope. This resulted in a multi-regulating bio-envelope design that can improve air exchange rates between indoors and outdoors, increase indoor cooling efficiency by dissipating excess heat, and benefit from the humidity in the surrounding environment. Through this result, the research concludes that, while translating natural models and strategies into architectural models remains a challenge and a multidisciplinary process, it is still possible to generate a design concept of multi-regulation envelopes in the presence of a well-structured methodology and the appropriate biological background it provides. Additionally, the research paves the way for more studies that address the generation of multi-regulation bio-envelopes, even leading them in further steps; digital simulation and the fabrication of physical prototype which were out of limit of this research.

Keywords

Global warming · Biomimicry · Multi-regulation · Biomimetic envelope · *BioGen* methodology

1 Introduction

1.1 Buildings' Contribution to Global Warming

Based on the special report released by International Panel on Climate Change (IPCC) on the potential consequences of global warming and further climate change risks, maximum efforts have been directed to reduce greenhouse gas (GHG) emissions leading to global warming.

N. H. Kamel (✉)
Art and Design Programs, Egypt-Japan University of Science and Technology (E-JUST), New Borg Al-Arab City, Egypt
e-mail: nada.kamel@ejust.edu.eg; Kamel.h.nada@gmail.com

N. Shehata · E. AlAkaby
Faculty of Fine Arts, Alexandria University, Alexandria, Egypt
e-mail: Nagwan.Shehata@alexu.edu.eg

E. AlAkaby
e-mail: eman.a.akaby@alexu.edu.eg

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Buildings have been found to generate approximately 19% of the world's greenhouse gas emissions. And according to the European Construction Sector Observatory, construction accounts for over 35% of global carbon emissions and 42% of global energy consumption. Furthermore, rising CO_2 levels in the atmosphere result in increased energy consumption in the built environment (Ilipinar et al., 2020). Therefore, a major opportunity to reduce emissions lies in improving building construction, and this can be achieved by ensuring the effectiveness of the building envelope, which has been seen as an important factor in reducing the operational energy consumption of buildings only relatively recently, after they were previously treated as fixed structures (Webb, 2021). Most importantly, this consideration of envelopes' designs and materials should be studied at the beginning phases of the projects.

1.2 The Century of Biology

Today, it is acceptable to assume that the twenty-first century is the century of biology, while the twentieth century was the century of physics (Aziz & El sheriff, 2015). In order to design building envelopes that are flexible, resilient, and adaptive to their surroundings, looking up to nature for inspiration provides innovative ideas and solutions that cannot be generated by conventional engineering (Webb, 2021). Natural selection affirms the wisdom of the survival strategies that living organisms evolved to adapt to a wide range of environments, over the course of approximately 3.8 billion years (Bernett, 2015). Furthermore, nature aims to improve, not to increase, using the minimum materials and energy required for optimal performance (Amer, 2019). They form their structural forms based on their functional requirements, resulting in efficient and multifunctional systems to meet the performance requirements of every living organism. (Chen et al., 2016). All these factors critically distinguish natural systems from many other man-made systems. Accordingly, biomimicry—the design that is inspired by nature in terms of functional concepts—is extremely important in today's globe, which is experiencing rapid climate change and environmental deterioration. It also provides intelligent answers for human requirements via translating process into a human context, where the design may differ from that of the parent organism/ecosystem but the functional concepts remain the same (Jamei & Vrcelj, 2021). Many natural strategies have been studied, whether of animals, plants or entire ecosystems in terms of maintaining thermal comfort, regulating water and light and achieving the required air flow, as well, all through balance and homeostasis, and without relying on non-renewable energy or materials (Cruz et al., 2017). However, biomimicry in architecture is still in the early stages of development and structuration due to the inherent difficulty of merging biology and engineering, and its application to building facades in particular has been limited to date (Webb, 2021).

1.3 Methodologies for Biomimetic Design Concept Generation

There are two approaches to biomimetic processes. Biomimetics is either employed as a problem-solving method or it is initiated by biological discoveries. Problem-solving reasoning has been the primary focus of engineering design research to date due to its potential practical implications. Biomimicry, like any other novel design theory, required a methodological framework to transform a theoretical concept inspired by live beings into a highly complicated technical solution. As a result, many methods have been developed to facilitate this complex multidisciplinary process and aid in the implementation of a technological pull strategy, such as the procedural model of implementing bionics, biomimetic design methodology, problem-driven analogical process, and so on (Grae et al., 2020). Many biomimetic design methodologies have emerged in the past decade to help this transition between fields, such as BioTRIZ, Biomimicry 3.8, and DANE (Kuru et al, 2020). However, clear indications of architectural design are still limited. Their complexity often increases, and conflicts arise, as well, when many strategies from different systems are combined to achieve a design solution (Badarnah, 2017). Additionally, among the challenges that designers face regarding biomimetics is the search and selection of the compatible strategies for their designs from the large database found in nature and the lack of design methodologies capable of summarizing successful natural strategies and mechanisms, especially if the designer has a limited biophysical background (Badarnah & Kadri, 2015).

1.4 Multi-regulation in Biomimetics Envelopes

Biomimetic envelopes mimic natural organisms regarding the regulation of environmental aspects such as air, water, light, heat, and acoustics, in order to ensure comfortable and stable indoor conditions regardless of the changes outside. (Cruz et al., 2017). But these envelopes need to be designed to regulate multiple environmental factors at one time, depending on the fact that the biological systems they are inspired by have multifunctional properties (Badarnah, 2012). Multi-regulation is one of the dominant aspects in natural systems. It evolved to help them change their character in response to environmental conditions over

time; this resulted in a compromise that satisfied partially contradictory objectives known as trade-offs (Kuru et al., 2020). Natural systems may perform air regulation, control humidity changes and heat transfer concurrently, and as these aspects are dependent on each other, the regulation of one affects the regulation of the others (Badarnah, 2012). Although a number of biomimetic building envelopes have been built over the past decade, they have fallen into a particular deficiency; only a few have dealt with the multi-regulation of environmental aspects (Cruz et al., 2021). Buildings techniques are still typically seen as monofunctional, stand-alone components.

Accordingly, the research concludes from the findings of previous research and studies, that despite the fact that biomimetics promise many ideas that have the potential to reduce buildings' contribution to global warming, and while many researches have already produced bio-designs that follow the approach of natural systems, the implementation of these designs in real world is still very limited. And if implemented, they address the regulation of only one environmental aspect, not multiple ones. In biology, multi-regulation is well understood; nevertheless, its use in architecture is limited (Kuru et al., 2020).

2 Motivation of the Research

Proceeding from all the above, this research comes to test the possibility of generating a multi-regulation bio-envelope design concept with the use of a well-structured biomimetic methodology that does not require an extensive biological background, as the relationship between biology and architecture can be built on loose or generic connections, and this does not preclude architects from using their creativity to generate biomimetic solutions. (Chayaamor-Heil & Vitalis, 2020). Accordingly, *BioGen* methodology by Badarnah and Kadri (2015) was chosen for this research to generate the design concept of the envelope which to be implied in an outdoor pavilion for universities' students. A pavilion can offer them an outdoor space for different activities, while enhancing their comfort and well-being, by mimicking the strategies of natural systems of regulating air, heat and humidity.

3 Methodology

BioGen methodology is a methodology for biomimetic design that facilitates the transition between the different stages of the design process and the search for compatible strategies. This methodology follows the "problem-based" approach, in which solutions are sought to solve specific problems (Badarnah, 2015). This methodology is chosen for this research because it is a systematic selective one that can find relevant systems and then moves by abstracting their strategies and mechanisms from level to level, in a gradual succession through well-coherent steps. What distinguishes this methodology is that it gives the designers the freedom during decision making without dictating the implementation of a specific strategy. The steps of the methodology can be summarized in:

Step 1: Defining the design challenge/problem.

Step 2: Exploring possible scenarios and identifying exemplary natural organisms and systems (referred to as pinnacles).

Step 3: Analyzing selected pinnacles.

Step 4: Deriving imaginary pinnacle, which is achieved through the "*Pinnacle Analyzing Matrix*".

Step 5: Outlining the design concept, using the "Design *path matrix*".

Step 6: Generating a preliminary design concept.

Step 7: Evaluating and validating the solution (Badarnah & Kadri, 2015).

However, before applying these steps of the methodology and as a preparatory step, exploration models need to be created. The exploration model consists of four hierarchical classifications, as follows:

(1) The data associated with **functions** at the first level: It corresponds to the problem or design challenge for which a solution is to be designed.

(2) **Processes** related to the corresponding functions: It includes the various approaches that may be adopted by the design solution.

(3) The **factors** responsible of the corresponding processes.

(4) And finally **pinnacles** at the fourth level: It represents the organism or living system that obtains the corresponding function, process, and factor (Badarnah, 2015).

Based on the purpose of the designed bio-envelope, the following exploratory models were used for each environmental aspect, air, heat, and water, regulated by living organisms in nature (Figs. 1, 2 and 3).

4 Case Study

In this section, the *BioGen* methodology is followed to generate the design concept of a pavilion's biomimetic envelope. According to Peters and D'Penna (2020), universities' environments that incorporate design elements associated with nature can increase restorative qualities of the environment, helping students focus on their learning and increase their productivity. Moreover, they have their

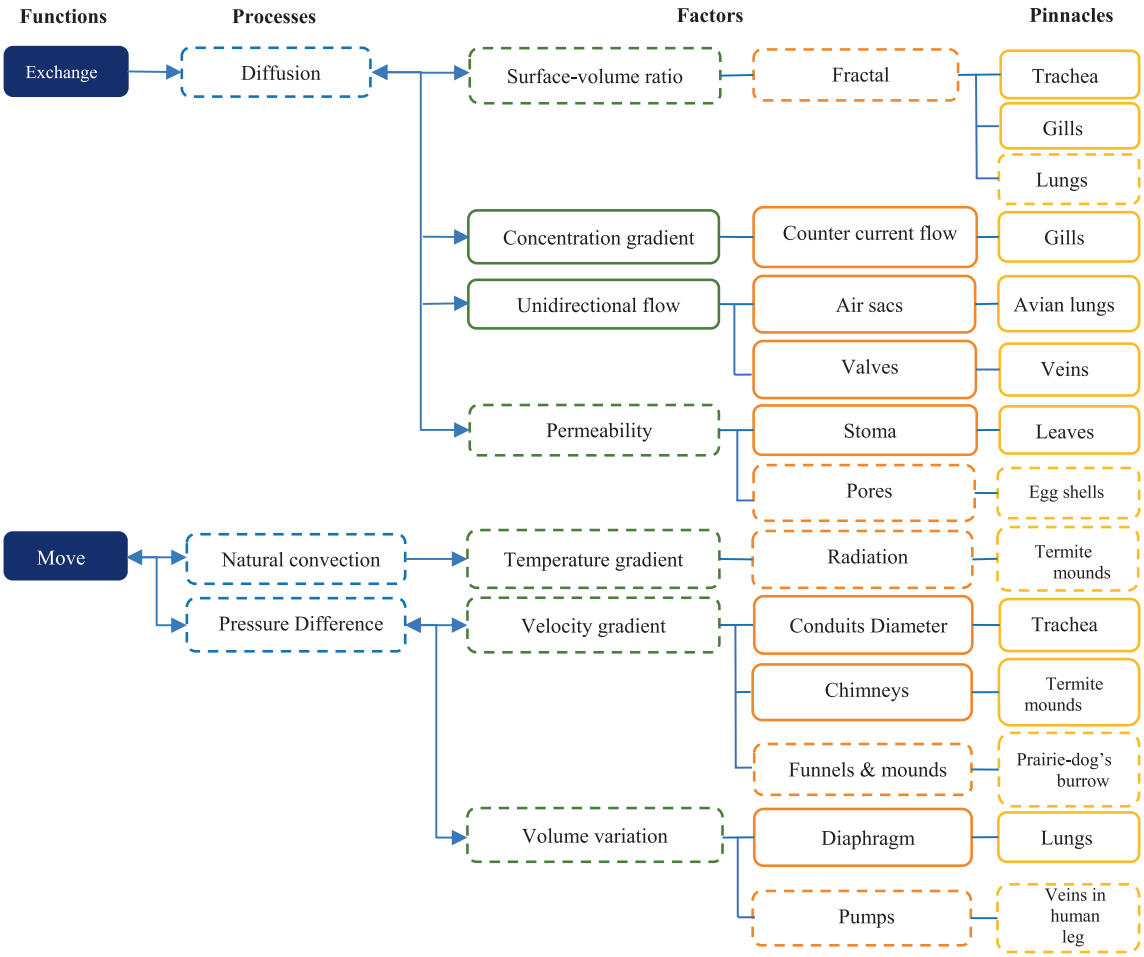

Fig. 1 Exploration model for air regulation strategies in nature. Adapted with permission from (Badarnah, 2012)

positive outcomes represented in the support of the physical and psychological comfort and well-being of students. Therefore, the pavilion is designed to be an outdoor haven for the students occupying universities' halls of residence, specifically the residence of Alexandria University.

Geographically, Alexandria is about 30° 50′ to 31° 40′ to the north and 29° 40′ to 32° 35′ to the east. The city has a 60 km waterfront along the Mediterranean Sea. Climatically, Alexandria is a semi-desert characterized by hot summers, mild winters, and little rainfall. There are only two seasons, a mild winter from November to April and a hot summer from May to October. Humidity in Alexandria is very high. However, the sea breeze keeps the humidity at a comfortable level (Khatri et al., 2007). Therefore, the pavilion is intended to be held between May and October as this period is the most suitable for outdoor activities, to avoid the cold weather and any rainfall. According to these parameters, the designed pavilion's envelope has to increase the indoor and outdoor air exchange rate, improve the thermal comfort of the students, and utilize the humidity of the environment by capturing water from fog which can help with water scarcity and efforts made to decrease water consumption.

Next, the steps of *BioGen* methodology followed to generate the design concept of the multi-regulation bio-envelope will be demonstrated, in detail.

4.1 Step 1: Defining the Design Challenge

The design challenges of this multi-regulation bio-envelope are

(1) Air: To provide adequate indoor air quality through passive ventilation principles, while enhancing air exchange rates between indoors and outdoors.
(2) Heat: To reduce the interior temperature of the pavilion while increasing the cooling efficiency by dissipating excess heat.
(3) Water: To utilize the moisture in the surrounding environment by capturing water from humidity, which can help with scarcity of water and the efforts made to save in water consumption.

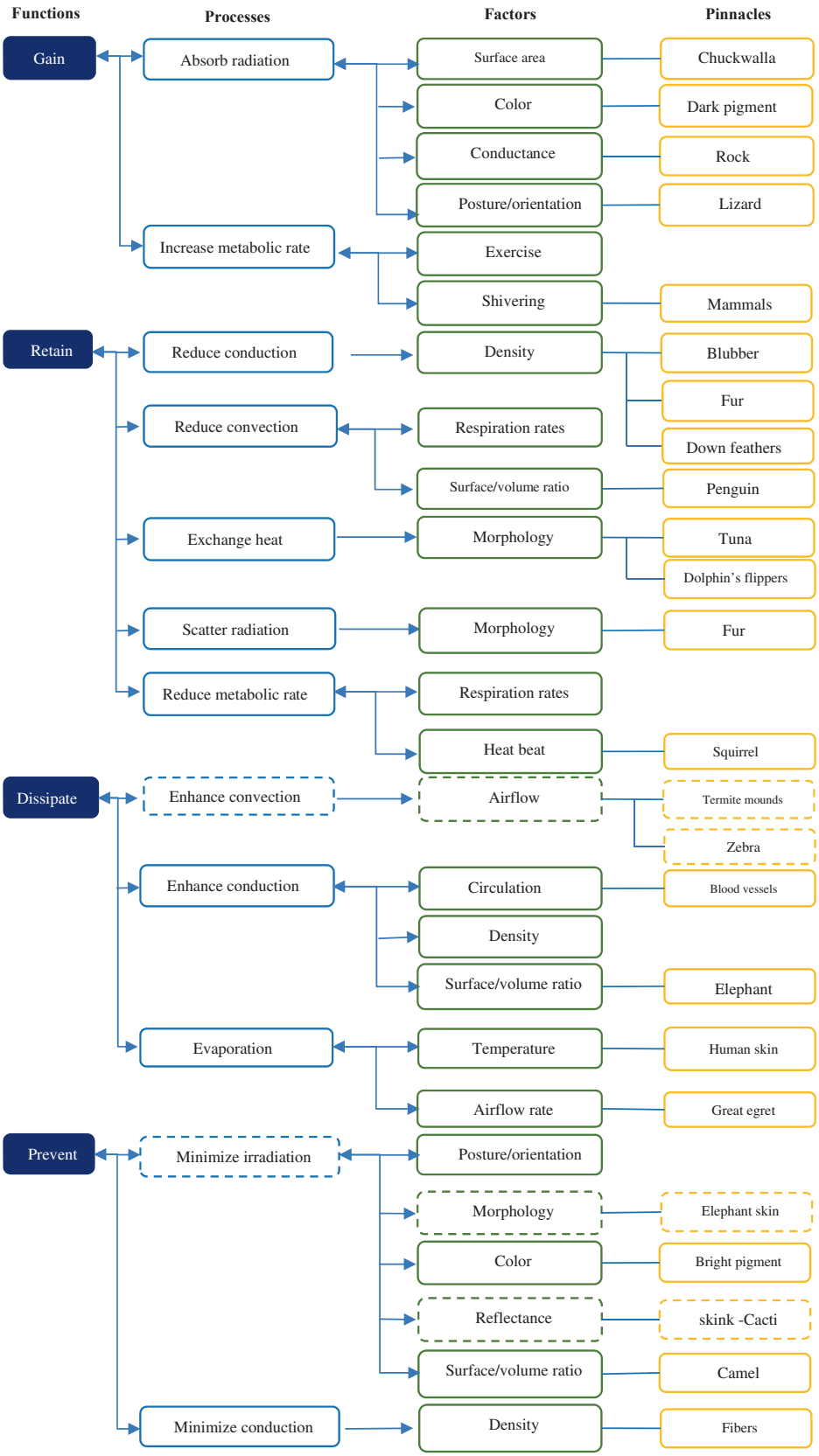

Fig. 2 Exploration model for heat regulation strategies in nature. Adapted with permission from (Badarnah, 2012)

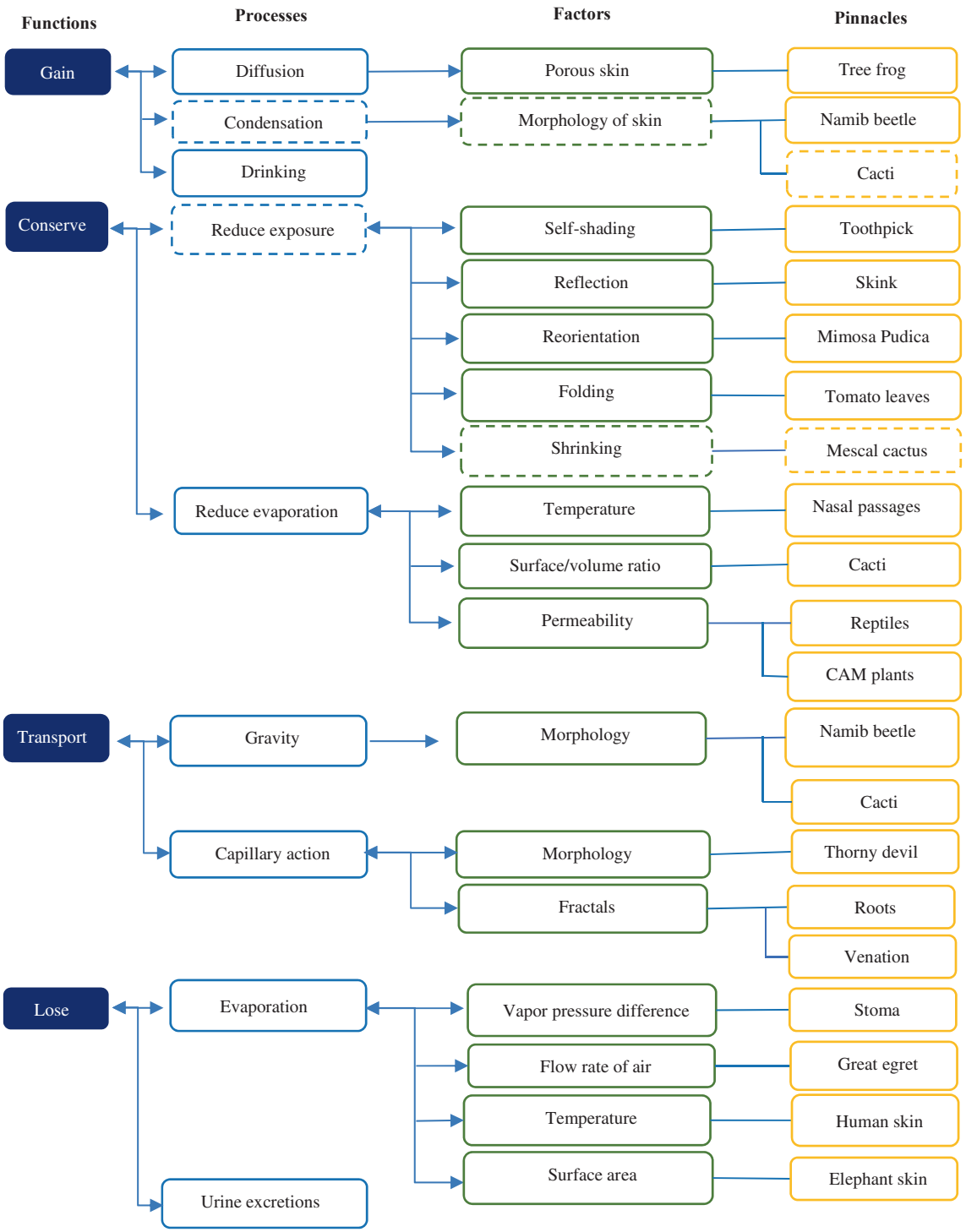

Fig. 3 Exploration model for water regulation strategies in nature. Adapted with permission from (Badarnah, 2012)

4.2 Step 2: Exploring Possible Scenarios and Identifying Exemplary Pinnacles

Once design challenges are identified, the exploration models provide several scenarios that lead to different related pinnacles. In this step, the design challenges are linked to the corresponding paths of the exploration model.

4.2.1 Air

Based on the design challenges, the first goal is to achieve "passive ventilation", which is based on transferring air from the inside to the outside, to be replaced by fresh air from the outside. Thus, according to the exploration model:

The **Function** corresponding to this purpose is *air movement.*

The **processes** corresponding to air movement function are:

(1)*Natural Convection and*
(2)*Pressure Difference.*

In this design, both processes will be applied, with their related factors and pinnacles.

The second goal is to "enhance air exchange", which can be translated to the function: *air exchange*, and the corresponding process is *diffusion.*

4.2.2 Heat

The design challenge of "reducing temperature" can be translated to the **function**: *prevent heat.* And the corresponding **process** is *minimize irradiation.*

And for "increasing the cooling efficiency by dissipating the excess heat", the corresponding **function** of the exploration model is *dissipate heat*.

From the corresponding **processes**, the researcher chose *enhance convection.*

4.2.3 Water

According to the exploration model, the **function** of "*water gain*" is the relevant function to "utilize the moisture in the surrounding environment", and the corresponding **process** chosen is "*condensation*".

As will be shown in the design later, the design required the imitation of an organism with the capability of water retention, so **function** of "*conserve water*" and the corresponding **process** of "*reduce exposure*" were selected.

In exploration models (Figs. 1, 2 and 3), the chosen paths are marked with dashed lines. In the next step, these selected pinnacles are analyzed and summarized.

We note that a number of pinnacles appeared more than once in the exploration models; such as termites and Cacti, which proves that these pinnacles already have multifunctional capabilities. Integrating these pinnacles in the design contributes to its practicality and ensures that there are no conflicts between its functions.

4.3 Step 3: Analyzing Selected Pinnacles

In Table 1, a summary for the analysis of the pinnacles extracted from exploration models is presented, each selected pinnacle is briefly analyzed regarding the strategy of its performance, the relevant mechanism, the main principle, and finally, the main feature of its performance.

The lungs (Badarnah, 2012; Jagan Kumar & Jayalalitha, 2019) and egg shells (Badarnah, 2012) represent mechanisms for air exchange, termite mounds, prairie dog's burrow and veins in human leg (Badarnah, 2012; Turner & Soar, 2008; Cruz et al., 2017; Paar & Petutschnigg, 2016) represents mechanisms for air move, termite mounds and zebra (Badarnah, 2015; Turner & Soar, 2008; Horváth et al., 2018) represent mechanisms for dissipate heat, elephant and Cacti (Badarnah, 2015; Cactus Adaptations, 2019) represent mechanisms for prevent heat, Cacti (Ju et al., 2012) represent mechanisms for water gain and Mescal Cactus (Cactus hides from the Sun, 2016) represent mechanisms for conserve water.

4.4 Step 4: Deriving Imaginary Pinnacle

In the fourth step of the *BioGen* methodology, each of the selected pinnacles will be analyzed in the *Pinnacle Analyzing Matrix*, in which the organisms selected for each of the challenges related to air, heat, and water are further analyzed in nine categories: processes, flow, adaptation, scale, environmental context, morphological features, structural feature, material features, and many other features. Corresponding features are selected for each "organism" in each category, and dominant features are highlighted for each challenge, which will represent imaginary pinnacle's features for each job.

After analyzing the pinnacles of each challenge individually in the *Pinnacle Analyzing Matrix*, those analyses are combined into the *Integrated Pinnacle Analyzing Matrix*.

If no features are identified for a category, then the category is irrelevant for the corresponding challenge of the design concept (Badarnah & Kadri, 2015). The big number of selected pinnacles leads to more reliable dominant features for the design of the bio-envelope. In this paper, only the *Integrated Pinnacle Analyzing Matrix* (Table 2) was presented—for short, which summarizes the characteristics of the imaginary pinnacle.

4.5 Step 5: Outlining the Design Concept

In the fifth step of the *BioGen* methodology, a second level of analysis is conducted for the imaginary pinnacles, in the *Design Path Matrix*, in order to further abstract the dominant features identified in the previous step, which will be incorporated into the integrated design concept. Dominant features, which are marked with red-dashed circles, are the features that have the more connections with different imaginary pinnacles (Badarnah & Kadri, 2015).

Based on the "*Design Path Matrix*", presented in Fig. 4, the features that will be integrated into the multi-regulation

Table 1 Brief analysis of the selected pinnacles from the exploration models, in terms of main mechanisms, principles, and features, to facilitate the design of the imaginary pinnacle

Pinnacle	Pinnacle's strategy	Mechanism	Main principle	Main feature
Air				
Lungs	The morphological adaptation of the respiratory system helps to provide an expanded surface area for diffusion. The branching hierarchy of the airways in the human lungs by systematic gradual division from the trachea to the ducts and air sacs greatly affects the efficiency of gas exchange	An orderly reduction of the airway diameter, thereby increasing the surface area for exchange	System branching based on hierarchy that allows for efficient gas diffusion transport	Fractal structure and Murray's law
Egg shells	The small openings in egg permeable shells act as filter medium between the organism and the surrounding environment	Gas exchange with the surrounding environment by diffusion	Diffusion Permeability	Pores
Termite mounds	Termites modify mounds in accordance with the environmental changes for homeostasis There are two distinct methods of termite mounds ventilation: 1. mounds with no chimneys and with air passages close to the surface. They ventilate through natural convection, and heat produced by the colony buoys the air and lifts it up the mound to the porous surface of the mound. There, the spent air is refreshed through pores with the exchange of heat, water vapor, and gases with the atmosphere 2. Mounds with chimneys that ventilate according to Bernoulli's principle	Structural features to move air such as variations in wall thickness, surface pattern, orientation, chimneys, passages, and porosity	Ventilation through natural convection Bernoulli's principle	Air passages and porous surfaces Chimneys
Prairie dogs' burrows	Prairie dogs burrows induce airflow into their long, narrow burrows	By shaping the two end openings of the burrow, one with a sharply shaped mound (which is of low pressure; expels air) and a rounded mound (higher pressure; sucks air in), produces velocity gradients at the surface of the ground, which induce air into the burrow	Bernoulli's principle	Different shaped openings
Big veins in human legs	Creates volume variations to move blood around the body	Muscles create pressure on the veins resulting in volume variation, forcing blood to flow and reach all parts of the body Valves in veins control the flow of blood in one direction and prevent the reverse flow	Chamber pump	Muscles and veins Valves
Heat				
Zebra	Dissipating heat of the surface by enhancing air flow	Cooling by air convective currents generated on the surface, as the heated air in contact and close to black stripes rises, and is replaced by cooler air close to the white stripes	Enhance convection by creating air currents that improve air flow over the skin and increase evaporation and cooling rates	Variation of colors or reflectivity of sunlight to improve air convection

(continued)

Table 1 (continued)

Pinnacle	Pinnacle's strategy	Mechanism	Main principle	Main feature
Termite mounds	Heat dissipation with enhanced air flow and ventilation	• Air flow in the outer channels is enhanced through the increased surface area of the mound, which enhances convection • Based on the fact that the large chimney openings experience higher wind speeds than the openings closer to the ground, fresh air is infused into the mound through ground level openings, then through the nest and finally out through the chimney	• Increase air flow near surface for ventilation and cooling by enhanced convection • "Induced flow" enhances air flow in the mound	Air passages and porous surfaces Chimneys
Elephant	Heat prevention through morphological features of the body surface	Minimizing the areas exposed to radiation, to prevent heat gain	Prevent direct exposure to the sun through shaded areas	Wrinkles
Cacti	The morphological composition of the surface of the cactus helps minimize irradiation	Prevent direct exposure to the sun through shaded areas created by spines grouped close to each other, light colors of these spines reduce sun damage by reflecting sunlight	Creating shaded area to prevent direct exposure to the sun Reducing radiation absorption by material reflection, color, and density	Dense, light, or pale colored spines shaped in groups
Water				
Cacti	The morphological formation of the spines on the surface of the cacti helps to collect water	Variations in the roughness of the surface parts of the spines (oriented barbs–oriented grooves–trichomes) and the alternating hydrophilic and hydrophobic areas help in condensation and movement of water along the spines	Condensation	Spines
Mescal cactus	Control exposure to the sun to conserve water	Mescal Cactus adapts to seasonal water availability via dehydration-induced shrinking below the desert floor and hydration-induced swelling to reemerge afterrainfall	Expansion and shrinkage in accordance with water saturation	Elasticity for expansion and shrinkage

Table 2 Integrated Pinnacle Analyzing Matrix, which summarize the features and characteristics to be implemented in the Imaginary pinnacles (Adapted with permission from (Badarnah, 2012)

Challenge	Processes	Flow	Adaptation	Scale	Environmental context	Morphological features	Structural feature	Material features	Other features
Air									
Exchange (E)	Diffusion (Diff.)	Passive	Morphological (Morph.)	Micro	Continental (Cont.) Moderate (Mod.) Tropical (Trop.) Arid	Fractals (Frac.)	Conduits (Cond.)	Porous	
Move (M)	Natural convection (Nat.) Pressure difference (Pre.)	Passive active	Morphological Physiological (Phys.)	Meso	Continental Moderate Tropical Arid	Funnels mounds	Conduits chimney (Chim.) Valves (Valv.)	Conductive (Cond.) Porous Elastic	Unidirectional flow (Unidirec.) Extracting and expanding
Heat									
Dissipate (D)	Enhance convection (Conv.)	Passive	Morphological	Meso	Tropical Arid	Branching (Branc.) Colors	Conduits		Unidirectional flow
Prevent (P)	Minimize irradiation (Irrad.)	Passive	Morphological	Micro Meso	Arid	Wrinkles (Wrin.) Spines	Grooves (Groov.)		
Water									
Gain (G)	Condensation (Cond.)	Passive	Morphological	Micro	Arid	Spines	Grooves	Hydrophilic Hydrophobic	
Conserve (C)	Reduce exposure (Expo.)	Active	Physiological	Meso	Arid			Elastic	

bio-envelope's design concept have been identified, and they can be summarized as follows:

1. Diffusion for "air exchange", convection and pressure gradient for "air movement", enhancing convection for "heat dissipation" and minimizing irradiation for "heat prevent", and for water, condensation is to "gain water", reduce exposure to radiation in order to "conserve water".
2. The flow is passive for all functions, except for both "air movement" through "pressure difference" and "water conservation" through "reduce exposure".
3. The type of adaptation is "morphological" in most of the processes, "physiological" in the case of "water conservation", and in the case of "air movement" through the pressure difference.
4. Some functions occur in the micro scale, while others are in the meso scale.
5. Most of the imaginary pinnacles share an arid ecological context. But this does not interfere with the designed envelope functioning in other environmental contexts.
6. Morphological features are independent for each specific function. But it is concluded that the fractal facilitates the process of "air diffusion", funnel and mounds facilitate "air move", conduits/branches and the contrast of colors—or the reflectivity of surface—facilitate convection, while wrinkles contribute to the "heat prevent" and spines contribute to "water gain" by condensation.
7. The most prominent structural features are conduits and grooves, while "air movement" processes include chimneys and valves.
8. As for the material features, "conductive", "elastic", and "porous" were the dominant features. It combined hydrophilic and hydrophobic for "water gain" process.
9. Other relevant features that can be addressed in the context of "processes" are unidirectional flow and expansion and contraction.

5 Results

The sixth step of the *BioGen* methodology, **Generating a preliminary design concept**, represents the result of this research. In this step, the dominant features and characteristics analyzed in the *Design Path Matrix* are translated into the design concept of the multi-regulation bio-envelope of the pavilion (Fig. 5). The envelope consists of two alternating sections: flat ones that include "Air pumping mechanism" in their lower parts, and openings in their upper parts, and sections that consists of projected slats. Next, how this envelope contributes to regulating air, heat and water will be clarified.

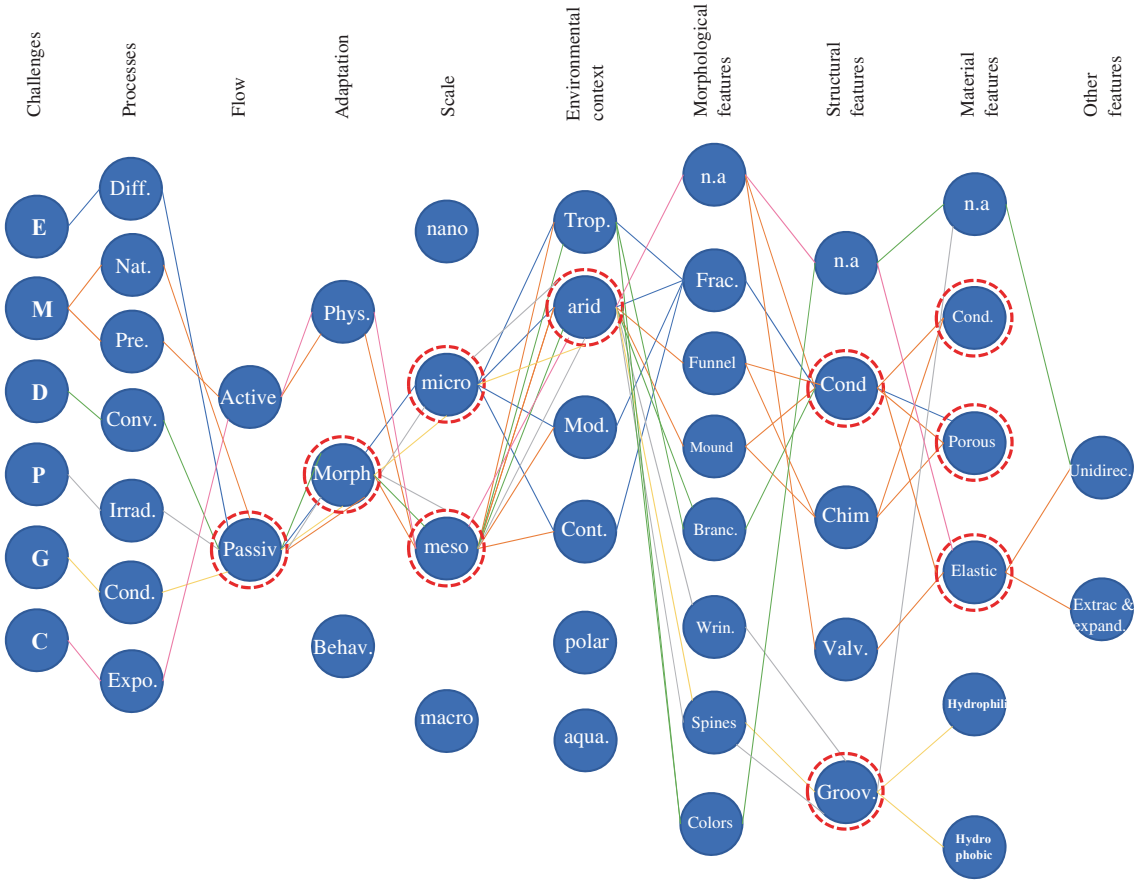

Fig. 4 *Design path matrix*. Adapted with permission from (Badarnah, 2012)

5.1 Air

In order to provide adequate indoor air quality through passive ventilation principles, while enhancing air exchange rates between indoors and outdoors, the design has been developed which mainly consists of two parts:

(1)A permeable medium with an "air pumping mechanism" (Part "1" in Fig. 5) that allow fresh air to enter the pavilion.
(2)A chimney to expel the spent air outside (Part "2" in Fig. 5).

Part "1" is a modular unit located at the bottom of the envelope, through which fresh air enters the pavilion. Its location is based on the movement of air through natural convection, like in termite mounds, the cooler and denser air is located at the bottom where it replaces the hot, less dense exhausted air. This part is designed of a porous permeable material, mimicking "air exchange" by diffusion, through pores in the eggshell. This permeable medium allows the new air to diffuse passively inward.

In case the movement of air outside the pavilion is insufficient or slow to achieve inward diffusion, "air pumping mechanism" (Fig. 6) was integrated into the permeable medium to pump fresh air into the pavilion. This mechanism is designed to work based on the process of "air movement" through "pressure difference", depending on variation in volume. Therefore, "air pumping mechanism" is designed mimicking the movement of blood in the large veins in the human legs, which occurs in response to the "chamber pump", in which the volume decreases due to the external pressure of other parts of the body.

The "air pumping mechanism" (Figs. 6 and 7)—uniformly distributed in the modular units—consists of chambers that mimics the muscles, made of elastic material—inspired by the Mescal Cactus—with the ability to expand and shrink (will be discussed in the part of Water p.

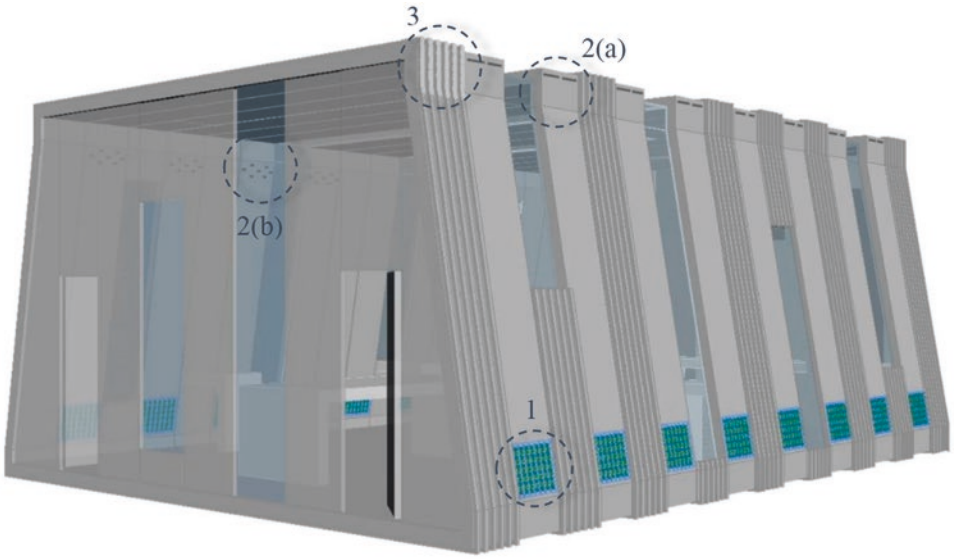

Fig. 5 Design of the resulted multi-regulation bio-envelope integrated into an outdoor pavilion. The façade of the pavilion is made transparent here for the inner face of the envelope to be seen

18). Distributed between these chambers are air channels of elastic material that mimic veins and are open from outside to inside the envelope.

When these chambers expand, they act as pumps for the air inside the channels; as the size of the channels decrease, the fresh air inside them is pushed inward the pavilion. When the chambers return to their normal size, channels return accordingly, and low pressure arises inside them, which leads the tubes to suck air from the outside, and so on (Fig. 7). Channels are designed with valves that control the flow of air in one direction and prevent the reverse flow.

The chimney responsible for expelling the exhausted air out (Fig. 5 Part "2a" and Fig. 8) is located in the thickness of the upper part of the envelope, based on the movement of air through natural convection. The chimney is designed simulating the ventilation strategy of chimneys of termite mounds, prairie dog burrows, and the fractal form of human lungs.

The chimney (Fig. 9) is designed of many generations of branches with a gradient in their diameters, according to Huss-Murray law, simulating the branching hierarchy of the airway in the human lungs. This fractal configuration of the branching chimney is designed to have several inlets and one output.

The chimney ends with small holes distributed on the inner surface of the upper part of the pavilion (Fig. 5, part "2b"). This morphological configuration increases the amount of expelled air as a result of the suction force generated in the upper opening of the chimney exposed to the wind flow.

The mechanism for expelling air out is based on Bernoulli's principle-mimicking prairie dog burrows, as follows; the sharp mounds of the chimney openings, located on the outer side of the envelope, cause lower pressure, and the round mounds of chimney openings located in the upper inner surface of the envelope generate higher pressure, and thus exhausted warm air is sucked from inside the pavilion "high pressure" to the outside "lower pressure", through the chimney. Moreover, taking advantage of the "Venturi effect", a decrease was made in the diameter of the main branch, because air pass from the larger diameter to the smaller one achieves an induced flow, which increases the speed of its exit from the chimney out, as well (Fig. 9).

5.2 Heat

In order to "dissipate heat" inside the pavilion, termite mound's strategy to "enhance convection" was utilized by creating air flow through chimneys. Additionally, to dissipate heat of the outer surface of the envelope, Zebra's morphology of color variation was simulated to improve airflow over the surface and increase cooling rates.

As analyzed in the previous steps of the methodology, the difference of temperatures of the air in contact with black and white stripes of zebra's body creates air currents that help cooling the surface. In the generated design concept, in order to create air flow, difference in air temperature is achieved by designing alternate areas that differ in their reflectivity to sun radiation. The reflective parts) Figs. 10 and 11)—the projected slats on the surface of the envelope—have dense light-colored spines, distributed in groups very close to each other, simulating those on the surfaces of Cacti. These dense spines reduce the absorption of solar radiation and scatter light on the surface of the pavilion. This keeps the air in contact with these slats cooler than the air in contact with the recessed parts. Spines provide shaded areas that help cool the surface, as well.

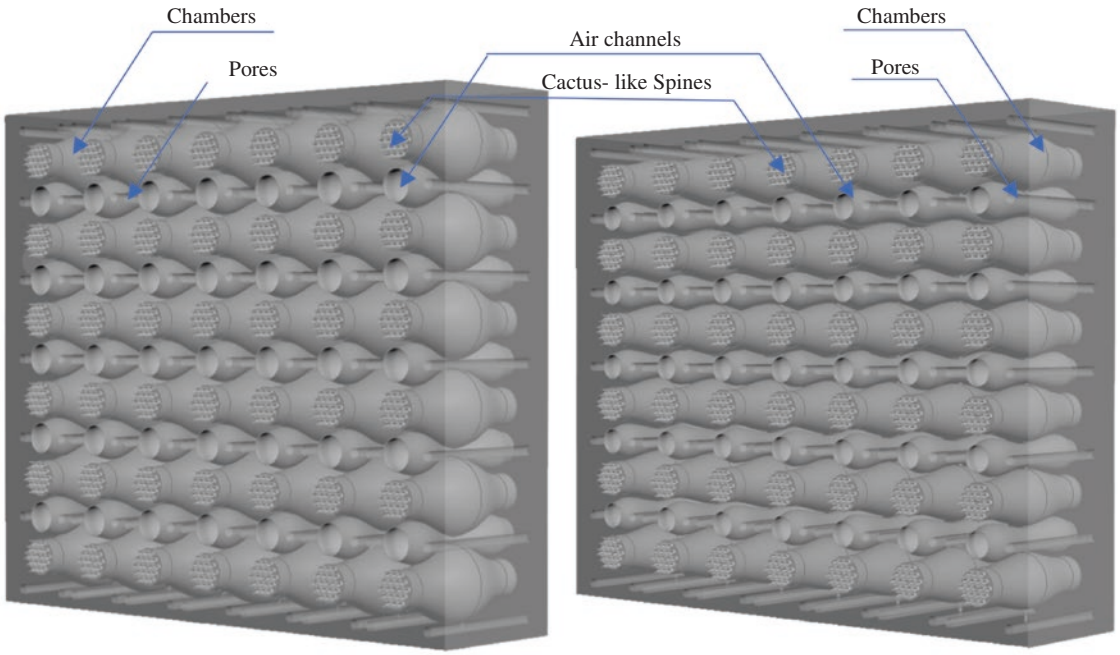

Fig. 6 Design of the "air pumping mechanism" integrated in the modular permeable units, in the case of expansion (left) and in its normal size (right). The pores allow fresh air to diffuse into the pavilion. Chambers and channels are responsible for the movement of air, if the pores are not sufficient, according to the air flow around the envelope

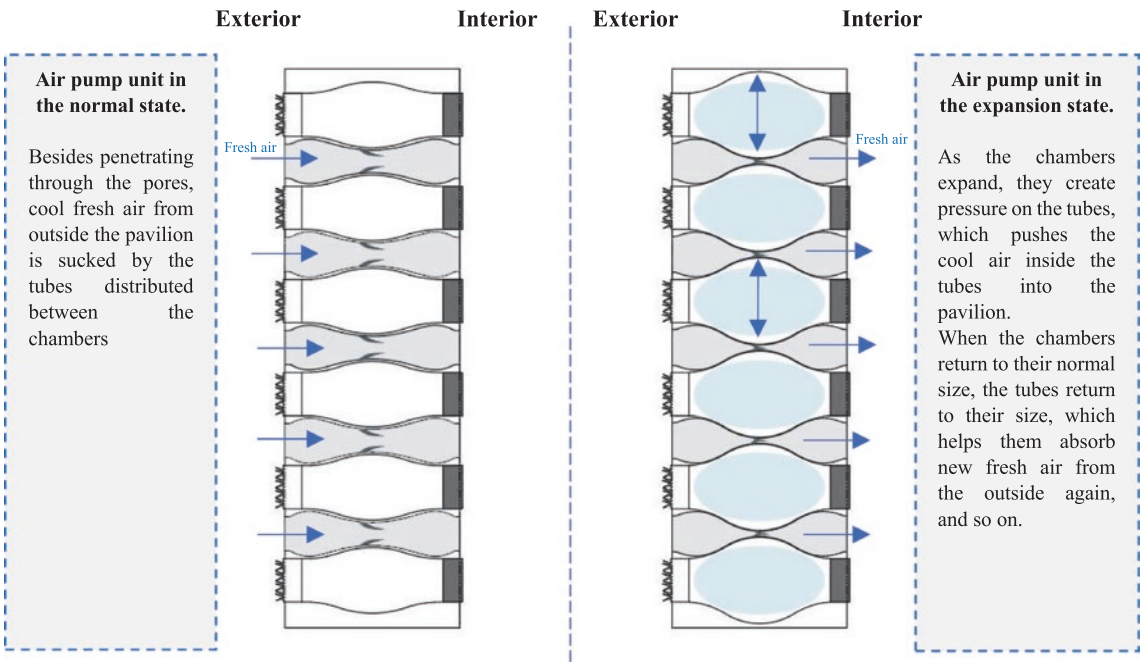

Fig. 7 Cross section of the "air pumping mechanism" in the case of expansion (right) and in its normal size (left)

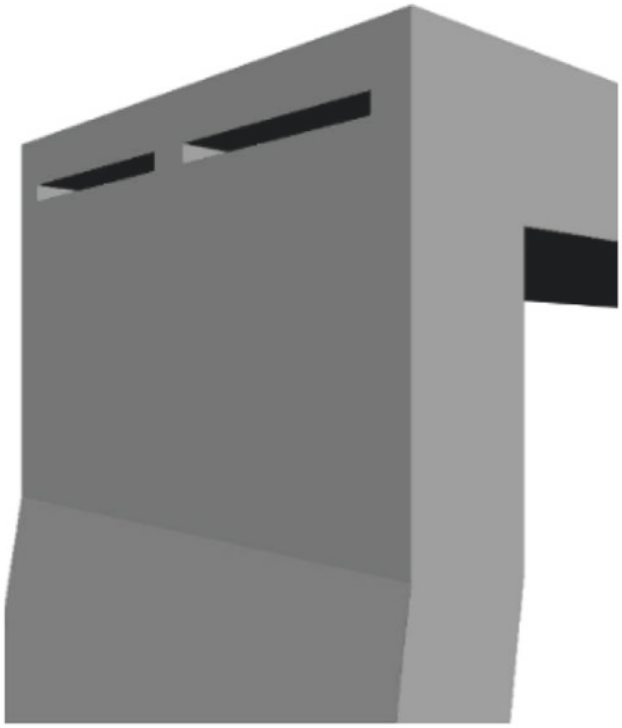

Fig. 8 Chimney openings on the outer upper side of the envelope, from which the spent air is expelled

These projected slats (Fig. 11) were basically designed mimicking grooves created by wrinkles of elephants' skins. They contribute to preventing surface heat by creating shaded areas that are not directly exposed to solar radiation which creates a gradient that facilitates circulation and minimizes heat absorption. Projected slats are designed to be the parts with light-colored spines distributed on their surfaces.

5.3 Water

The design idea takes advantage of the airborne humidity that exists in the surrounding environment, in order to activate the "air pumping mechanism"—which was previously mentioned in the "air" part, by condensing it. The condensed water from humidity acts as the controlling element in the expansion of the chambers in the "air pumping mechanism", which in turn stimulates the pumping of fresh air into the pavilion.

The condensation process happens as following, the outer face of the "air pumping mechanism" chambers (facing the air outside the pavilion) is covered with a layer of biomimetic cactus spines and implemented by 3D printing, designed by Li et al. (2020), Figs. 12 and 13. These spines work to condense the water in humidity and direct it into the chambers, just like the Cactus surface strategy.

The expansion and shrinkage of the chambers of the "air pumping mechanism" due to water were inspired by Mescal Cactus plants. Mescal Cactus, as previously mentioned, adapts to seasonal water availability through shrinkage caused by drought and expansion due to water saturation.

After the condensed water is directed into the chambers, the surface of those chambers expands and acts as pumps for the air inside the tubes below and above (previously mentioned in the section of air), which pushes fresh air inside these tubes into the pavilion. The inner face of the chambers (facing the interior of the pavilion) is made of fibrous material that absorbs water from inside the chambers, which helps to return them to their normal size to remove the pressure resulting from those chambers on the channels, and thus introduces new fresh air to the channels and so on.

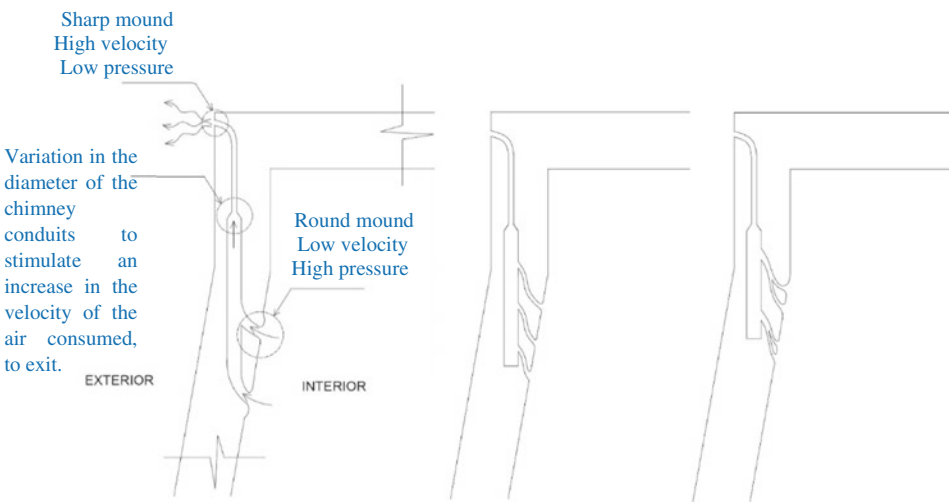

Fig. 9 Three suggested designs for a cross section of the chimney in the upper part of the envelope, all applying the same principles for expelling exhausted air outside; "Bernoulli principle", "Huss-Murray" law and "Venturi effect"

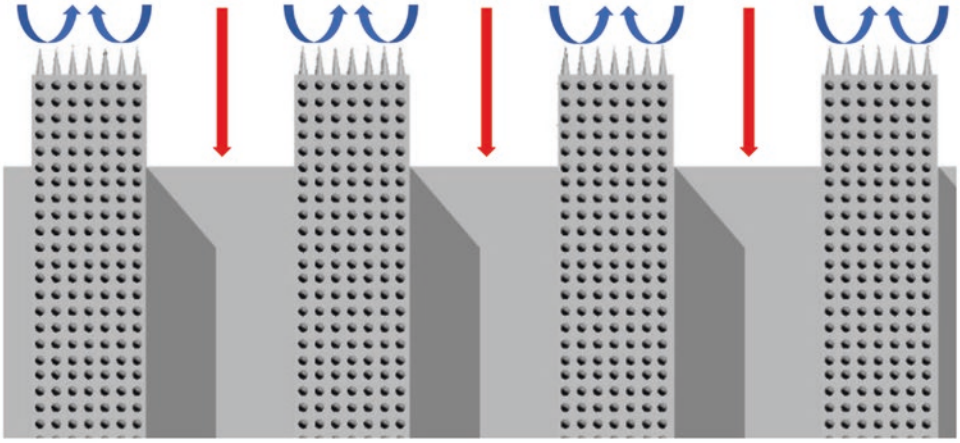

Fig. 10 Close-up of (Fig. 5, part "3") showing the spines fixed to the projected slats on the outer surface of the envelope. These dense light-colored clustered spines help reduce solar radiation absorption and scatter light on the envelope surface. While the darker, recessed parts do not reflect solar rays, generating air currents contributes to the cooling of the pavilion's surface

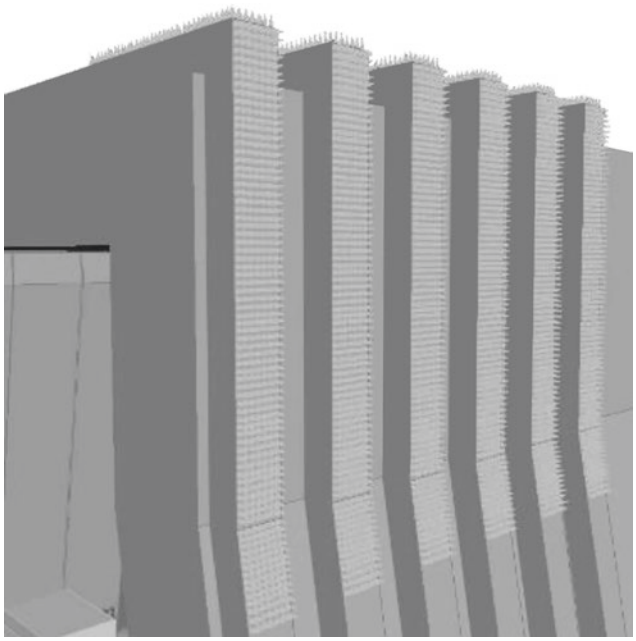

Fig. 11 Vertical projected slats along the outer surface of the pavilion. These slats create partial shade to mitigate heat and exposure to direct sunlight, cooling the air in the shaded parts to create a gradient that facilitates air movement and reduces heat absorption

In order not to waste the water collected in this fibrous part of the chambers, it is directed through a thin tube toward containers in the ground, for reuse (Figs. 13 and 14).

Regarding the materials suggested for the pavilion, the authors chose biomaterials that complement the ultimate goal of biomimicry, which are as the following, in correspondence to Fig. 15:

Material (1). Biowood Composite Timber

Biowood is a biocomposite of wood and plastic, a sustainable and eco-friendly alternative to natural wood, with added benefits such as durability and strength.

It is free from toxic chemicals, which ensure IEQ and water resistant (less than 0.05% water absorption) which means no chance of mold and termites and is fire resistant. It is low maintenance, as well.

Using a biomaterial alternative to wood, mimicking the shape of natural wood helps emphasize connection to nature. Incorporating aesthetically pleasing elements into the design would implant a sense of comfort for students (Biowood & It's brilliant benefits, 2020).

Material (2). Electrochromic Glass "Sage Glass"

It is an electronic "photovoltaic" glass technology. It is tinted automatically or on demand to control sunlight, without blinds, which provides visual comfort, keeps students in touch with the surrounding nature, and reduces energy consumption. The main inspiration for this technology is passive pigmentation found in many species of lizards in nature (How dynamic glass works, n.d.).

Material (3). Sharklet™

It is an adhesive surfactant suggested to cover all the multi-touch surfaces of the desks existing in the pavilion. This material controls bacterial growth by 80%. Moreover, it contains no chemicals and uses no antibiotics and antimicrobials. Therefore, it contributes to providing a healthy and

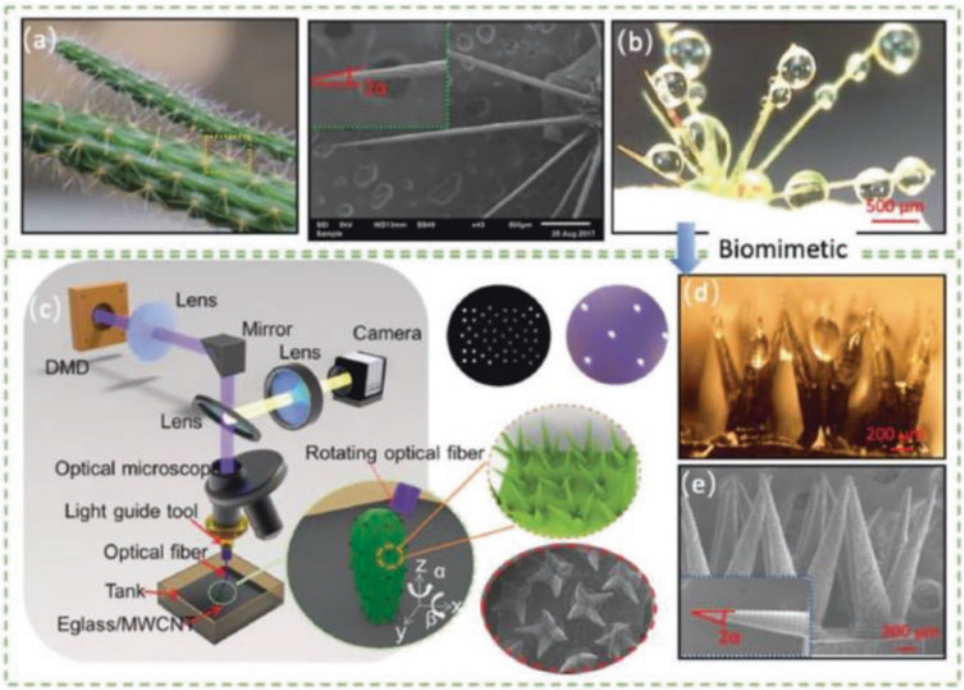

Fig. 12 Biomimetic water collection structure designed by (Li et al., 2020). **a** A picture of a natural cactus using a scanning electron microscope (SEM); **b** spines and their water-collecting ability; **c** schematic diagram of the ISA-based 3D printing process, (ISA-3DP); **d** capacity of the biomimetic spines to collect water. A nanoscale hydrophobic coating is sprayed onto the surface of the 3D-printed spines to accelerate the rate of water collection. Permission and courtesy from *Xiangjia Li*

clean environment for students and guarantee IEQ. It draws inspiration from the shape and pattern of the dermal denticles of sharkskin. (Adhesively-backed film, n.d.)

Material (4). Bioplastic Chair

Authors suggested using chairs made of bioplastic. It is a bio-alternative to traditional plastic. It has similar properties to traditional plastics but is made from renewable, plant-based sources. It is a completely recyclable material and has a significant environmental advantage as it reduces greenhouse gas emissions (Imani et al., 2018), while the materials for the permeable medium with the "air pumping mechanism" will need further laboratory empirical tests to design a biomaterial that have the same material features of the mimicked systems and can act the same in response to the surrounding factors.

Finally, the final renders of the pavilion with the multi-regulation bio-envelope are presented (Figs. 16 and 17).

6 Discussion

As a step to shed light and encourage more research on multi-regulation biomimetic designs, this research followed the sequential systematic steps of *BioGen* methodology to generate one, starting with the selection of specific organisms from the large database of nature, which were summarized in the *exploration models*, depending on the challenges faced by the envelope, then the analysis of these organisms' strategies to deal with those challenges, after that the study of how to translate these strategies into architectural design solutions, and finally integrating them into one design.

While following the steps of the methodology, it was noticed that the bigger the number of strategies incorporated, the more complicated the design gets. Moreover, the realization of specific techniques required the simulation of additional organisms, which accordingly participated in further regulation of the environmental aspects. For instance, in the section of regulating air, the design needed the selection of a living organism that has the ability to expand and contract, to be the pressure factor on the air tubes, to ensure pumping the fresh air inside them inward. Accordingly, Mescal Cactus was chosen, as it expands and contracts in response to its saturation of water. This inspired the designer that while regulating air, the design can contribute in regulation water. By simulating cactus spines, they contributed to activating the "air pumping mechanism" through condensation, as well as regulating the humidity in the surrounding air and even the reuse of the collected water. Also, in order to take advantage of the role of zebra's morphology in creating air flow that would dissipate excess heat, which is achieved based on temperature difference of adjacent areas, due to color variation. While the dyes were not the subject of the research, the strategy was translated by differentiating the temperature of adjacent areas due to variation in reflectivity, rather than difference in color. Here, came the role of the simulation of cactus.

In summary, the design of a multi-regulation envelope resembles working on a puzzle, where combinations and

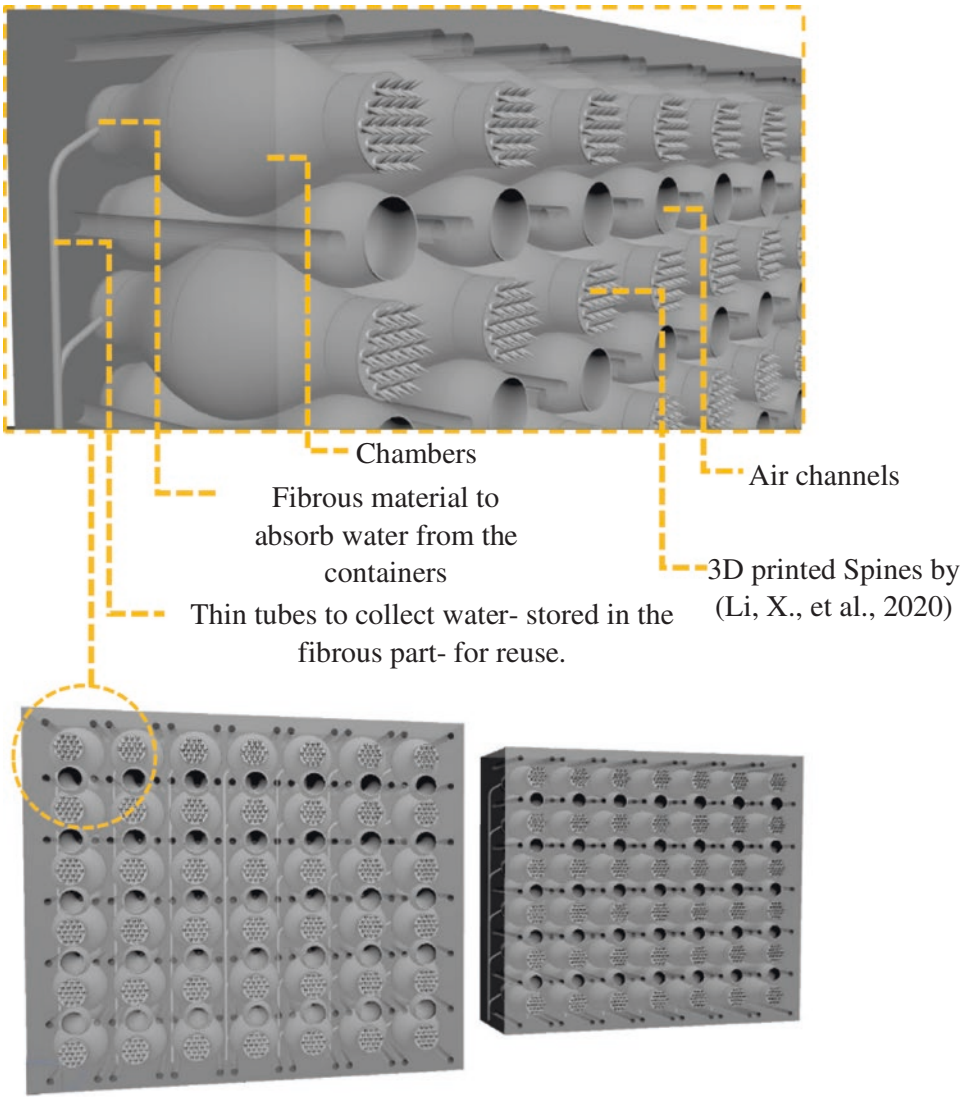

Fig. 13 Water condensation units in the "air pumping mechanism"

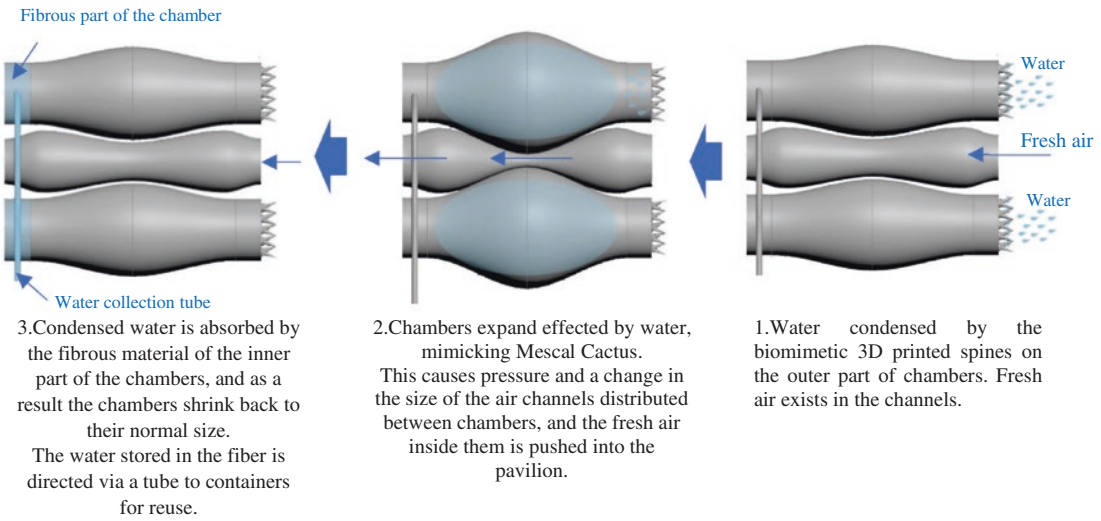

Fig. 14 Water path through the chambers, with air pumps distributes between them, in "air pumping mechanism"

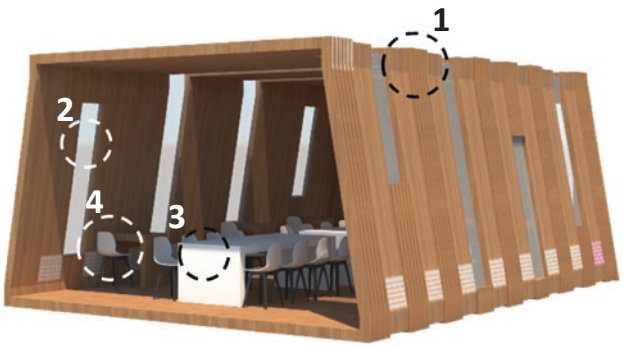

Fig. 15 Indications for the materials suggested for the pavilion

exchanges are made between living organisms' strategies, and the main drivers are the challenges to be solved by the design.

7 Conclusion

Undoubtedly, biomimicry paves the way for producing abundant ideas and technologies that work to improve human well-being along with positive environmental impacts and without depriving non-renewable sources. It has already granted us with fair number of designs that guarantee cleaner world and more comfort.

This research highlights the significance of the strategies of natural systems and advocates multi-regulation biomimetic design, which have the potentials to reduce the operation energy consumed in buildings, thus reducing their contribution in climate change, as a promising method to developing ecologically sustainable building systems, for the well-being of both the environment and human.

Although designs of multi-regulation still have a long way to go, the result of this research of the conceptual design of multi-regulation bio-envelope shows that the existence of a simple and organized methodology smoothens the way to generate design concept of a biomimetic envelope that addresses multiple environmental factors concurrently—air, heat, and humidity in this research. Therefore, more research could be done on biomimetic frameworks and methodologies to reduce the complexity of generating design concepts for multi-regulation biomimetic designs.

Computational simulation and numerical calculations were out of the limit of this paper; however, further work is suggested to assess the constructability of the proposed envelope and the exact expected effect on the performance of the buildings. This multi-regulation bio-envelope will need further empirical research to elaborate, avoid any conflicts of functions, and to transform to a full-scale model. Moreover, there is no doubt that the simulation engines and software needed for multi-regulation envelopes would differ from simulation engines for a single environmental aspect.

Fig. 16 Final design of the multi-regulation bio-envelope integrated into the pavilion. The figure shows the flat sections of the envelope alternating with the projected ones. It shows the chimney openings on the outer surface of the envelope, the "air pumping mechanisms" distributed in the lower part of the envelope, as well

Fig. 17 Inner face of the multi-regulation bio-envelope integrated into the pavilion. It shows the inner side of the "air pumping mechanisms" in the lower part of the envelope, besides the chimney holes in the upper part of the envelope

Last but not least, implementation of these types of multi-regulation bio-envelopes requires development of smart biomaterials in parallel, material that can act like the organisms mimicked in the design.

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Conflict of Interest The authors declare that they have no conflict of interest.

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The Role of Architectural Heritage in Offering a More Resilient Lockdown in Egypt

Tarek Teba, Nada Muhammed Elzoghby and Nevin Gharib

Abstract

Heritage buildings play an essential role in representing people past, preserving their culture and social identities and accommodating contemporary functions that support cultural activities. These buildings employ key design principles that anchor the formation of the space and its landscape into the cultural aspects of the communities and the environmental conditions of their location. During COVID-19 pandemic, contemporary buildings have struggled to provide comfortable and effective context for people who had to isolate individually or as a group, while the heritage buildings that mostly serve for cultural purposes have been closed and their functions suspended with another challenge arising of accommodating people in need for self-isolation. Therefore, this paper aims to investigate whether heritage buildings could have performed better than contemporary buildings that were used for individual and mass isolations in Egypt and if key design principles and strategies could be learned from heritage buildings to inform future architectural approaches in the country in order for the built environment to be more resilient in time of pandemics. This question is explored through a comparative empirical study between heritage and contemporary buildings regarding key design principles and strategies and their impact on people's physical activities, mental well-being and social life during the isolation time. By investigating and comparing their architectural and landscape designs, materiality and environmental aspects (indoor air quality and lighting quality in particular) in both individual and mass isolations situations, the article aims to assess the performance of heritage buildings in such scenarios and highlight key design strategies and features that could inform future buildings and their contribution to users' experience and resilience during isolation. Results demonstrate that contemporary housing designs negatively impact people experience and health during isolation while contemporary public buildings perform better considering that they were designed based on good standards and assuming that they have the right orientations and landscape, which is not consistently applied. On the other hand, heritage buildings can consistently contribute to positive experience during individual and mass isolation. In addition, key features such as privacy, open spaces and landscape and good ventilation, which have huge impact on users' satisfaction, are lost or less effective in contemporary residential and public buildings.

Keywords

Heritage resilience · Heritage and society · Heritage and COVID-19 · Lockdown and well-being · Heritage-informed development

1 Introduction

The coronavirus pandemic has had devastating health consequences globally since its emergence in December 2019. Many countries have responded with various measures to contain the spread of the virus, like enforcing strict lockdown and cancelling all kinds of social, cultural and sporting events. This might have helped in curbing the spread of the virus; however, it took a huge toll on mental and physical well-being. As a result of the lockdown, heritage buildings that usually serve as cultural institutions were closed and were not adapted to serve in fighting the pandemic and providing a space for isolation. This rises a crucial question regarding the potential role and effectiveness of these

T. Teba (✉)
University of Portsmouth, Portsmouth, England
e-mail: tarek.teba@port.ac.uk

N. M. Elzoghby · N. Gharib
Alexandria University, Alexandria, Egypt

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buildings in accommodating people with isolation requirements as well as whether their architectural strategies and principles could inform future design methodologies for residential and public buildings to be ready to play a role in future pandemics.

COVID-19 pandemic has enforced people to lockdown individually and in large groups (mass isolation). In both cases, people required a healthy, well designed, ventilated and lit environment to help them cope with the lockdown experience, maintain minimum level of social interaction as well as protect them from the transmission of the virus between individuals, so social distancing. Also, lockdown experience has been mostly different owing to the lack of interaction with people and the built and natural environments, such a quality many contemporary residential and public buildings are missing. Therefore, this paper intends to evaluate whether heritage buildings in the city can be used as resources for devising effective strategies for a more resilient and healthier lockdown/isolation as means to respond to the pandemic. The article will compare how traditional and contemporary design strategies and features contribute to COVID-19 lockdown experience. The work will focus on exploring contemporary and heritage buildings from different scales that would suits different forms of individual and mass isolation and will analyse the contribution of traditional architectural and landscape features and design strategies to people's experience during lock down in comparison with contemporary models, so highlighting design principles that could improve the readiness of our contemporary buildings to support users during difficult time of lockdown.

The literature review will explore theoretical and practical attempts of analysing the quality and contribution of heritage buildings in relation to COVID-19 lockdown experiences, and the design explorations that responded to the COVID-19 pandemic between 2019 and 2022. Also, the impact of lockdown on individuals' well-being, linked to the spatial settings, materiality and social interaction will be investigated in order to highlight the key factors that contributes to the lockdown/isolation experience; these factors will be utilised in the empirical analysis of selected heritage and contemporary buildings in order to investigate the research question and objectives. The research conducts a two-level comparative analysis: the first is concerned with the individual's isolation (i.e. when individuals have to isolate at their own properties, and the second is concerned with the experience of a group isolation—referred to as "mass isolation"—for example, when a group of people travelling together/working together have to isolate owing to contracting the virus or as a precautionary procedure. In this article, traditional heritage buildings will be analysed and explored as alternative to apartments or schools that were used in Egypt for individual or mass isolation respectively.

Henceforward, this article will be divided into four key section through which relevant literature will be analysed, the methodological approach will be explained, key selected contemporary and heritage buildings will be analysed and the results of the comparative approach will be discussed bringing to light relevant conclusions and recommendations.

2 Literature Review

As previously mentioned, this paper addresses whether heritage buildings could have performed better than contemporary buildings used for individual and mass isolations in Egypt. Accordingly, different studies on this matter have been reviewed and arranged as follows: (1) studies addressing private outdoor spaces, (2) studies on the interior design of houses, and (3) previous relevant work regarding heritage context.

Regarding private outdoor spaces, (Amerio et al., 2020) have stated the different factors of lockdown affecting an individual's mental health including the lack of sufficient space, balconies[1] and a good view. This study has statistically mentioned the effect of early lockdown in Italy through a web-survey such as moderate and severe depression. The findings of this study have stated that "*built environment is a key determinant of health, the quality of which depends on the availability of resources, site location planning, and green spaces*". It recommended that housing design strategies should consider "*larger and more liveable living spaces facing green areas"*. This meets with (Khalil & Eissa, 2022) that highlights the importance of outdoor spaces and how private outdoors can help ease the lockdown experience for either patients or non-patients through the reuse of balconies in apartment buildings. The study observed a change of pattern of people's usage of their own balconies in terms of frequency and the types of hosted activities. It also expanded on spatial qualities of balconies that promoted their use. "*The study emphasises the significance of such outdoor private spaces in apartment buildings and puts forward balconies as an essential element of future dwellings design for the multiple benefits they behold*".

As for the interior design of houses, (Zaher, 2020) focused on the post-coronavirus phase where the interior design of existing or new spaces should become environmentally sustainable using design solutions for the shared and public spaces. This was supported by Shamaileh (2022)'s study whose findings suggested current and future

[1] IN this study the focus was on apartment buildings; therefore, private outdoor spaces were perceived as balconies.

responses that may be applied to adapt with lockdown and pandemic setbacks in terms of houses' interior design. Shamaileh (2022) applied their theory through a conceptual design model to demonstrate the impact of theories and highlight their contribution to users' experience.

Baggott (2020) and Sofaer et al., (2021) have addressed the contribution of heritage context to COVID-19 and lockdown residence anchoring their argument onto an urban scale and the national and cultural values of the heritage context. These studies did not address landscape and architectural/interior dimensions and design features and their role in providing a better lockdown experience. The architectural and interior scales are considered significant in this case owing to the fact that users during lockdown and isolation interact mainly with these two dimensions/scales.

These studies thoroughly state how to make use of currently occupied spaces, either by individuals or groups, patients or non-patients, in order to improve the lockdown experience. They focused on the adaptation of contemporary buildings or the urban scale of heritage context and investigated only parts of the user experience in different settings, but not how this experience could be promoted and the contemporary spaces could be informed by traditional design features and principles that contribute to better environmental and social dynamic of the contemporary buildings that could serve better in urgent situations (such as a pandemic).

3 Methodological Exploration

3.1 Research Methodology

The study uses an empirical approach with qualitative conducted assessments to answer the main research question. To set up the theoretical ground for the empirical investigation, the article explores the theoretical context related to the impact of lockdown on people's physical and mental health and social life and the design parameters/factors that are related to these three aspects and the comfort of users during the lockdown experience. The empirical exploration will use a comparative approach that is applied to two typologies of heritage buildings that are usually used for sole cultural purposes but have been closed to the public since the lockdown measures were first followed in Egypt in March 2020 and with counterpart contemporary buildings that were used for individual and mass lockdown. The first heritage case study is a typical Arabian private house (Bayt Al-Suhaymi), while the second one is a public building (Caravanserai/ Wekalat Bazar'a) which is used as a cultural centre and was originally dedicated to be a mixed-use building with provisions for commercial space on the ground floor and residential space in floors above. Each building typology is compared to its contemporary counterpart, where Bayt Al-Suhaymi is compared to a typical apartment model, used in individual isolation, and the Wekalat is compared to a typical government school used for mass isolation. Case studies are analysed regarding the explored design factors (i.e. architectural design strategies, materiality, environmental settings) and their contribution to privacy, comfort, resilience and social interaction in time of COVID restrictions. The study further uses a qualitative rating scale from 1 to 5 to evaluate the heritage and contemporary buildings performance and discuss the contribution of their design features and principles to users' lockdown experience and resilience. The rating is used to simply translate the qualitative literature and empirical analysis findings into measurable values in order to summarise and represent the study's results and draw key design conclusions and recommendations. The following sections intend to contextualise the methodological approach and its parameters/factors.

3.2 Impacts of Lockdown (Problems)

The associated impacts with pandemics, such as COVID-19, have been explored over the history in an attempt to help individuals, both patients and non-patients, to have a better lockdown experience. This revealed a wide range of impacts on people's well-being linked to their physical activities, mental well-being and social interaction (Fig. 1).

The Physical Impact

According to (Goethals et al., 2020), the spread of COVID-19 virus has affected the rate of individuals' Physical Activity (PA). The sports trainers interviewed for this research stated that the rate of physical activities has decreased by almost 20%. One reason is the enforcement of lockdown which forced people to stay indoors; another reason is that people were concerned with the hygienic standards in gyms even when the lockdown was eased. This has resulted in a reduced PA and promoted sedentary behaviour, especially amongst the elderly.

This is consistent with a survey conducted by Yorkshire Cancer Research and published by the Independent Newspaper over 2000 typical adults (Knight, 2020). It showed that one-third of participants stated that they experienced weight gain and that a typical adult was spending less time on daily workouts. There is a direct proportional relationship between physical activity and mental health as stated by Lautenschlager et al., (2004). Lautenschlager et al. also discussed how physical activity acted as a natural antidepressant for older adults in home lockdown. In

Fig. 1 Diagram that shows the main aspects affected by the lockdown as suggested by the researcher

addition, studies have widely acknowledged that depression is one of the worst outcomes of lockdown and staying home with less PA (Benke et al., 2020; Fountoulakis et al, 2021; Khubchandani et al., 2021; Rehman et al., 2021).

Mental Well-Being (State of Mind)

Not only does the lack of PA negatively affect an individuals' mental state, extended lockdowns and quarantine measures can also lead to other social and health consequences. This includes boredom, loneliness, anger, stress issues such as PTSD, frustration, etc., in addition to Obsessive Compulsive Disorder (OCD) syndrome that may develop because of the constant fear of being infected by the virus. (Brooks et al., 2020; Moreira et al., 2020).

Such behaviours and syndromes were common even during the outbreak of the Severe Acute Respiratory Syndrome (SARS) in 2003. During the early phase of SARS, a range of psychiatric illness was reported, including recurrent depression, anxiety, panic attacks, psychotic symptoms and even suicidal tendencies (Maunder et al., 2003; Xiang et al., 2020). All the symptoms reported were related to either being home quarantined or caught by the infectious virus.

Both aspects of physical activity and the mental state of an individual are also directly linked to the third aspect concerned with their social life.

Social Life

The lockdown has forced people to live indoors for months thus completely snapping social ties. The lack of social activities and interaction has resulted in a renewed sense of loneliness (Goethals et al., 2020). During the lockdown, social media platforms have been increasingly used as tools for social interactions; more people migrated to these platforms for their social, professional and educational needs. However, social media despite its merits cannot be a replacement for socialising in real life (Bhat et al., 2020). For example, a concern raised by mothers in the UK that their children have grown more self-enclosed and introverted during the lockdown (Darke, 2020). There are growing concerns that children might be losing the opportunity to develop vital social skills required for their growth and well-being.

To sum up, the three aspects of (PA, mental health and social life) are inseparable, interrelated and are affected by connected factors related to the spatial and social contexts. It is clear that the spatial and environmental characteristics of a space, where people have to spend most of the time during lockdown/isolation, have a great impact on people experience. Thus, the next section will explore these design factors/characteristics in the light of lockdown/isolation experience.

3.3 Factors of Assessment and Points of Comparison

The impact of isolation can become apparent when the context lacks proper design, privacy and comfort factors. In addition, the hygienic factor is essential when fighting against COVID-19 and building and indoor materials has a role to play in that as some materials can easily facilitate the spread of infection compared to others. Also, air and light qualities play a key role in this and help to establish a more satisfying user experience. Hence, the study suggests some factors that need to be taken into account when assessing the users' experience of their spatial environment within lockdown/isolation, which are: architectural design, materiality and environment (Fig. 2b).

3.3.1 Architectural and Indoor Design

Firstly, it is important to explain the link between 'user comfort' and the adverse impact of lockdown on a person's mental well-being and social life as shown in Fig. 2a. According to Moore (1979), the psychological comfort is impacted by different stimuli such as the physical surroundings, the environmental settings, the cultural background as well as the social network (See Fig. 3a).

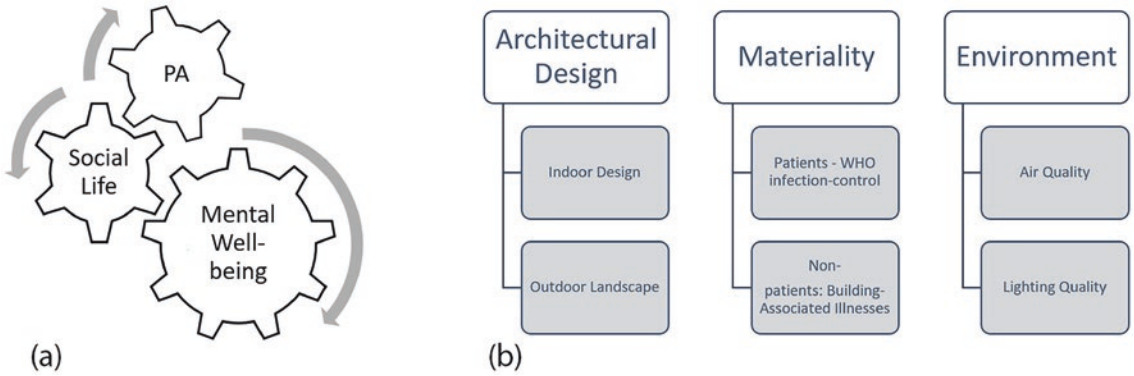

Fig. 2 **a** Inseparable and interacting relations between the aspects affecting the lockdown impacts. Source: The researcher. **b** Classification of factors of assessing user satisfaction as suggested by the researcher

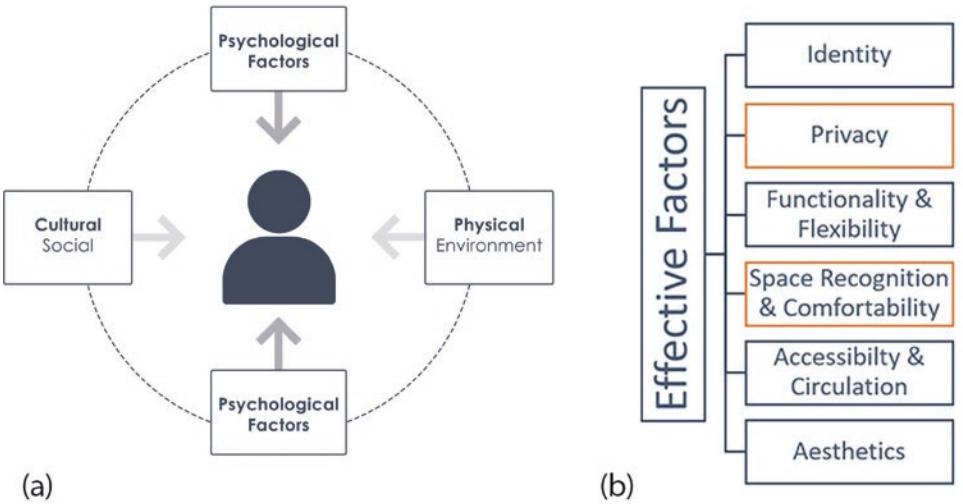

Fig. 3 **a** Factors affecting human psychology as suggested by Moore (1979) and illustrated by the researcher. **b** Most effective factors over the human factor as suggested by Mahmoud (2017) and illustrated by the researcher

Different studies have argued that architectural design not only affects the user's satisfaction, but also their general well-being. This factor is divided into two sub-factors: interior design and outdoor landscape design.

A study by Mahmoud (2017) suggests that there are certain factors of interior design that tend to provide a positive psychological comfort to the user. Such factors are clearly illustrated in Fig. 3b. However, only privacy and space recognition will be explained in this section owing to their direct relevance to the scope of the study. As for the other factors, their impact is nearly negligible when it comes to human survival tolerance. Both factors (privacy and space recognition) are explored below in terms of their psychological impact and application considering the interior architectural design.

(a) Privacy

Psychological Impact: According to (Hall, 1990), the concept of human privacy is largely dependent on four factors that reside within our immediate environment (See Fig. 4). Generally, the lack of privacy or sudden unwanted exposure makes people react with anxiety and sometimes anger. This response varies from one individual to another based on their culture and social background.

Application: The objective of this process is to achieve a balance between privacy and social relationships. This is dependent on a range of parameters (i.e. window-wall ratio, soundproofing, partitions, interior circulation design, the level of integration between indoor and outdoor spaces, etc.).

There is often a strong connection between an individual's private physical space and the extent to which it can keep the person in an isolation and protected without exposing them to the virus. This is also related to the quality of space recognition and the ability of the user to make clear differentiation between public, semi-public and private spaces inside the building and how this affects

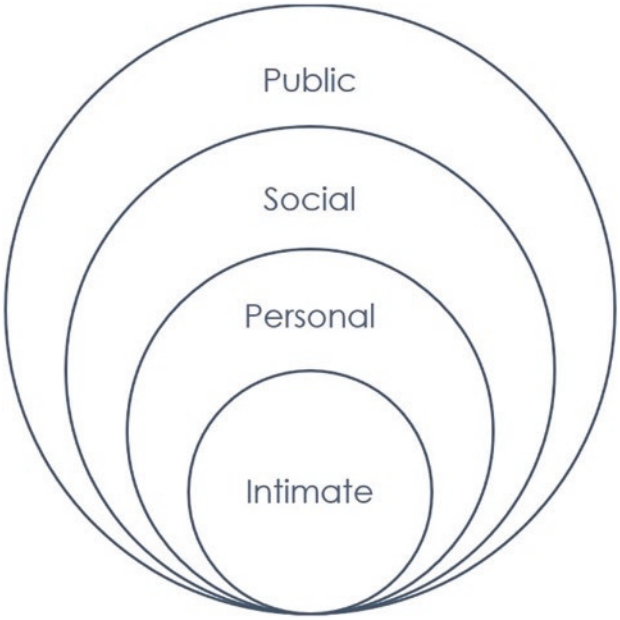

Fig. 4 Four levels of human sense of privacy as suggested by Hall (1990) and illustrated by the researcher

infection-control attempts. The public space of a building is usually more prone to infections due to its direct contact with the outdoor environment. Such contact gradually decreases as the user transitions to semi-public and private zones where the infection possibility drops down to the least.

(b). Space Recognition and Comfortability

Psychological Impact: Bonnefoy (2007) has emphasised the importance of the quality of housing conditions and its effect on residents' well-being. He also states, *"Many health problems are either directly or indirectly related to the building itself, because of the construction materials that were used and the equipment installed, or the size or design of the individual dwellings*" (Bonnefoy, 2007: p.412). Feeling secured in one's home, which is a refuge from daily life, directly affects individuals' mental state and well-being (Mahmoud, 2017). Not only security is a factor but also the sense of space recognition is a key factor for a user's comfort.

Application: Several factors affect the sense of safety. This includes well-recognised spatial dimensions and boundaries, temperature, natural lighting, fencing, a clear ability to differentiate public from private spaces, interior levelling, materiality, comfortable furniture, etc. All these factors must coincide with the user's needs and comfort.

3.3.2 Outdoor Landscape Design

Several studies have stated the importance of landscape design and its effect over general health of humans. Abraham et al. (2010) observed landscape impact over three levels: mental state, physical well-being and social bonding (explained below). The study was conducted on an urban scale but its general framework can be adaptable to landscape and architectural scales too.

Mental State: Landscape as a restorative environment

Landscape is a strong asset for enhancing mental well-being through different aspects including attention restoration, stress reduction, and recalling positive emotions. This is done by pursuing both physical and social well-being.

Kaplan and Kaplan (1989) explained the possible influence of landscape design on the users' general health while focusing on their mental state, especially their cognitive attention restoration.[2] Kaplan & Kaplan's published book: "*The Experience of Nature: A Psychological Perspective*" established four characteristics for restorative environments (Fig. 5).

Abraham et al. (2010) explain these four characteristics: The first feature of restorative environments allows users to find refuge and temporarily disconnect from their daily life. This further enables them to slowdown and reflect on their busy everyday daily life activities. The exercise enables propel to get rid of negative thoughts that they might have experienced throughout the day. The second feature is to attract users' attention to features in the surrounding spaces encouraging reflection and positive thinking. Thus, they become more aware of their surroundings, which enables constant discovery of new things and recognition of existing information in the surrounding environment. As for the fourth and last feature, it is about reconnection with the users' intentions as illustrated in Fig. 6.

Physical Well-being

Having well-designed and built urban landscape is crucial for the residents' physical health and well-being. As for their daily life, it is important to have spaces allowing outdoor physical activity. Leisure time can be ensured through effective land mix-use, i.e. relaxing outdoor zones, safe kids' play grounds, *"aesthetically appealing landscapes*", and possible opportunities for neighbour-interaction (Abraham et al., 2010) which consequently affects social well-being.

Social Well-being

Armstrong (2000) and Leyden (2003) have stated that urban parks and other public places can enhance social integration

[2]Attention Restoration Theory, or ART, states that being exposed to nature, aside from being an enjoyable activity, can help individuals enhance their focus and concentration abilities. Source: (Ohly et al., 2016).

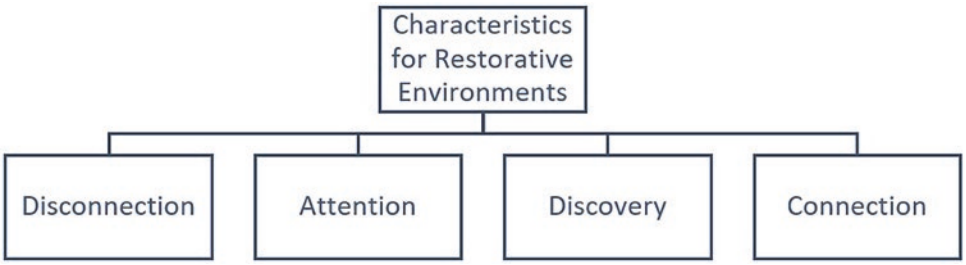

Fig. 5 Four characteristics for restorative environments as explained by Kaplan and Kaplan (1989) and illustrated by the researcher

Fig. 6 Heuristic framework on the health-promoting impact of landscapes as suggested by Abraham et al., (2010) and illustrated by the researcher

if they facilitate social contacts, exchange, collective work, community building, empowerment, social networks and mutual trust. It is also important to highlight the role of landscape in enhancing social integration among different categories of people including the elderly (Booth et al., 2000). Different studies such as (Baum & Palmer, 2002; Coley et al., 1997; Kuo et al., 1998; Leyden, 2003; Sullivan et al., 2004) have pointed out that an efficient urban landscape design must be safe, attractive, easily walkable, multi-purpose and rich in vegetation in order to encourage social integration/interaction.

To conclude the first factor of assessment namely the architectural design, it is important to understand the appropriateness of such design by adopting the right evaluation tools. According to Mahmoud (2017), the successful indoor design should create positive vibes, and this can be achieved by creating a balance between the most effective factors as previously explained. "*Ultimately the success of setting up interior architectural design with active psychological conception judged by how the design fulfils values, needs, preferences and satisfactions of users.*" (Mahmoud, 2017: p.9).

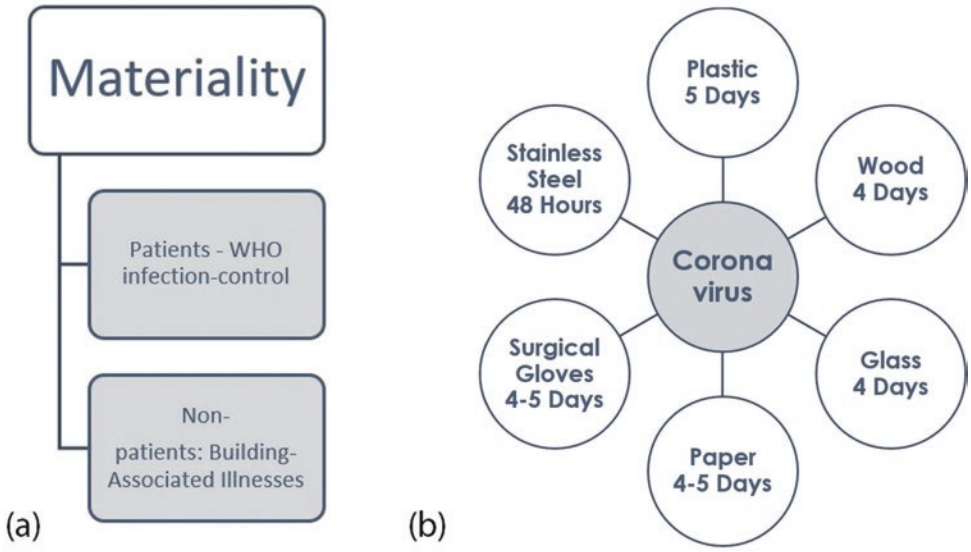

Fig. 7 **a** Scenarios discussed regarding materiality, as suggested by the researcher. **b** Different time spans that COVID-19 virus spends on different materials as suggested by J. Hosp. Infect 2020 and illustrated by the researcher

For the outdoor landscape design, it is not only related to private gardens and domestic backyards. "*Landscape should be understood to be a multi-faceted resource for physical, mental and social health and well-being*" (Abraham et al., 2010:p.65) thus giving individuals a wider range of activities aside from their daily life routines. However, the current common housing system in Egypt does not provide the luxury of having either a personal garden landscape or public landscape, hence affecting the general well-being and social interaction of the residents.

3.3.3 Materiality

The second factor for assessing user comfort is the materiality. It is known that a building material is chosen based on different factors (i.e. the choice of the client, the financial budget, the material's adequacy with respect to the function, etc.). However, it is also important to observe the material's impact over the user's health.

In this section, the materiality is discussed based on two scenarios. The first is mainly related to COVID-19 patients and the guidelines set by the WHO regarding the safe materials and surfaces that limit the spread of the virus, whereas the second is concerned with non-patients placed in home-quarantine and exposed to the toxic building materials causing different diseases including sick building syndrome (SBS), Fig. 7a.

In 2018, the WHO has published a health and housing guideline where it stated a detailed guideline for improving housing conditions (WHO, 2018). Improving housing conditions greatly contributes to saving lives, disease and poverty reduction, enhancement of quality of life, and toning down the effects of climate change. In addition, it helps to fulfilling some of the Sustainable Development Goals (SDG)[3] addressing health and sustainable cities. This list of guidelines expands to include building materiality for sustaining a healthy housing environment.

Scenario I: concerned with patients (WHO infection-control guidelines concerning surfaces)

Since the outbreak of the COVID-19 virus, both WHO and Centres for Disease Control and Prevention (CDC) have published several statements concerning infection-control methods against the virus. With the enforcement home lockdown worldwide, the concern of WHO and CDC was to raise the awareness about how the virus spreads and how different domestic surfaces assist in the spread of the virus.

The surfaces that can sustain the life of a virus vary. WHO published information about longevity of the virus on various surfaces at the beginning of the crisis (See Fig. 7b. For example, a virus can survive on stainless steel for 48 h whereas it can live for 4–5 days on paper. However, the virus almost dies instantly on any surfaces if it is cleaned with diluted chlorine or ethanol (WHO, 2020).

A study by Fiorillo et al., (2020) has reviewed a number of different studies exploring the COVID-19 Surface Persistence aiming to study the life span of the virus over different materials including building materials through various experiments carried by different researchers. The study analysed given data through four main criteria: the virus

[3] Sustainable Development Goals (SDG) are the blueprint to achieve a better and more sustainable future for all. They address the global challenges including those related to poverty, inequality, climate change, environmental degradation, peace and justice. Source: (United Nations, 2016).

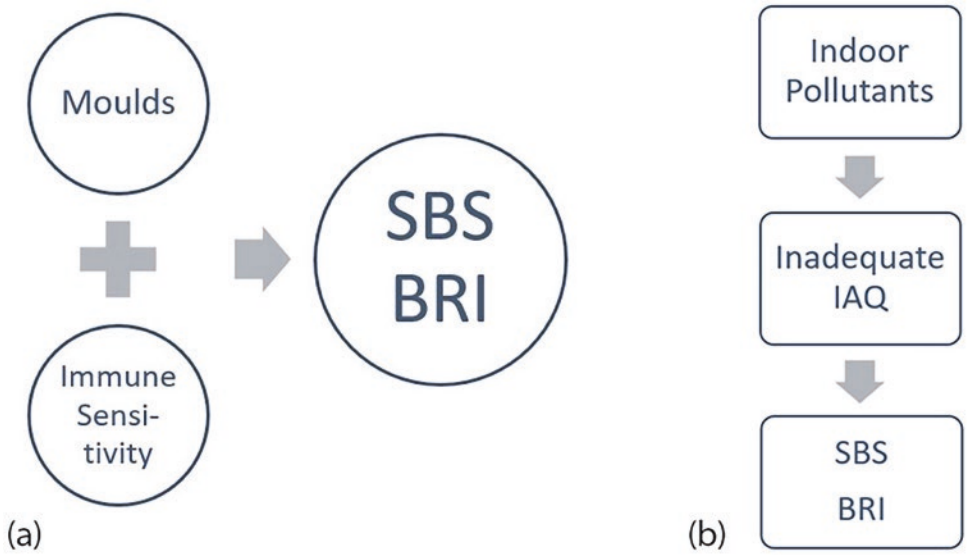

Fig. 8 **a** Main causes of SBS as described by Crook and Burton (2010) and illustrated by the researcher. **b** Conclusion of SBS causes. *Source* The researcher

type (studying several types of the coronavirus family), the reference experiments, the investigated materials and the time span of the virus.

The tested materials included: Teflon, (PVC), ceramic tiles, glass, aerosols, plastic, cardboard, paper and stainless steel studied by Kampf et al., (2020), Van Doremalen et al., (2020), Warnes et al., (2015). The virus's persistence had a minimum of five days (and three days for silicon rubber which is used in windows and doors insulation) at 21 C. However, brass, zinc and copper nickel surfaces proved to shorten the virus's persistence to less than an hour. Also, (Warnes et al., 2015) discussed how increasing the percentage of copper can lead to enhancing its antiviral properties.

Scenario II: concerned with non-patients (building-Associated Illnesses)

The term "building-associated illness" refers to any disease caused by inappropriate indoor environment. They are subdivided into two main categories: sick building syndrome (SBS) and building-related illness (BRI) (Seltzer & Diego, 1991). The difference between the two categories remains vague as there is an entity overlap between both (Crook & Burton, 2010). There are many common factors between them; however, this section focuses on the materiality factor. The common cause is fungi or mould spores that might take place seasonally due to ill indoor air quality (IAQ) and their potential reaction when it interacts with the human immune system. The symptoms of such reaction mainly affect the respiratory system such as asthma, bronchitis and rhinitis (Fung & Hughson, 2003), see Fig. 8a. This is supported by the guidelines set by Passarelli (2009), World Health Organization (2018) which indicate that building-associated illness can be caused by the contamination of chemical materials of construction such as volatile organic compounds (VOCs).

Although it is more common in office environments, SBS cases have been reported due to poor IAQ in housing buildings (Crook & Burton, 2010). The question is however, how is mould related to building materials and do certain materials have a greater contribution than others to assist mould formation?

According to the (Canadian Construction Association, 2004), construction materials and indoor furnishings contribute to mould habitation. This includes either "*cellulose in wallpaper, or starch in wallpaper paste, the toxigenic mould Stachybotrys sp. can grow on the paper covering on gypsum plaster boards*". Not to mention that both wooden furnishings and fabrics can assist mould habitation, supported by organic elements such as soil, dust and food waste.

Therefore, some countries have established new environmental-friendly standards for construction practices. Some of such standards are associated with general health, including non-toxic building and insulation materials that contain neither formaldehyde nor asbestos. (Gibbs et al., 1998) defines asbestos as a "*group of minerals currently or historically used for many products*". Its applications in the building industry include the manufacturing of cement, both thermal and electric insulation, fire blankets and industrial fire curtains. Such material has been proven to be a carcinogenic (IARC Monographs, 2012; WHO, 1998).

Kemp et al., (2003) argue that any mould activity would not occur without the right conditions allowing its growth; that is mainly water and heat. Such conditions are often provided by a relative humidity exceeding 60% throughout a building or in localised areas supported by enough warmth. This is likely to be caused by poor ventilation and maintenance, water intrusion and using (HVAC) systems.

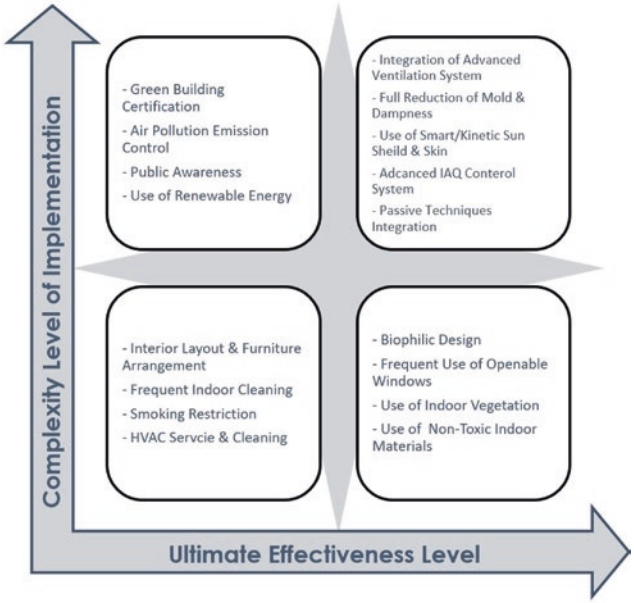

Fig. 9 Showing a matrix for SBS reduction by comparing between the effectiveness and complexity of the suggested strategies as suggested by Ghaffarianhoseini et al. (2018) and illustrated by the researcher

This leads to presenting the next factor of this literature, which discusses the environmental conditions affecting user comfort, including both indoor air quality (IAQ) and the lighting quality.

Accordingly, the causes of SBS expand to involve all types of indoor pollutants (moulds, humidity, chemical contamination, etc.) which affect the indoor air quality and thus leads to causing the different symptoms of SBS as shown in Fig. 8b.

The most interesting feature of SBS is that its symptoms begin to gradually withdraw within a few minutes after the user leaves the unhealthy environment, while some severe symptoms can last for a few days later (Passarelli, 2009). Ghaffarianhoseini et al. (2018) have suggested few strategies to reduce the triggers of SBS. Such strategies are briefly summarised according to different building types; including housing. Also, it is represented as a matrix comparing both the complexity and effectiveness of the suggested strategies in Fig. 9.

The suggested strategies for reducing SBS triggers in housing are mentioned by Lu et al., (2016) as follows:

- Reduction of mould/dampness.
- Control air pollution emissions from home renovations.
- Enhancement of building ventilation.

3.3.4 Environment

In this section, the environmental aspects related to the comfort of domestic user are thoroughly studied through two main inseparable dimensions: the indoor air quality IAQ and the lighting quality.

Indoor Air Quality (IAQ)

"It refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants" (USEPA, 2020b). Therefore, home-quarantine offers a good opportunity to study its air quality. The properties of having the ultimate IAQ are mainly concerned with proper ventilation of the indoor space and the ultimate control of pollutants.

Despite different factors affecting IAQ, having poor indoor ventilation tops the list. A presentation by the National Institute for Occupational Safety and Health (NIOSH) on the problems of indoor air quality (IAQ) in 2003 (Fig. 10) indicated that inadequate ventilation represents nearly 48% of the reported problems; it also determined the other factors representing the rest of the problems; such factors include different indoor pollutants that have been previously illustrated with the SBS.

For residential buildings, IAQ issues are vastly common between separate family houses and block apartments (USEPA, 2020a). The same agency has also advised users with few tips to enhance IAQ, which includes:

- Controlling the sources of pollution.
- Increasing ventilation; especially natural ventilation.
- Installing air cleaning devices.

Using natural ventilation is one of the key contributors to IAQ. This is a common factor in different studies and guidelines such as (ASHRAE, 2009; Harvard Health, 2018; USEPA, 2020c; Willmert, 2001) and is recommended in the preliminary studies of architectural design. Scholars have proposed different methods for applying natural ventilation, each to be applied when appropriate, depending on the space type and use. According to Ashrae (2009) *"naturally ventilated buildings do not aim to achieve constant environmental conditions but do take advantage of, and adapt to, dynamic ambient conditions to provide a controllable, comfortable indoor environment for the occupants"(P.166).* The study illustrates a specific method of using natural or mixed-mode ventilation. This method suggests a few key issues to be considered regarding the building design when deciding on natural indoor ventilation. Such design guidelines and theories are applicable to different types of buildings including housing. They consider:

- Reducing indoor pollutants by allowing sufficient outdoor air without compromising the thermal comfort.
- Blocking undesired elements in polluted outdoor air.
- Observing airflow through passive and/or active ventilation methods using well-designed systems with a

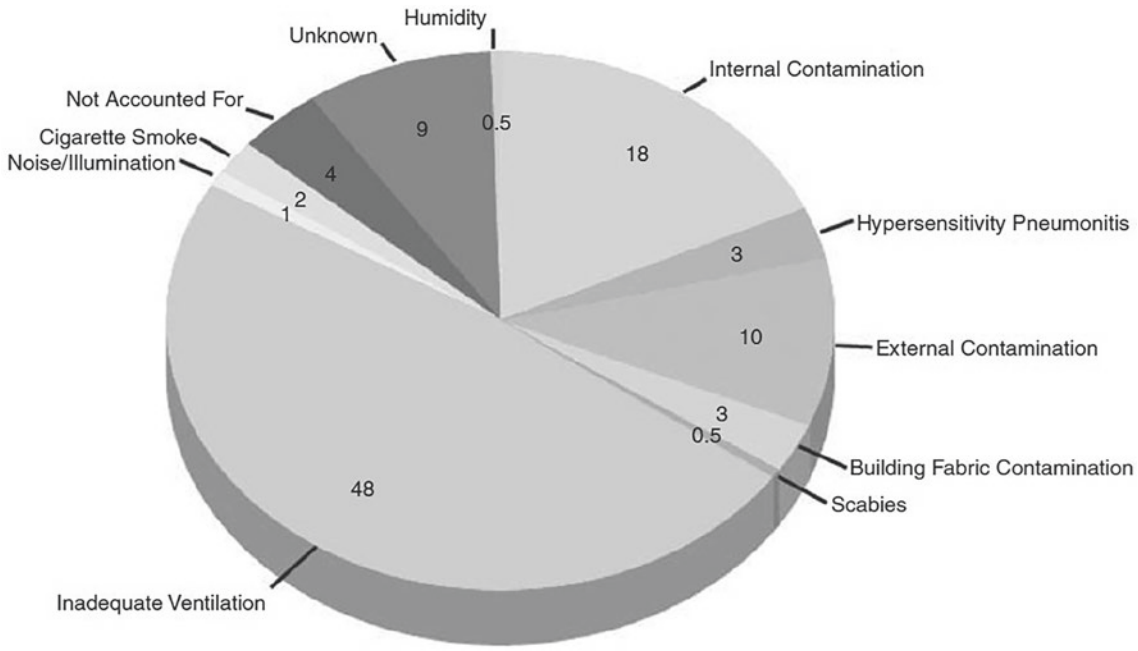

Fig. 10 Main problems of IAQ as investigated in 2003. *Source* The National Institute for Occupational Safety and Health (NIOSH)

thorough consideration of different airflow scenarios according to the weather conditions applied on the building.

- Controlling smoke as it can flow through natural ventilation routes. This requires the integration between the fire-safety strategy and the natural ventilation design.
- Providing safe accessibility to openings/control devices of different natural ventilation openings found at remarkable heights above floor level.

In the different studies of green and environmentally-friendly buildings, natural ventilation, especially passive systems, is related to the wind direction and affects temperature conditions (Norazman et al., 2018). This is directly related to lighting quality, natural lighting in particular.

Indoor Lighting Quality

Natural light is important owing to its recovery properties in the times of global pandemics. Having a well-lit interior space is one of the key factors affecting users' comfort. For example, natural light is defined by Inan (2013) as "the full spectrum of light that is most suitable to the human visual response". Additionally, Li et al. (1999) state that natural light is key for the comfort of interior spaces. In this section, the effect of natural lighting on both the physical and mental states is explored.

Asikkutlu et al. (2018) state that lighting can enhance user's experience and comfort, and strategies of natural lighting are being adopted owing to their energy efficiency in newly designed and constructed buildings. This follows the designer's ability to use the environmental conditions to create balanced natural lighting quality inside a space.

(a) The Physical Impact

Recent studies are focusing on medical effects of daylight in combating COVID-19 virus. Enwemeka et al. (2020) discuss using phototherapy which dates back as a proved method to reduce the impacts of the 1918 Spanish Flu. The evidence findings by that study stated that violet/blue (400–470 nm) light has antimicrobial properties against different types of bacteria.

The same study states another evidence that exposure to sunlight during the 1918 Spanish Flu helped reduce the flu-related reported deaths (American Public Health Association, 1918; Hobday & Cason, 2009), (Fig. 11). Patients who were exposed to the sunlight showed faster and better recovery (Brooks, 1918). Not to mention the role of daylight in provoking the formation of Vitamin D.

(b) The impact on the state of mind

In their studies, (Asikkutlu et al., 2018; Javadnia, 2016; Shishegar & Boubekri, 2016) also illustrate the significant impact of daylight on a person's subjective mood, cognitive performance, quality of attention and sleep, in addition to alertness of both workers and students. Javadnia (2016) argues that natural lighting contributes to better relationship between the user and nature, in addition to its positive effects on the eye's health and enhancing the users' management and control of their anxiety.

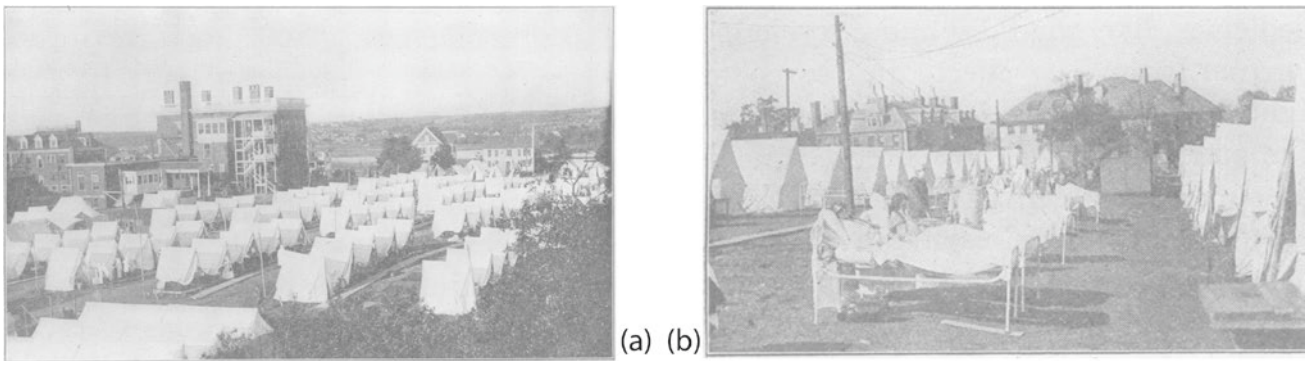

Fig. 11 **a** Outdoor tent-ward at Gloucester Hospital. **b** Open air and sunshine for patients, Camp Win. H. Brooks, Corey Hill. *Source* Boston Transcript Newspaper

4 Summary of Analysis Factors and Parameters

The previous literature has explored lockdown effects on human well-being and different design, materials and environmental factors that play a role in mitigating such impacts. It aimed to inform the analysis of whether heritage buildings can have a role in providing a more resilient lockdown for users in the time of isolation/lockdown, in comparison with contemporary buildings currently used for individual and mass isolation.

The key to the analysis is to understand how each factor affects the user experience, regardless of their background, needs, culture, etc. and how, although each factor has its independent effect, still has direct interrelationships with other factors. For example, architectural design process decides on both interior and exterior spaces, their materials and the design strategies for their ventilation and lighting qualities. The perception of interior and exterior spaces is affected by the type of its building materiality and its chemical qualities as well as by the environmental surrounding such as air and lighting quality (both natural and mechanical), see Fig. 12. The notion of these factors will underpin the comparative analysis of contemporary individual and mass isolation case studies and their alternatives from heritage assets in the city that could play a better role in the case of isolation for people comfort and well-being.

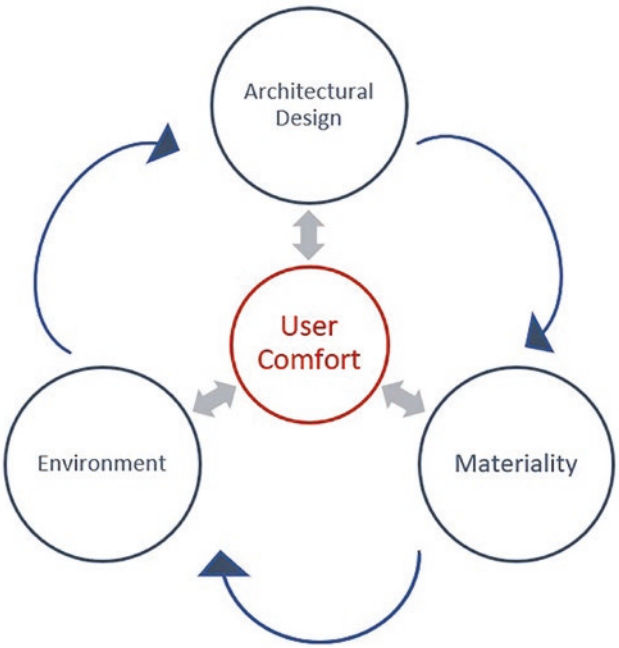

Fig. 12 Diagram showing the main affecting aspects of the user comfort. *Source* The researcher

5 Comparative Analysis (Two-Levelled Comparison)

The purpose of the literature is to offer insight to a comparative analysis, which is conducted at two levels of individual and mass isolation. Each level assesses whether problems arising because of the lockdown (Physical impact, mental state and social impact) can be minimised by traditional architectural heritage building designs. This section analyses both levels considering the three aspects of architectural design, materiality and environment as shown in Fig. 13; however, the analysis is more oriented to assess whether heritage buildings can be more effective to be used for isolation during the lockdown.

Since this section uses different terminology from Islamic architecture, it is important to review them from Table 1 before commencing the intended analysis.

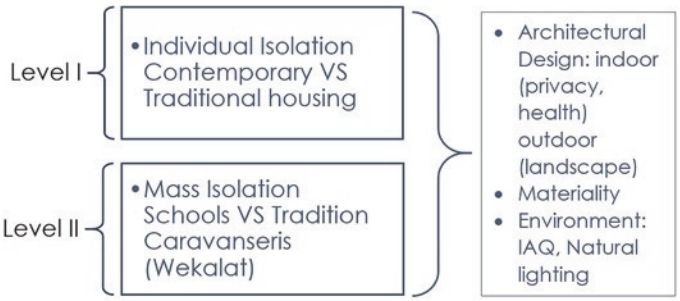

Fig. 13 Comparative analysis with the points of comparison decided. *Source* The researcher

Table 1 Brief definitions for traditional house elements as derived from Abdelkader and Park (2018), Archnet (2020), Maarouf et al. (2018), Center of Planning and architectural studies, & The Reviving legacy of Islamic architecture Center (1990)

Term/element	Description
Courtyard	Main outdoor space found in the middle of either the Salamlik, Haramlik or both
Haramlik	Indoor private space for women
Iwan/Takhtabush	Mainly found in the Salamlik Area Rectangular space, usually vaulted, walled on three sides, open on the fourth side Overlooks and opens onto the courtyard, furnished with seating where morning business meetings were held
Loggia/Maq'ad	Usually found the Haramlik Area as a terrace or an informal living space
Majaz	Main house entrance usually opens to an L shape hallway which in turn leads to the main courtyard
Malqaf	Wind Catcher
Mashrabiya	Wooden lattice window with conspicuous geometric patterns
Salamlik	Indoor public space for men
Shukhsheikha	A sky light feature—also aiding natural ventilation
Wekalat (Caravanserai)	A building found inside cities near trading region specified for traders coming from near-by countries to stay and store goods Mixed-use building: Commercial and Residential

5.1 Level One: Individual Isolation

This level aims to compare between the traditional design of Bayt Al-Suhaymi in old Cairo and the common design of a contemporary apartment.

5.1.1 Bayt Al-Suhaymi

The Ottoman Cairene house was built in 1648 with further additions in 1796 (Archnet, 2020). As a national heritage asset, it is now used for cultural events instead of its initial use as a private family accommodation. However, since the pandemic, all activities in the building have been fully suspended due to the lockdown. According to (ElSorady & Rizk, 2020), the elements in are identified on the ground and first floors and illustrated in Fig. 14.

Architectural Design

Privacy

The traditional Ottoman housing design ensured utmost privacy for its residents without compromising the landscape or a delightful view of the terraces. This was the main concept of Islamic house design in general with Bayt Al-Suhaymi being included in the traditional housing typology of "Houses with courtyards" according to the classification stated by Salama (2006). The privacy concept is achieved by both the Majaz (bent entrance) and the courtyard which all spaces in the house look over (Fig. 15).

This feature is not only beneficial for preserving the residents' privacy; it also significantly reduces the possible transmission of virus. For instance, a user entering the house must first go through the three-walled Majaz, then to a hallway leading to an open private courtyard representing the centre of the house. It also reduces the noise transmission from outside.

Space Recognition and Comfortability

AAs previously stated, one of the key factors that can contribute to user's comfort is easy space recognition. This factor is clearly illustrated in Bayt Al-Suhaymi design. For example, it is easy to define public, semi-public and private spaces of the building (Fig. 16). It is clearly noticed how the first floor is entirely private except for a Maq'ad, while

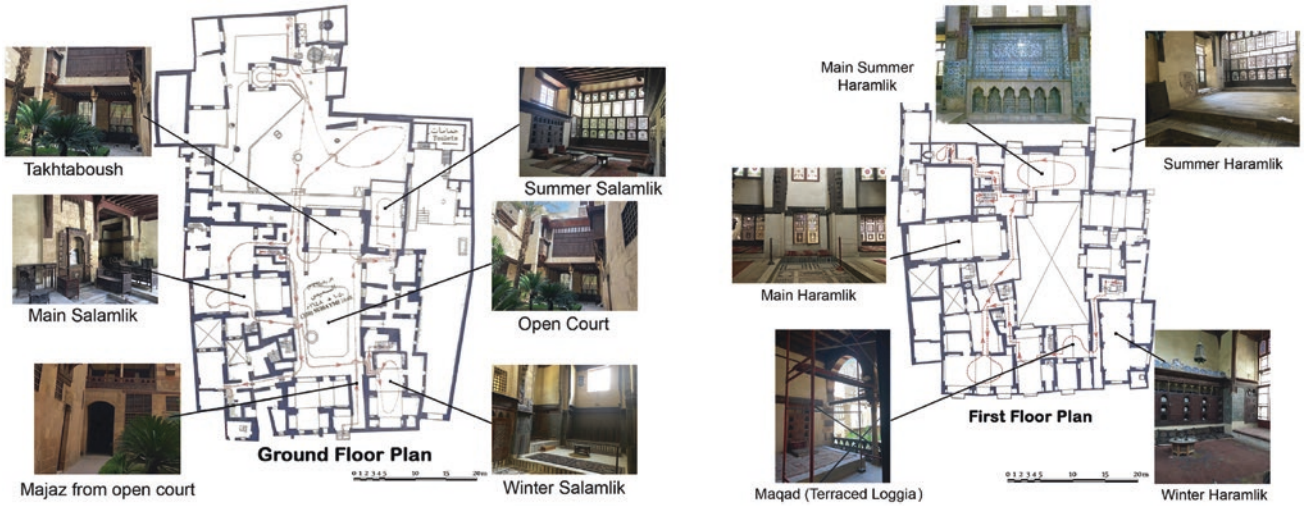

Fig. 14 Bayt Al-Suhaymi: traditional Architectural elements of ground and first floor. *Source* ElSorady and Rizk (2020)

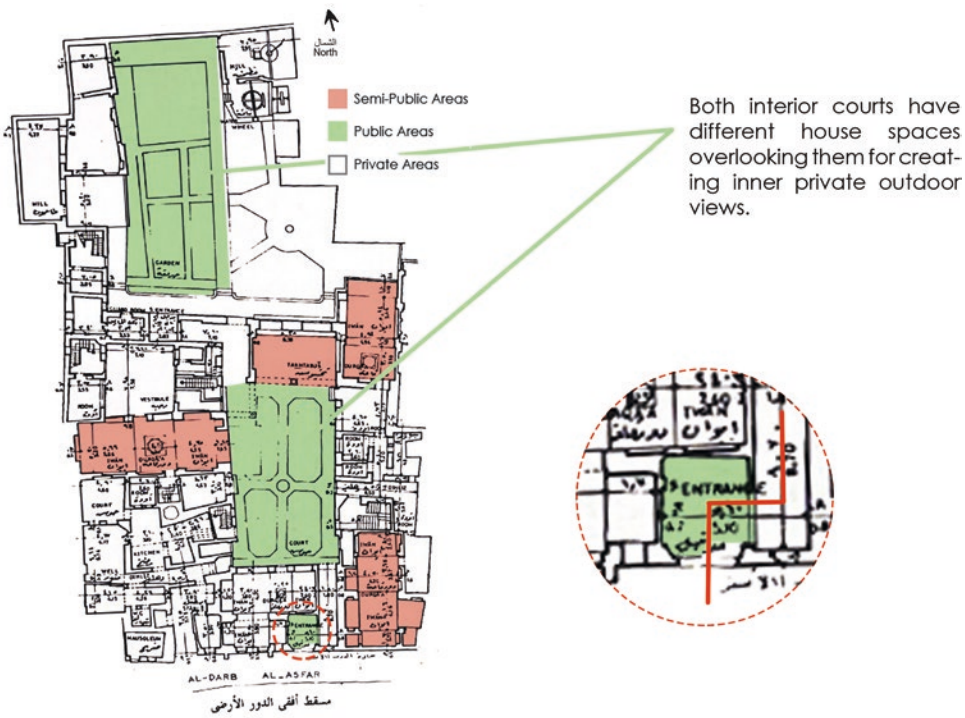

Fig. 15 Majaz direction relating to the rest of the house, in addition to the main courts. *Source* The Organization of Islamic Capitals and Cities (OICC); analysis by the researcher

most of the ground floor area is occupied by both public and semi-public spaces. This is also considered as an asset especially during lockdowns because of the wide separated private spaces with respect to public and semi-public areas which are also considered spatially separate and hence providing physical distancing.

Outdoor Landscape

The position of the courtyard serves different purposes related to certain social, religious and environmental considerations (ElSorady & Rizk, 2020). Islamic houses courtyards are oriented through East–West axis in order to respond to the hot and arid climatic conditions (Ezzat & Talaat, 2013). The courtyard is an essential design and landscape device in such context and provides an alternative landscape in times of isolation. It is noticed in (Figs. 14 and 17) how certain zones/spaces of the house look over the southern (main) court while others love over the northern one.

During lockdown, this feature is considered a key asset for keeping physical distancing between residents in

Fig. 16 Analysis of public, semi-public and private spaces for (Left: Ground Floor) and (Right: First Floor). *Source* The Organization of Islamic Capitals and Cities (OICC); analysis by the researcher

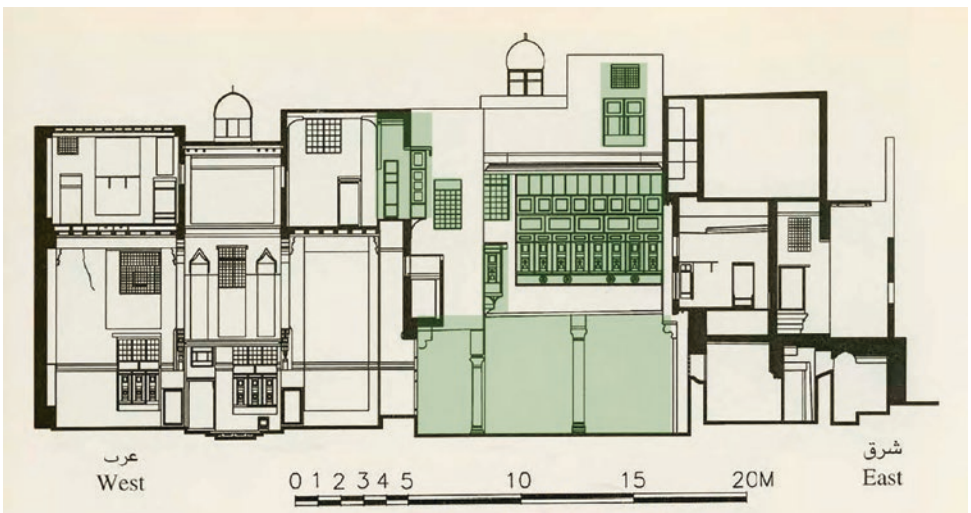

Fig. 17 Section of Bayt Al-Suhaymi showing the number of spaces overlooking the main courtyard, either private, semi-public or public spaces are all visually connected by the presence of the court; yet separated by use. *Source* Nadim Foundation (1997); analysis by the researcher

addition to maintaining social solidarity by allowing the users into open outdoor venues without the risk of infection. As mentioned above, the outdoor spaces are deigned in such a way that it provides comfort to user's mental state, which is even more pronounced in the times of isolation and lockdown. In addition, the water fountain is a landscape feature and not only uplifts indoor aesthetics but also a soothing touch to the environment. Different studies have highlighted that the courtyards facilitate internal thermal comfort of the house (ElSorady & Rizk, 2020) and encourage natural light and ventilation (Ezzat & Talaat, 2013). This is explained in detail below.

Environmental Features

ElSorady and Rizk (2020) have assessed Bayt Al-Suhaymi according to the LEED credentials and found that the building scored 17 out of 22 points for indoor environmental quality due to factors like air quality, cleanliness, daylight, thermal comfort. Therefore, it is considered friendly and safe for habitation during the isolation or lockdown enforced by the COVID-19 pandemic. The following section illustrates this in the context of IAQ, natural lighting and materiality.

Indoor Air Quality (IAQ)

Using a comparative approach, Ezzat and Tallat (2013) investigate the courtyard feature in different typologies and architectural designs of historical houses from different periods, such as Pharaonic, Islamic, and modern. The results showed that Islamic housing structures are amongst the best design for natural ventilation. Design devices implemented in these houses have inspired passive systems that have been reinterpreted into modern housing structures when possible. Osman (2011) sets different strategies for natural ventilation aided by courts, as illustrated in Fig. 19a.

These strategies are obtained from natural drivers of ventilation, which, in turn, are based on two key principles. Firstly, air flows from higher (positive) pressure zone to a lower (negative) pressure zone, whereas the second principle depends on the thermal buoyancy effect that encourages air movement depending on the air temperature, and hence density, which encourages 'stack effect' ventilation. In both cases, the pressure difference induces air movement throughout the courtyard.

There are other natural ventilation inducers such as wind catchers (Malqaf), wind towers, envelope projections and double façades (Ezzat & Talaat, 2013; Osman, 2011), and some systems are designed to combine more than one inducer. In the case of Bayt Al-Suhaymi, the applied inducers include the Malqaf and the Shukhsheikha, see Fig. 18. Not to mention the design of the traditional Mashrabiya as explained by Abdelkader and Park (2018), see Fig. 19b.

Natural Lighting

The importance of natural light has been previously illustrated as an effective factor in reducing the risks of COVID-19. Consequently, this section briefly elaborates on this aspect in Bayt Al-Suhaymi.

One of the key advantages of the courtyard is that it provides natural light to almost every corner of the house, aided by certain features applied such as the Shukhsheikha in the reception halls and the right distribution of windows. The presence of the courtyard improves the flow of natural light in the building and allows self-shading in different areas during the day based on its location and orientation as shown in Fig. 17. This is important as it allows defused and constant natural light inside the spaces without direct solar radiation/heat gain, and thus without compromising the overall indoor thermal comfort.

Materiality

Bayt Al-Suhaymi, similarly to other houses in the historic neighbourhood, is built using limestone, (Saleh & Saied, 2017). Limestone is used for building walls with different thicknesses based on the floor level (the typical loadbearing wall system). The walls were either built using homogenous solid stone blocks or two faces of solid ashlar masonry with its core filled with rubble stone (Saleh & Saied, 2017).

Concerning the environmental aspect of materiality, Saleh and Saied (2017) states that most of the stone remained intact even under intense humid conditions. This plays an important role in preventing the growth of germs and viruses arising from damp mould which reduces the chance of having BRI and SBS. Even during its restoration in 1997, cement-free mortar was used to preserve the same features of the building (Nadim Foundation, 1997).

In addition, Fahmy et al. (2019) studied the building materials of Wekalat Al-Ghouri and conducted a comparison between limestone as a main building material and the typical Concrete Masonry Unit (CMU) used in modern constructions, See **Error! Reference source not found**. The study showed that sandstone as a material also contributes to thermal comfort based on its good thermal conductivity in comparison with modern materials such concrete (Fahmy et al., 2019).

Referring to the negative impacts of the lockdown as previously explained, Bayt Al-Suhaymi offers more information in relation to the physical well-being, social life and mental state of individuals. The physical well-being is positively affected when the architectural design allows better physical distancing, more natural ventilation, better natural lighting with better thermal comfort. Social life can be conventionally sustained as the courtyard offers a vast space for social communication while maintaining physical distancing, social solidarity and emotional support during the time

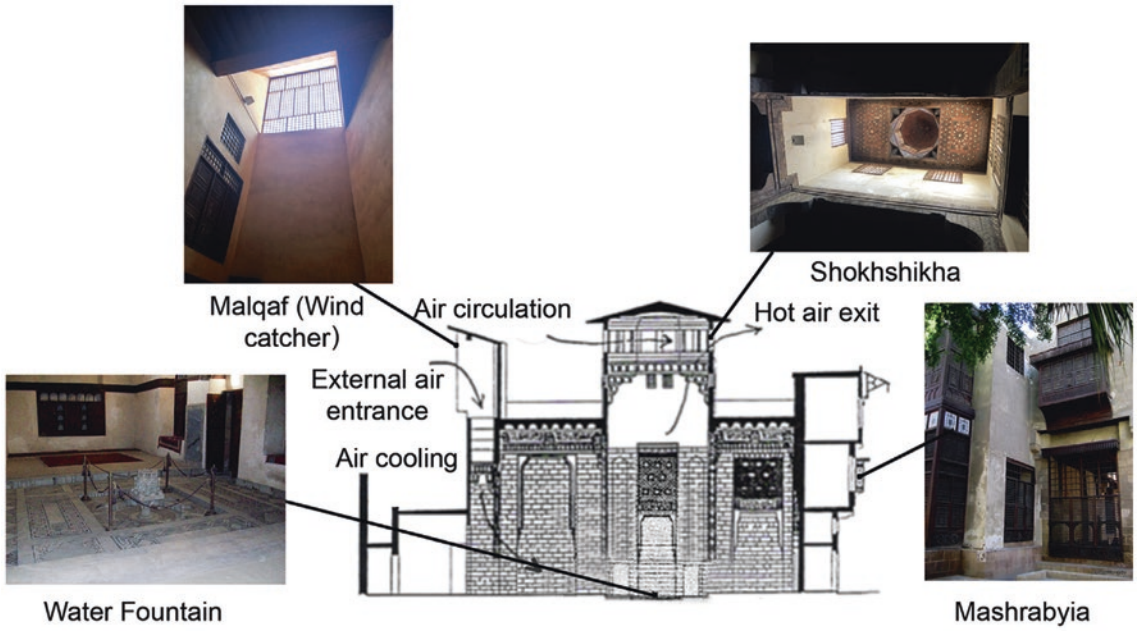

Fig. 18 Diagrammatic section showing the application of two wind inducers; the Malqaf and the Shukhsheikha in a hall design of an Islamic house and photographs showing these elements in Bayt Al-Suhaymi. *Source* ElSorady and Rizk (2020)

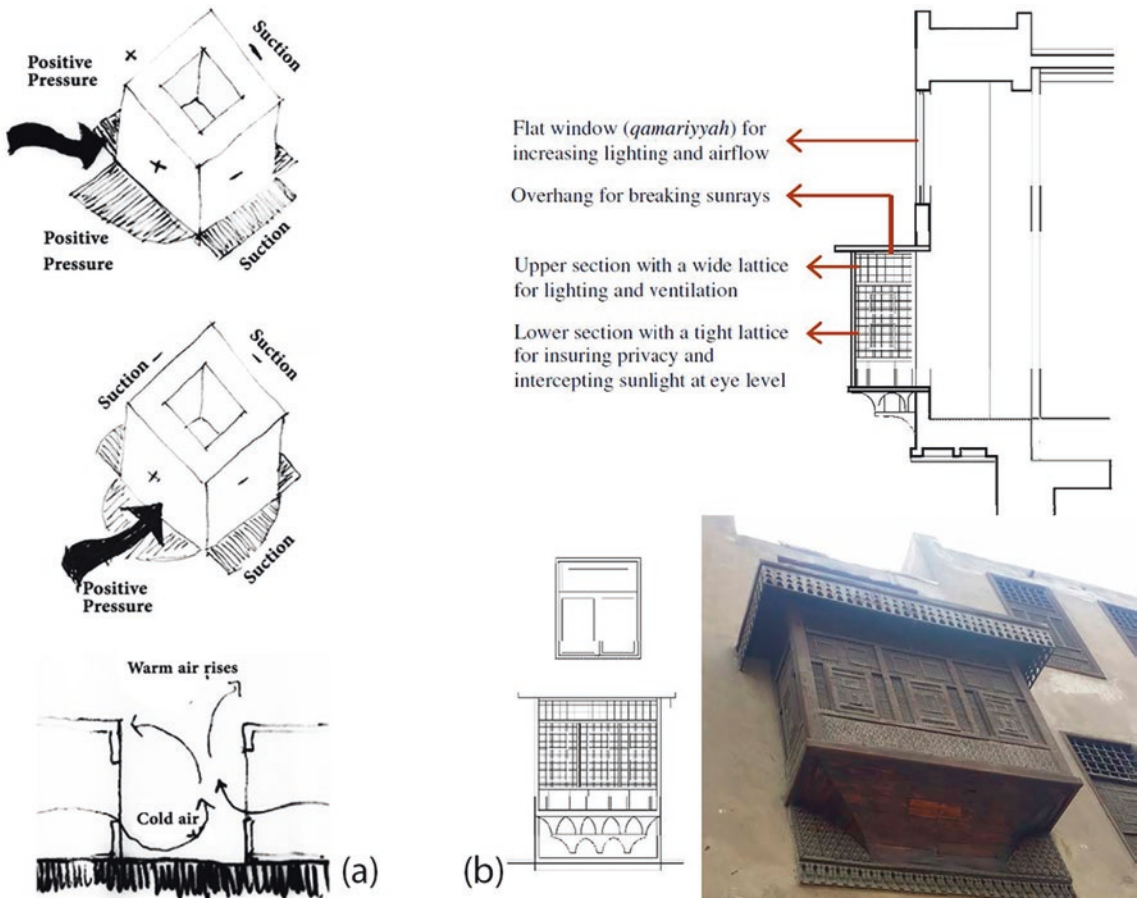

Fig. 19 **a** Wind ventilation strategies as set by Osman (2011) and edited by Ezzat and Talaat (2013). **b** Mashrabiya design as explained by Abdelkader and Park (2018) based on the work of (Mohamed & Ali, 2014)

of global pandemic. It becomes even better as separated rooms; for example, the first floor offers good views that maintain connection with neighbours. This consequently promotes good mental health for the residents, as they do not feel lonely, stressed or anxious.

5.1.2 Apartment Building (Common Housing System in Egypt)

The following part analyses a typical apartment housing as a counterpart example to the traditional house. The chosen apartment model is located in south Alexandria and is situated within a residential block complex. It is important to highlight two aspects:

- This specific type of housing was chosen, as it is the most common design throughout the country regardless of its location. Working on this model will help making this analysis useful to contribute to solve relevant problems in wide range of housing complexes in Egypt; see Fig. 20a for the master plan of the selected apartment.
- The chosen model lies in a complex with no public/green spaces designated for the residents, which is the reality for majority of the residents in Egypt.

By studying the same aspects evaluated in Bayt Al-Suhaymi, the research has concluded to the following observations:

Architectural Design

The housing category is entirely different from Bayt Al-Suhaymi and thus resulting in different zoning aspects.

Privacy

Figure 20b shows the hierarchy from public to private areas; however, the difference is about ownership of these spaces. The study observed that the owned terraces provide less open private spaces in comparison with the public outside area. In addition, the terrace does not provide a private environment as it looks over a secondary street (Fig. 20a), is partly separated from the neighbouring apartment terrace and is exposed to apartments from the opposite blocks. Also, there is no transitional semi-public spaces in the apartment. The hierarchy goes from public zones directly to private ones with a publicly shared services shaft, not to mention the easy noise transmission between different apartments which compromises the user's privacy and comfort.

Space Recognition and Comfortability

Every space is clearly visually defined, and despite the smaller areas, it is well-recognised and experienced without confusion.

Outdoor Landscape

As previously described, the owned outdoor area (the terrace) is small compared to the total area of the apartment, and it is only accessed through an indoor private reception, whereas in Bayt Al-Suhaymi, it was exactly the opposite. This kind of planning reinforces the residents to use outdoor public landscape which is associated with anxiety of being infected, in comparison with the open courtyard of Bayt Al-Suhaymi.

Accordingly, the typical apartment model found in Egypt is restricted and does not necessarily provide positive vibes

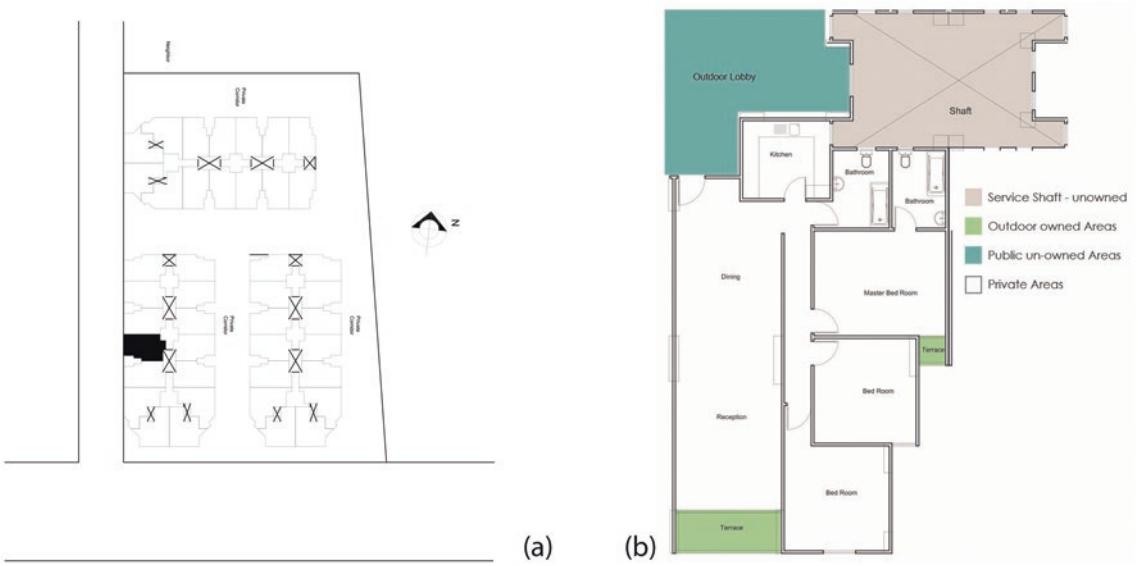

Fig. 20 **a** Location of the chosen apartment regarding its neighbouring ones in the block. Source: The researcher. **b** Apartment's plan zoning and hierarchy of spaces regarding privacy and ownership. *Source* The researcher

that can promote mental or physical well-being. The problem is further worsened during the lockdown/isolation where any kind of socialisation and interactions is temporarily suspended.

Environmental Features

IAQ and Natural Lighting

Different studies about the IAQ and natural lighting in Egypt were conducted to assess the environmental situation of the Egyptian housing system.

Mossaad et al. (2016) studied two apartments of almost the same design in a low-income housing project in Alexandria. The purpose was to assess the potential of providing natural ventilation. The findings of their study showed that their case studies have failed to provide proper natural ventilation by over 90%. This directly affects the user's physical well-being as discussed in the literature above.

The apartment model shows inadequate proportion between the areas of spaces and their openings especially in the private zone (bedrooms). This leads to poor IAQ and natural lighting. This is also seen in the ventilation and lighting of the service spaces (kitchen and bathrooms) whose windows look over a publicly shared shaft without adequate considerations for either air flow or natural lighting potentials.

Materiality

It is commonly known that in Egypt, the construction structures of most buildings, especially residential ones, is the bulk skeleton system that mainly depends on concrete construction including the Concrete Masonry Units CMU. As previously discussed in Table 2, the comparison between limestone and CMU showed that the CMU had lower density values leading to more heat and harmful UV conductivity, which negatively affects the users' health and comfort. Not to mention the effect of indoor materials concerning the BRI and SBS.

Consequently, it is possible to say that the environmental aspects are almost overlooked in this typical design because of the constant demand for residential apartments. The builders are in a rush to complete the building projects and thus compromising the health and safety/comfort features of the structure.

5.2 Level Two: Mass Isolation

This level aims to compare between the common design of a typical governmental school, which is used for mass isolation, and the traditional design of Wekalat Bazar'a in old Cairo.

5.2.1 Wekalat Bazar'a (17th Century)

It was one of the most remarkable caravanserais built in the Mamluk era in Cairo and had different names before settling on Bazar'a in the ninetennth century. Like Bayt Al-Suhaymi, it is also used for cultural activities owing to its heritage value; activities were suspended since the COVID-19 outbreak.

Architectural Design

Wekalat Bazar'a contains two main parts (Maarouf et al., 2018):

- The commercial zone on the ground and first floor.
- The residential zone occupying the second and third floor.

The Wekalat's spaces surround an open courtyard that open up directly to the commercial zones; some spaces open out to the main street too.

Privacy

The plan of the Wekalat follows the same features of the Mamluk Wekalat as the architect used the indoor open court surrounded by different spaces and features. Since

Table 2 Thermal properties of different wall envelopes in Wekalat Al-Ghouri

Thermal data	First envelope		Second envelope		Third envelope	
	40 cm limestone	40 cm limestone	12 cm CMU	25 cm CMU	12 cm CMU (insulated)	25 cm CMU (insulated)
U-value (W/m^2, °k)	3.149	2.110	6.298	4.431	The same data as column 4 + Using 2.5 cm polystyrene insulating board	The same data as column 4 + Using 2.5 cm polystyrene insulating board
Conductivity (W/m, °k)	1.259	1.259	0.959	1.350		
R-value (m. K/W)	12.502	18.649	6.251	8.880		
Density (kg./m^3)	2707.12	2707.12	1361.56	1217.40		
Specific heat (kJ/kg. °K)	908.53	908.53	837.36	837.36		

Source Fahmy et al. (2019)

Fig. 21 Zoning of both **a** ground floor plan and **b** first-floor plan. *Source* The Organization of Islamic Capitals and Cities (OICC), edited by the researcher

the building combines both commercial and residential use, (i.e. a public and a private use), it was designed to have two entrances. The main entrance leads directly to the main courtyard and was wide enough to allow carts and groups of people entering together, whereas the private entrance was completely detached from the courtyard and opens to a staircase leading to the second and third floors where residential rooms are found, see Fig. 21.

The spaces, used to be part of the commercial zone in the ground floor, are now mostly administrative areas for the building. During the lockdowns, users could access these spaces for various activities without risk of getting infected. This includes reading, watching a live show or engaging in mindful activities, such as meditation. The rooms with their access to the large courtyard allow flexibility and some degree of freedom and mobility for users to maintain their privacy or get proper social interaction, albeit within a closed building during the lockdown. This enriches users' experience and avoids them loneliness and depressive feelings.

The residential units are found above the commercial areas where each unit consists of two levels: an entrance, a reception space, a living area, a small kitchen, a bathroom and an interior staircase leading to the bedroom area above.

Both second and third floors look over the courtyard through "*mashrabiyas"*(Torky, 2020). This is one of the strongest points of the building is it allows residents to experience the courtyard without compromising their privacy.

"By this means, the design of the caravanserai facilitated some social interaction amongst residents, while ensuring their privacy, as each apartment was separated both vertically and horizontally from the next" (Torky, 2020). This is highly important in terms of infection control during the lockdown.

Space Recognition and Comfortability

This aspect of human comfort is sufficiently achieved in Wekalat Bazar'a owing to the distribution of spaces and their categorising between private and public. The user has direct access to the areas that are designated to their use of the building (i.e. residents have their own private direct entrance to the residential floors, while a clear entrance is dedicated to provide access to commercial spaces). Recognising the space types is also clear considering the façade design where the main entrance is two-storey high and the residential areas have their windows designed by distinctive *mashrabiyas* which indicates residential function of these spaces.

Outdoor Landscape

The traditional Wekalat design used the main open courtyard as a gathering space before shops came up. It is also stated that the courtyard once contained a fountain; however, some traces of it are visible now (Torky, 2020). The environmental advantages of having a courtyard in the Wekalat design resembles that in Bayt Al-Suhaymi as a traditional house design.

The design of Wekalat Bazar'a is better suited for quarantines. The distribution of both its interior spaces and courtyard means that individuals can be physically separated in their rooms and yet remain socially connected to their neighbours in the sense that they can see and chat to each other from a distance as shown in Fig. 22.

Environmental Features

Maarouf et al (2018) conducted a study to find out the energy efficiency of Wekalat buildings. They studied Wekalat Bazar'a and Wekalat Al-Ghouri as case studies with full analysis and LEED credentials assessment. The results of this study showed that Wekalat buildings are more energy efficient owing to the applied passive systems in their design like Bayt Al-Suhaymi. Such systems include "*an indoor court, natural ventilation, natural materials (combining stone and wood) and a daylight system*" (Maarouf et al., 2018).

The LEED credentials assessment came in two schemes; LEED for BD+C (Building Design and Construction) and LEED for ID+C (Interior Design and Construction). The study showed that the Wekalat building typology could not fulfil both assessment schemes. However, with the aid of contemporary green technology, it can easily meet the LEED criteria. This is different from Bayt Al-Suhaymi which did achieve, nearly a gold LEED certification.

Accordingly, and similarly to the case in Bayt Al-Suhaymi, this type of buildings is considered good for ensuring safe quarantine even if the environmental features achieved lower grades.

5.2.2 Typical Government School

The chosen school building model is located in north Alexandria and within a group of school buildings; however, the selected design is a typical Egyptian school model across the country regardless the location. It is important to note that the chosen building is an extension to an existing school that was built in 1925, Fig. 23a. During the outbreak of COVID-19, a suggestion was proposed to transform schools into quarantine hostels in the event the hospitals ran out of beds. Since most of Egyptian schools especially primary schools are designed in a similar way, exploring the same factors here will highlight the suitability of using such buildings for isolation in time of this or future pandemics in comparison with heritage building, taking into account that both functions have been suspended in the time of COVID-19 lock down.

Architectural Design

Privacy

The school is a five-storey building. A typical floor plan consists of four large classrooms, a smaller room for younger children and two supervision stalls (see Fig. 23b). The function of the yellow space differs from one floor to another (e.g. Main principal's office (first floor), classrooms for younger students (second and third floors) and a teacher's lounge (fourth floor).

Fig. 22 Inner courtyard of Wekalat Bazar'a. *Source* Torky (2020)

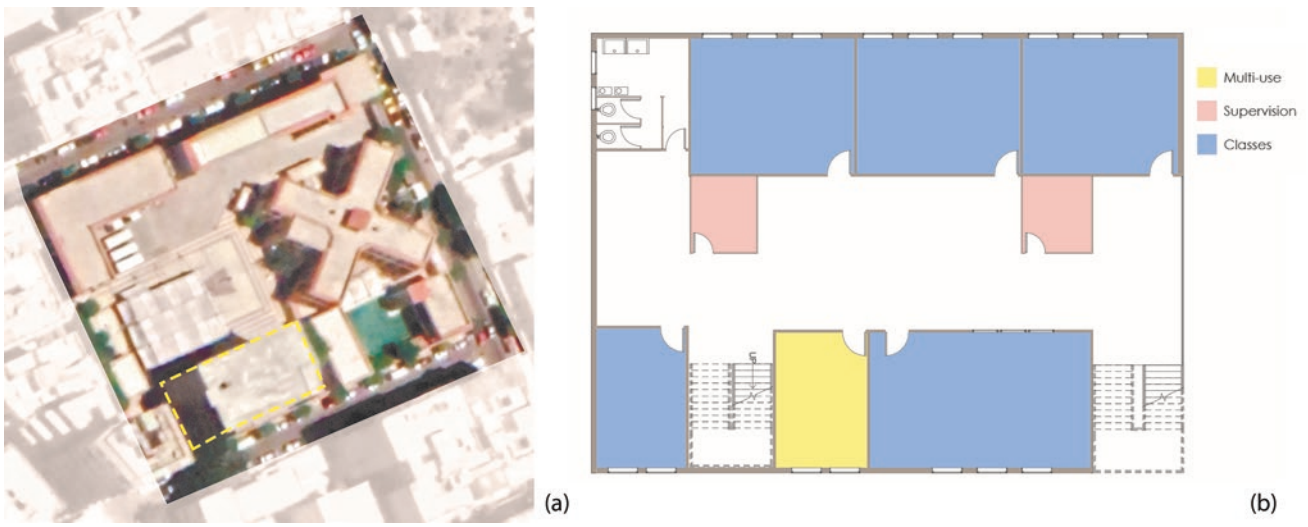

Fig. 23 **a** School site with highlight over the chosen building. Note that the cross-shaped building is the oldest one in the complex and to which other buildings were attached. *Source* Google Maps, 2020, edited by: the researcher. **b** Typical Floor plan. *Source* The researcher

Normally during isolation or quarantine in a hospital, the privacy of the patient is generally overlooked, especially in the general wards. This can be even more difficult when there is a massive surge of patients as during the COVID-19 pandemic. Schools too are a public interactive building and not designed to house patients so the privacy is even more compromised.

Another setback is the fact that the entire floor is equipped with one bathroom space (and possible two shower rooms by converting the two supervision stalls). This highly contributes to the risk of contamination, unlike the Wekalat where each residential unit had its own private bathroom.

Space Recognition and Comfortability

As a newly designed building, this shows same findings to the apartment case study. Every space is clearly visually defined and well-recognised and experienced without confusion. Although private spaces are accessible directly from public corridors, boarders and the threshold between the two entities are easily identified.

Outdoor Landscape

As in all typical schools, a playground surrounds the main school buildings. The open landscape consists mainly of hard landscape such as a paved basketball court. There is no green infrastructure dedicated for student use. This does affect the experience, the perception as well as the environmental qualities of this landscape. Also, this is a shared open space and the privacy in using such open space is compromised in comparison with the Wekalat Bazar'a building.

Environmental Features

Indoor Air Quality (IAQ)

Theoretically, the model shows adequate proportions between the given spaces and their corresponding openings owing to the fact that it is designed as a typical school model. In addition, more openings are provided to the terraced lobby at building edge which is providing better air flow through the heart communal area of the building and thus better ventilation.

However, it is important to note that this model might be more successful in some regions rather than others as air flow depends on the building's location, orientation and environmental treatments (louvres, shelves, etc.).

Natural Lighting

Standard wise, a classroom needs about an average of 300 lx of lighting to attain the minimum comfort according to different activities held in the classroom (de Bruin-Hordijk & de Groot, 2007). The lux levels remain bearable provided the proper orientation of the building since luminance intensity varies throughout the day. The design of the school with side windows for all classrooms to achieve this level of lighting provides a positive impact to the light quality; that said, it is impacting on the privacy aspect of people isolating in these classrooms.

Materiality

As a newly designed building, this shows same findings to the apartment case study, as it is using similar materials and construction methods.

Consequently, it is possible to state that schools can be suitable to quarantine patients during the lockdown provided that the building orientation is compatible with the environmental conditions of its location.

In the context of the school, keeping patients in quarantine can only have a positive impact on their well-being if there is a provision for natural ventilation and lighting due in the school's architectural design. As for the social life, the schools are planned to promote social bonding amongst students so physical distancing can get compromised. The mental state of the patient can be good if there is some degree of socialisation; however, it can be negatively affected if physical activities are compromised owing to the limitation of private open spaces.

6 Results and Discussion

TThe study's findings on the comparative analysis are represented in **Error! Reference source not found.** with a qualitative-driven scale from 1 to 5 where (1 = very poor, 2 = poor, 3 = fair, 4 = good, 5 = very good) (Table 3).

The provided results show that Bayt Al-Suhaymi has the highest score for overcoming the negative impacts of lockdown, while the typical apartment model has the least rating. On the other hand, the results of Wekalat Bazar'a and the government school indicate less gap in performance between the two buildings mainly because the school has been already designed based on good standards in terms of space quality, light and ventilation. Therefore, it is important to unpack these results in the light of what design strategies and features have contributed positively and negatively to these outcomes.

The traditional courtyard has helped to achieve greater perception of privacy at both interior and landscape scales and allowed better interaction with the landscape and green infrastructure while maintaining the privacy and recognition of space hierarchy. The courtyard has also helped in promoting environmental performance in terms of the light and air quality in comparison with the apartment. Of course, the economic challenges and the increasing land values make it difficult to design in traditional model with individual

Table 3 Qualitative scale to conclude the comparative analysis

Parameters of Comparison (with rating scale from 1–5) (1 = very poor, 2 = poor, 3 = fair, 4 = good, 5 = very good)			Bayt Al-Suhaymi	Apartment	Wekalat Bazar'a	Government al School
Architectural design	Indoor design	Privacy	5	2	5	3
		Space recognition and comfort	5	3 ——— 4—recognition 2—comfort	5	3.5 ——— 4—recognition 3—comfort
	Outdoor landscape	Privacy	5	1	5	4
Materiality	Patient—WHO		5	2	5	2
	Non-patient—SBS		5	2	5	2
Environment	Indoor Air Quality (IAQ)		5	2	4	4
	Natural Lighting Quality		5	1	4	4
Total Scaling			35	13	33	22.5

Source The researcher

private courtyards. That said, the developers' intention to make profit out of residential developments has contributed to completely overlooking how these aspects could be better achieved even with apartments models and how the concept of courtyard can be better reinterpreted and integrated into the contemporary residential apartment schemes in Egypt. Using the concept of courtyard in a contemporary residential model could also contribute to the hierarchy of spaces and the concept of privacy where the courtyard could work as a semi-public space that organises the circulation, provides a social hub and brings higher lighting quality into the heart of the building, while its green infrastructure contributes to the building landscape, environment and air quality.

As for mass isolation, the main argument is that the school, although it has a clear design and regular shape of spaces and in terms of assessment performs relatively well, it is not designed for proper social interaction and the typology with large spaces and common wet services does not fit with the pandemic requirements in terms of protection from virus transmission and social distancing. In terms of social distancing, Wekalat performs better because it provides the large private landscape and in the meantime facilitates social distancing in terms of isolation spaces and services with visual and physical access to the landscape. Also, the condition of orientation is key in the school to achieve the good assessment in terms of lighting and ventilation, while Wekalat typology with large courtyard and protected windows facilitates effective light and air quality while orientation play less effective role in achieving that. The original function of Wekalat that brought public and mixed use in the ground floor while maintaining private and comfortable stay in upper floors with visual and physical access to an open space and landscape does contribute to the potential positive performance of such typology in current and future pandemics. Since such a building does not have a role during lockdown, it is of a great potential to contribute to the society resilience and fighting against pandemics. Also, the design concepts and methodologies of educational and mixed-use buildings could really adapt the social and the environmental design features and methods of Wekalat that are anchored to the culture and the climate of the place. This promotes the performance of these contemporary buildings in normal times but also makes them prepared to be a hosting environment for large group isolation during pandemics.

7 Conclusion

The two heritage buildings have very good environmental performance with a caveat that Wekalat Bazar'a is attributed to a slightly less environmental design quality in comparison with Bayt Al-Suhaymi as stated by Maarouf et al., (2018). Although the school was rated relatively good in comparison to Wekalat Bazar'a, the school's score remains arguable as four out of seven assessment factors were entirely relative to whether or not the building is properly oriented with a well-designed playground and landscape. This clearly illustrates that heritage buildings represent a strong asset in providing a better lockdown for patients or quarantined citizens in individual or mass isolations. In addition, the design features and methodologies of both heritage typologies are contributive to the contemporary residential and public buildings not only in times of pandemic but also in normal time and original private or public uses. This points out an important opportunity in contemporary design theories and practice of how the traditional and historic concept could be preserved and reinterpreted for current and future design methodologies to first of all make

new buildings socially, culturally and environmentally relevant to the users as well as enhance their adaptability to different and urgent functions.

This paper provokes an argument about the common housing system in Egypt and its durability and how heritage buildings can inspire some aspects of housing design in the country. Also, it addresses crucial questions of how heritage buildings can be adaptable and contribute to different situations of people's life when they cannot contribute with their dedicated functions as heritage and cultural centres. This subsequently triggers substantial questions of how conservation strategies for heritage buildings could consider their adaptability and promote their role and performance during critical times of global pandemics/crises.

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Evaluating the Summertime Overheating Signature of Domestic Buildings Using Synthetic Temperature Data

Paul Drury, Arash Beizaee and Kevin J. Lomas

Abstract

Overheating occurs when the indoor thermal environment presents conditions in excess of those acceptable for human thermal comfort or those that may adversely affect human health. Summertime overheating of homes without active cooling has been demonstrated across diverse locations, such as the UK, USA, and New Zealand. Climate change is predicted to cause hotter summers in many countries with more frequent and intense heatwaves. There is, therefore, a need to understand the likely overheating risk of homes in these future summers. Simple physics-based models are very limited in their ability to produce valid assessments of overheating. More complex modeling using Dynamic Thermal Simulation (DTS) software can simulate internal temperatures when the modeled building is subjected to future weather files. There are, however, acknowledged uncertainties attached to the overheating determined from these simulations. Data-driven models can use temperature monitored in existing buildings to predict future overheating risk. This paper presents the idea of 'overheating signatures', simple mathematical models which relate the internal temperature in spaces to the external conditions and occupant behavior. Synthetic data from a single-zone building were used to derive such models and evaluate their ability to 'predict' overheating for different UK weather conditions. Analysis of the data revealed that there was a strong correlation between number of hours overheated and the warm period average outdoor air temperature (R^2 above 0.94). Applying the regression model to two different UK locations showed high correlation between overheating results predicted by the mathematical model and those from dynamic thermal simulation (R^2, 0.94 to 0.98). Based on these findings, we conclude that data-driven models have an important role to play in evaluating overheating risk. Future work is, however, needed to refine the mathematical models with data on a daily timescale and to test them on real-world buildings. Although this research has a focus on the UK dwellings, it is likely of interest to other countries with a temperate climate.

Keywords

Summertime overheating · Dwelling · Building simulation · Prediction models

Nomenclature

ΔT	Difference between measured operative temperature and T_{max} (°C)
$\Delta T_{o,\ mean}$	Anomaly of mean outdoor dry-bulb air temperature compared to TRY, 50th percentile weather file calculated over period 1 May to 30 September (°C)
HVAC	Heating, ventilation, and air conditioning
NH_o	Number of hours overheated (% of occupied hours)
$T_{i,\ mean}$	Mean indoor operative temperature calculated over period 1 May to 30 September (°C)
T_{max}	Maximum acceptable temperature for a Cat II space in CIBSE TM52 (°C)
$T_{o,\ mean}$	Mean outdoor dry-bulb air temperature calculated over period 1 May to 30 September (°C)
Top	Indoor operative temperature (°C)

P. Drury (✉)
London-Loughborough (LoLo) Centre for Doctoral Training in Energy Demand at the School of Architecture, Building and Civil Engineering, Loughborough University, Loughborough, UK
e-mail: p.drury@lboro.ac.uk

A. Beizaee · K. J. Lomas
Centre for Doctoral Training in Energy Resilience and the Built Environment at the School of Architecture, Building and Civil Engineering, Loughborough University, Loughborough, UK

A. L. Pisello et al. (eds.), *Building Resilient and Healthy Cities: A Guide to Environmental Sustainability and Well-being*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-031-33863-2_7

1 Introduction

Average global temperatures have increased 1.2 °C above preindustrial levels and there is high confidence that global warming will reach 1.5 °C between 2030 and 2052 if it continues to increase at the current rate (IPCC, 2018). This rise in global temperatures is having serious impacts on people's health, with increases in mortality and morbidity (Watts et al., 2021).

The attention of European Government heat-health planning is typically focused on raised outdoor temperatures (Basarin et al., 2020), but housing is a critical factor in heat vulnerability (Samuelson et al., 2020). People can spend up to 80% of their time indoors, with this figure being greater for the elderly or other vulnerable groups (Bone et al., 2010). During the 2003 European heatwave, high indoor temperatures were identified as a key factor in heat-related deaths (Kenny et al., 2019).

There are varying interpretations of what constitutes indoor overheating. An accepted definition states that, 'Overheating occurs when the local indoor thermal environment presents conditions in excess of those acceptable for human thermal comfort or those that may adversely affect human health' (AECOM, 2019).

Evidence shows that in countries with typically moderate summers, exposure to high temperatures can have a greater impact on health due to people being less accustomed to the heat (Beckmann et al., 2021). The summer of 2020 saw an estimated 2556 excess heat-related deaths across the UK—the majority of these being people over 65 years old (Public Health England, 2020). It is predicted that without effective mitigation, there could be up to 7000 heat-related deaths each year by 2050 (Hajat et al., 2014).

Although attention is slowly being paid to the design of new UK housing to minimize overheating risk (AECOM, 2019; Good Homes Alliance, 2019), there are significant numbers of the existing English housing stock that are exhibiting overheating in both cool and hot summers (Beizaee et al., 2013; Lomas et al., 2021). These and other studies have started to identify the types of dwellings at greatest risk of overheating, but there is stated to be no plan in place by the UK government to 'understand overheating risk and adaptation needs in existing homes' (Climate Change Committee, 2021).

There is a lack of a definitive methodology to determine the summertime overheating risk of existing UK homes. Common approaches involve modeling the housing stock either with simple physics-based models (Tillson et al., 2013) or by using dynamic thermal simulation software (e.g., Gupta & Gregg, 2012; Mavrogianni et al., 2012; Porritt et al., 2012). However, Lomas and Porritt (2017) identify that simple steady-state physics model is inappropriate for producing credible overheating predictions. Furthermore, dynamic thermal simulation is prone to prediction uncertainties pertaining to the accuracy of the model inputs and the way thermal processes are calculated within the software (de Wilde & Tian, 2012).

Alternative methods of assessing overheating include occupant surveys (Hulme et al., 2013), evaluating reported overheating from environmental health officers (Taylor, 2014), and building surveys carried out following the Housing Health and Safety Rating System (Dengel et al., 2016). It should be noted that neither of the latter two methods involve the collection of internal temperature data. The report from Dengel et al. notes that, 'the surveyor has to determine whether any risk is especially significant during a brief survey inspection' and, more worryingly, 'any risk should 'leap out' at the surveyor'. This inevitably means that overheating risk assessment using these methods is subjective.

Monitoring of internal temperatures, using sensors installed in rooms, can provide the most comprehensive and objective indication of overheating risk (Lomas et al., 2021). There are, however, some limitations to this approach. Firstly, monitoring campaigns are carried out during different spells of weather, making comparison or synthesis between studies difficult. Secondly, there is no current method of using monitored results to predict overheating in future weather conditions. Thirdly, temperatures are interpreted using criteria designed for overheating assessment by dynamic thermal modeling and dictate protracted monitoring periods such as a year or five months (e.g., CIBSE, 2017). Monitoring of indoor environmental conditions in occupied homes is costly and presents practical challenges to maintain data veracity (Gupta et al., 2020). Thus, a valid overheating risk assessment produced from shorter periods of monitoring would be beneficial to many stakeholders.

Most homes in the UK operate in a 'free-running' mode, that is, they do not have heating or cooling during the summer season. In free-running buildings, the thermal performance of the building fabric becomes the dominant factor in maintaining comfortable indoor conditions. Previous work has demonstrated that relationships between indoor and outdoor temperatures can be derived, which lays the foundation for empirical models (Nguyen et al., 2014; Nicol et al., 2020). Such models use data collected in existing buildings to evaluate building performance. They can be used both for prediction purposes or for deriving specific thermal properties of the building (Wang & Chen, 2019).

The adaptive approach to thermal comfort shows that in free-running buildings, the indoor comfort temperature—the temperature at which the majority of people will be comfortable—tracks the outdoor temperature (Nicol &

Humphreys, 2002). The setting of an upper threshold from this comfort temperature—accounting for the different sensitivities of occupants—means that overheating is deemed to occur when the indoor temperature is above this threshold (see CIBSE, 2013). Importantly, it means that overheating can be determined from just two variables—the indoor temperature and the outdoor daily mean temperature.

Methods of standardizing for outdoor temperatures, using linear regression models, to allow comparison between different homes have been previously applied to winter conditions in the UK (Hamilton et al., 2017; Oreszczyn et al., 2006). Similar techniques were adopted by Petrou et al. (2019) for summer periods, with the inclusion of global solar radiation into a multiple linear regression model, which produced a standardized internal temperature for each home. A study by Coley and Kershaw (2010) identified a linear response of indoor mean to changes in external mean temperatures using Dynamic Thermal Simulation models of different building variants. The latter studies have some limitations in their focus on mean, median, or maximum indoor temperatures rather than any of the overheating metrics commonly applied in built environment guidance documents and standards (e.g., CIBSE, 2013, 2017).

The work presented here is the first part of a doctoral research project to investigate the overheating signature of UK homes. The aim of this paper is to establish whether certain building spaces have a characteristic response or 'overheating signature' when exposed to outdoor conditions. These simple date-driven models would allow comparison between studies by 'standardising' overheating results, and the prediction of future overheating risk based on projected weather data. Applying the predictive models to national datasets would enable a 'mapping' of homes at risk of overheating. This would be of great benefit to inform future policies to make homes resilient to the effects of climate change.

2 Methods

This study used synthetic internal temperature data generated by dynamic thermal simulation of simple single-zone buildings located in the UK. The focus of analysis is on the warm period of the year from 1 May to 30 September. The use of synthetic data rather than data from field studies is beneficial in removing the effects of numerous unaccounted for secondary influences, or noise, to create a 'clean' or 'idealized' dataset (Reddy & Claridge, 1994). The method also allows the researcher to choose the external conditions to which the building or space is exposed: something that is very difficult to achieve in actual real-world buildings. Methods using synthetic data to identify a mathematical model structure are a common approach in research (Abdellatif et al., 2022; Reddy & Claridge, 1994; Uchida Frausto & Pieters, 2004).

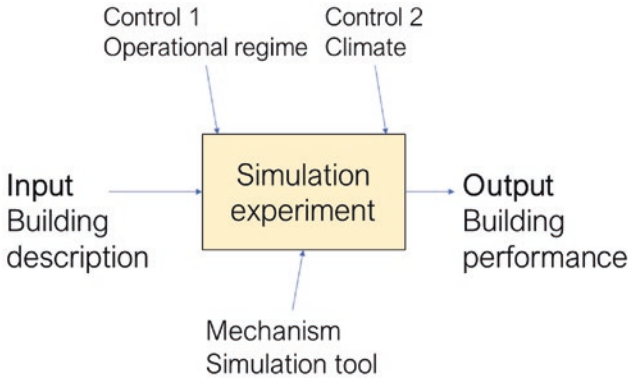

Fig. 1 ICOM framework for simulation experiments

This research adopts the inputs, control, output, mechanism (ICOM) framework for simulation 'experiments' (Augenbroe & Park, 2005; de Wilde, 2018) to generate internal temperature data as the output (Fig. 1). The ICOM framework allows a series of 'experiments' to be created by subjecting the input (building/space) to a series of different control parameters. The process of creating the synthetic indoor temperature data follows the stages below:

(1) Define the simulation software tool (Sect. 2.1).
(2) Define the building to include dimensions, layout, and construction details (Sect. 2.2).
(3) Define the climate and weather data files (Sect. 2.3).
(4) Define the operational regime of the building (Sect. 2.4).

2.1 Simulation Tool

EnergyPlus dynamic thermal simulation software version 8.6 was used as the simulation tool (EnergyPlus, n.d.) to generate the synthetic indoor temperature data. EnergyPlus is widely used within the research community for modeling and predicting overheating in buildings (Baniassadi & Sailor, 2018). EnergyPlus does not have a graphical user interface, so DesignBuilder software version 5.5 (Designbuilder, 2021) is used for modeling purposes. DesignBuilder software allows for the construction of 3D building models, data entry, and display of output results in tabular and graphical format.

The building models were simulated with four timesteps per hour (15 min interval). It is recommended to have as small a simulation timestep as possible when simulating one or more HVAC systems (CIBSE, 2015b). However, these simple building models are 'free-running' making a 15-min timestep appropriate. Outputs are reported as hourly values for the warm period of the year, 1 May–30 September.

Table 1 List of building simulation parameters

Case	BESTEST model	Infiltration (ach)	Window orientation	Window state	Location	Köppen climate classification
1	600FF	0.5	South	Closed 24/7	Loughborough	Cfb
2	600FF	0.3	South	Closed 24/7	Loughborough	Cfb
3	600FF	0.5	North	Closed 24/7	Loughborough	Cfb
4	600FF	Variable	South	Open 24/7	Loughborough	Cfb
5	600FF	Variable	South	Open when T_{op} > 25 °C	Loughborough	Cfb
6	900FF	0.5	South	Closed 24/7	Loughborough	Cfb
7	900FF	0.5	North	Closed 24/7	Loughborough	Cfb
8	600FF	0.5	South	Closed 24/7	Edinburgh	Cfb
9	600FF	0.5	South	Closed 24/7	Southampton	Cfb

2.2 Building Description

This study used simple building models representing a single-zone space. More complex building models require more parameter estimations, which can increase the risk of bias in the underlying assumptions (de Wilde, 2018). The method adopted is similar to that adopted by Mantesi et al. (2015) and uses the buildings developed for the Building Energy Simulation Test (BESTEST) diagnostic method (Judkoff & Neymark, 1995).

The BESTEST buildings were created for the purpose of comparative testing of building energy simulation software, and they consist of a series of carefully specified, test case buildings that progress from the extremely simple to the relatively realistic. There is confidence in the validity and quality of the BESTEST models as they have gone through a process of comparative testing (Judkoff & Neymark, 1995).

The BESTEST building models used were, 600FF and 900FF, representing a lightweight and heavyweight construction type, respectively (Table 1).

The case study 600FF building is rectangular with a single-zone (internal dimensions: 8 m × 6 m × 2.7 m) and two windows (3 m × 2 m) placed on the south-facing façade (Fig. 2). Sensible internal heat gains are set at 200W continuously. The 900FF case has identical dimensions, orientation, and operational regimes as the 600FF case, but the walls and floor are constructed of higher mass materials than the 600FF case. The detailed material and thermal properties of the case study buildings are tabulated in Appendix (Tables 2 and 3) and Judkoff and Neymark (1999).

The output internal temperatures from the 600FF and 900FF building models, simulated using the test protocol weather file (DRYCOLDTMY), were validated against results tabulated in a DesignBuilder validation report (Designbuilder, 2017).

Simple modifications were made to the original BESTEST building model by changing the orientation of the building (North facing glazing) and improving airtightness (infiltration rate reduced from 0.5 ach to 0.3 ach).

2.3 Climate and Weather Data

In building performance simulation, weather data are used to define the external conditions that a building or space is exposed to. The following criteria were used to select the weather files:

(1) Available for a whole year, (2) in a format suitable for simulation in DesignBuilder using EnergyPlus simulation engine, (3) representative of a wide range of outdoor dry-bulb temperatures that might be experienced in a UK context, (4) readily available and from a trusted source.

Weather files in the epw format were obtained from the COLBE project, which has data available on a 5 km × 5 km resolution across the UK (Eames et al., 2011; Liu et al., 2016). The case study buildings were simulated using 18 different weather files representing conditions between 1961 and 1990 and future projections for the period from 2070 to 2099. Three different types of weather file were used: (1) Test Reference Years (TRY) created to be representative of up to 30 years of meteorological data, (2) Design Summer Year (DSY)—fourth hottest weather of a 30-year period, and (3) Hot Summer Year (HSY)—selected based on the weighted cooling degree hours (see Liu et al., 2016). Each weather file has probabilities at the 10th, 50th, and 90th percentiles. That is, the 90th percentile weather file represents only a 10% probability that it will be hotter. Three UK locations were chosen representing the North, the Midlands, and the South: Edinburgh, Loughborough, and Southampton, respectively. Overall therefore, 18 weather files (current and future; 10%, 50%, and 90% percentile; and TRY, DSY, and HSY) were used for each of the three locations.

The TRY, 50th percentile, is used as the baseline file for calculating the anomaly ($\Delta T_{o,\ mean}$) for the mean outdoor dry-bulb air temperature over the warm period, for each of the other 17 weather files. It is calculated as the difference between the mean outdoor dry-bulb air temperature over the 1 May to 30 September period for the TRY, 50th percentile,

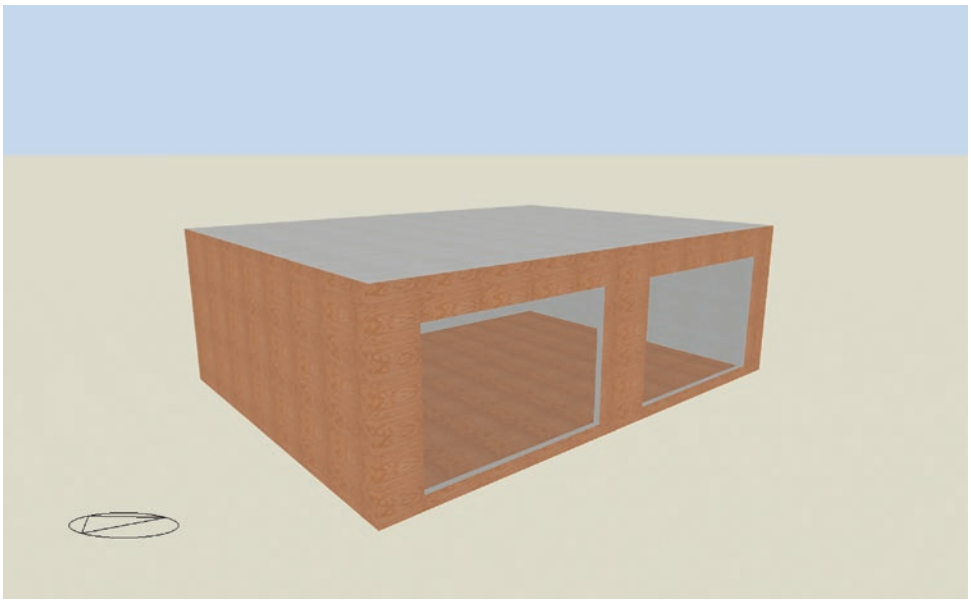

Fig. 2 DesignBuilder software rendered view of the BESTEST case 600 building

and the weather file in question. For example, a $\Delta T_{o,mean}$ value of zero means that the weather file had the same mean outdoor dry-bulb air temperature over the period.

2.4 Operational Regimes

The buildings modeled were 'free-floating' (no heating or cooling) which is the typical condition of most UK housing during the warm summer period. Simple modifications were applied to the window opening schedules to investigate the impact on overheating (Table 1, case 4 and 5). Natural ventilation is modeled dependent upon wind and outside temperature-driven exchanges following guidance in Garg et al., (2017: Ch 10). This was deemed important in building simulations investigating overheating (Schunemann et al., 2021). Each of the nine building cases were simulated with each of the 18 weather files making a total of 162 simulation 'experiments'.

2.5 Overheating Metrics

For the purposes of overheating analysis, the space is assumed to be occupied for 24 h each day. Thus, for the 1 May to 30 September period, the number of occupied hours is 3672.

Overheating metrics focus either on the protection of occupant health or on the thermal comfort of the occupants. For long-term thermal comfort evaluation, there is a myriad of different metrics (Carlucci & Pagliano, 2012). These range from simple single-parameter metrics to those requiring up to six different parameters (ibid.). Indoor air or operative temperatures[1] can be used as an indicator of indoor comfort conditions. Although humidity, in certain contexts, is an important factor for human thermal comfort, the effect is small enough to be neglected in the UK buildings (CIBSE, 2015a, 2015b).

Adaptive comfort theory is gaining widespread use in built environment regulations and standards (de Dear et al., 2020), and it is applied in recent work evaluating summertime overheating of English homes (Lomas et al., 2021). Adaptive comfort theory suggests that where the thermal environment creates discomfort, people will use available opportunities to restore their comfort (Nicol & Humphreys, 2002). In a home environment, people generally have greater agency to maintain their thermal comfort.

In order to assess the thermal comfort of occupants, and thus overheating risk, the methodology prescribed in CIBSE TM52 (CIBSE, 2013) was used. The standard is based on the adaptive comfort approach and makes a comparison of the actual indoor operative temperature with a daily maximum acceptable temperature, which increases with the exponentially weighted running mean of the mean daily outdoor temperature (see CIBSE, 2013: 7 for calculation method). The maximum acceptable temperature also depends on the needs of the building occupants. Category I is recommended for spaces that might be occupied by sensitive or vulnerable persons, whereas Category II is for a normal level of comfort expectation. A value for ΔT is obtained from the difference between indoor operative temperature (T_{op}) and the maximum acceptable temperature

[1] The operative temperature is a weighted mean temperature between air and radiant temperatures.

(T_{max}). The value of ΔT is rounded to the nearest whole degree (i.e., values between 0.5 K and 1.5 K round to 1 K). The total number of hours where ΔT is equal to or greater than 1 K is determined and expressed as a percentage of the occupied hours for the analysis period (NH_o). The space is deemed to be overheated according to criterion 1 of TM52 when $NH_o > 3\%$ of occupied hours between 1 May and 30 September.

The following metrics were applied in this study:

- The mean value of indoor operative temperature $T_{i,mean}$ (°C), calculated as the arithmetic mean of the 3672 hourly values from 1 May to 30 September.
- Number of overheating hours NH_o expressed as a percentage of total occupied hours (%), calculated following the procedure for a Category II comfort expectation.

Data manipulation and analysis were carried out in MS Excel. The hourly indoor operative temperature time series from 01:00 on 1 May to 24:00 on 30 September produced from each simulation experiment was used to calculate the two overheating metrics. A bivariate linear regression model was fitted to each data series with the overheating metric ($T_{i,mean}$ or NH_o) as the dependent variable and the anomaly ($\Delta T_{o,mean}$) of the mean outdoor dry-bulb air temperature as the independent variable. The coefficient of determination, R^2, was calculated for each regression model. The R^2 value represents the proportion of information that is explained by the mathematical model. It is important to state that R^2 is a measure of correlation, not accuracy of the mathematical model (Kuhn & Johnson, 2013). A residual plot was produced and evaluated to ensure the validity of the regression models.

3 Results

This section outlines the results of the study. It can be seen (Fig. 3) that (1) the response of the mean indoor temperature ($T_{i,\ mean}$) to the mean temperature anomaly ($\Delta T_{o,\ mean}$) over the five month period is strongly linear, (2) changes to the window opening, infiltration rate, and orientation lead to different gradients in the regression line, and (3) due to the fact that linear regression models are highly interpretable, a value of the gradient above 1 indicates that the whole period indoor mean temperature is amplified for each unit increase in the outdoor mean temperature.

Cases 6 and 7 (omitted from Fig. 3 for clarity) had an almost identical response to cases 1 and 3, even though the construction materials were heavyweight and lightweight, respectively. This is as expected because the fabric heat loss parameters of these cases were identical: the temporal

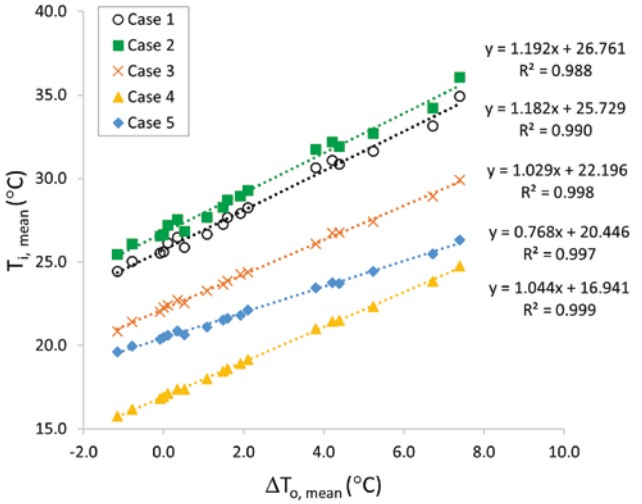

Fig. 3 Results from the simulation experiments for cases 1 to 5 together with the linear regression lines and coefficient of determination, R^2

effects on indoor temperature of different thermal masses are being 'averaged out' over the five month analysis period.

Although mean indoor temperature can indicate the propensity of a building space to be overheated, the analysis cannot be used to define overheating according to the contemporary criteria (e.g., CIBSE, 2013). Figure 4 shows for cases 1 to 5, the variation in the percentage of overheated hours (NH_o) with the mean temperature anomaly ($\Delta T_{o,\ mean}$) of the weather files. Similar to Fig. 3, there is a strong linear relationship across the different cases with the gradient of the regression line changing with the characteristics of the building and its operation.

It can be seen from Fig. 4 that case 4, in which the windows are open, has a gradient less than cases 1 to 3 where the windows are closed. Case 5, in which the windows are open when the indoor operative temperature is above 25 °C, had an even lower slope than all the other cases. We might tentatively suggest that ventilation, and especially temperature controlled ventilation, makes spaces more 'resilient' to future increases in warm period outdoor temperatures. This aligns with previous findings in overheating research on the benefits of controlled ventilation to reduce overheating risk (e.g., Mavrogianni et al., 2017).

The true test of a prediction model is its accuracy when fed by data not used in its creation (Kuhn & Johnson, 2013). In this work, it is especially important to demonstrate that the regression line is an inherent feature of the space (and independent of the weather data), i.e., that the linear relationships represent the overheating signature of the test case. To do this, the percentage hours overheated (NH_o) were predicted using the regression equation for case 1 using the Southampton (case 9) and Edinburgh (case 8)

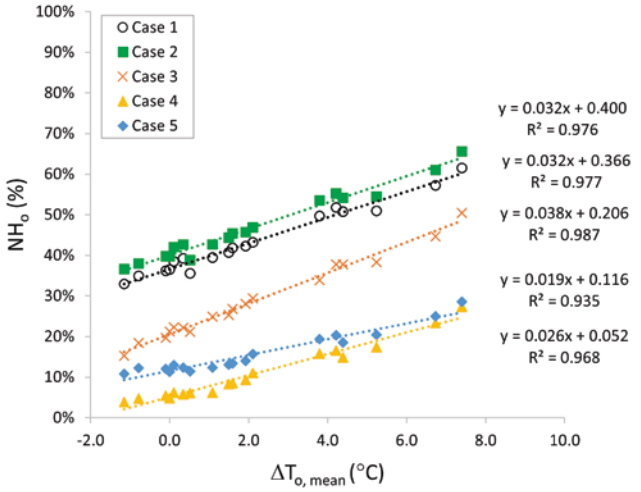

Fig. 4 Results from the simulation experiments for cases 1 to 5 for percentage of overheated hours together with the linear regression lines and coefficient of determination, R^2

weather data anomaly ($\Delta T_{o,\ mean}$). These resulting values were then compared to the percentage of hours overheated, synthesized for each of the 18 weather files using dynamic thermal simulation, cases 8 and 9. The corresponding regression line and R^2 value show the degree of fit between these two sets of values (Fig. 5).

Figure 5 shows that the regression model was able to predict the number of overheated hours for the same building located in a different location and experiencing different weather.

4 Discussion

Previous studies have found a strong linear association between outdoor temperatures and indoor temperatures in free-running building spaces (Coley & Kershaw, 2010; Nguyen et al., 2014). This study has gone further by determining relationships between a commonly applied overheating metric (percentage of hours overheated) and mean outdoor air temperature in the warm period of the year (May–September). This, we call, the overheating signature of the building space.

It is important to note that the average indoor temperature and overheating hours during the May–September period is much higher than plausible (or at least tolerable) in real-occupied homes. However, the results do illustrate the potential of these sorts of plots as the basis for overheating signatures.

Consistent with some of the current knowledge on summertime overheating in the UK homes (see Lomas & Porritt, 2017), this study has shown the impact that building orientation, and window opening regimes have on the percentage of hours overheated. A thermally lightweight building with glazing oriented to the south and windows closed all the time exhibiting a high percentage of hours overheated. The gradients of the regression equations, of overheating against outdoor temperature, differ between building spaces that have different characteristics (e.g., orientation or ventilation regime).

Of particular interest are the derived regression coefficients, which indicate that certain characteristics can lead to a greater impact on indoor overheated hours with respect to a rise in the warm period mean outdoor temperature. This is the first step in identifying an 'overheating signature' and identifying the homes that are at potentially greater overheating risk due to the projected increase in summertime temperatures.

The regression model developed in one location has been used to predict the likely overheating in another geographical location. There was very good correlation between the values predicted by the overheating signature and the synthetically overheating hours (as generated by dynamic thermal simulation experiments). These findings could have important implications for developing simple data-driven models that could be used to 'standardise' an overheating risk assessment for existing buildings. This could be

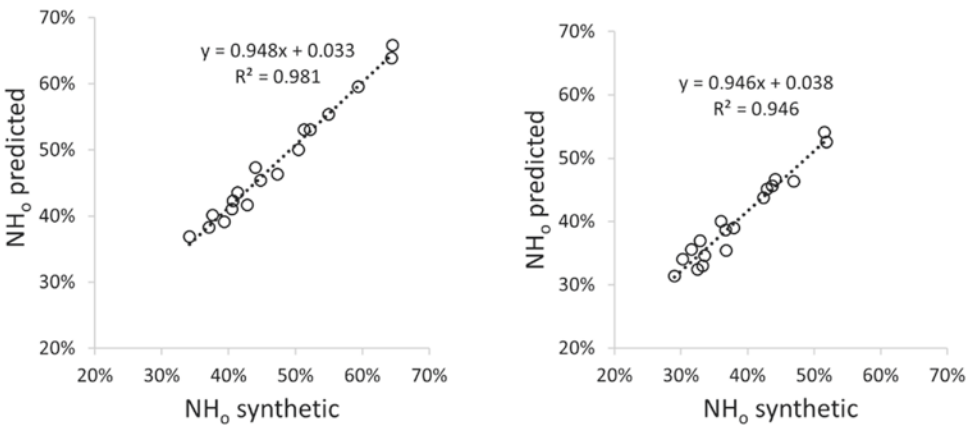

Fig. 5 Comparison of the number of overheated hours between the synthetic overheating values and values predicted by the linear regression model for case 1 located in **a** Southampton and **b** Edinburgh together with the linear regression line (dotted line) and coefficient of determination, R^2

achieved by reporting overheating in a 'reference year'—similar to that prescribed for quantification of overheating by simulation (see CIBSE, 2017).

The study has indicated the potential to use simple linear models that only require the collection of outdoor air temperature data—which is widely available for many countries—to make predictions of future overheating risk. Using data collected from a representative sample of homes would allow scaling and the prediction of future overheating in national housing stocks.

Further work is required to establish the viability of the technique in determining overheating risk of rooms in actual occupied dwellings, firstly under controlled laboratory conditions and then using data from field studies.

This study has some limitations. The synthetic data were generated by the EnergyPlus software, which, like all dynamic thermal modeling software, can only be expected to present an approximation of reality (de Wilde, 2018). The BESTEST building model is a simplified single-zone enclosure representing a building with poor energy efficiency, e.g., below that of the current UK building regulations (Mantesi et al., 2015). The enclosure is highly solar driven and so it overheats well beyond that expected in real dwellings. The synthetic data produced by EnergyPlus simulations did not account for inter-zone heat transfer, the variability of internal heat gains, or complex occupant behavior of the type which may occur in an actual occupied dwelling.

5 Conclusions

Being able to predict the summertime overheating risk of existing UK homes is important to ensure the health and well-being of occupants as the climate warms. Synthetic temperature data produced from dynamic thermal simulation of single-zone building models located in the UK were used to determine the relationship between indoor and outdoor temperatures. The idea is that this relationship would represent a unique overheating signature for the building.

Simple regression models of average indoor operative temperature against the anomaly of outdoor average air temperature, for the period 1 May–30 September, showed a strong linear correlation ($R^2 = 0.99$). Further analysis using a commonly adopted overheating metric as the dependent variable (percentage of hours overheated) also revealed a strong linear correlation ($R^2 = 0.94$–0.98).

The different building ventilation strategies and orientations produced different slopes of the regression lines indicating that these characteristics make a space more or less 'resilient' to rises in average summertime outdoor temperature.

The robustness of the simple regression model for one space was tested on synthetic data not used in its creation for two very different UK locations. High coefficients of determination of up to $R^2 = 0.98$ were achieved.

This combination of findings provides support for the conceptual premise that different spaces in buildings have a distinctive 'overheating signature'. The signature derived from one set of monitored data will enable the risk that the space will overheat to be predicted for different and future weather conditions.

More work is, however, needed to explore the relationships between indoor and outdoor temperatures on, for instance, a daily basis, and to test the methodology on data collected in actual occupied buildings.

Acknowledgements This work was conducted as part of a research project pursued within the London-Loughborough (LoLo) Centre for Doctoral Training in Energy Demand. The EPSRC funding for the center is gratefully acknowledged (grant number EPL01517X1).

Appendix

See Tables 2 and 3.

Table 2 Case study building 600FF construction parameters

Element	k	Thickness	U	R	Density	C_p
	W/(mK)	m	W/(m^{2}K)	(m^{2}K)/W	kg/m^3	J/(kgK)
Exterior wall (inside to outdoors)						
Interior surface coefficient			8.290	0.121		
Plasterboard	0.160	0.012	13.333	0.075	950	840
Fiberglass quilt	0.040	0.066	0.606	1.650	12	840
Wood siding	0.140	0.009	15.556	0.064	530	900
Exterior surface coefficient			29.3	0.034		
Total air–air			0.514	1.944		
Total surf–surf			0.559	1.789		
Floor (inside to outdoors)						
Interior surface coefficient			8.290	0.121		
Timber flooring	0.140	0.025	5.600	0.179	650	1200
Insulation	0.040	1.003	0.040	25.075	0	0
Total air–surf			0.039	25.374		
Total surf–surf			0.040	25.254		
Roof (inside to outdoors)						
Interior surface coefficient			8.290	0.121		
Plasterboard	0.160	0.010	16.00	0.063	950	840
Fiberglass quilt	0.040	0.1118	0.358	2.794	12	840
Roofdeck	0.140	0.019	7.368	0.136	530	900
Exterior surface coefficient			29.300	0.034		
Total air–air			0.318	3.147		
Total surf–surf			0.334	2.992		
Sensible internal gains		ach	Volume, m^3			
200W (60% radiative, 40% convective)		0.500	129.600			

Table 3 Case study building 900FF construction parameters

Element	k	Thickness	U	R	Density	C_p
	W/(mK)	m	W/(m^{2}K)	(m^{2}K)/W	kg/m^3	J/(kgK)
Exterior wall (inside to outdoors)						
Interior surface coefficient			8.290	0.121		
Concrete block	0.510	0.100	5.100	0.196	1400	1000
Foam insulation	0.040	0.0615	0.651	1.537	10	1400
Wood siding	0.140	0.009	15.556	0.064	530	900
Exterior surface coefficient			29.3	0.034		
Total air–air			0.512	1.952		
Total surf–surf			0.556	1.797		
Floor (inside to outdoors)						
Interior surface coefficient			8.290	0.121		
Concrete slab	1.130	0.080	14.125	0.071	1400	1000
Insulation	0.040	1.007	0.040	25.175	0	0
Total air–surf			0.039	25.366		
Total surf–surf			0.040	25.246		

(continued)

Table 3 (continued)

Element	k	Thickness	U	R	Density	C_p
	W/(mK)	m	W/(m^{2}K)	(m^{2}K)/W	kg/m^3	J/(kgK)
Roof (inside to outdoors)						
Interior surface coefficient			8.290	0.121		
Plasterboard	0.160	0.010	16.00	0.063	950	840
Fiberglass quilt	0.040	0.1118	0.358	2.794	12	840
Roofdeck	0.140	0.019	7.368	0.136	530	900
Exterior surface coefficient			29.300	0.034		
Total air–air			0.318	3.147		
Total surf–surf			0.334	2.992		
Sensible internal gains		ach	Volume, m^3			
200W (60% radiative, 40% convective)		0.500	129.600			

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Calm Space, an Outdoor Escape Area: A Feasibility Study on Social Participation of Children with Autism

Ali Hamzehloui

Abstract

Autism spectrum disorder (ASD) is a behaviorally defined neurodevelopmental disorder characterized by social-communication deficits and restricted, repetitive behaviors. It affects ~1 in every 54 children in the USA. These autistic children suffer from anxiety, particularly when they engage in outdoor activities, mostly due to environmental stimuli and unawareness of communicating with them. While the evidence suggests that engaging in outdoor activities can improve the quality of life of autistic children, they reportedly rarely engage in outdoor activities. Therefore, they are introduced to autism centers with well-established quiet spaces and retreat areas by their mentors and are guided to gradually use them to relieve their stress/anxiety. They can return to the classroom when they feel calmer. Unfortunately, they lack access to such spaces in public areas when overstimulated. This research aims to conduct a feasibility study on designing calm spaces in public areas for children, including autistic ones. The required data were collected by performing an extensive literature review on autism design features. Then, questionnaires were distributed among experts regarding the types of calm spaces and design features. The Delphi method is employed to conduct the questionnaire survey and continue in three rounds until the experts reach a consensus. The final result approved one out of the three types of calm spaces. The expert panel also agreed on all design features attributed to autism.

Keywords

Autism · Social participation · Calm space · Delphi method

1 Introduction

Socialization is an essential part of human life that can benefit both individuals and the community. People spend a considerable amount of time every day in public places, walking on crowded streets, communicating with other citizens, and recognizing emotional cues by reading their facial expressions. However, a group of people, including those with autism, experience severe stress whenever they go to public places. Autistic people are more sensitive to environmental stimuli (e.g., ambient light intensity or surrounding sounds) and lack basic communication skills that come naturally to others. They get stressed whenever they step outdoors or come across someone, and thus, they avoid outdoor activities. However, research has shown that engaging in outdoor activities can help autistic people improve their social skills and adapt to outdoor environments. We can help autistic people improve their social presence and quality of life by preparing outdoor environments in a way that helps reduce their stress levels.

1.1 Definition of Autism

Autism spectrum disorder (ASD) is a "behaviourally defined neurodevelopmental disorder associated with the presence of social-communication deficits and restricted and repetitive behaviors" (Ousley & Cermak, 2014). The evidence suggests an increase in the total prevalence of ASD. From 1997 to 2017, the prevalence of various developmental disabilities significantly increased (by 38.3%) from 12.84% to 17.76%. Strikingly, ~1 in 54 children has been identified with ASD among 8-year-old children in 11

A. Hamzehloui (✉)
Ahvaz, Iran
e-mail: Hamzehloui.ali@gmail.com

A. L. Pisello et al. (eds.), *Building Resilient and Healthy Cities: A Guide to Environmental Sustainability and Well-being*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-031-33863-2_8

sites of the USA, according to estimates (Maenner et al., 2020). Regarding this remarkable prevalence, the social participation of individuals with ASD has been associated with many problems originating from their sensory processing disorder (SPD).

1.2 Social Participation of Children with ASD

Participation is defined by the International Classification of Functioning, Disability, and Health (ICF) as the "involvement in life situations," expressing supporting and hindering environments for participation partly involving environmental factors (Organization, 2001). According to ICF, participation is affected by environments, defined as "the physical, social, and attitudinal environment in which people live and conduct their lives." People with autism indicate lower participation levels in their private lives (Lamash et al., 2020) and enjoy group physical activities less than others (Stanish et al., 2015). Due to their social, intellectual, and sensory disabilities, the community often does not meet autistic children's needs adequately. Their meager participation can be attributed to unfair judgment faced by them and their parents (Ryan, 2010).

Increased sensory processing in children with High-Functioning Autism Spectrum Disorder is one of the obstacles to physical activity participation (Hochhauser & Engel-Yeger, 2010). Although this trait encompasses the entire spectrum of autism, HFASD children are hypersensitive to environmental stimuli such as light and sound (Nagib & Williams, 2017). Inclement weather, noisy spaces, perplexing surface textures, crowds on a sidewalk, or even misinterpreting people's facial expressions when interacting with them can all trigger hypersensitivity reactions (Obrusnikova & Cavalier, 2011). Attending social functions and walking among a crowd of people are sometimes unavoidable, and for most children with ASD, this experience is traumatic. In essence, evidence shows that autistic people have a greater interpersonal distance than non-autistic people (Gessaroli et al., 2013).

Wandering is another issue that can quickly escalate into a disaster. Wandering, also known as elopement, is a behavior that occurs when children attempt to flee from a current situation (indoor or outdoor) to avoid environmental agitation and non-preferred activities (Phillips et al., 2018). Almost half of the children with ASD are said to wander, posing a serious risk of bodily harm (Anderson et al., 2012). While a lot of wandering happens in public places (Rice et al., 2016), designing outdoor environments for autism is a good way to control the sensory stimuli in open spaces and increase social participation. "Encouraging learning, promoting autonomy, making it easier to socialize, ensuring independence, or even preserving the dignity of the person with autism" are some of the goals of autism design (Segado & Segado, 2013). Mostafa was one of the first to develop the ASPECTSS design index, which comprises seven major ASD principles and serves as a design criterion for architects. Acoustics, spatial sequencing, quiet, compartmentalization, transition spaces, sensory zoning, and safety are the seven factors (Mostafa, 2014). She paved the way for other architects who were interested in designing for people with autism.

2 Designing for Autism

Designing could be difficult because of the properties that must be accommodated for both hypersensitive and hyposensitive individuals. Concepts of autism-friendly architecture can act bilaterally in terms of sensitivity, weakening one feature while strengthening another (Kinnaer et al., 2014). Also, as Mostafa (2014) pointed out, while a customized design may work extremely well in environments where only one autistic user's needs are met, it would be much more difficult to transfer to group settings where users' needs may be vastly different. As a result, the concept could lead to a controllable area with a variety of comfort features that, on the one hand, eliminate stimulations. On the other hand, intensify stimuli. Table 1 shows the factors that influence design for autistic children.

Sensory zoning is a sensory filtration technique that divides spaces into high, moderate, and low stimulation zones based on their sensory stimulation levels (Mostafa, 2019). When a person is anxious inside, there must be a way out. Quiet spaces, also known as low-stimuli spaces, are the most recommended stress-relieving spaces by both architects and autistic children's mentors.

As previously stated, numerous studies demonstrate the importance of people with autism participating in public spaces. Statistics also show that these people have a low social presence due to the sensory-cognitive issues mentioned earlier. As a result, reducing these issues is expected to increase social participation among people with autism in the community. However, in educational settings such as autism centers, some of these issues have already been addressed using quiet space.

3 The Role of the Escape Space

An escape space is a "small, defined, and discrete sensory-neutral environment throughout a building easily accessible to autistic users" that must be physically and virtually enclosed (Mostafa, 2019). They are, in fact, semi-private areas that range from "Snoezelen" rooms to craft/hobby rooms to sun/porch areas, all of which provide privacy

Table 1 Factors affecting the autism design

Factors affecting design	References
Light	Mcallister (2010), Whitehurst (2006), Mostafa (2007), Humphreys (2011), and Richer and Nicoll (1971)
Calmness, order, simplicity, and minimizing the use of decorations	Mcallister (2010), and Humphreys (2011)
Color	Whitehurst (2006), and Mostafa (2007)
Space organization	Khare and Mullick (2008), Whitehurst (2006), Vogel (2008), Mostafa (2007), and Richer and Nicoll (1971)
Predictable spaces	Vogel (2008), Mostafa (2007), Khare and Mullick (2008), and Mcallister (2010)
Privacy, personal space	Mcallister (2010), Humphreys (2011), and Richer and Nicoll (1971)
Acoustic	Mcallister (2010), Whitehurst (2006), Humphreys (2011), and Mostafa (2007)
Safety	Ahrentzen and Steele (2009), Mcallister (2010), Khare and Mullick (2008), Vogel (2008), and Humphreys (2011)
Heating and ventilation	Whitehurst (2006), and Mostafa (2007)
Pattern and material	Whitehurst (2006), and Mostafa (2007)

through choice and control (Gaines et al., 2016). This space can be created by dividing rooms into small partitioned areas and used to take refuge from overstimulation environments (Nagib & Williams, 2017) or by creating a quiet closet decorated with soft light and pillows (Gaines et al., 2016; Nagib & Williams, 2017). The effectiveness of this area has been demonstrated by ASDs who have described narratives as a safe haven (Kinnaer et al., 2016) and has been recommended as an autism-friendly architecture principle (Ghazali et al., 2019; Kinnaer et al., 2014). Individuals should not be separated from their classmates in escape spaces in the classroom, nor should they be mistaken for a rest area (Kabot Susan, 2010). When children are calm, they should be taught how to use the space. Assistants may, however, be required to provide verbal direction (Colvin & Sheehan, 2012).

3.1 The Definition of an Escape Space by Architectures

Autism's involvement in non-psychological issues had not been common in the past. Autism awareness has increased as a result of media and related organization activities (Wilingham, 2014). As a result of the increased attention, scholars and organizations have come out in favor of the autism-friendly approach. The world's attention has clearly been drawn to autism by tracking the term "autism-friendly" frequently on the internet between 2004 and 2018 (Fig. 1). Architecture, too, takes an autism-friendly approach, and architects and autism experts have formed a collaborative relationship. Architects have been allowed to focus on dedicated spaces as a result of this opportunity. Escape space is one of the necessary but underutilized spaces. Magda Mostafa first introduced the escape space (Mostafa, 2008) and developed it as a small Snoezelen (Mostafa, 2014, 2019).

Working on escape space as a de-escalation strategy later catches the attention of researchers. A team of researchers developed a Visual Sensory-Based Quiet Room (both the quiet room and the escape space have similar functions). This room is based on three parameters: the calming function of quiet rooms as transmitted from previous quiet room theories, safety, and visual comfort (Marwati et al., 2021). Escape space is also listed as one of the spatial criteria in a scoping review on built environment design for autistic people published in 2021 (Tola et al., 2021). Architects have also put what they have learned about quiet rooms into practice. Creating quiet rooms in airports (Harpaz, 2017) and amusement parks designed specifically for people with autism (Amusement Park Offers Autism "Calming Room", 2018; Autism Center—Activities & Theme Park Resources, Sesame Place, 2018) is just a few examples of architects' efforts in this field.

4 Calm Space as an Outdoor Escape Space

Despite some difficulties in everyday outdoor activities, ADSs can participate more effectively at home or in the classroom. One of the main problems is that they have a sensory disorder, which causes anxiety. Stimulus minimization is a technique for helping children manage their emotions and behaviors. The presence of a calm space in these places is one of the most effective ways to maximize the participation of people with autism in social situations. A calm space is modeled after the quiet area found in autism classrooms. It can be used in public spaces with some modifications. Like a telephone kiosk, these spaces

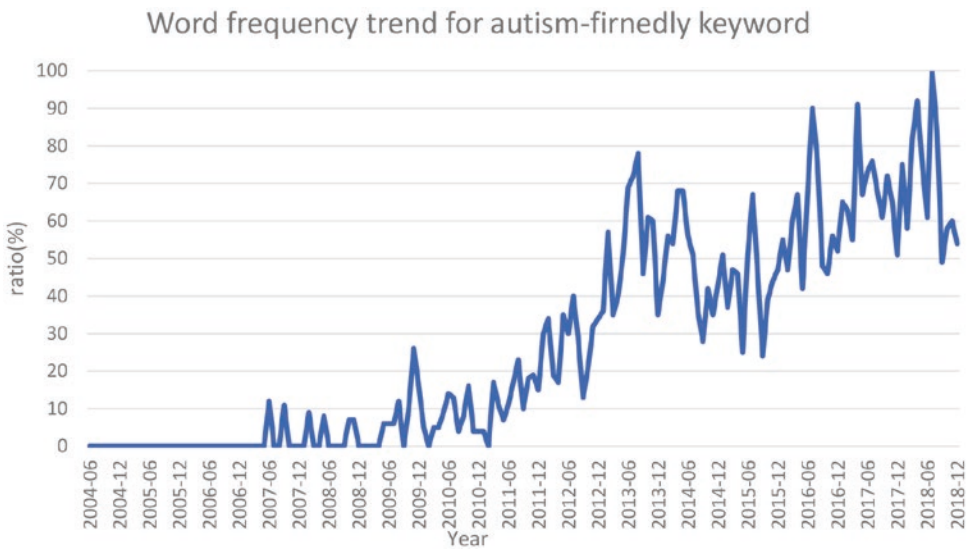

Fig. 1 Frequency of using the word "autism-friendly" between 2004 and 2018 in Google Trends

can be installed in any desired location or in a room within the urban wall. Smart applications can be used to provide the location of a calm space for people with autism or their parents. The calm spaces can also be in the form of a small portable tent or an open space, ready to be used when the person with autism is experiencing extreme stress or tensions due to their surroundings. This study aims to gather expert opinions on the new concept of calm outdoor space. They also assessed the significance of calm space design features.

5 Methodology

The procedure begins with data collection based on a literature review. The data included different types of considered calm outdoor spaces, as well as design features for autistic children. Then, experts were asked to fill out a questionnaire about the different types of calm spaces and design features. Three rounds of questionnaires were used to conduct the survey. The expert panel gave their opinion in each round, and the result was shared with other participants who did not know each other. If all questionnaire items meet consensus criteria in any round, they are removed from the next round. The blank area at the end of the questionnaire is for more suggestions or additional explanations that experts prefer to include.

5.1 Delphi Method

The Delphi method was used to conduct the survey. Delphi is a research method that involves gathering and categorizing expert knowledge, administering a series of questionnaires to experts, and receiving feedback after each round (Ziglio & Adler, 1996). The Delphi method is useful for generating ideas and prioritizing tasks (McMillan et al., 2016). Delphi is a method that allows experts to share their ideas without having to face each other, thereby reducing bias. Because there are no established guidelines for the number of rounds (Rådestad et al., 2013), the number of rounds in this study was set to three. Because the Likert scale is the most commonly used Delphi technique (Zartha et al., 2018), questions were collected using a five-point Likert scale. It consisted of 37 questions, each of which was graded on a scale of "strongly agree (5 points)" to "disagree (1 point)."

5.2 Delphi Procedure

Nominated participants received questionnaires to respond to in the first round. They were asked to rank the importance of each item on a scale of one to ten. The median score of each answer was highlighted in the second round as feedback from the previous round. This feedback reveals a wide range of expert tendencies when it comes to scoring specific questions. In addition, some experts suggested that some questions can be clarified further to avoid misunderstandings. For respondents' imagination, render frames were used to depict calm space types. All of the experts were given copies of the attached explanations. Questions that received unanimous approval were moved to the next round. Four open-ended questions were added to ask any remaining questions that the Likert scale could not answer in this round.

5.3 Questionnaire

Two experts review the questionnaire to ensure it is free of double-barreled questions. Participants in questionnaire-based surveys must be fully aware of the items before providing accurate responses (Aithal & Aithal, 2020), to ensure that respondents understood the problem and the purpose of the study and that the researcher delivered a questionnaire and explained all of the items once. The questionnaire was given to two architecture professors because reliability and validity are important when evaluating a questionnaire (Kachroo & Kachen, 2018). They aided in the organization and simplification of the questionnaire's items. The main framework, public awareness actions, and design features are all divided into questions. The main framework questions the feasibility and necessity of having fixed and portable calm spaces. A set of plans for introducing calm space to consumers is known as public awareness actions. The statements in this section of the questionnaire can be used as a starting point for further investigation. Designers can be aware of the importance of escape design criteria in urban environments thanks to design features.

5.4 Consensus Criteria

The expert panel consensus is measured using three mixed criteria. The interquartile range number (IQR ≤ 1), the standard deviation (SD)<1, and the median number ≥ 4 are among the criteria (Musa et al., 2015). The questionnaire was send to the expert panel in three rounds. Each item that met all of the criteria was considered a complete agreement and was not considered in the following round. Eventually, inquiries that were not met the criteria in three rounds were assumed as a disagreement.

5.5 Sampling

Experts were chosen based on four criteria. Four criteria for this matter are knowledge and experience, a desire to participate, communication skills, and adequate time for participation (Rådestad et al., 2013). Using Delphi for studies with less than ten participants is uncommon. However, given the scarcity of specialized experts in some fields, a small group of experts can be surveyed with high level of confidence (Akins et al., 2005). For instance, a Delphi study on the therapeutic significance of drug interactions was conducted with only five members in the expert panel (Malone et al., 2004). Seven people were invited to participate in this study, and five of them responded. All of the experts on the panel (Table 2) have practical experience with autism. Two of them are more involved (the autism center's headmaster). The remaining three experts have more academic experience (two of them are faculty members of the rehabilitation campus, and one left is a faculty member of the Nursing and Health Research Department). Four out of five experts were given the questionnaire in person, and one was notified via email. There are at least 45 days between each round to reduce the chance of experts memorizing answers.

6 Data Analysis

Descriptive and frequency statistics from SPSS are used to evaluate the questionnaire. The median number of scores, SD, and IOR number are all used to evaluate each item. According to Table 3, experts agreed on 13 items in round 1, 17 items in round 2, and 5 items in round 3. Two items did not pique the respondent's interest.

6.1 Descriptive Statistics

Round 1 has a significant number of questions with a standard deviation number greater than one, as shown in the bar graph (Fig. 2) (seven items with SD1). While it decreased in round 2 (two items with SD1), it is now over in round 3. Overall, the main framework and spatial features' sections had more instability than the other sections. Additionally, fluctuations in graph bars during rounds are related to eliminating items (problematic items remain for the next round). However, the average SD in the final round indicates a degree of consensus (third round SD = 0.550.57 = total average SD).

During three rounds of approval, all of the design sections were fully approved. Participants' early agreement on all items in the sensory features section (Fig. 3) can be seen in comparing sections related to design features (Fig. 3) (from 100% means fully disagree to 0% means fully agree). Spatial, qualitative, and public awareness features are graded (with approval rates of 88.8%, 85.6 percent, and 71.3% until round 2), respectively.

Parks and shopping malls were identified as the best locations to build calm spaces in the last round's open-ended questions (Table 4). According to the expert panel, sensory stimuli are the most important factor, which should be controlled by the calm space. They also mentioned that people's abusive behavior stemming from a lack of understanding of autism is the main cultural feature that can influence the use of calm space. People may stigmatize parents of autistic children, which reduce the likelihood of using calm space. Two experts mentioned that they would like to see more features in the calm space. The ability for children to return to their previous situation quickly, as well as having instruments in an indoor space for children's distraction, is expert comments.

Table 2 List of expert panel specifications

Expert's code	Sex	Age	Field of study	Work experience
1	Male	56	(Ph.D.) Intellectual and Developmental Disabilities (IDDs)	15 years—Research Associate at the Ulster University
2	Male	47	(Ph.D.) Occupational Therapy (OT)	25 years—Assistant Professor of Occupational Therapy at Ahvaz Jundishapur University of Medical sciences
3	Female	39	(Ph.D.) General psychology	11 years—Manager of Nahal Autism Center-(Ahvaz)
4	Female	39	(Master's degree) Occupational Therapy (OT)	13 years—Instructor of Occupational Therapy at Ahvaz Jundishapur University of Medical sciences
5	Female	47	(Master's degree) Psychometrics	6 years—Manager of Behdad Autism Center (Ahvaz)

Table 3 Round Delphi survey result and agreed items based on consensus criteria

Subsection	Item numbers	Mean R(1)	SD R(1)	(IQR) R(1)	Mean R(2)	SD R(2)	(IQR) R(2)	Mean R(3)	SD R(3)	(IQR) R(3)	Agreement
Main framework	Q1	4	1.22	2.00	4	0.83	1.50	4	0.83	1.50	No
	Q2	5	1.09	2.00	4	0.83	1.50	4	0.54	1.00	Yes
	Q3	3	0.89	1.00	3	0.89	1.50	3	0.54	1.00	No
Public awareness actions	Q4	5	1.30	2.00	5	0.89	1.50	4	0	1.00	Yes
	Q5	5	0.54	1.00	–	–	–	–	–	–	Yes
	Q6	5	0.89	1.50	5	0.44	0.50	–	–	–	Yes
	Q7	5	0	0	–	–	–	–	–	–	Yes
	Q8	5	0	0	–	–	–	–	–	–	Yes
	Q9	4	0.44	1.50	4	0.83	1.50	4	0.70	1.00	Yes
	Q10	5	0.83	1.00	–	–	–	–	–	–	Yes
Sensory features	Q11	4	0.89	1.50	4	0.44	0.50	–	–	–	Yes
	Q12	4	0.83	2.0	4	0.54	1.00	–	–	–	Yes
	Q13	5	1.00	1.50	5	0	–	–	–	–	Yes
	Q14	5	0.89	1.50	5	0	–	–	–	–	Yes
	Q15	5	0.89	1.00	–	–	–	–	–	–	Yes
	Q16	5	0.54	1.50	5	0	–	–	–	–	Yes
	Q17	5	0.89	1.50	5	0	–	–	–	–	Yes
	Q18	5	0.89	1.50	5	0	–	–	–	–	Yes
	Q19	5	0.89	1.00	–	–	–	–	–	–	Yes
	Q20	5	0.54	1.00	–	–	–	–	–	–	Yes
	Q21	4	0.54	1.00	–	–	–	–	–	–	Yes
Spatial features	Q22	4	0.54	2.00	5	1.34	1.50	4	0.70	1.00	Yes
	Q23	4	1.30	1.50	4	0.54	1.00	–	–	–	Yes
	Q24	5	0.83	1.00	–	–	–	–	–	–	Yes
	Q25	4	0.54	2.00	4	0.44	0.50	–	–	–	Yes
	Q26	4	1.00	1.00	5	0.54	1.00	–	–	–	Yes
	Q27	4	0.70	0.50	–	–	–	–	–	–	Yes
	Q28	5	0.44	1.50	5	0	–	–	–	–	Yes
	Q29	5	0.89	1.00	–	–	–	–	–	–	Yes
	Q30	5	0.54	1.00	–	–	–	–	–	–	Yes

(continued)

Table 3 (continued)

Subsection	Item numbers	Mean R(1)	SD R(1)	(IQR) R(1)	Mean R(2)	SD R(2)	(IQR) R(2)	Mean R(3)	SD R(3)	(IQR) R(3)	Agreement
Qualitative features	Q31	5	0.54	1.50	5	0	–	–	–	–	Yes
	Q32	4	0.89	1.50	4	1.00	2.00	5	0.54	1.00	Yes
	Q33	5	1.09	1.00	5	0	–	–	–	–	Yes
	Q34	5	0.54	1.00	–	–	–	–	–	–	Yes
	Q35	5	0.54	1.50	5	0	–	–	–	–	Yes
	Q36	5	0.89	1.50	5	0	–	–	–	–	Yes
	Q37	4	0.89	1.50	5	0	–	–	–	–	Yes

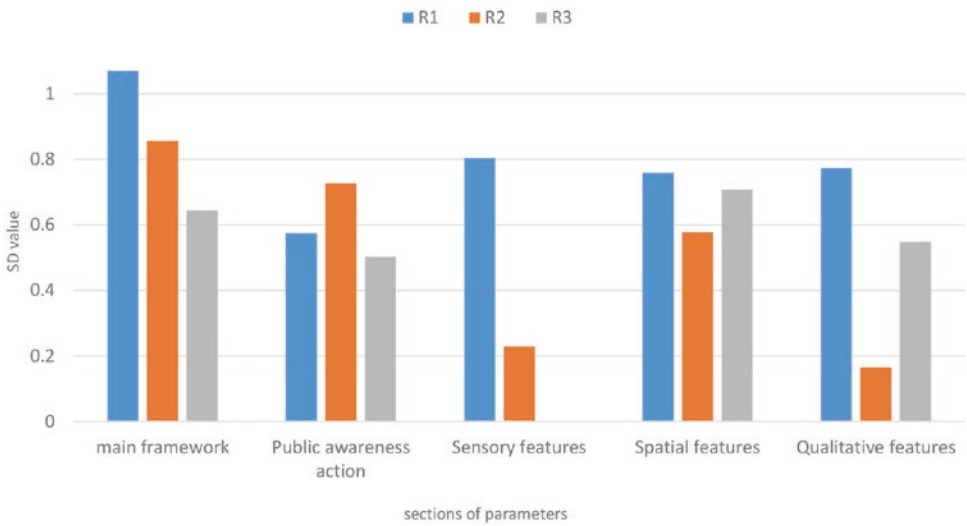

Fig. 2 Comparison of SD numbers among questionnaire sections

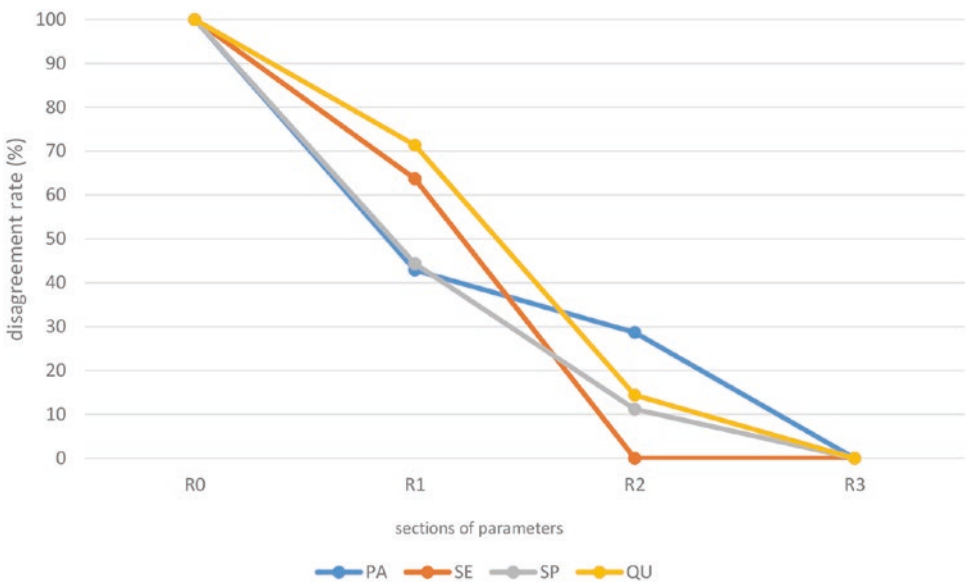

Fig. 3 Mean of the sections related to design features

Table 4 Summary of open-ended survey responses

Expert's code	Questions			
	What are urban areas suitable for locating a calm space?	What is the main factor that needs to be considered in a calm space?	What cultural features can influence the efficiency of a calm space?	What function or feature can be added to a calm space?
1	School park	Control the sensory stimuli	Autism parental discomfort from stigma	Help keep children in touch with the surroundings the ability for children to get back to the former situation immediately by utilizing portable gadgets
2	Park-shopping mall	Well-accessible location	Societal attitudes toward autism	None
3	Shopping mall	Neutralize sensory stimuli	Public knowledge about autism	Instruments in indoor spaces for children distraction
4	Shopping mall-sidewalk	Thermal insulation for more comfort	Increasing public awareness to de-stigmatize calm space users	None
5	Park	Control the sensory stimuli	Societal attitudes toward autism	None

Table 5 Evaluation of a calm space in three rounds

Calm spots' illustration			  
Calm spots' explanation	Fix calm space embedded in urban facades or shopping malls	Fix calm space as urban furniture—like a telephone booth	Portable calm spaces
Consensus criteria test (round 1)	MD: 4	MD: 5	MD: 3
	SD: 1.225, IQR: 2	SD: 1.095, IQR: 2	SD: 0.894, IQR: 1
Consensus criteria test (round 2)	MD: 4	MD: 4	MD: 3
	SD: 0.837, IQR: 1.5	SD: 0.837, IQR: 1.5	SD: 0.894, IQR: 1.5
Consensus criteria test (round 3)	MD: 4	MD: 4	MD: 3
	SD: 0.837, IQR: 1.5	SD: 0.548, IQR: 1	SD: 0.548, IQR: 1
Result	Fail	Pass	Fail

7 Conclusions

The results of the expert brainstorming show that the expert panel prefers fixed, calm spaces to portable ones. During the three rounds, two of the three types of calm space were refused. As Table 5 shows, consensus criteria ($MD \geq 4$, $SD < 1$, and $IQR \leq 1$) were counted for types of calm spots (green is considered for accepted values). Another clear result was the high level of agreement in most sensory and qualitative characteristics. While these characteristics are the foundation of the calm space, the implication was foreseen. Because there is an interdisciplinary approach to the spatial field, finding a significant relationship between respondents' knowledge and given data causes uncertainty in answers. The experts' consensus appears to be positive. Expert responses may show hints of hesitation if there is a calm space in public specifically designed for children with autism. The specialists were not unfamiliar with the concept of calm space. It was inspired by the escape room and incorporated elements from the sensory room. Some of the experts in the first meeting had similar images of calm space. They compared the calm space to similar spaces they had read about or visited, such as escape space and Snoezelen, and wondered if the survey was accurate. In the calm space, experts insisted on obsessively controlling sensory input data on autistic children. They pointed out that the broad definition of calm space appears to be effective, but more details need to be discussed. It allows researchers to look into supporting details about calm space.

8 Research Limitations

The questionnaire's features were limited in their selection. The article's definition of "space" refers to a temporary location that serves as a safe haven for autistic children, which supports the study's goal. As a result, if the portable calm space is considered, it will require additional new features. The pilot location's cultural background and climate study are not considered in this study because it needs to investigate the pilot location's cultural background and climate study. There is also a broader range of disorders that can benefit from a calm space (like sensory processing disorder). Autism society, on the other hand, is considered the target population, which includes both autistic children and the rest of the related disorders, because autism has more intense behavior.

Appendix

Feasibility study and evaluation of calm spots in public spaces			Significance				
Creating calm spots in public spaces–			Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
The main framework	1	Designing fixed, calm spots in public spaces as part of the urban wall (such as a room embedded in the direction of urban buildings)					
	2	Designing a calm spot as an urban component (such as a telephone kiosk in a park or a pedestrian zone)					
	3	Designing portable, quiet spaces for use in public spaces as a temporary enclosure (such as a small travel tent, a special hat, or even virtual reality goggles)					

Feasibility study and evaluation of calm spots in public spaces			Significance				
Creating calm spots in public spaces–			Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Public awareness actions	4	Design in such a way that a calm spot can be seen by the community (community should accept autism as a disorder)					
	5	The effectiveness of calm spaces in reducing stress-induced escapes (like elopement) through training as an alternative escape shelter					
	6	The effectiveness of calm spaces in increasing autistic user's social participation					
	7	Teaching children how to use spaces					
	8	Being aware of the community about the existence of a calm spot (children and citizens' parents)					
	9	Determining certain city locations to inform users of the calm space venue beforehand					
	10	Providing a location map of calm spaces in the city to present to parents					
Sensory features	11	Neutralizing external sensory stimuli by creating other sensory stimuli in a calm spot (playing music or showing a cartoon)					
	12	Neutralizing external sensory stimuli by eliminating stimuli in a calm spot					
	13	Indoor air conditioning (regardless of outdoor air)					
	14	Avoid using allergens in space					
	15	Avoid using complex visual patterns					
	16	Using soft and neutral colors					
	17	Controlling the light brightness					
	18	Using natural light					
	19	Controlling color temperature					
	20	Color temperature the light source turning on/off					
	21	Providing direct light					

Feasibility study and evaluation of calm spots in public spaces			Significance				
Creating calm spots in public spaces–			Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Spatial features	22	Using space for a short time					
	23	The geometric shape of the space					
	24	Space height					
	25	Enclosed area (the number of environmental stimuli can be controlled(					
	26	A view from inside the space to the outside (predictability)					
	27	A view from outside the space to the inside (security)					
	28	Visibility of the exit door by the child (release from space if decided)					
	29	Simplicity in design for ease of use					
	30	Providing space for more than one person (at most two people) for the child's companion					
Qualitative features	31	Preventing non-user entry to the calm space using tech					
	32	Cost of use (including the cost of buying and renting a product, the cost of using the space)					
	33	Designing safety standards					
	34	Texture quality of materials used (softness or roughness)					
	35	Weight (for portable spaces)					
	36	Volume (for portable spaces)					
	37	Durability (for portable spaces)					

Post other items or necessary explanations about the desired option

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Landscape Assessment as a Tool for Improving Green Infrastructure Planning in Central Mexico

Isaías Daniel Hinojosa Flores and Jairo Agustín Reyes-Plata

Abstract

Green infrastructure has become a recent point of interest because of growing concerns about the global environmental crisis and human challenges in urban contexts. Green infrastructure systems contribute to reach sustainability goals for reducing the environmental impact of human settlements by generating ecosystem services, create more resilient cities, reduce poverty, create better work options, and improve the food supply. Research was carried out in Guanajuato's industrial corridor, where transnational auto companies have been operating for 30 years and have changed the rural landscape. In this sense, landscape cartography was developed, considering urban and physical elements. On one hand, we consider land use/land coverage and geomorphology as elements of landscape unity, and on the other hand, the marginalization index was linked to a social development perspective. Furthermore, based on cartography, a visual assessment was conducted throughout the corridor, in order to support the understanding of fine processes otherwise not allowed in general analyses of cartography. As a result, north–south corridors are crucial to sustain cohesion between different ecosystems caused by the presence of an agricultural barrier and the growth of north-eastern metropolitan areas as an artificial barrier; most small localities are near less affected areas and could be used as nodes for green corridors, as well as a source of employment.

Keywords

Green infrastructure · Landscape assessment · Ecological restoration · Central Mexico

1 Introduction

According to the World Bank (2020, as cited by Vaca, 2022), 55.7% of the world's population lived in cities as of 2019. This means that more people would suffer risks related to the effects of climate change in cities in North America, as well as increased risk of flooding and large wildfires; declining air quality and municipal water contamination is an issue, with consequences such as endangerment of lives, livelihoods, mental and physical health, property, key infrastructure, and economic activities (Holsman & Lucatello, 2022). In this regard, sustainable city planning is crucial because of climate change risks as well as the trend of fast-growing cities in this and the next decade (Van der Berg, 2018), increasing the needs of successful planning that will foster global, social, environmental, and economic sustainability as established in the 17 SDGs, and particularly, the 11th Goal (United Nations—UUNN, 2015). In this context, in order to achieve sustainable cities, we should consider an integrated perspective of landscape usage as a social metabolism (Padró et al., 2020), allowing opportunities for including elements of social development as described in European policies concerning Green infrastructure (Thomas & Littlewood, 2010) and considering different urbanization processes and its impacts on functional urban regions (Antrop, 2004).

In this sense, green infrastructure (GI) is essential for providing the beneficial influences of nature; however, a connection between green places and surrounding residential neighborhoods is necessary for achieving the best benefits and effectiveness (McMahon, 2000). In this sense, GI is related to a spatial relationship between green elements, inside or outside cities, which provide ecosystems with

I. D. Hinojosa Flores · J. A. Reyes-Plata (✉)
Escuela Nacional de Estudios Superiores, Unidad León, Universidad Nacional Autónoma de México, León, Mexico
e-mail: jreyes@enes.unam.mx

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diversity and functionality (Mell, 2008); it could be represented in a landscape analysis (Godron, 1981) consisting of a matrix of land use and green corridors. However, discussions are ongoing about the general benefits of corridors (Simberloff et al., 1992; Tzoulas et al., 2007), specifically because of the lack of evidence of their contribution to faunal diversity, mainly birds, and the differentiated benefits because of natural or human-made origin (Gilbert-Norton et al., 2010; Velázquez et al., 2019). Nevertheless, corridors guarantee connectivity and landscape diversity, as shown in Spain's Castille and León region (Velázquez et al., 2019), or improvement of the urban ecological environment as shown in Nanchang (Li et al., 2015).

Nevertheless, it is crucial to understand GI beyond landscape structure and the relationships between human and nature (McAlpine et al., 2013); there is a need to visualize the complexity of events in a given place in order to understand how both elements, human and nature, change the place as a spatial phenomenon and, eventually, how both could coexist. Green infrastructure must create a bridge between science and the comprehension of a place through the senses and particular beliefs, that is, a balance between ethos and science (Cirella et al., 2020). In this respect, landscape as a complex view could offer a tool for understanding the complexity of reality. In this sense, landscape analyses offer an understanding of space not only by layering components and places, but also by analyzing the view through an understanding of historical and spatial process as well as configuring the meaning of a place in a given space; in other words, landscape should be understood as a centripetal force acting over a place, attaching all perspectives inside of it in order to understand the reality, even integrating a unified conception of nature and culture (Martínez de Pisón, 2010). Since landscape is a perceptual element, it relates to observation, and subsequently, analyses of its structure, dynamic, territoriality, functions, components, history, units, facets as well as its cultural context; in this sense, as these elements exist in a geographic reality, therefore, landscape is a tool for understanding and managing social complexity in space (Martínez de Pisón, 2010).

Because the landscape is proof of human actions in space, there is also the possibility of a relationship between human health and landscape degradation. In this regard, as the importance of biodiversity and human health is connected to the earth system [World Health Organization (WHO), 2016a], we could consider the importance of landscape in the social and natural systems at a local scale. In this regard, Connor et al. (2004) found evidence of distress caused by environmental changes such as mining and power station activities; on the other hand, even though the global per capita disease burden is in decline, this trend could decrease or revert if landscape degradation associated with environmental services increases (Myers et al., 2013). Although more research on this matter is required, we should think about the importance of natural and societal well-being, including research on this matter, as a one of the most important challenges in the Anthropocene (Whitmee et al., 2015).

GI, therefore, is linked to human-nature processes that impact social development. For instance, green areas provide multiple benefits to landscape, such as improving social and natural capital [Valente et al., 2020; World Health Organization (WHO), 2016a], ecological restoration [Sun et al., 2021; World Health Organization (WHO), 2016a], aiding physical activity in cities (World Health Organization, 2016b; Coombes et al., 2010; Jones et al., 2009), cultural services linked to improving social health (Jennings et al., 2019), improving sleep quality (Feng et al., 2020; World Health Organization, 2016b), and others. Aside from the multiple benefits of green areas in landscape, GI has important benefits in both, air and water quality. GI has an important role in reducing air pollution (Hewitt et al., 2020; World Health Organization, 2016b) including monetary value in catching air pollutants (Russo et al., 2021); however, more evidence is required in order to establish a clear relationship between air quality and GI (Kumar et al., 2019) as well as the kind and structure of vegetation and policy interventions related to GI (Hewitt et al., 2019; Abhijith et al., 2017). On the other hand, GI could also be a factor in removing pollution caused by storm water runoff (Sharma and Malaviya, 2021; Wise, 2008) and reducing water flooding risks (Webber et al., 2019) with multi-criteria goals (Li et al., 2020).

In this sense, this paper has the purpose of evaluating landscape conditions in order to generate GI management proposals with ecological and societal benefits inside of the GIC. With this perspective, GI management considers landscape elements such as land use, geomorphology, and peripheral urban patches in marginalized social conditions. However, we should focus not only on natural landscape elements, but also on urban fringes connected to social marginalization in order to conceive of landscape restoration from a multi-criteria green infrastructure view.

2 Methodology

The methodology was structured with the objective of recognizing different aspects of landscape inside the GIC and includes two different steps: (1) a literature review, (2) GIS analyses including physical landscape analyses as well as socio-spatial analyses. The literature review was conducted on related topics that support the understanding of landscape degradation; moreover, the review also supports planning by detecting main issues that should be considered in proposals of GI management inside of GIC. GIS landscape

analysis of GIC was based on three different criteria of focusing on places and characteristics for establishing a green infrastructure corridor. First, the analysis was focused on finding the distribution of vegetation patches and their condition: primary, secondary, secondary with trees. Second, geomorphological aspects were included with the aim of understanding patterns and liability of establishing corridors; finally, the marginalization index of the National Council of Population (CONAPO, 2021) was considered for evaluating the social condition in urban places, relevant for planning GI social management.

The first criteria, land use and vegetation, were taken from official data on vegetation and land use cartography from the National Institute of Geography and Statistics (INEGI, 2016), and three main elements were chosen: (1) type of land use and vegetation, (2) condition (primary, secondary vegetation with trees, and secondary vegetation without trees), and (3) difference between tropical and temperate vegetation. However, land use and vegetation are not enough for knowing the potential for establishing a corridor. Therefore, the second criteria, geomorphology, play an important role in recognizing patterns of land use, as well as risks of landscape change. Geomorphology on GIC was based on the vertical dissection method proposed by Priego-Santander et al. (2010), using 15 m as the "Mexican elevation continuum" from INEGI and by using Q-GIS software. Vertical dissection was calculated by recognizing different patterns of elevation inferred by the density of contour lines; the limits from each kind of geomorphology were based on suggestions by Priego-Santander et al. (2010) as well as direct observation. Particularly, piedmonts were calculated only by direct observation due the impossibility of an automated methodology. Finally, the "Marginalization index by Locality" (CONAPO, 2021) was analyzed in order to find some relationship between socioeconomic conditions and urban context. Research proposes the marginalization index by virtue of their spatial precision and their integrated indicators.

3 Results

3.1 Landscape Analyses' Condition in GIC

The industrial growth that took place in Mexico from the middle of the twentieth century had an important impact on urban growth; first, due to increasing economic growth post-WWII and second, because of the necessity of supporting the growth rate, impossible for a central government in the 70s, by the so-called "shared development" with the participation of the private sector (Tetreault, 2012; Vilalta, 2010, p. 97; Cárdenas, 1993). As a consequence, the urban population increased three times: from 22.7% in 1970 to nearby 72% in 2005 (Hábitat, 2015; Garza and Schteingart, 2010, p. 12). However, urban growth did not translate into social improvement, since industrialization caused poverty in the rural economy of field workers (Calva, 2003, p. 200). In the same way, at the start of the twenty-first century, cities could not assimilate all the human resources from rural places, offering no formal and stable jobs, consequently causing complex patterns of temporal migration that had an influence on both, rural and urban spaces (Carton de Grammont, 2009).

In this context, Guanajuato's Industrial Corridor (GIC) in Central Mexico is an important example of how agriculture, agroindustry, and industry have changed the landscape causing an impact on natural connectivity. Land use was steadily increasing since modernization policies started in the middle of the twentieth century. However, the presence of the automotive industry since the 1990 decade has been a factor in landscape change for both the urban and rural landscapes. Increasing labor caused by industrial growth was a factor in the expansion of urban areas and the rupture of natural spaces as well as degradation due to increasing land use. Moreover, this fragmentation has been shown as a factor in the increasing bad air quality conditions, increasing flooding events by runoff and general biodiversity loss. In this sense, the article shows a proposal of creating green infrastructure in GIC with the aim of reducing environmental impacts as well as promoting the increase of regional biodiversity.

Even though GIC is growing and creating industrial bridges with other states and over other municipalities, it is possible to recognize a belt inside of the state of Guanajuato, where agroindustry, industry, urban, and metropolitan areas are located. Figure 1 shows how road and highway mobility is predominant from the east–west, which may cause a rupture in the landscape process from south to north. Besides, according to the delimitation of Mexico's metropolitan areas (CONAPO, 2018), it is possible to recognize inside of the GIC, three different metropolitan areas, León, Celaya, and Apaseo el Alto as an interstate conurbation with the City of Queretaro. However, a fourth metropolitan zone is considered (Irapuato-Salamanca) because of its growth in the last 10 years (Fig. 1).

Particularly, in the State of Guanajuato, until the twenty-first century, the same pattern was replicated, recognizable all over Mexico, based on a private export-oriented agroindustry that narrowed the relationship with international actors, resulting in increased investment as well as rapid growth of the urban population (Graizbord et al., 1995; Ramírez & Tapia, 2000). In addition, significant investment in infrastructure was made since the establishment of the Mexican Petroleum refinery (PEMEX) in 1950, a

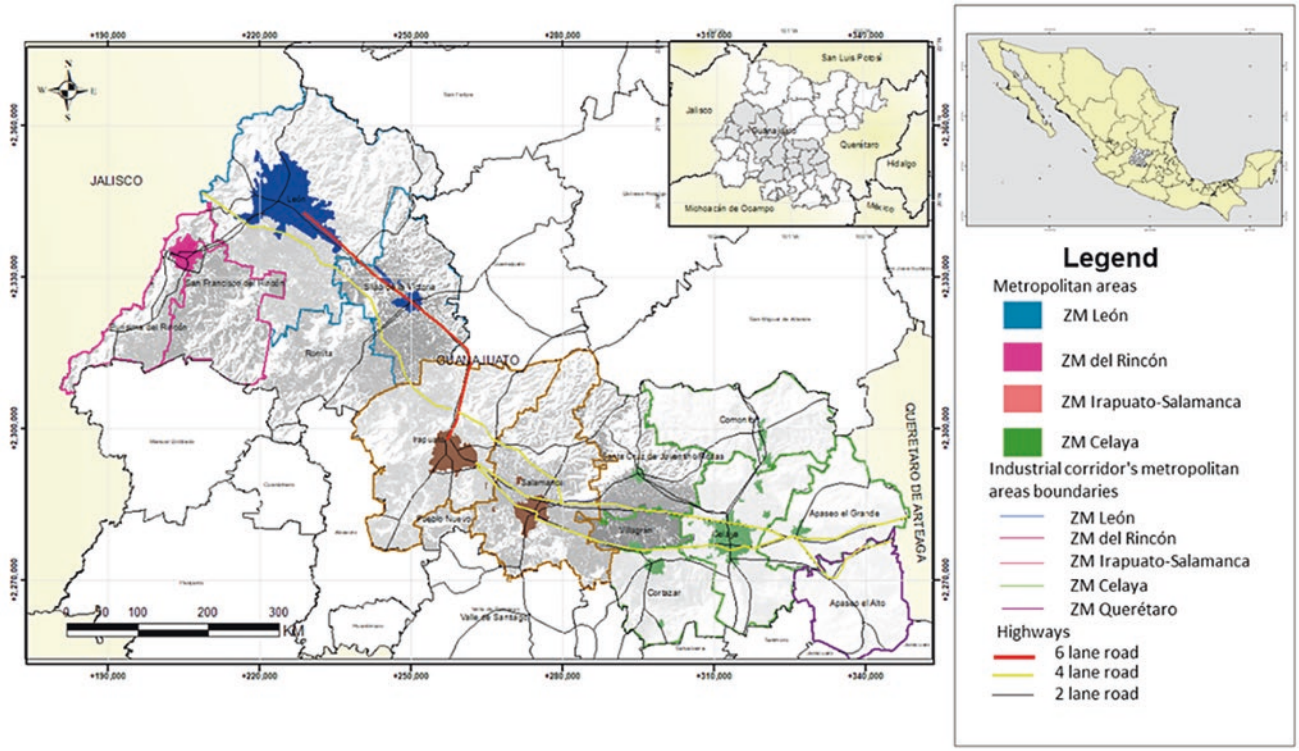

Fig. 1 Guanajuato's industrial corridor, location, and metropolitan zones. Adapted from Herrera (2021)

thermoelectric plant in 1968–1969, both in the municipality of Salamanca (Valencia, 1998, p. 83) as well as road and railroad improvements with the goal of attracting foreign investments, mainly in the automotive industry as shown in the Guanajuato government's third report (1998).

In this scenario, the industrialization in the state begins to develop in two directions: the consolidation of small businesses and family workshops (textile industry, footwear, and tanneries) and the creation of modern industry; however, the creation of a polarized structure expresses an apparent structural duality while promoting a development model that excludes large sectors of the population from the dominant center of the economy (Valencia, 1998, p. 67). The countryside and city social categories play an important role in the economic, social, and territorial issues, not only when there is wage inequality, but also because they create a very significant regional disparity. High population density, large urban areas, and extensive networks between agricultural and industrial activities have characterized the Central Region, the industrial epicenter of Guanajuato state (Fig. 1).

The change from rural social tenure to rural modern agroindustry resulted in a deforestation process. As evidence, Rodriguez (2001) shows the deforestation of 80 ha of vegetation in Cubilete Hill, while Rivera et al. (2019) refer to the removal of crasicaule shrubs of *Opuntia spp* from several areas in Northern Guanajuato. However, the most important change in the GIC is associated with export-based agroindustry development that started mainly in the 1970s (Ramírez and Tapia, 2000), with the clear urban area growth because of the increase in labor reached 6th place in population at the national level in the 1990s (Graizbord et al., 1995) when the automotive industry started in GIC, and increased by a further 50% in 2020 (INEGI, 2021).

For instance, urban sprawl increased by almost three times from 1992 to 2020, as shown in Figs. 1 and 2. The original urbanization is displayed in black, urban growth in 2020 in gray and plot land in 1992 in light gray; the entire urban core experienced evident growth, with an increase in small urban places (population over 2,500); at the same time, urban areas grew over agricultural lands showing a land use change (LUC) relating to urban priorities. Possibly, urban growth was a consequence of industrialization, switching the importance from rural activity to industrial activities. As a result, labor migration in a context of staff turnover left new urban spaces without citizen appropriation that has, as heritage, natural degradation. This means that citizen vulnerability increased with the growing gray infrastructure without a balance of green infrastructure: this is evidenced in air quality and water scarcity.

In reference to air quality, according to National System of Environment and Natural Resources Database (BADESNIARN), the pollutant with more prevalence in

Fig. 2 Urban growth from 1992 to 2020. Data collected from INEGI, Geostatistics frame from 1990 to 2020

CIG is the PM10 and SO_2, with average bad air quality days per year between 18 and 68, in which Celaya (situated at the center-west of the Corridor) shows more frequent bad air quality days (Table 1). Moreover, it is important to note that the GIC's SO_2 emissions are mainly associated with refining processes in Salamanca city; furthermore, a particular prevalence of particles smaller than 10 μm in diameter (PM 10) and those smaller than 2.5 μm in diameter (PM 2.5) originated by air erosion over land plots or unpaved rural roads surrounding cities is considered to be an important factor of respiratory disease prevalence (SMAOT, 2017). This pollution has an important impact on the population's health, especially in school age children, who could suffer oxidative stress as a risk of a decreased respiratory capacity inside of the GIC (Romero-Calderón et al., 2017; Linares Segovia et al., 2014).

Regarding water scarcity, according with the Guanajuato's Institute of Planning, Statistics and Geography (IPLANEG, n/d) Guanajuato was the second-ranked state in Mexico in terms of groundwater use. As shown in Table 2, excluding the Silao-Romita aquifer, the balance between extraction and recharge inside of the GIC is negative, increasing the vulnerability of urban activity. It is demonstrated with the conflict between the social actors of Jalisco and Guanajuato states because of the construction of El Zapotillo dam, in an attempt to supply their biggest cities (León and Guadalajara), despite the fact that it would necessarily cause flooding in rural communities in Jalisco (Pacheco Vega, 2014). The conflict was figured out in 2021 by federal government, who ordered that all the dam's water must go to Jalisco, in order to avoid a dam level increases and the flooding of communities; however, the city of León will struggle with water

Table 1 Number of bad quality air days with 75% sufficiency

Municipality	Days of bad air quality (av 2006–2018)			
	O_3	PM10	PM2.5	SO_2
Celaya	2	68	9	–
Irapuato	16	33	6	–
León	18	67	15	–
Salamanca	6	37	9	9
Silao	1	18	–	–

From "Air quality by pollutant with 75% of sufficiency, 2000–2018," by National System of Environment and Natural Resources Database (BADESNIARN, 2019). http://dgeiawf.semarnat.gob.mx:8080/ibi_apps/WFServlet?IBIF_ex=D3_AIRE01_20&IBIC_user=dgeia_mce&IBIC_pass=dgeia_mce&NOMBREANIO=%2A

Table 2 Recharge and extraction volume of aquifers inside the GIC

Aquifer	Average recharge volume (hm^3/year)	Extraction volume (hm^3/year)
Silao–Romita	280	165.19
Valle de León	124.5	176.37
Río Turbio	110	163.35
Valle de Celaya	317.1	429.11
Irapuato–Valle	507.8	546.6

From "Disponible water by aquifer" by National Water Commission (CONAGUA, 2020). https://sigagis.conagua.gob.mx/gas1/sections/Edos/guanajuato/guanajuato.html

scarcity despite prior investment from the state of Guanajuato in the El Zapotillo dam (Huerta, 2021).

In contrast, there was water scarcity in a flooding year scenario in the GIC. The main rivers recharge from a high basin in the Guanajuato northern region, causing high levels in tributary rivers to the Lerma River, one of the biggest in Mexico. Floods cause financial loss from damaged crops, but also in the automotive industry as seen in the Mazda and Honda plants (Espinosa, 2018; Medrano, 2021; NOTIMEX, 2018; Tamayo, 2018; Trejo, 2021). In this sense, the GIC has the greatest risk of flooding in Guanajuato state as demonstrated by CONABIO (2012, p. 60) (Fig. 3). Moreover, there is ground water contamination associated with over-exploitation of aquifers. High concentrations of arsenic and fluorides have been found in several groundwater wells inside the GIC area (Arzola & Li, 2016; Tovar et al., 2016); their consumption may cause decreased IQ as well as genotoxicity (Guzmán et al., 2016).

However, the main concern about environmental issues is regarding society's vulnerability. Land use change (LUC), made over and surrounded by plot land, overexploitation of aquifers, and poor air quality are synonymous with social risk and are increasing with growing population in marginalization conditions. Although, according to the National Commission for the Evaluation of Social Development Policy (CONEVAL, 2018), the extreme poverty rate fell to almost half from 2008 to 2018, but this did not mean a corresponding reduction in the total amount of poverty, which still represented 40% of the total population in Guanajuato in 2018. Accordingly, CONEVAL (2018) also showed in the same period an almost two-fold increase in vulnerable population by income, that is, those without work stability. Although CONEVAL (2018) concludes that more than a half of the population is still under the poverty line, the marginalization index (CONAPO, 2021) showed that more than 80% of localities inside of the GIC has no marginalization condition.

GIC's social space could read as a high degradation and high social vulnerability space. It is possible to read in the landscape cartography view, where few primary condition vegetation patches exist, high urban density with few green infrastructure components, and no connectivity between countryside green areas and urban inner green areas. However, degraded vegetation is still visible inside of a continuous plot area, showing potential for connecting a green belt outside cities (Fig. 4); it is important to note the presence of arboreous degraded vegetation, which is a step closer to continuing a restoration of ecological succession.

Considering a regional scale, geomorphology could allow us to see a pattern in term of impacts on landscape associated with land use and vegetation information. In this sense, it is important to recognize the geomorphology associated with land use in order to characterize a possible establishment of green corridors, with special attention to high amplitudes in order to prevent runoff and improve infiltration. According to proposal analyses in methodology between INEGI (2016) and geomorphology assessment, these are the landscape classes with the most area occupied inside of GIC:

Agriculture: Occupyies 64% of total area of the GIC. Its distribution reflects a major problem in the sense of continuity of vegetation and creates a rupture between the continuity of temperate ecosystems (north) and tropical dry ecosystems (south). At the coarse scale, the lack of incorporation of trees or natural vegetation inside the agriculture continuum is evident. Moreover, most agriculture (59%) is on sub-horizontal plains (the flattest terrain), and almost all are on flat geomorphology. Only 8% is on piedmont areas and less than 4% are on hills.

Urban: Occupyies around of 8% of total area, and is the second class in total area inside the GIC. Almost all urban surfaces are built on sub-horizontal plains (72%).

Temperate primary vegetation: Occupyies near to 2% of the total area. About 75% is found in high amplitude terrain, as smooth hills (22%), high dissected hills (47%), and smooth mountains (28%).

Natural grassland: Covers 3% of the total area, and almost half are found in hills and another half on plains (mostly medium plain hill).

Shrubs: Account for only about 2.5% of total area; 65% of total are found in plains; however, a quarter of the total is associated with hills and piedmont geomorphology.

Tropical secondary vegetation: Accounts for 7.5% of total area. Almost half is found in mountains and hills, another half in plains. As it is not associated with primary vegetation, it should be connected and protected to promote ecological succession, as well as to create a bridge between temperate and tropical species.

Temperate secondary vegetation: Covers 3.5% of total area; nearly 75% is found in high amplitude geomorphology as hills and light mountains. It is highly associated with the presence of primary vegetation—for instance, it should

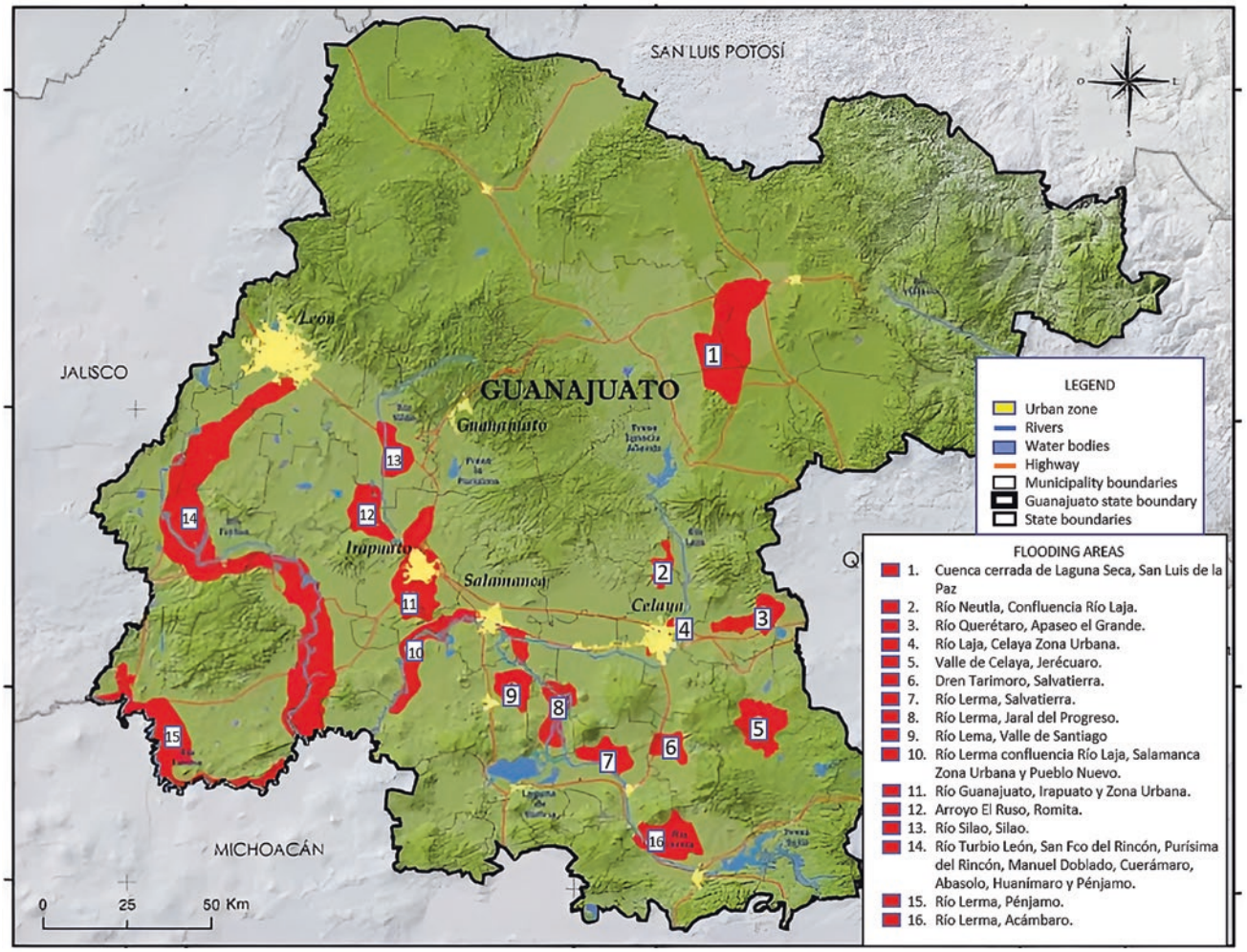

Fig. 3 Areas vulnerable to flooding in Guanajuato State. From "Zonas inundables de Guanajuato" (1st ed., pp. 60) by CONABIO (2012), CONABIO

be protected even if it is not closely related to establishing a green belt, as its protection will promote the growth of primary temperate vegetation areas.

In context of a socioeconomical view, even though data on marginalization index (CONAPO, 2021) have shown almost all the GIC corridor localities at a low and very low marginalization level, the localities showed a negative trend between average population by locality and marginalization condition (Table 3).

4 Discussion

According to the main characteristics found in the GIC's cartography, it is possible to propose principal actions for developing green connectivity as green belts around cities based on landscape planning (Fig. 5). The map is integrated by the kind of vegetation, geomorphology, and marginalization index. In this, it is possible to detect four principal issues concerning physical and social issues. First, the potential of generating ecosystemic services by conservating the secondary vegetation and shrubs, as nodes of green infrastructure; these are found as spots in the overall GIC, although their persistence is not safe, because the plain or piedmont geomorphology is associated with agricultural land use. Second, the capacity for revegetation linked to more complex geomorphology, as in hills, is observed close to big cities; mainly because of their lower suitability for farming due the higher slopes and less soil farming properties, better suitability for capturing moisture and creating microsites as well as their proximity to vegetation spots that provide seeds. Third, the establishment of a continuous plot land over the GIC has caused a lack of connectivity between south and north; for instance, it is necessary to create south–north corridors for promoting linkage between these two ecosystems, basically by linking secondary tropical vegetation to temperate vegetation. Fourth, the growth of small urban areas surrounding big cities, linked

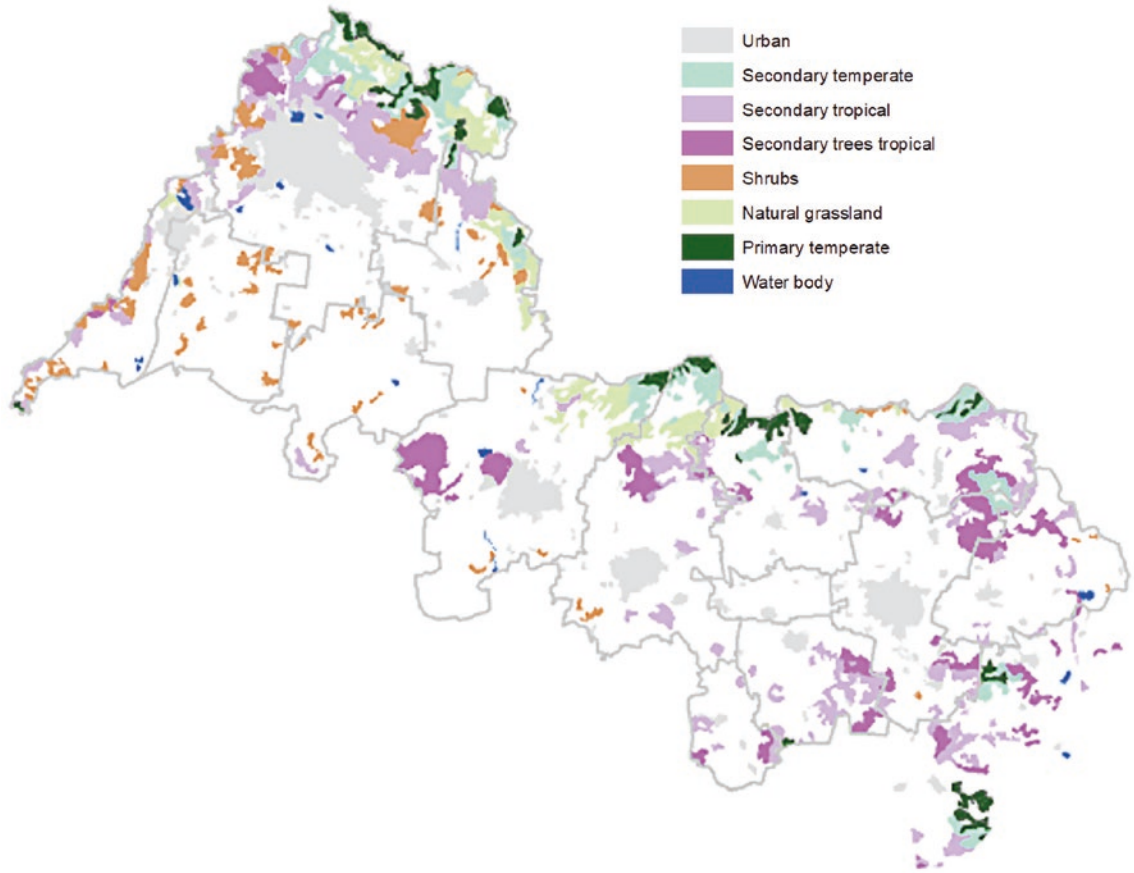

Fig. 4 Vegetation and its condition inside the GIC. Elaborated from information of INEGI (2016)

Table 3 Relationship between marginalization condition and average population in localities inside the GIC

Marginalization condition	Total localities inside the GIC	Average pop by locality
Very high	35.9	98.6
High	90.7	338.8
Medium	209.4	805.1
Low	510.6	4,289.4
Very low	3,911.7	11,057.3

Information taken from INEGI (2021) and CONAPO (2021)

to the possibility of higher marginalization rates, could be included as nodes inside of green corridors as an opportunity for both seasonal and permanent labor as well as in a landscape context, integrated by isolated trees and non-paved roads. In this sense, it is important to focus on increasing labor in small localities with high seasonal labor mobility and high rates of poverty.

In this sense, we proposed four main areas where it is possible to connect tropical and temperate relicts near big urban cities, all of these compounded by patches and belts. Considering the presence of vegetation, urban patches and, when present, hills, seven spots of green corridors were selected as potential green belts for big cities. The first, near the city of Leon, natural landscape elements to the west and north of the GIC make south–north connectivity with conservation and restoration of present secondary vegetation possible. North and west conditions could be part of a green corridor in the south of the city, between patches of small urban places and in the east of the city of Leon, with a belt that joins shrubs to the piedmont of northern mountains. As an important node for linking Leon's south and east belts, revegetation of hills in the south should be integrated. The second, near the city of Irapuato, in the narrowest part of the GIC, linking natural grassland in the north to the city of Irapuato with the secondary tropical trees in the south is proposed by establishing two spots; the first spot starts by creating a corridor from small urban areas as a link between secondary tropical tree patches and a second spot between small urban patches, the city of Irapuato, and hills situated in the north. It is important to promote the conservation and restoration of hills in the north of the cities of Irapuato and Salamanca, as a key node of green belts. In third place, in the city of Salamanca, three nodes are thought of; in the

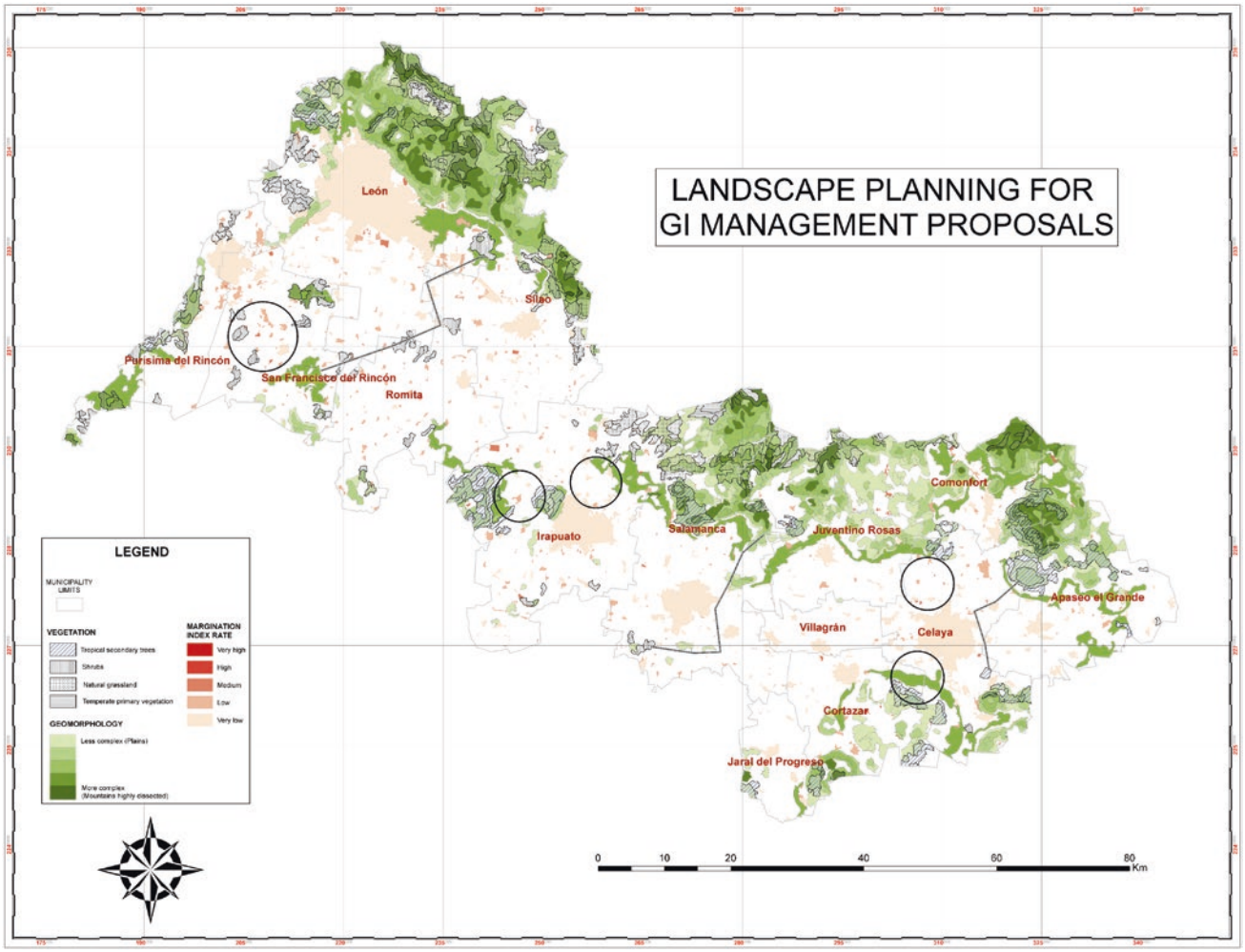

Fig. 5 Map of the landscape planning for GI management proposals

south, joining shrubs and secondary vegetation, a belt of secondary vegetation and hills from south to north, and a spot that joins the belt with hills and secondary tropical trees patches in the north. Finally, in fourth place, in the city of Celaya, the lack of connectivity from southern elements with the northern hill-and-mountain temperate conditions is more evident; therefore, two nodes in the north and east are proposed as corridors, between small urban patches, while in the south, the presence of mountains makes it possible to link secondary tropical trees and the city of Celaya.

5 Conclusion

The assessment results show a proposal that could integrate different societal and natural conditions by considering multiple factors that should be involved in landscape planning related to GI management in the GIC. Mainly, we propose two main actions: the increase of total tropical vegetation and connectivity from south to north (tropical-temperate bridge). In the first proposed action, as a primary target, the connection of secondary tropical forest is needed because of a high reduction in isolated patches. In this sense, it is important to introduce primary tropical trees in secondary tree vegetation, for promoting seed dissemination over secondary vegetation. The second proposed action consists of increasing connectivity to be considered between a large matrix of plot land. In this sense, it is necessary to consider as a focus the highest geomorphological amplitude, for limiting runoff, and after that, allowing reforestation of non-paved rural roads by a windbreak tree system. It should be promoted mainly with higher tree species, aimed at low porosity that filters the wind (Abhijith et al., 2017). However, the cooperation of farmers is necessary, by implementing a planning subsidy or tax deduction strategy over regional agroindustry to alleviating the decrease in productivity in the shaded surface. On the other hand, the windbreak systems allow the possibility of employment in small urban localities, although more research should be carried out in order to understand the relationship of labor

costs in GI management and the reduction in medical costs due to decreasing respiratory diseases.

It is important to note the increase in isolation between vegetation patches to the east of the GIC, mainly in the city of Celaya. The common exposure of population to PM10 particles could be reduced by this initiative as well as the runoff control over the rest of the GIC by controlling the recharge of the Laja River, which crosses from the east to the west of the GIC. However, costs would be higher in the west because of its conditions; therefore, subsequent research should be conducted in order to recognize the level of participation of the population in small urban areas and the interest of the municipality in financing strategies.

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Principles of Green Urbanism and the Transformation to a Greener Sustainable Environment

Greenification of Dense Neighborhoods Through Pocket Parks—Inspiring Small Spaces to Transform Cities: The Case Study of Tirana, Albania

Rovena Plaku

Abstract

Continuous development and densification are occurring as a result of dense population in cities, which, according to the United Nations, will increase to 68% by 2050, causing serious problems such as environmental stress, unhealthy living, and densification without planning policies and strategies. As a result, there are an ever-increasing need and demand for environmentally oriented urban development concepts (of any scale or size), particularly in areas of cities that are experiencing significant densification. Pocket parks are a form of the notion that can help cities and neighborhoods become more green and inclusive. Tirane, Albania's capital, is used as a case study to shed light on the development of public spaces and pocket parks within the city, as well as initiatives undertaken by the municipality of Tirane MoT and non-governmental organizations in collaboration with residents. The paper emphasizes the significant potential of urban pocket parks to improve community interaction, maintain a healthy environment, and encourage people to walk and cycle through neighborhoods rather than driving. Furthermore, transforming these underutilized and neglected areas into new green spaces can meet the WHO requirements that users walk no more than 5–10 min to reach them.

Keywords

Pocket parks · Communal spaces · Green initiative · Community engagement · Inclusive neighborhoods · Public realm

R. Plaku (✉)
German Federal Environmental Foundation (Die Deutsche Bundesstiftung Umwelt DBU), Osnabrück, Germany
e-mail: rovenaplaku1@gmail.com

1 Introduction

Public space is an integral component of city spatial structure. It connects developed neighborhoods and serves as a transit hub for people who reside, work, or just hang out in the city. As a result, protecting and restoring existing public green spaces are an important component of sustainable urban growth. However, in large cities where high-density housing development predominates, the issue of maintaining enough supply of green spaces arises. In addition, the increase in mass development and the uncertainty of land ownership have led to a decrease in public space (UN Habitat, 2016).

Densification projects in vital cities are facing a growing demand for communal green spaces that are not necessarily spaces for high-budget development. They can be, and often are, most effective when they occur in unused urban gaps that already exist in the neighborhood. These spaces have the potential to become "pocket spaces", a type of community space that has been successfully implemented in several countries and has had a major impact on increasing the liveability of their neighborhoods. Furthermore, the transformation of these unloved and abandoned areas into new green spaces can effectively meet the requirements of the World Health Organization, WHO, which states that residents should not walk more than 5–10 min to reach neighboring public spaces. In addition to achieving the goals of the New Urban Agenda, is important to engage and invite cities and local governments to adopt a transdisciplinary approach to create public spaces that are inclusive, safe, and accessible for all. It means working with a wide range of stakeholders and organizations, including civil society, academia, and the private sector. The promotion of socially inclusive, integrated, connected, accessible, gender-equitable, environmentally sustainable, and safe public spaces is fundamental to the implementation of the New Urban Agenda and the Sustainable Development Goals. It states that the Government is committed to ensuring universal access to safe, inclusive, and accessible green and public

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spaces, especially for women and children, the elderly, and people with disabilities by 2030 as part of SDG Sustainable Development Goal 11.7. Rules and laws ensure that public spaces exist and are accessible, while urban planning and design ensure an adequate supply of quality public spaces. However, in many cities, weak legal frameworks combined with inadequate policy and political attention will have led to insufficient public land, private actors taking advantage of it, and conflict between communities and government over the use of public space (UN Habitat, City-Wide Public Space Strategies: A Compendium of Inspiring Practices, 2019). This was also reflected in Tirana, Albania's capital, where rapid growth has taken place over the years, either intentionally or unintentionally consuming open space. Although Tirana has a large green area (the Great Park of Tirana), it does not cover the entire city's population's demand for green space. Furthermore, the needs of people living in densely populated areas in the city cannot be met. While there is no hierarchy between these green areas (particularly in the city center) and the city's existing public spaces, they cannot work together to form a functional green system that addresses the city's lack of small parks.

Following the fall of the Communist regime, public spaces underwent a major transformation, as evidenced by their neglect, invasion by cars, and land privatization. As a result, the research aims to determine the viability of transforming and rehabilitating Tirana's pocket parks. The current state of these micro-spaces between buildings is being investigated to gain a better understanding of them. The research also focuses on identifying and analyzing potential pocket spaces in Tirana neighborhoods, which are referred to as the "light at the end of the tunnel", implying that there is still hope to find and transform such spaces for the city's and residents' benefit. Finally, it finishes with some recommendations and possible concepts for establishing how to set up such spaces in the given context to increase social interactions.

2 The Problem Statement

Demographic estimates indicate that 68% of the world's population will live in cities by 2050 (United Nations, 2018). This is due to the rapid growth of existing urban settlements and the development of new ones, as well as the increased density and use of urban areas. This focuses on urban development such as road and transportation infrastructure, but also the planning and use of open and green spaces.

Existing open and green spaces in cities are frequently threatened with privatization or the loss of their original functions and identities, particularly in rapidly developing cities. This is exemplified by the case study of Tirana, Albania, which still has small spaces, neglected and forgotten between buildings. These spaces, on the one hand, are a point of conflict and debate among the inhabitants living in the same building over who will own the space, while on the other hand, they neglect management, mainly by the residents but also by the building's administrators.

If the Municipality, responsible sectors, Non-Governmental Organizations NGOs, and residents themselves gave these spaces the proper attention, they would not only improve the image of the neighborhood by providing small green spaces, but they would also generate a wide array of environmental benefits and encourage community interaction as well.

3 The Aim

This research aims to bring to the attention of the public and the government the existence of potential pocket spaces in the city as spaces that could revive the city's image and its neighborhoods economically, socially, and environmentally, while at the same time promoting resiliency for the future.

A pocket park, depending on its purpose, can complement a larger park and meet the need for people to feel close to nature (Peschardt et al., 2014). They also meet a variety of needs and functions including small event spaces, play areas for children, spaces for relaxing or meeting friends, taking lunch breaks, and so on (Blake, n.d).

At first glance, these spaces appear unimportant or even unnecessary in bringing positive changes to a city and its neighborhoods, but when successfully implemented and transformed, they have the power to accidentally change the lives of citizens. Whether large or small, forgotten spaces can be transformed into green spaces that can transform the lives of tens of thousands if recreated properly.

4 Methodology and Data Collection

Considering the purpose of this research and the interdisciplinary nature of such spaces, a mixed approach will be adopted. Based on the findings of this study, the following methods have been used:

- A literature review was conducted to promote the creation and study of pocket parks, including their definition, characteristics, funding, and administration.
- An exploratory approach based on the selection and investigation of Tirana's pocket parks and the initiatives done so far is discussed to improve their implementation.
- Finally, an analytical method was used to evaluate the current state of these spaces, applying SWOT analysis to

identify the Strengths, Weaknesses, Opportunities, and Threats that exist within them.

The article concludes with some recommendations and lessons learned from the Tirana case to address the current challenges of urban development and densification.

Considering that the goal of this research methodology is not to provide answers, but rather to look at the present situation of this kind of space in Tirana from a qualitative perspective to identify some "lessons to be learned" as valuable results.

5 Pocket Park Concept

A pocket is a small patch, so we can put our hands on it to experience warmth, security, and privacy (Peschardt et al., 2014). According to Hajime (1988), a pocket park is a "hand-made warm space" that creates a tiny respite for people, while Gollwitzer (1968) defines pocket parks as small spaces in congested urban settings enclosed by multi-story buildings and only open on one side.

The concept of small-scale spaces as restorative "pockets" in densely populated areas originated in a 1963 presentation entitled New Parks for New York, in which Robert Zion suggested the idea of a network of pocket parks across New York. Thus, Paley Park in New York, established in 1967, served as a template for other pocket parks throughout the world (Frankel & Johnson, 1991). An example like this perfectly depicts the idea of a micro-space and the concept of place-making, which has been promoted and developed by the New York-based organization Project for Public Spaces (PPS).

Pocket parks, as the name implies, are a type of public space that falls under the larger category of "parks". They are known by various names in the literature, including mini-parks, vest-pocket parks, and neighborhood parks. Pocket parks are urban open spaces on a small scale (Seymour, 1969). A pocket park is commonly thought to be a space between a square and a park. They can take the form of park characteristics when green elements are abundant, but they can also take the form of urban open space that does not always include greenery.

They are described as small, intimate public spaces in urban environments. They are typically only a few acres and they aim to provide respite from busy, noisy city life. These parks can be designed for many different activities such as walking, picnicking, sports, or meditation. A pocket park is often created through the use of existing urban design techniques or it may be a new design. Pocket parks are created with the intent to offer city dwellers of all ages an area of nature in an otherwise chaotic environment. The idea came about due to the growing popularity of suburbia where fewer people live near green space and there is more "nature deficit".

5.1 Characteristics

Pocket parks in the scientific sense are the result of a bustling ecosystem. These little gems can be found throughout our planet and they provide an oasis for both wildlife and humans alike. From the dense jungles of fast-developed cities and neighborhoods, it is fair to say that wherever you go, there is always a pocket park waiting for you!

According to the National Recreation and Park Association (NRPA), successful pocket parks have four key qualities:

- They are accessible.
- They let users engage in activities.
- They are comfortable spaces with a good image.
- They are sociable places where people meet each other and take visitors.

What can be gathered from the literature review is that pocket parks fall into the category of public spaces. Therefore, this research reckons that characteristics and benefits of public spaces can be correctly applied to pocket parks within their given context.

5.2 Benefits

Pocket parks can provide a variety of ecological, social, and health benefits. Pocket parks can inspire neighbors to meet and create ties on a social scale. When neighbors use public areas more frequently, it can contribute to a sense of community liveliness and investment in public spaces. The existence of actively used public places has also been linked to greater safety and crime reduction. In terms of health benefits, pocket parks encourage people to get outdoors, encourage physical activity, can help with stress reduction, and can improve mental health. From an ecological point of view, pocket parks support the goal and objectives of climate resilience insofar as they relate to increasing ecological and social resilience. Being more natural and permeable surfaces, they can reduce rainfall runoff and increase water infiltration; vegetation can create habitats for local species, especially birds; tree canopies can be used to shade and cool park visitors while blocking carbon dioxide (Metropolitan Area Planning Council, 2019).

5.3 Funding and Management

A pocket park is an excellent option for communities wanting to revitalize a neglected little space. These spaces are frequently funded by a combination of public and private donors where a signed agreement is reached by both parties. The private sector may not want to donate cash and is willing to donate materials such as urban furniture as long as the logo of the investor is on it. The municipality could double the funding already collected by NGOs and the investors if the locals themselves maintain the park as a partner in the investment process. If the developer wants to invest in a pocket park, the municipality must submit an annual financial report where the reimbursement of development costs must be based on actual costs and should not exceed the estimated costs agreed upon. Those responsible for applying for funding should be one or two people from the neighborhood committee. This way, good planning will increase the chances of getting a grant while ensuring that people get as much input and help as possible, including land acquisition, fences, gates, benches, plants, information, etc. Each individual and family who uses the park shall be responsible for maintaining it. Consequently, once a pocket park has been established, the local community is responsible for the maintenance costs; this means that they should set up a maintenance schedule and assign specific tasks to the local community. Typically, a town council or community association is involved in the pocket park process. Accordingly, they usually allocate some funds to cover these costs, if street vendors want to rent the park for some time before it is established as a permanent location (Co-PLAN I., 2012).

6 Introduction to Tirana

In densely populated areas of Tirana, with limited amenities and the inability to build large parks, developing pocket parks as a stand-alone network may be a beneficial alternative for improving outdoor spaces and recreation opportunities for residents. Similarly, densely populated low-income neighborhoods, with a high demand for open space, could benefit the most from increased amenities in open spaces (Metropolitan Area Planning Council, 2019).

Accounting for a third of the country's total population, Tirana is unsurprisingly marked by intense densification of existing neighborhoods along with the creation of self-built informal housing patterns in its previously rural periphery. Despite being compact, it is also densely populated, especially in the city center where people live in 8- to 10-story high apartment houses (Spaan, 2017). The current municipal attempts to embed greenery in the smaller neighborhood scale will be explored and critiqued. Further, a positive example of a pocket park in this city will be discussed as well as reflections on further potentials for these parks to exist and improve the socio-ecological reality of the two cities.

6.1 A General Overview

Tirana is the capital of Albania, a small country of 28,748 km^2 (Geography of Albania, 2021) in the Southeast of Europe. Albania shares borders with Greece, North Macedonia, Kosovo, and Montenegro, and roughly half of its perimeter forms a coastline along the Adriatic and Ionian Seas (part of the Mediterranean Sea) (Fig. 1). Tirana is conveniently positioned in central Albania, only 30 km east of the Adriatic Sea. Tirana's origins date back to the seventeenth century while Albania was under Ottoman rule, but its story as a capital is a fairly new one, only being established in 1920. At that time, it had just 15,000 inhabitants while the rest of the country was still largely rural. Today, Tirana is the political and economic capital of Albania and a bustling city with 850,000 inhabitants (Table 1).

In the late 1990s, Albania emerged from one of the most brutal authoritarian regimes of the Cold War period and began a process of radical change. Consequently, there has been a 30-year transition to a market economy, unrestrained capitalism, and large-scale migrations to cities and abroad since then. Due to this growth, Tirana continues to absorb a steady influx of newcomers from all over Albania (Les Ateliers, 2021).

Fig. 1 Map of Albania and surrounding countries. *Source* (Biberaj & Prifti, 2019)

Table 1 Population, density, and surface of Albania

	Albania	Tirana
Population	2,845,955 inhabitants (2020)—0.6% drop from 2019	842,019 inhabitants (2020) + 1.64% growth from 2018
Surface	28,748 km^2	1110 km^2
Density	104.6 inhabitants/km^2 (2018)	Habitants/km^2 (2019)

Source INSTAT (2021) and Municipality of Tirana (2017)

During the fall of the communist regime, the right of movement made a large number of people migrate to the capital in search of better possibilities for employment and living conditions. This migration led to a massive formal and informal surge of construction in the city and its surroundings.

6.2 Development of Tirana's Public Spaces

Tirana is a city in which rapid growth has occurred in the last few years, either involving free spaces intentionally or not. Although the city has a large green space area (Tirana's Grand Park), the park is not reachable for the citizens of the whole city. Furthermore, the requirements of people (transportation, services, and infrastructure) in high-density neighborhoods cannot be met. While there is no hierarchy with the other existing public spaces in the city, the pocket parks cannot be linked to building a functional green system to overcome the absence of small parks. In addition, in both theory and practice, there is no connection with existing parks as a network of green corridors, sidewalks, street trees, and waterways. Apart from these, the concept of pocket parks appears to be a decisive factor for better living conditions, air quality improvement, particle absorption in air, and the degradation of public spaces.

One of the significant changes the government took in 2015 in the implementation and management of public spaces was the establishment of the Parks and Recreation Agency APR. This shift marks a transition from traditional governance, where its control is fully centralized in the public sector (in this case, the Municipality), to managerial governance, where regulations and control functions are institutionalized and given to management agencies (Zamanifard et al., 2018). However, the division of responsibilities within these public authorities remains unclear due to the variety of public space types. The APR is the regulatory authority for all forests and natural parks and, in addition, for recreational areas such as playgrounds for children and sports fields within the municipal jurisdiction. Other categories of open public spaces (such as squares and promenades) are managed and administered by the Municipality's planning departments.

6.2.1 Law 107/2014

Law 107/2014 "On Territorial Planning and Development" (NTPA, 2014) governs all laws, conditions, and processes governing the use and management of public spaces. The minimum green public space ratio per capita is then expressed on Tirana's General Local Plan TR030 (Boeri, UNLAB, & IND, 2017):

- Inside the development unit of at least 2.5 m^2, including children's playground.
- At least 4 m^2 of consistent greenery per capita in mass inside parks.
- Greenery in road infrastructure, promenades, and squares of at least 2.5 m^2 per capita.

As a result, every individual should have access to a minimum of 9 m^2 of green space. Additionally, every neighborhood block in a radius of 400 m should have a minimum of 2.5 m^2 of green space.

6.2.2 Plans and Policies

By the legislation, as shown in Fig. 2, the principal governing bodies issue regulatory plans. Detailed Local Plans (DLPs) can also be prepared locally with guidance from the Tirana General Local Plan (TGLP), based on privately operated initiatives. A DLP is a legal document that describes numerous instruments that can be used to establish public spaces, along with the roles and benefits during the implementation process. It is also possible to generate public spaces based only on GLP. Some of these instruments stated in the Co-PLAN Technical Manual (2015a) generate financial support for public space developments:

- Expropriation of public sector services.
- Intensity of building with conditions.
- The transfer of development rights.
- The fair distribution among stakeholders of costs and profits.
- Public servitude and preferential rights.
- Programs like Business Improvement District (BID), Tax Increment Financing (TIF), or Special Assessment District (SAD).

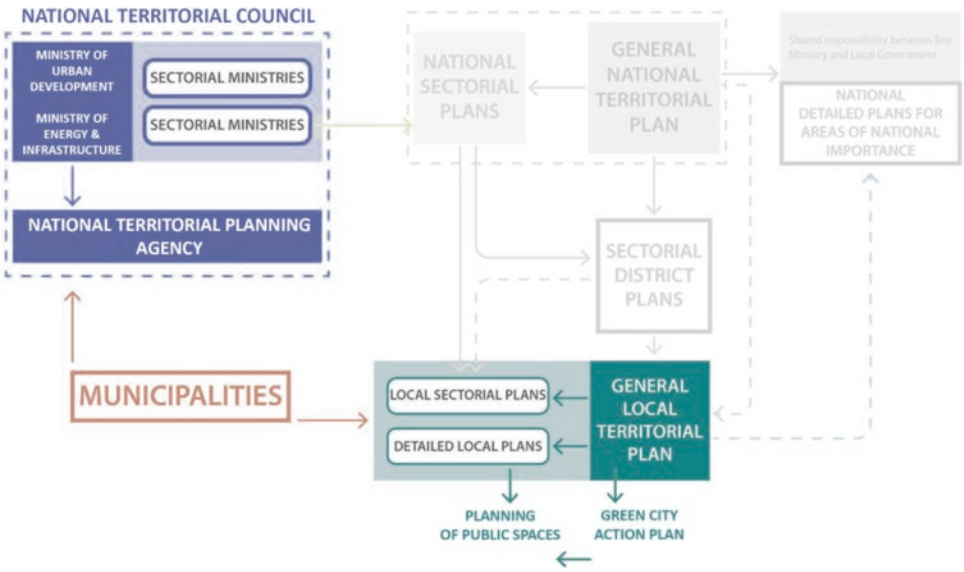

Fig. 2 Governing bodies issuing regulating plans. *Source* Bufi (2019) based on Papa and Dhiamanti (2017)

The most recent General Local Plan for Tirana (TR030) proposes to create a Sectoral Plan for the management of public spaces proposed by the approved DLPs. On a city scale, the GLP only envisages a growth per capita of green space ratio through two strategies—the Orbital Forest and two Green Belts, resulting in an additional 60.04 ha of green space. On a block scale, this proposal does not tackle greening initiatives.

6.2.3 The Green City Action Plan (GCAP)

The Albanian government undertook a significant territorial reform in 2014–2015, rezoning how cities and municipalities were organized. The reform expanded Tirana's surface territory by approximately 25 times, including more regional territory. This was the trigger for the implementation of the Tirana Council's ambitious plan to become a prosperous and desirable European destination for people to live, work, and travel. The GCAP was an expansion of the GLP to prevent and solve through sustainable development the increasing challenges of urban stress and climate change. Access to clean water, greening the city to enhance air quality, citizens' well-being, energy usage, and green infrastructure are some of the primary concerns of this plan. Creating urban microclimates to tackle not only greenhouse gas emissions but also mitigate the impacts of climate change is key to this plan.

The GCAP is part of the Green Cities Program established by the European Bank for Reconstruction and Development (EBRD). In 2015, the EBRD and the Municipality of Tirana MoT signed a Memorandum of Understanding on collaboration in areas such as urban transport, road infrastructure, water and wastewater systems, solid waste management, street lighting, and overall energy efficiency improvements. The GCAP is sponsored by the Federal Ministry of Finance of Austria under the DRIVE Fund of the Western Balkans.

Following public consultation and discussion with other countries, the top priorities have been chosen:

- Land Use.
- Transport
- Solid Waste.
- Water Supply and Wastewater Treatment.
- Energy.
- Buildings.
- Climate Change Resilience and Adaptation.

One of the most impressive aspects of GCAP is the time for execution. It took less than a year to develop and authorize. Some projects were already initiated even before the strategy was completed, including tree planting and cycling promotion. One of their first projects was the local commitment of citizens and businesses to plant 2 million trees in Tirana by 2030. It was a positive activity for residents to get involved and learn more about the GCAP in detail. This demonstrates that the plan adopts a performing planning approach that triggers strategic development and community building instead of a simple implementation plan.

In addition, the GCAP also involves the development of greenery on a community scale, in the form of pocket parks, promising a 20% rise in green spaces. GCAP aims to build five new pocket parks between 500 and 10,000 m^2 by 2030. Finally, both GLP TR030 and GCAP do not specify whether and how they intend to achieve the required per capita area of green space (9 m^2/capita). GLP TR030 only discusses an additional number of 2 million trees in the city, although GCAP does not estimate to what extent will the proposals comply with the legal requirements.

6.2.4 The Role of the Sustainable Development Goals (SDGs)

The SDGs were at the core of the GLP General Local Plan—Tirana 2030. It highlights various goals, measures, and plans for implementation, including community development and access to natural resources and services for all residents.

The GCAP is based on the Green Cities Program, established by the European Bank for Reconstruction and Development EBRD, methodology, and frameworks.

The role of the SDGs in the plan is to serve as a guide to promote the ongoing development of the plan. For Tirana and Albania, SDGs are very important as they seek to become sustainable leaders in Europe and worldwide. For the country, learning from others and tracking progress through the SDG measurement framework are important orientations for their development.

6.3 Public Green Space Actual Situation

Tirana has been facing rapid population growth over the last 28 years and urban development has thus evolved faster than the necessary infrastructure to support its growth (Table 2). The population of Tirana rose from 280,000 in 1989 to 842,000 today. The urban expansion did not follow sustainable living standards; however, it created a wrong philosophy in which the only important things were housing and construction, and all the rest were diminished, such as green or public space, which meant that the distribution of green space versus buildings was notable unequally (Sustainable Cities Platform, 2017).

The Tirana studies indicate that the proportion of open green space for 100,000 inhabitants is only 4.6 m^2 Compared to other cities in the world, this number is pretty low according to the standard rate for the green space coefficient which is 7m^2/inhabitant) (EBRD Green Cities, 2018). Two surveillance stations in the city of Tirana have also demonstrated that since 2013 air pollution is at a very high level. The situation worsened when the territorial reform of the MoT increased the city's area from 42 to 110 km^2 in 2015.

Table 2 Urbanization–public space ratio

Tirana city area	40,000,000 m^2
Green subdivisions of the city	Existing surface
Park area	100,000 m^2
Sport terrain area	100,000 m^2
Leisure area approximately	100,000 m^2
Project (design) area	700,000 m^2
Forest area	1,000,000 m^2
Urbanization–public space ratios	
Public space–urban space ratio	1.3% (Tirana, city)
Green space–urban space ratio	0.5% (Tirana, city)
Public space–urban space ratio	5.2% (Tirana, including forest)

Source Guri (2015)

According to the World Health Organization (WHO), *residents of urban areas should have access to green space of at least 0.5–1 hectare at a distance of 300 linear meters (5-min walk) from their homes.*

Given this fact, starting from a central area (mixed land use) of Tirana to reach the green areas outside of the city, citizens who use cars must travel for a minimum of 15 min and a maximum of 30 min depending on the traffic situation. Figure 3 demonstrates the time distance between each ring, for example, traveling by car from one ring to another takes 10–15 min, traveling by bicycle takes 15 min, and so on.

Today, the city faces the mistakes of the past, caused by the transformation of the socio-economic system, by the collapse of the economy, society, and culture, and also by repeatedly building as an individual sporadic initiative without permission.

Due to uncontrolled economic and demographic growth, water and green networks have become severely damaged and ecology has been neglected. As a result of Albania's inefficient transport system which is influenced by a car culture that views the car as a status symbol, severe traffic gridlock occurs, which has negative economic, ecological, and health effects. Consequently, the importance of preserving the built environment was not appreciated, which caused a massive loss of public space for social interactions (Les Ateliers, 2021).

Thus, there is a complete lack of open green spaces in the residential areas, especially once you leave the city center. As a result, the proportion between concrete and green space is at alarming levels. Over the past decades, green and recreational spaces within residential blocks, known as Urban Pockets or Pocket Parks, have been present in almost every area of Tirana. Their disappearance came as a consequence of their alienation into private spaces, usually with fragmented ownership, primarily restaurants and private car parking (Fig. 4).

According to Co-PLAN Institute for Habitat Development (2015b), based on the Tirana development strategy, public spaces are in decline, or their creation is affected as a result of:

- The mechanism of privatization through the acquisition of property and the provision of compensation.

The continuous development of multi-story buildings is based on the "development rights granted to the first investor" model. In this model, each property is built to its

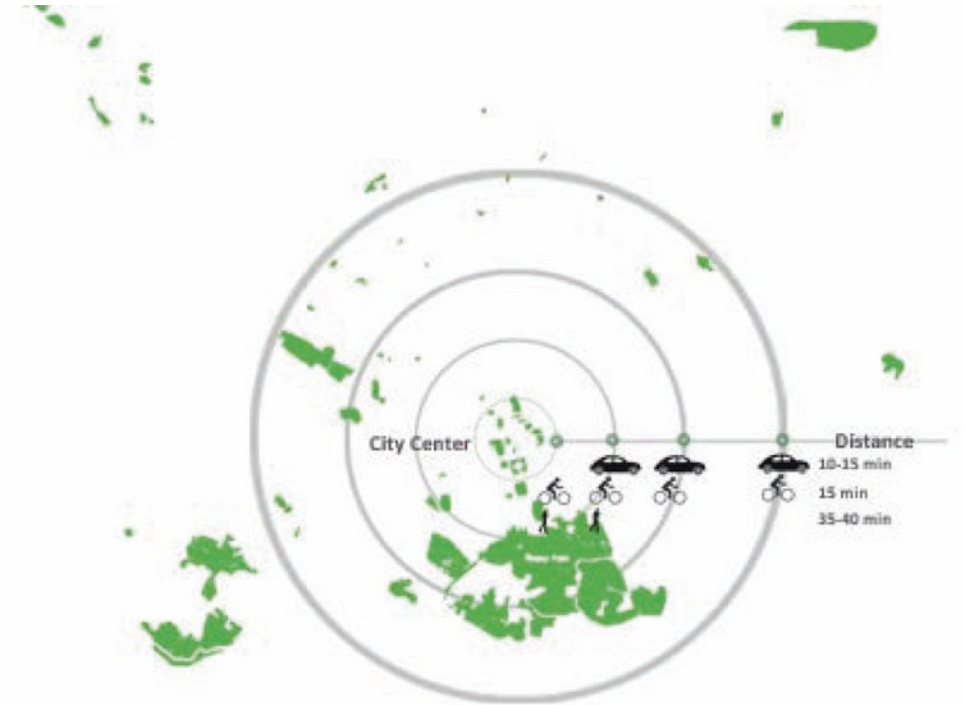

Fig. 3 Actual distance radius to reach green Spaces sf Tirana. *Source*: Co-PLAN Institute for Habitat Development (Co-PLAN, 2015b)

maximum capacity, while the adjacent land, whose owner has not yet applied for the building permit, would generate the public space (Fig. 5). In conclusion, the development conditions for the area (building intensity, building distances, and land use coefficient) are met without creating any public space, while the remaining properties remain empty and are not capable of achieving the right level of development.

- Confusion over ownership of public spaces in multi-story buildings due to private investments. Under a contractual arrangement between the landowner and the developer, these areas are owned by the land developer. Nevertheless, due to the requirements outlined in the building permit, these spaces are naturally used by the public, or at least semi-publicly by the residents. Hence, under the Building Co-ownership Act, these areas are not subjected to tenants' maintenance unless previously indicated in a signed agreement. Therefore, the management of these spaces remains the responsibility of the developer, who is generally not involved in doing so.

This explains the reasons for the deterioration of courtyards in multi-story buildings. Nevertheless, the Territorial Planning and Development Act, which came into force in July 2015, stipulated that, for the first time, these public spaces created on privately built residential blocks could be transferred under public ownership (Dita, 2015).

6.4 Pocket Parks of Tirana

The MoT currently implements projects for the creation of micro-spaces in public land only (focusing again at the center of the city) and not yet in those common spaces with common ownership between the buildings (Fig. 6).

Fig. 4 Lifecycle of a public space in Tirana. *Source* Author

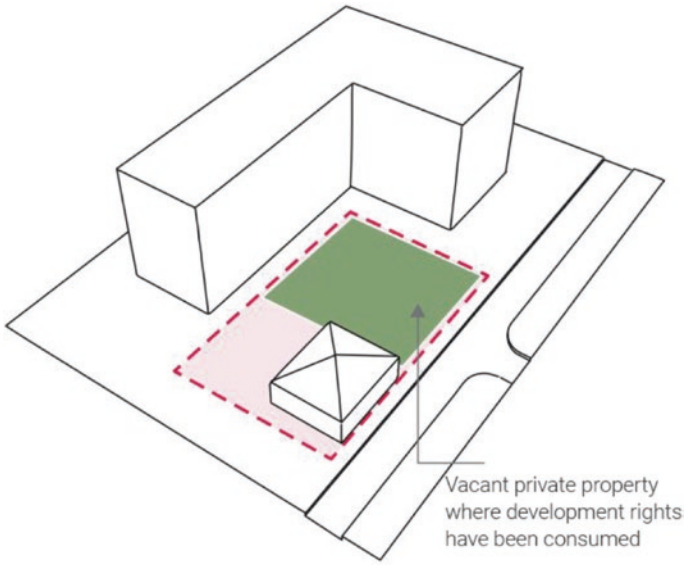

Fig. 5 Example for building on an undeveloped private property. *Source* Co-PLAN Institute for Habitat Development (2015b)

These projects have envisaged three typologies of intervention in public spaces.

- Interim public spaces.
- Retrofitting existing spaces.
- Open spaces between buildings or otherwise called urban pocket parks. Some of these pocket parks which have been completed today have had a positive impact on the affected neighborhoods and their inhabitants.

As a result, the outskirts of the city are still being ignored when it comes to providing the inhabitants with more open green spaces. The full potential of these spaces was never fully realized as a means of addressing certain environmental issues. This means not only bringing them back to the people but also bringing a change to their communities as a whole.

For this reason, most of these spaces are common spaces (used without restrictions by residents), but the problem lies in their ownership, maintenance, and management by the citizens and municipality, unclear location and identity, not appropriate design features, degraded environmental situation as well as private car occupation as illegal/informal parking.

As discussed above, according to the World Health Organization (WHO), *residents of urban areas should have access to green space of at least 0.5–1 hectare at a distance of 300 linear meters (5-min walk) from their homes.*

Fig. 6 Proposed pocket parks located mainly in the city center. *Source* Municipality of Tirana MoT

Therefore, reclaiming and transforming pocket parks in the city, whether they are green or not, proximity and accessibility would not be an issue for residents to reach open spaces. The proximity is a European Common Indicator of local public open areas which does not measure the achievement of targets and objectives and is not specifically focused on green space, but is based on a similar metric—the percentage of citizens living within 300 m from a public open area of minimum size 0.5 hectares (Ambiente Italia Research Institute, 2003). Pocket parks, as a result, are important walking destinations and settings in neighborhoods, and various aspects of pocket parks can influence walking. Their proximity to residents is an important urban design issue that should be considered when distributing such resources within neighborhoods, and it is worthwhile to investigate how pocket park proximity may influence residents to walk. The nature of these spaces varies depending on their functions, use, presence of greenery, and so on. Table 3's comparing scheme reflects some of these similarities and differences:

6.5 SWOT Analysis of Pocket Parks of Tirana

Understanding Tirana's pockets requires knowledge of their current situation. As a result, a SWOT analysis is carried out as a strategic method based on literature standards for assessing the Strengths, Weaknesses, Opportunities, and Threats in these spaces.

The advantages of pocket parks apply to the dimensions that are considered critical components of the method/analysis discussed below. Weaknesses refer to perceived dimensions that these spaces fall short of. Concerning opportunities, they seek to open a dialog on potential changes or new approaches to keeping these spaces enticing. Park threats include both future and current challenges that may jeopardize the viability of neighborhood and city assets.

+ Strengths

Most of the strengths of these tiny spaces which contribute as an added value to their future development are described:

- Tirana has gained experience through other urban development initiatives and with the sharing of perspectives, mainly expressed in recent urban initiatives.
- There is a gender and age group distribution in the use of the city's public spaces, thus promoting social exchange and inclusion (Lekaj et al. 2018).
- Such pockets are also found in some neighborhoods in a form of vacant lands (Fig. 7), easily accessible from the local's homes within a radius of 300 m of linear distance, about 5 min' walk (according to the WHO).

– Weaknesses

Based on a variety of academic and professional study analyses as well as previous readings, experiences, and dialogues, the weaknesses identified in these spaces include:

- The municipality has not yet put pocket parks as a priority, especially beyond the downtown area and outskirts.
- Private owners consider the revitalization of pocket parks unimportant, and without understanding, how these types of spaces will improve the value of their land.
- The lack of maintenance and cleanliness is followed by the neglect and abandonment of public spaces and, in the majority of cases, by the transformation into another category of land use.
- Some of these types of spaces are used as informal parking lots (Fig. 8) or for commercial uses, such as bars.
- The remaining spaces lack lighting and urban furniture.
- The abandonment of these spaces has resulted in an uncontrolled, chaotic development, and a lack of space for pedestrians.
- Clarification on ownership status is pending.

Table 3 Similarities and differences between the proposed spaces

Similarities	Differences
Illegal/informal parking	Different area surfaces varying from 100 to 700 m^2
Lack of greenery	Mismanagement and maintenance
Surrounded space is not well organized	Environmental situation
Design features (lighting, plants, benches, shades, structures, playground, etc.)	Various age group users of these pockets
Inappropriate road infrastructure	Morphology: terrain, orientation (sun/shadow)
Users	Ownership

Source Author

Fig. 7 The potential presence of greenery and the lack of maintenance of a pocket park in Tirana. *Source* Author

O *Opportunities*

- There are municipal programs and policies in some neighborhoods close to the city center that reflect the shift of pocket packs from informally occupied spaces to public open spaces.
- They make neighborhoods attractive to reinvest.
- Can contribute to economic growth, indicating more open space, more community spaces, and more small businesses around.
- Tackle traffic issues and find best practices for cycling and walking.
- Improving connections and increasing social interaction among residents.
- They can initiate more Public–Private Partnerships as the city has been familiar with this concept over the past few years in different types of projects.
- Fostering private sector, government, and civil society partnerships.
- Make the outskirts of the city attractive and improve living conditions for all strata of population and newcomers.
- Create some connection between the central area, nearby green spaces, and the neighborhoods around it.
- Improving living standards and rising land value in the ignored areas.

X *Threats*

- Growth of the population and urban development does not always strive to meet future needs and requirements.
- A weak planning structure and inappropriate strategies do not result in planning results adequately and sustainably.
- The lack of participation of citizens in the planning process will make them be against any projects by ignoring their needs and opinions.

Fig. 8 Pocket park sidewalk used as informal parking. *Source* Author

Fig. 9 Pocket park transformation. *Source* Co-PLAN Institute for Habitat Development

Fig. 10 "Pallati me Shigjeta" pocket park today. *Source* Author

- Private investors do not have sufficient incentives to invest in these spaces and are also uncertain about their future benefits.

6.6 Initiatives

Aside from the ineffective practices of public officials, there is little evidence of grassroots initiatives by citizens to get involved in their neighborhoods. Explanations for lack of community involvement include citizens' lack of trust in the effectiveness of participation, low confidence in public institutions to make proposals, etc. (Pojani and Maci, 2015). The lack of interest in providing adequate knowledge, combined with the passivity of the community, results in a relatively low level of public involvement (Theodori et al., 1995). Nonetheless, recently the local population seems inclined and eager to engage in the development of public spaces in the vicinity of their residential blocks.

On the bright side, between September 2014 and January 2015, the development of public places with community participation in mind has been achieved successfully in Tirana through the transformation of a pocket space close to the "Pallati me Shigjeta" neighborhood (Figs. 9 and 10). The pocket is surrounded by high buildings looking down on it facilitating the sense of community and a potentially higher interest in maintaining it. The path is very narrow but located near a high-traffic street that could be used for marketing. The success of the park stems from the neighborhood's maintenance of the pocket as well as being surrounded by small businesses that serve the residents as well as visitors of various ages and categories, including students from a nearby high school.

In 2015 Co-PLAN Institute for Habitat Development in Tirana carried out an initiative to transform a left unused space in a neighborhood far from the city center of Tirana. This initiative was brought off in cooperation with POLIS University and Tirana Municipality as part of their "Urban Activisms for Civic Democracy" program, sponsored by the US Embassy in Tirana, Deutsche Zentrum, and the Balkan Art Angle. The project's purpose is to increase community participation in processes that identify and address issues of collective concern in city-making processes and to assume responsibility for decisions affecting the city. Through urban activism and the participation of residents, the project focused on the greening of these areas and an improvement of the division of public spaces. Several meetings and collaborations with local community members were required to redesign the space. Field experts worked together with local stakeholders to accomplish this. A two-stage project addressing community-identified problems was developed and agreed on jointly throughout the project, providing an excellent example of participatory planning and citizen involvement in decision-making. This two-stage initiative addresses problems identified by the community in a way that has been developed jointly (Co-PLAN, 2015b).

A recent similar initiative that took place in the city center was the implementation of the #PublicMicroSpaces project launched by the MoT (Fig. 11), with a total value of 83,706,530.00 €. It aims at creating and reconceptualizing existing public spaces.

The main goal of the public micro-space project is to create and rethink the existing public spaces, no matter how large or small they are, they have the power to strengthen the created poles and to create or strengthen the identity of these poles. The MoT's public interventions (Skenderbej Square, the New Bazaar, the Grand Lake Park, the New Boulevard) prove an immediate absorption into those areas

by the city's inhabitants while at the same time revealing how much they have missed green spaces over the years and a strong desire to have as many as possible in the city (Fig. 12). The city is experienced intensively, the value of the properties around has increased, and the offer for tourists increased significantly. These investments are concentrated primarily in the city's central area as an immediate need. The first phase of the project begins with 11 public spaces in poles that have already been created, visible, and with immediate impact, where the project can continue in an exponential form in the future by expanding it into the neighborhoods and suburbs.

There are three typologies of intervention in public micro-spaces as also a location in Fig. 13 which are:

- Intermediate public spaces: Intermediate public spaces transform traffic areas that are overused and unnecessary into public spaces. These spaces redesign unsafe or abandoned intersections, transforming them into landmarks of the city and impacting surrounding neighborhoods. In this project, there are six intermediate public spaces Cafe Fora, Street Kont Urani, Selvia, Medreseja, Dinamo Stadium, and Blloku Partizani.

Fig. 11 Micro-space transformation from the MoT initiative. *Source* Author

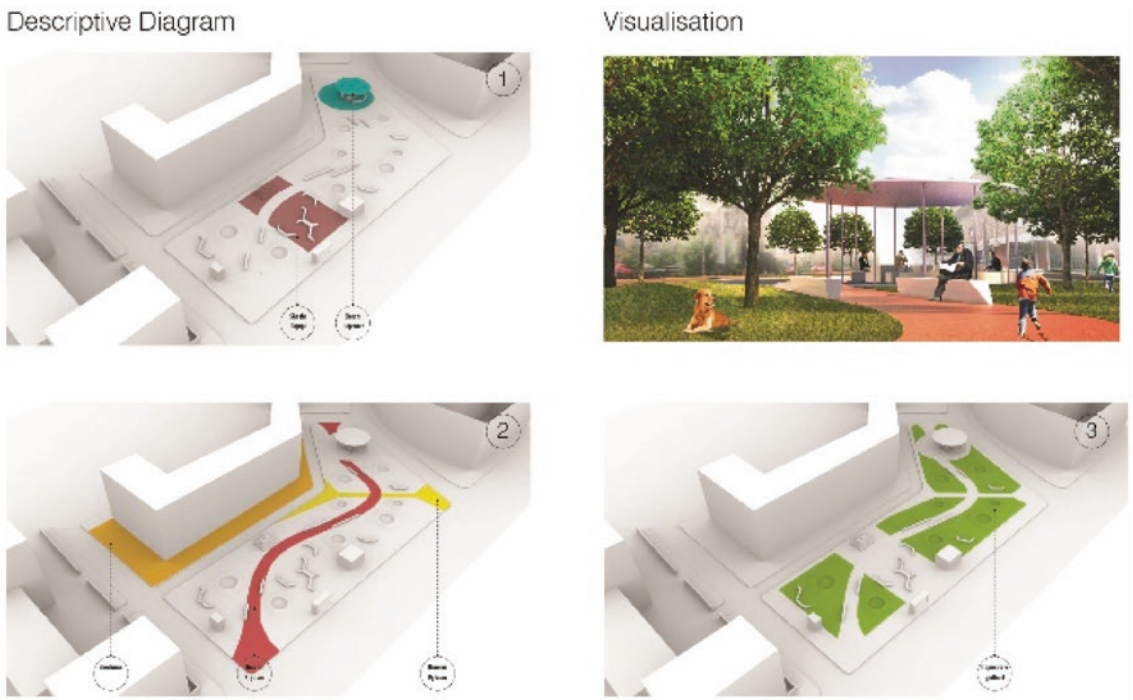

Fig. 12 Re-treatment of existing urban park micro-space. *Source* MoT (2018)

Fig. 13 Location of proposed projects. *Source* MoT (2018)

- Re-treatment of existing spaces in this project are Kashari Square, Çajupi Garden, and 5 May Street.
- Public spaces between buildings: in this project are Lapraka and Selita residential block and headquarters.

The novelty of this project is related to the fact that it has a design strategy on how to transform these spaces. Spaces such as these are designed to be distinct from one another, promote new functions, and be public spaces that have distinct identities.

Each of the spaces has a specific element designed particularly for that space. The forms utilized are primitive and make the public space functional but at the same time artistic, serving as fundamental functions for sitting or shading. They also provide sub-functions such as auditoriums, shadows, reflections, landmarks, urban games, to create a separate network of sensory public spaces.

Unfortunately, there is a lack of community engagement and participation in this project's decision-making. Consistent information and transparency, both in terms of legislation, urban planning, and design, would be the basis for raising awareness of the community's role. As long as residents are unaware of their basic civil rights concerning their urban living environment, it is useless to engage them. Awareness that public space directly affects users can only promote their active participation with information in the urban planning of their neighborhoods or define their will.

True community leaders could enhance community engagement in this regard.

The government appears to accept (at least theoretically) the residents' role in the development of public places as well as their indirect responsibility in their maintenance. The establishment of a building administrator is regarded as a positive step toward community activation, but it is a role that needs to be fostered and not only exist formally. If APR claims that each project is preceded by "informing" or even "consultation" and "involvement", the residents are still predominantly not aware of these processes. If these practices are indeed taking place, then more outreach and showcasing are needed. In any case, there was not any indication of efforts for introducing any participatory approaches into a legal framework, apart from the existing law on public informing. On the other side, the Co-PLAN project proves that the local community seems inclined and willing to participate in the creation of public spaces close to their residential blocks if such a possibility is given.

7 Conclusions

Cities today have the responsibility not only to conserve natural resources, but also to create ecological centers in the concrete jungles which we have created, bringing back the color green, and handling various requirements such as population growth, economic development, and so on. Pocket parks are social places that offer layers of services including mitigating climate change, maintaining a living ecosystem in urban settings, improving safety, promoting social inclusion, and providing an attractive medium for economic establishment and urban food production. Infusing such concepts in the micro-urban context facilitates socio-ecological integration, making urban sustainability more approachable and materialized in our daily lives (Elmqvist et al., 2013).

Pocket parks are downsized community parks that appear due to the need for accessible public spaces in dense cities which typically lack developable land for public recreational areas. They work on the hidden potentials of leftover urban spaces. They do not concern themselves with grand sizes, but rather purpose. They work on the intimate neighborhood level to create a democratic place of knowledge exchange and build a sense of community in an act of community activism (Banerjee, 2001). By targeting specific groups of people who use and maintain their space, they encourage new social connections through a variety of activities. The activities appropriate for pocket parks are whatever activities that satisfy the community's needs. Such functional flexibility and intimacy turn them into urban social living rooms, differentiating them from typical parks and their associated recreational activities.

Pocket parks' most significant challenge lies in their maintenance. Even though they are easy to build, they can quickly deteriorate without practical design, community support, usage, and maintenance (Blake, n.d). A critical point to the success of pocket parks is the ability of the community to self-organize their volunteering individuals. Case studies of successful pocket parks around the world indicate that design flexibility and user involvement are necessary for pocket parks to succeed, so that they can evolve along with ever-changing cities and changing communities. Bottom-up participation of users who are familiar with these spaces allows them to build objects and activities that they think can benefit the community; thus, designing a gradual process of place-making in their open-air social living room. Instead of resting, socializing, and recreation, pocket parks are adapted for learning, cooking, childcare, gardening, beekeeping, maintenance, tending to animals, and every other thing that people would like to do; transforming dormant urban vacuums into something more sustainable.

8 Outlook

In the Tirana case study, claiming the land for private or public pocket parks is strongly linked to finding a car solution. In a society, in which the car remains the quickest way to travel from one point to another inside the city, the idea of switching the car park to pocket parks will not happen without inconsistencies. In this regard, local governments need to develop an efficient and trustworthy public transport system. It may take less time to provide a reliable alternative to cars than waiting to change people's mindsets.

On the other hand, the possibility of overcrowded green areas decreases if pocket parks and community gardens are built on a network with the green infrastructure of the city. For a large number of residents to be adequately accommodated, the municipality needs to figure out how to best incorporate these existing spaces.

It may be more suitable to create multifunctional small spaces in crowded neighborhoods with sitting and shading elements and some vegetation, offering more possibilities at less cost than what would have been involved in constructing a large park. For instance, parking areas or vacant lots have great potential for rapid and highly efficient conversion.

Schoolyards, the gardens of governmental institutions should also be publicly accessible. Furthermore, cyclists and pedestrians need space where they can commute around comfortably with enough distance between them. Many cities deal with these problems. For example, Brussels just launched a new traffic concept for its inner-city, and Munich has introduced pop-up trails.

More measures can be implemented by individuals, alongside the idea of pocket parks, such as green roofs and walls that contribute to providing economic, ecological, and social benefits, which of these measures works best has to be decided on a case-by-case basis.

The living conditions of people are dissimilar and so are their problems, which call for numerous solutions. Those of us who live in small apartments with no balconies or gardens are going to be more challenged than those who live in big outdoor homes. It is important to take into account these sorts of social aspects.

9 Lessons to Be Learned

The idea of pocket park creation seems to be completely sound and valid and might be one of the concepts if the goal of a sustainable city is to be achieved. However, it appears that more attention should be paid to the political and administration aspect (a range of politics and strategies).

The paper investigated how pocket parks can adapt to and answer the range of contextual needs in dense mixed-use residential neighborhoods. The aim and purpose of creating pocket parks in Tirana (previously and recently) are to make residents aware of the value of these spaces as strategies and activities for sustainable development. To this extent, it is entirely feasible for the municipality and government to increase their number spread in the city by communicating and coordinating meetings with the citizens of a specific area about pocket parks and public space projects. More participatory planning of smaller neighborhood projects should also be implemented to adapt the function and design of public spaces to people's needs and to allow the transformation of neglected public spaces into attractive areas that reflect the population's needs.

That being said, a possible solution to increase the number of such spaces in Tirana is to close some unnecessary roads for cars, start organizing parking areas more efficiently, and engage residents in activities in these newly freed spaces. Furthermore, housing should be built with public space in mind.

The main concepts will appear to be solutions-based for this research:

- The bottom-up approach is a concept that emphasizes the participation of the local community in development initiatives and also ensures community ownership, and commitment in these common spaces (Kaiser, 2012). With the support of established incentives, the partnership process (Municipality-Residents-NGO-Private Entities) may begin either from the bottom (community) or from the top (local government) to establish pocket parks (for example utilizing the Community Fund). Practices such as structured partnerships, building capacity, and co-design might be as fully potential applicable models.
- Public–Private Partnerships as cooperative arrangements between two or more public and private sectors, typically of a long-term nature. In other words, it involves government and businesses that work together to complete a project and/or provide services to the population (United Nations, 2015).
- Placemaking as a multi-faceted approach to the planning, design, and management of public spaces. It capitalizes on a local community's assets, inspiration, and potential, to create public spaces that promote people's health, happiness, and well-being (Jalkh, 2017).
- Enhancing the goal of SDG 11 (sustainable cities and communities) in line with the long-term goal that livable cities must be green–blue infrastructure, which not only benefits climate change adaptation and mitigation (SDG 13) but also gives us space for leisure and recreation, and ultimately contributes to human health and well-being (SDG 3).

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Guardians of Urban Public Spaces: How Green Markets Enhance the Notion of Sustainability

Sara Ursić, Nika Đuho and Anka Mišetić

Abstract

Sustainability has become one of the most popular discourses of our societies. Importance of sustainability arises from the fact that societies are facing numerous (especially, ecological) risks. But there is no universal *recipe* for achieving sustainability. In fact, sustainability is being oriented towards *locality*—public places of living, working and recreation where the idea of sustainability reaches full purposefulness, especially for urban citizens. Seeking sustainability on local levels is justified by the fact that our communities are spatially, ecologically and culturally specific and in which individuals have specific needs and demands. In these circumstances, the question of attitudes towards transforming potentials of public spaces becomes one of the key determinants of development strategies (Auclair and Fairclough in Theory and practice in heritage and sustainability, Routledge, 2015). From the reflections of Max Weber to contemporary urban studies, green markets are most central and resilient public spaces, drivers of the development of *urbs* which encourages us to analyse them as important *locality* connecting it with new postmodern and sustainable city paradigm (Seale in Markets, places, cities, 2017; Visconti et al. in J Macromarketing 34:349–368, 2014; Watson in Urban Stud 46:1577–1591, 2009). Its central place in city structure means the green markets are strongly embedded in urban identity, providing idea of urban community as a place of everyday social interaction, space of exchange and diversity. Bearing this in mind, we will argue that green markets have the potential to become creative and sustainable public spaces due to their potential to be *green* literally as well as conceptually. To test our hypothesis, we explored citizen's perceptions and attitudes towards green markets as public spaces important to community sustainability. This research was conducted in the two largest cities in Croatia (Zagreb and Split) using a quantitative research methodology. The results broadly confirmed that green market is compatible with the principles of postmodern urbanism, such as sustainability, participation, social inclusion and the potential for social innovation.

Keywords

Sustainability · Local community · Green markets · Urban public spaces

1 Introduction

Sustainability has become one of the most popular discourses in contemporary society. While the debates on sustainability started in the 1980s, the meaning of the concept has been constantly changing. As a result of increasing urbanisation, for example, one of the current approaches to sustainability is the "territorialisation" perspective (Beriss, 2019). This shows how the concept should not be perceived as a universal process or a globally prescribed solution, but rather as a dynamic requiring contextualisation through local frameworks to answer the needs of specific communities (Zeman & Zeman, 2010). In urban contexts, sustainability is also determined by the quality of public spaces. Urban public spaces are defined as institutions that can have several and often intertwined functions, including economic, political, religious, social, symbolic, ecological or cultural ones (Abercrombie et al., 1994). In Europe, urban public spaces are typically represented by squares, green markets, streets or parks. Sociologists usually

S. Ursić (✉)
Institute of Social Sciences Ivo Pilar, Zagreb, Croatia
e-mail: sara.ursic@pilar.hr

N. Đuho
Catholic University of Croatia, Zagreb, Croatia
A. Mišetić Faculty of Architecture, School of Design, Zagreb, Croatia

A. L. Pisello et al. (eds.), *Building Resilient and Healthy Cities: A Guide to Environmental Sustainability and Well-being*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-031-33863-2_11

consider these spaces as traditional urban institutions due to their links with Europe's heritage. Urban public spaces are important not only because of their physical appearance but also because they enable social interaction and create a sense of predictability in everyday life (Mumford, 1970). In addition to being physical elements of the city, they contain symbolic and cultural meaning. These spaces also combine the usual and the unusual, the repetitive and the spontaneous, and the predictable and unpredictable. While considering them as traditional institutions, however, we should bear in mind that urban public spaces are embedded in the socioeconomic, cultural and political contexts of particular societies. Their nature, therefore, is inevitably fluid and dynamic (Čaldarović & Šarinić, 2015).

In this paper, we focus on the potential of green markets as urban public spaces with a long history, which makes them public spaces par excellence. Throughout history, cities and markets have always sustained each other. From Max Weber to contemporary urban studies, green markets have been considered as the most resilient of public spaces and as drivers of urban development. The city offers green markets a location, demand and social context, while green markets bring profits to the city and sustain its culture (Janssens & Sezer, 2013). Green markets are usually located in city centres, which are usually the historical hearts of urban settlements; they thus carry a strong symbolic and emotional meaning. Green markets have persisted throughout history and still play a key role in the life of many European towns, which is why some of them continue to be known as market towns. Green markets differ considerably in size; most importantly, they differ in location and function. Tunbridge (1992) identifies four types of green markets: traditional markets (located in unrevitalised parts of the city), public markets (located in revitalised parts), farmers' markets (located on the city's edge) and festival markets (temporary markets aimed especially at tourists). Traditional, public and farmers' markets may occasionally serve as festival markets.

Green markets can be best studied through the actions that take place in them: buying, selling, watching, talking, eating, touching, smelling, moving, socialising, observing, documenting and photographing. These actions show how our senses are "emplaced", that is, connected to a particular place (Seale, 2017). Mumford (1970) argued that contact in public spaces among the city's inhabitants is the ultimate expression of urban life. He considered the city as an entity that had to be scaled to a human dimension to meet people's needs. In addition to their economic function, green markets have also a social, cultural and ecological role, which is a precondition of their continued existence. From an economic perspective, these markets are places of supply, trade and exchange that foster local entrepreneurship and nurture the local economy (Beriss, 2019). But green markets are also nodes of interaction among different vendors, consumers, and between vendors and consumers. These places can be analysed as sites of folk ethnography. Within them, people are constantly exposed to the unusual and have the opportunity to challenge themselves mentally, emotionally and socially (Janssens & Sezer, 2013).

Green markets incorporate a specific type of social structure based primarily on face-to-face interactions; they do not depend just on an abstract price mechanism (Storr, 2008). They offer opportunities for connection, inclusion and the building of a sense of local community (Watson & Studdert, 2006). From a cultural point of view, green markets promote and maintain both tangible and intangible heritage; they preserve the specific way of life of each community, thus serving as a node where past and present meet. Green markets play also an ecological role by influencing the quality of consumers' life, promoting healthy food and nutrition and maintaining rural–urban linkages (Crespi-Vallbona & Dimitrovski, 2016).

The current increased popularity of green markets can be explained through several factors. More and more, consumers desire fresh and locally produced food. In this context, green markets appear to be part of an alternative food system because they re-territorialise food (connecting it to a particular location) and re-socialise it (encouraging interaction and trust between producers and customers) (Giampietri et al., 2016). Green markets may also be understood as places of resistance to globalisation. When seen through the lens of resistance to multinational corporations, food localisation becomes a metaphor for a politics of place and the defence of heritage and material cultures of production (Beriss, 2019). Brown et al. (2007) also note that external factors can contribute to the popularity of green markets, such as growing awareness that these places stimulate the local economy. Research has shown that visitors usually go to such markets not only because of the food's quality and the chance to communicate with producers, but also because of intangible attributes such as supporting the local economy and protecting cultural heritage (Brown et al., 2007; Vecchio, 2009).

2 Green Markets in Croatian Context

In Croatia, green markets are usually open every day from early morning to early afternoon. They mostly offer fresh fruits, vegetables, eggs and dairy products. Surveys conducted in other countries have shown that the typical green market consumer is a middle-aged woman who visits green markets weekly or monthly and has a higher education and an average socioeconomic status (Seale, 2017). However,

in the Croatian context, green markets can be divided into Mediterranean and continental ones. Mediterranean green markets are usually open public spaces located in the very centre of town (Fig. 2).

Their openness is determined by a specific Mediterranean lifestyle: spontaneous meetings, leisure activities and socialisation in outdoor spaces. For example, the market in Split (known as Pazar) is surrounded by local hardwood trees and is located next to Diocletian's Palace and the Church of St. Dominic (Fig. 1). The site is considered to be the heart of Split and is also a popular tourist destination. Pazar's position near Diocletian's Palace (a UNESCO world heritage site) preserves social life in the palace and contributes to the market's exceptional value. Because many people socialise in the city centre regardless of age and gender, Pazar contributes to the general social life of Split. Thanks to its proximity to the heart of the city, the market is visited regularly. Pazar represents also an important urban and regional infrastructure where agricultural goods from the surrounding area are sold to customers daily. The market embodies the spirit of Dalmatia and the Mediterranean through the colours, flavours and aromas of its fresh fruits and vegetables, as well as its yelling and bargaining. In Pazar, the characteristics of the Mediterranean diet are highlighted by the preparation of fresh seasonal foods, especially fruits, vegetables and fish. Continental green markets, such as those in Zagreb, are recognisable for their combination of outdoor and indoor spaces. In addition to the city centre, they can also be located in neighbourhoods. In Zagreb, almost every neighbourhood has a green market. However, the city's biggest and most famous market is Dolac, which is located just a few metres from the main square and connects the oldest parts of Zagreb, Gradec and Kaptol (Fig. 2). The women selling the goods,

Fig. 1 Pazar market—plan (*Source* https://dalmatinskiportal.hr/vijesti/vizija-pazara-prezentacija-koja-je-odusevila-vijecnike/121621)

Fig. 2 Position of main green market in the city centre in Zagreb (Dolac) and Split (Pazar) (*Source* Authors)

known as "kumice", are central to Dolac's identity, creating a unique and familiar atmosphere. Especially in Zagreb, green markets are also renowned for the unique umbrellas that protect vendors' stalls. The food on offer is mostly fresh fruits, vegetables and meats. The continental diet is based on meat and pickled spices, primarily as a result of Hungarian and Turkish influences. Unlike green markets in smaller towns, Dolac offers also souvenirs, clothes and handicrafts. Larger cities, including Zagreb, are characterised by anonymous crowds and haste. In this context, green markets can function as spaces of relaxation and socialisation, especially during weekends. When Dolac closes, it becomes a gathering place for the young and tourists, which confirms its importance for the city's cultural identity.

In the survey "Consumer Satisfaction with City Markets in Croatia", Radman et al. (2002) examined differences in satisfaction according to place of residence. They confirmed that there was no significant difference between consumers in Zagreb and Split. The average satisfaction of respondents in Zagreb was 3.82, while in Split it was slightly greater, 3.94. After analysing the existing research on green markets in Croatia, we found their weaknesses to be higher prices than in supermarkets, lack of parking spaces, unfavourable working hours (especially, for full-time employees and parents with children), dependence on weather conditions, insufficient infrastructure and slow adaptation to innovation in sales and marketing (Strategija razvoja hrvatskih tržnica, 2013). However, it is also important to stress green markets' strengths, such as the cultural importance they have for the wider community and their role in promoting entrepreneurship, socialisation, healthy foods and lifestyles and ecological awareness (e.g. food sold without unnecessary packaging and with fewer food miles) (Strategija razvoja hrvatskih tržnica, 2013).

3 Methodology

This research is part of the project "Sociocultural aspects of farmers' markets in Croatian towns". The project adopted both a qualitative (interviews and storytelling) and quantitative (survey) methodologies. In this paper, we present the results of the survey, which was conducted in the spring of 2020. Due to the COVID-19 pandemic, the survey took place online (via Facebook) and the sampling was based on the snowball method. Using Facebook as a platform for collecting data was based on the fact that it enables to select groups of interested public. Researching green markets

during a period of social distancing and lockdowns was limiting; however, it provided the opportunity to explore the phenomenon's social resilience. Social networks-based surveys have shortcomings in terms of representativeness, but as Baltar and Brunet (2012) suggest, this approach reduces financial, temporal and spatial costs. Furthermore, the use of random virtual groups lessens selection bias. Nevertheless, some steps must be taken to guarantee scientific validity, such as including "time limits for collecting data, building sample frame and defining control variables to validate results" (Baltar & Brunet, 2012: 16). In our study, we adopted all the above measures.

The research is based on three hypotheses: (1) There is no statistically significant difference between respondents from Split and Zagreb regarding attitudes towards the importance of green markets as urban public spaces. (2) There is a statistically significant difference between respondents from Split and Zagreb regarding the frequency of market visits. (3) There is a statistically significant difference between respondents from Split and Zagreb regarding attitudes towards green markets as social spaces.

The survey comprised 373 respondents; 78.3% were from Zagreb and 21.7% were from Split. In terms of gender distribution, 82% of respondents were female, while only 18% were male. The majority of respondents (83.1%) had a higher education degree, while 16.9% had a high school degree. Furthermore, 80.7% were employed and 39.9% thought that their financial status was average, while 38.9% thought that it was above average. The sample does not represent the entire Croatian population; however, it does represent the interested public.

4 Results and Discussion

This paper aims to compare green markets' potential as resilient urban public spaces in two Croatian cities that differ in size, climate and culture—all elements that influence everyday life. Considering the specificities of each city, the goal is to identify differences in frequency of usage and attitudes towards the meaning of farmers' market.

According to 94.9% of survey respondents, green markets are significant spaces that embody a specific culture and mentality (Fig. 3). A high percentage of respondents agreed that green markets represent authentic urban places (90.7%) and allow unique experiences (86.9%) through sight, smell, sound, taste or touch (90.9%). These results show that respondents were well aware of the importance of green markets as urban public spaces.

Attitudes towards the uniqueness of green markets are corroborated by the fact that 48.7% of respondents were regular market visitors (Fig. 4). Almost half of the respondents visited farmers' markets weekly, which means that they participate regularly in activities connected to green markets. Even if they only come to buy food, they are still immersed in the interactions that take place in the market. However, we found a statistically significant difference between the two cities in terms of the frequency of visits. In Split, more respondents visited green markets daily than in Zagreb. This difference might be explained by the fact that Zagreb is four times bigger than Split; thus, daily commutes in Zagreb take much longer, making it more difficult to pay daily visits to the market during office breaks.

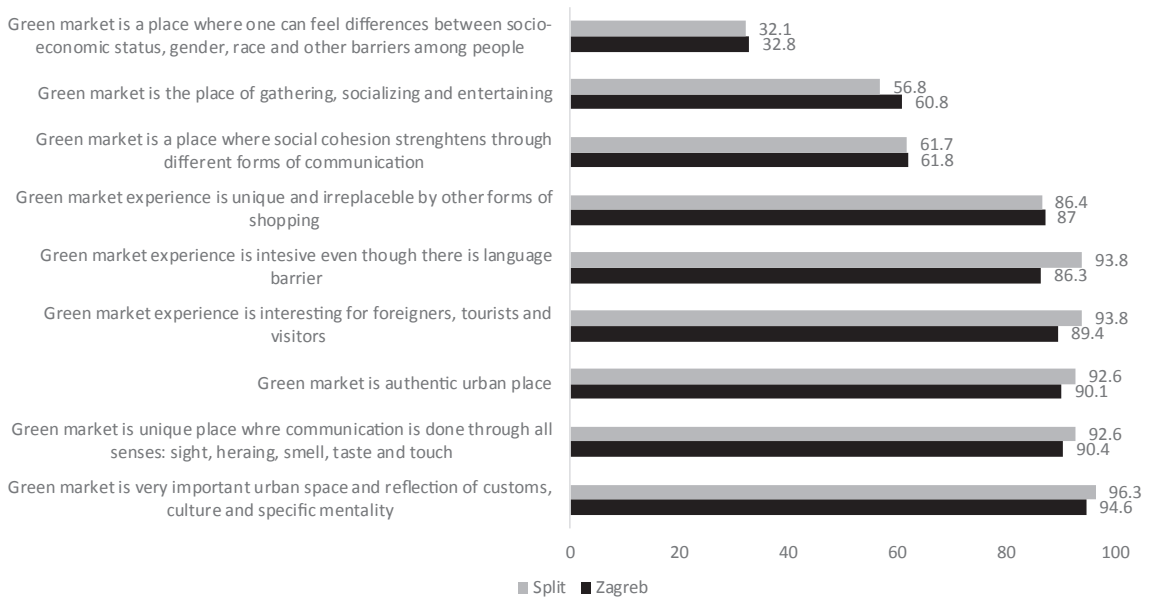

Fig. 3 Attitudes on green market as urban public space (% of answers important and very important)

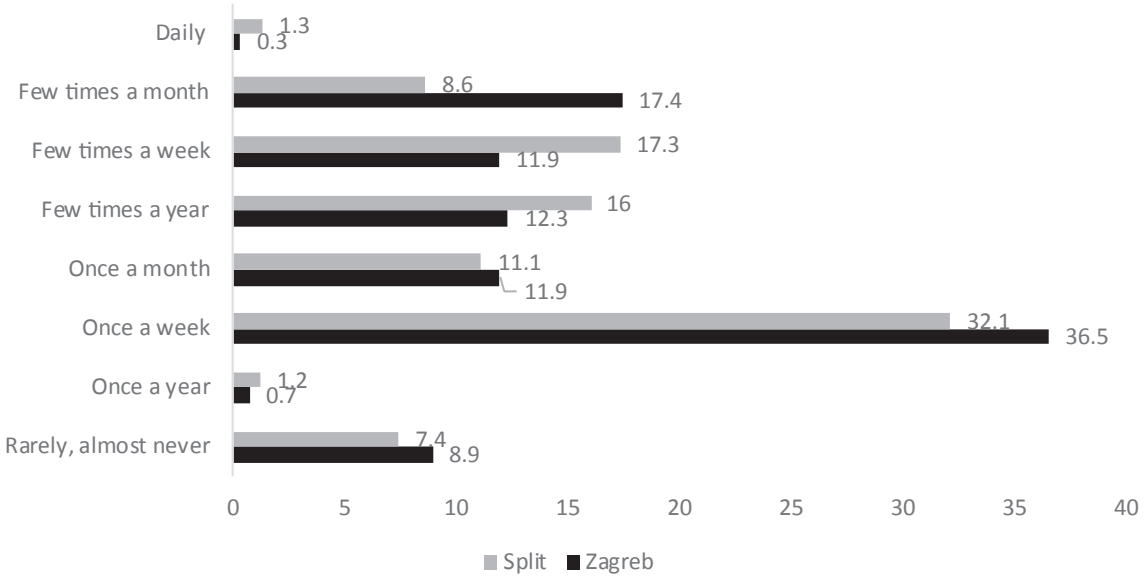

Fig. 4 Frequency of green market visits (%)

We also wanted to identify the importance of specific elements in green markets to understand respondents' motivations and the markets' functions (Fig. 5). The results indicate three groups of functions: fresh food shopping, the servicing of green markets and socialising. For 98.2% of respondents, the most important aspect of green markets was the "quality and freshness of the produce", followed by "diversity of choice" (94.3% of respondents) and "local production" (94.1%). These results show the functional and pragmatic importance of these markets, which is embodied in shopping for quality and locally sourced food. However, in essence, these practices are also rooted in the broader postmodern values of a sustainable lifestyle. Also very important are the "price/quality ratio", which was mentioned by 89.6% of respondents, and the "relationship between vendor and buyer" (78.6%). The latter is based on trusting that the food sold is local and fresh, which further highlights the localisation discourse as an important aspect of green markets in Croatia. Only 25.1% of respondents said that green markets should be sources of groceries from other culinary cultures and geographic locations. This confirms the abovementioned "local vs. global" narrative.

Elements related to the servicing of green markets (e.g. toilets, parking spaces, ATMs, stores, opening hours and location) were also important for respondents. Regarding "closeness of the market", we found a statistically significant difference, with respondents from Zagreb considering closeness to be more important than those from Split. This is another consequence of the city size factor. Although Zagreb has many neighbourhood markets, living and working in the city still require a more complicated organisation to reach these spaces, which makes location more significant. The least important elements appear to be those connected to the social function of the market, such as mingling (30.7%), exchanging culinary advice (21.9%) and the chance to haggle (19%).

Regarding green markets' benefits to the local community, respondents highlighted the "availability of food" (95.7%), "strengthening the local economy" (92.8%) and contributing to the "health of the community" (78.3%). Interestingly, "affordable prices" were seen as the least significant benefit to the community (Fig. 6). According to more than 70% of respondents, green markets can enhance community life by connecting people and providing entertainment and opportunities to communicate.

Since green markets constitute vital place-based experiences for the community, we wanted to explore which variables correlate with the perception of such markets as social spaces and understand possible differences between respondents in Zagreb and Split (Table 1). The data show that the perception of green markets as social spaces is highly correlated with the following statements: "green markets offer a unique shopping experience"; "green markets offer a unique sensory experience"; "green markets enable human interaction and contribute to community vitality"; "green markets are places of socialisation"; "green markets are urban public places embedded in a specific culture and mentality". While there was a high degree of correlation with these statements in both Zagreb and Split, we found a slight difference regarding the following two: "green markets are urban public places embedded in a specific culture and mentality" and "green markets are places of socialisation". It seems that the social role of green markets in Split is connected to the aforementioned

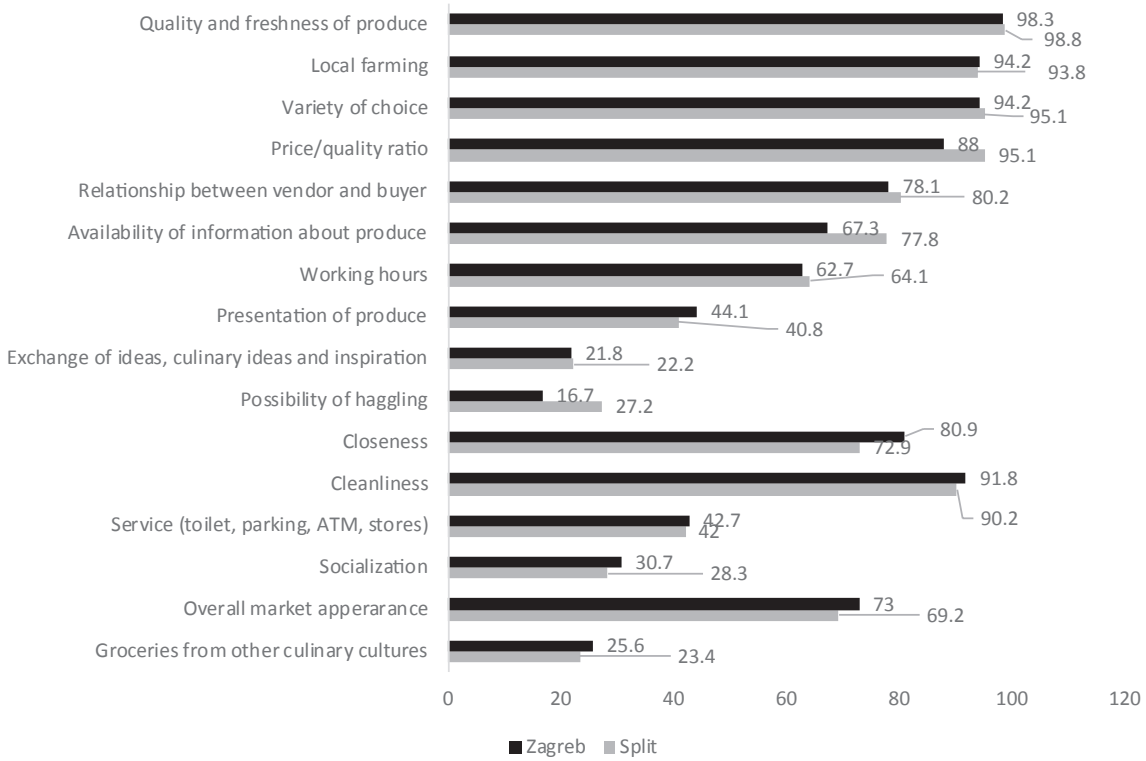

Fig. 5 Elements that are important for overall quality and functioning of green markets (% of important and very important)

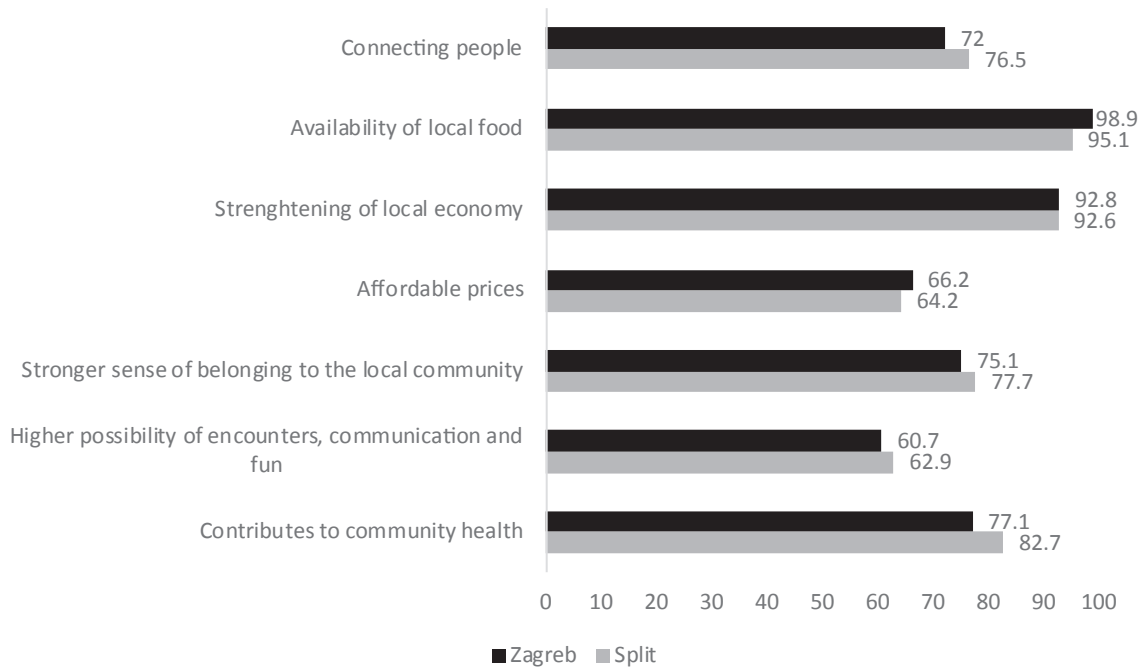

Fig. 6 Benefits of green markets to local community (% answers mostly contributes and extremely contributes)

Mediterranean way of life ($r = 0.783$, $p < 0.05$) consisting of spontaneous meetings, leisure activities and socialisation in outdoor spaces. In a Mediterranean context, everyday life is strongly dependent upon open public spaces, including green markets. In the case of Zagreb, there was a higher correlation with green markets as places to socialise

Table 1 Perception of green markets as social spaces

Variable	GMs are specific urban public spaces embedded in culture and specific mentality of community	GMs are places for socialisation	GMs contribute to social vitality of community	GMs are unique shopping experience	GMs are unique sensory experience
Zagreb	0.692	0.748	0.769	0.794	0.776
Split	0.783	0.696	0.754	0.769	0.721

($r = 0.748$, $p < 0.05$). Since larger cities, such as Zagreb, are characterised by anonymity and haste, green markets are perceived more like community hubs where people come to spend time together, hang out and interact with others or just enjoy the atmosphere.

5 Conclusion

Starting from the premise that green markets are important and resilient urban public spaces, this paper explored such spaces from the perspective of social sustainability. To address the specific aspect of sustainability as locality, the paper compared attitudes and behaviours regarding green markets in Croatia's two biggest cities, Zagreb and Split. The research set out three hypotheses, which included (1) attitudes towards green markets as urban public spaces, (2) as social spaces and (3) the frequency and use of green markets. The first hypothesis ("There is no statistically significant difference between respondents from Split and Zagreb regarding attitudes towards the importance of green markets as urban public spaces") is mostly confirmed. A very high percentage of respondents stressed the importance of authenticity, uniqueness and sensory experiences in green markets as urban spaces par excellence. Furthermore, they said that these markets constitute interesting experiences for tourists. Therefore, they should be presented as city landmarks.

The second hypothesis ("There is a statistically significant difference between respondents from Split and Zagreb regarding the frequency of market visits") is also confirmed. Even though the results indicate that half of the respondents were weekly visitors, the difference between the two cities is found in the daily visits. If we consider respondents' answers from the perspective of social sustainability, we could interpret them less in reference to pragmatism (e.g. city size) and more to the local way of life and culture. The evidence may be a result of the everyday rhythm of the city, which is part of the local mentality. As a Mediterranean city, Split lives outdoors. It has one designated centre that attracts a heterogeneous population and its green market is located at the intersection of the main streets, which makes it more accessible.

Finally, the third hypothesis ("There is a statistically significant difference between respondents from Split and Zagreb regarding attitudes towards green markets as social spaces") is also confirmed. As one of the oldest urban institutions, green markets are embedded in urban identity and represent spaces of interaction. The primary function of green markets is to allow the buying and selling of fresh and locally grown food. The results confirm that food's quality, freshness and local origin are the most important perceived elements of green markets. However, these places are social phenomena underpinned by a system of social norms and interactions that makes them more than just a physical space. They are social processes. Even people who simply walk across the stalls without interacting with the vendors and the shoppers are not completely passive participants; by being there, they contribute to the visual event and other people's experiences. In both cities, the results indicate that the social aspects of green markets are perceived as being of less importance. However, in Zagreb, respondents emphasised the markets' social function more compared to Split. As explained above, Split's everyday rhythm allows daily visits to the market as part of normal routines, which are often intertwined with other errands, spontaneous meetings and socialisation. In Zagreb, people visit green markets on weekends as part of their weekly grocery shopping with somewhat less spontaneity. In that city, the market has a stronger social function and serves as a community hub where people hang out. Overall, despite small differences in attitudes that can be interpreted as a result of different urban traditions, our research confirmed that green markets harbour a special form of socialisation. They represent one of the distinctive public spaces where different urban actors meet each other. In these encounters, the typical urban character (Simmel's "stranger") communicates spontaneously and casually, thus ignoring the established social boundaries. This is one of the most important contributions that green markets can make to the sustainable development of the city.

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Environmental Assessment for Sustainable Land Use in Protected Landscapes: The Case of Vesuvius National Park

Alessio D'Auria and Irina Di Ruocco

Abstract

The Vesuvius National Park (VNP), with its approximately 110,000 inhabitants within the park area and over 600,000 in the territory of the municipalities, is the most populous in Italy and the most densely populated. But it is also a park with unique environmental and landscape values recognized on a global scale: MAB UNESCO biosphere reserve, two Site of Community Importance (SCI) areas, and one Special Areas of Conservation (SACs). Therefore, the dichotomy between nature conservation needs and local development instances, here more than elsewhere, demands a solution rooted along a path of sustainability. Furthermore, it must be considered the peculiarity of being one of the most potentially dangerous volcanoes in the world: due to the risk to which inhabitants and activities are subjected, the entire area is declared "red zone" by National Civil Protection Office and is consequently prevented any increase in volume, necessarily shifting the orientation of development policies toward sustainable supply chains: tourism (naturalistic but also religious and cultural ones), fine agricultural production, conversion of old farmhouses, etc. Starting from the preparation of the Environmental Report and the Impact Assessment for the Urban Plan of a municipality belonging to the so-called "Vesuvian crown" composed of 13 cities lying inside the boundaries of the VNP, we aim to identify an operational methodology that can be adopted by all the municipalities within the park territory. The Vesuvian territory contains a plurality of different and unique elements in their identity: natural areas, local products of high food and wine quality, paths and nature trails, ancient farms. But it is also characterized by a very strong soil consumption: during the 70 s until some years of the 2000s, a rapid urbanization phenomenon almost devoured the protected area, aggravated by phenomena of illegal building. Thus, the study has highlighted the conditions of fragility and vulnerability of the Vesuvian area, with special concern to soil consumption, potentially compromising landscape and ecological values. The assessment of environmental suitability of plan actions has addressed the strategic choices toward sustainable development, through conservation of natural resources and biodiversity, relocation and concentration of production activities, protection of cultural heritage, mitigation of hydraulic risk, moving in the direction of a conscious and rational use of the "soil" resource.

Keywords

Strategic environmental assessment · Protected areas · Soil consumption · Land use planning · Territorial risks

1 Introduction: Natural Parks Between Conservation and Development

The theme relating to the government of the territory in protected areas is a subject under constant discussion in a country like Italy, defined as "the European country with the greatest biodiversity of species and ecological processes" (Ministry of Ecological Transition, 2010), due to the significant presence of anthropic activities within them or in the surrounding areas: the Italian National Parks, in fact, also include densely urbanized areas (Cilento National Park, Cinque Terre Park, Vesuvius Park), in which the human intervention has not always developed in a way that is coherent or at least compatible with the needs of protecting the environment and biodiversity (D'Auria, 2009).

A. D'Auria (✉)
Università Degli Studi Suor Orsola Benincasa, Naples, Italy
e-mail: alessio.dauria@docenti.unisob.na.it

I. Di Ruocco
Università Degli Studi Dell'Insubria, Varese, Italy

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In this overall framework, an increasingly open approach to the dynamism of the territories, to pursue the integration between conservation and development, assumes ever greater centrality to give concrete answers to the conservation needs of biodiversity, also contemplating the satisfaction of the needs of the local populations concerned. The goal is to create a planning of anthropogenic interventions that can guarantee the maintenance of the vitality of ecosystems, as an essential prerequisite for the quality of a territory and the life of the population who insists on it.

According to the aforementioned study by the Ministry of Ecological Transition (formerly known as Ministry of the Environment), the "Brief Guide to the National Strategy for Biodiversity" elaborated in 2010, Italy, is among the European countries that has established more protected areas, thanks to the Framework Law on Protected Areas (L. 394/91), and the Law for the Defense of the Sea (L. 979/82). This is driven by the strong naturalistic presence of our country, and 20% of the national territory is covered by areas of the Natura 2000 network and 6% of the national territory by national parks. The Area 2000 Network ensures the long-term protection and conservation of species and habitats, preserving their biodiversity (European Union, 2017). The conservation of biodiversity in protected areas and natural areas is essential to preserve a vulnerable resource, connected with the territory and with the anthropogenic presence in the landscape. The impact of human activities on the territory directly and indirectly affects the destruction of the habitat. Fundamental for the safeguard is not only the implementation of territorial policies but mechanisms on the dissemination of knowledge of the places, strengthening the local and natural memory, in this way, parks, natural areas and protected areas can be leverages of a type of development characterized by intangible assets. At the EU level, the European Union provides valuable support for issuing implementation plans, strategies, and financial tools, through regulatory instruments such as the Community Directive 92/43/EEC "Habitat" and 79/409/EEC "Birds". It is important to underline the principle on which the European directives are based, that is the principle of subsidiarity, through which Europe has defined the objectives to which the states must respond by identifying the sites and providing for their protection. At the national level, Law no. 157 of 11/02/1992, Ministerial Decree of 25/03/2005 "Publication of the SCI list" GU n. 157 of 08/07/2005 and Ministerial Decree of 25/03/2005 "Publication of the SPA list" GU n. 168 of 21/07/2005 identify natural areas in SCI and SPA areas, providing a collection and organization relating to habitats.

Natural areas are inherently sensitive, and interaction with the external environment can cause negative effects, aggravating them in a state of artificial vulnerability (Bastmeijer, 2016). Analyzing the Campania Region, it is observed that it ranks among the first in Italy for protected area which, if we also include Natura 2000 sites, reaches almost 40% of the entire regional territory. However, local authorities encounter considerable difficulties in managing natural areas, increasing the distance from the protection objectives of the regulatory instruments at national and EU level.

2 The Vesuvius National Park

The study has highlighted the conditions of fragility and criticality as well as vulnerability of the Vesuvian area, especially by taking a close look at the municipality land which reveals that it is in a sensitive geographical position. The paper will analyze soil consumption and its temporal evolution, evaluating the characteristics and trends of use-consumption. In this way, it will be possible to have a clear vision of the impact that generates the increase in surface coverage and above all the qualitative impacts in terms of the type of coverage configured, in order to weigh the natural functions respected, lost and under threat. The Vesuvius National Park (VNP), with its approximately 110,000 inhabitants within the park area and over 600,000 (Parco Nazionale del Vesuvio, 2018) in the territory of the municipalities, is the most populous in Italy and the most densely populated. But it is also a park with valuable environmental and landscape values recognized on a global scale: MAB UNESCO biosphere reserve, two Special Areas of Conservation (SAC), according to European Union's Habitats Directive (92/43/EEC), and one Special Protection Area (SPA), according to European Union Directive on the Conservation of Wild Birds, Council Directive (2009/147/EC) (European Environment Agency, 2021).

Concerning the landscape, the 56.5% of the surface of the National Parks is used for agricultural purposes. The consumption of land for agricultural purposes by the VNP has decreased sharply since the establishment of the Park in 1995, although the Vesuvius area has a strong agricultural vocation. Among the various causes of the decrease in the Utilized Agricultural Area (UAA), there is also the increase in infrastructure and construction observed throughout the Vesuvius area. The increase in land consumption in protected areas in 2016 was equal to 2.3%, while the VNP recorded an increase of 8.7 and 8.9% in 2017.

A study carried out by the Ministry of the Environment, Economy sector, indicates that Vesuvius has the record for the park with the largest population, and the resident population in the National Parks is 110,414.

Furthermore, VNP is a unique volcanic complex: Somma and Vesuvius (8482 ha), that is the most important volcanic complex still active in continental Europe.

The VNP includes 13 municipalities of the Vesuvian crown, of which Sant'Anastasia is part of this geographical subdivision (Fig. 1).

The Vesuvian landscape is rich in diversity and contrasts, in which there is the coexistence of a new artificial landscape and of the duplicity of the natural and vulnerable landscape. The complexity of the VNP is highlighted by the simultaneous presence of two aspects that represent the natural area: the Park Authority and the protected area. Both parties have the objective of safeguarding the natural area such as Volcano, as a place of High Biodiversity, a place of high-quality products (typical local products), and the landscape potential encouraged by the Great Vesuvius Project, a project born after the fires developed in 2017, which aims to plan interventions for the remediation and recovery of areas affected by fire; the redevelopment of the network of paths with the recovery of historical paths and the definition of additions to the "green" infrastructure network; finally, the implementation of low environmental impact accessibility projects.

The VNP recorded seven hundred thousand tourists in 2018 at the "Large Cone of Vesuvius" with an increase of 9.2%, or 55 thousand tourists more than in 2017, confirming the great activity of the VNP as an engine of tourism and economic development. The great tourist success is a testimony of a proactive will of the territory, to overcome the constraint of territorial fragility and to promote itself as sustainable tourism, a meeting place between nature, man, and culture. A sustainable approach that can be considered "contemporary" was to replace the romantic image of Vesuvius as a mountain system consisting of Vesuvius and Monte Somma, but to consider it as a volcanic complex, in which there is a highly destructive volcano surrounded by an area with population density among the highest in Europe. The new vision of Vesuvius risk aims at converting risk into a resource, mitigating its criticalities through mitigation measures. The strategy for the protection of the population provides for the preventive removal of the resident population in the 18 municipalities of the red zone. The population surrounding the volcano has taken on a variable trend; in the year 2004, the area affected by the volcano includes a territory with a population of about 550,000 inhabitants. In 1999, the total population was 578,175 inhabitants with several families equal to 173,377. The greatest danger for the soil, in terms of land use risk, is the anthropic action, since the territory is a meeting place of natural and human activities. The latest SNPA (Sistema Nazionale per la Protezione dell'Ambiente—National System for Environment Protection) study in 2021 (SNPA, 2021) and demographic data show a slow decrease

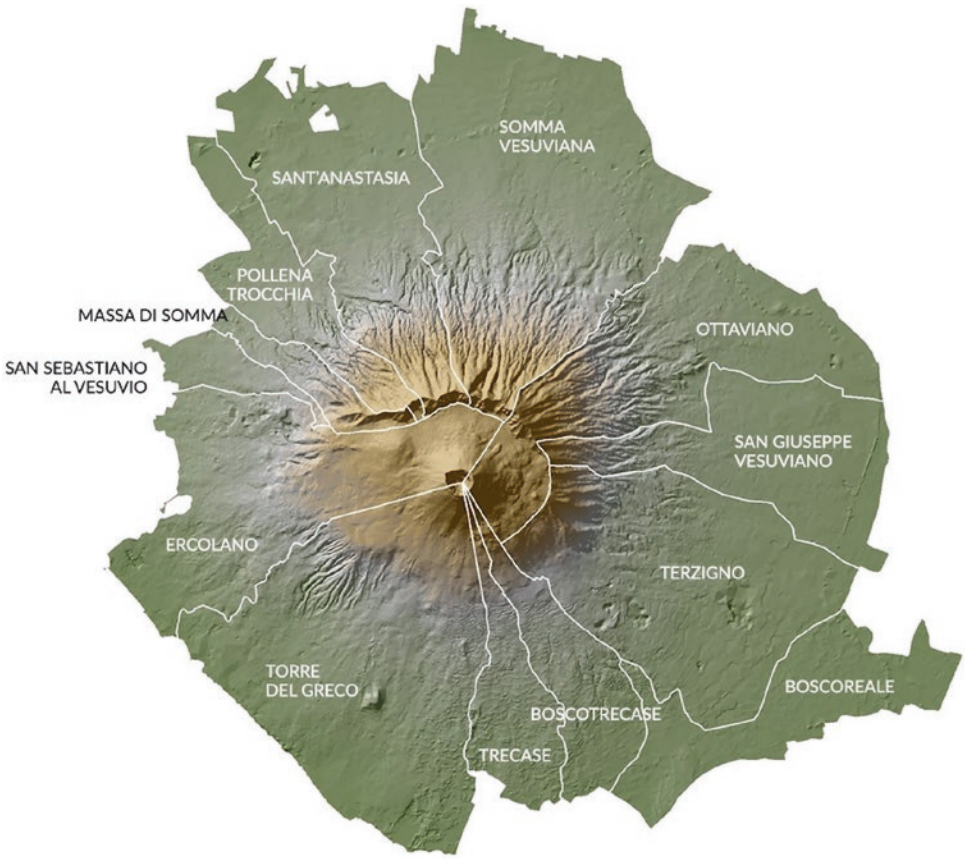

Fig. 1 Sant'Anastasia and the other municipalities of the Vesuvian crown. Source: Museo Parco del Vesuvio (2015)

in population, which will be analyzed in the course of the paper, as an element of strategic opportunity.

The interaction between the actions proposed in the Municipal Urban Plan and the Natura 2000 areas and the Vesuvius National Park has been evaluated. The main actions do not fall within these areas, while it has been preferred to think about strategies to enhance the natural heritage. A recent threat of protected areas has been recorded due to the fires that occurred in the summer of 2017, altering the balance of diversity, consuming soil, negatively affecting the ecosystems of the Vesuvius National Park, as well as having been a risk to human lives. The Park lives in a state of instability in which environmental protection is subjected to numerous risks that increase its vulnerability and fragility. During the fires, more than 3000 ha of soil and vegetation were lost. The study of the territory was carried out starting from standard indicators that describe the process of urban metabolism and focused mainly on the knowledge of the links between the individual elements that make up the built environment of the city and the natural areas in which there are protected areas SCI and SPA. Among these, there is the role that the population plays on the territory through activities of production, processing of goods. Analyzing the demographic census (from 1991 to 2011), the settlement and dynamic characteristics and the productive fabric highlight the social status of the city.

The trend of the incidence of the surface area of the centers and inhabited nuclei is decreasing in 1991; it presents a peak in the year 2001 and a decrease in 2011. The Density of Housing in 2017 is 1477.4 inhabitants/km^2, and in 2011, it is 1456.5 inhabitants/km^2. It is important to evaluate the relationship between man, nature and Nature Volcanic Park and to analyze the expansion of building construction in towns and cities which slowed down in 2011 with a value of 1.6, while the value recorded in 1991 was 10.0. The settlement processes, followed by the expansion of urban areas in the municipality, lead to a sharp acceleration of the processes of consumption of agricultural land or natural.

3 The Case of Sant'Anastasia

3.1 Analysis of Sensitivities, Criticalities, Potentialities of Urban Territory

The following elaborations were drawn up as part of the Environmental Report subjected to Strategic Environmental Assessment for the Municipal Urban Plan of the municipality of Sant'Anastasia, elaborated during 2019.

An integrated sustainable approach allows a rational use of the resources that the territory offers. Sant'Anastasia contains a plurality of different and unique elements in their identity: natural areas, local products of high-quality food and wine, protected areas, religious tourism, nature trails, and paths. To promote truly sustainable urban development, strategies aiming at economic growth and environmental protection must be activated.

The territorial wealth of Sant'Anastasia boasts fine food and wine products, such as the Protected Designation of Origin (PDO, in Italian: DOP) wine and the apricot called "Pellechiella" as well as the "Piennolo" tomato, thanks to the fertile territories of the agricultural areas of the VNP. Sustainable strategies aim to use the territory in terms of land and "rational" and "sensitive" land consumption. Land consumption is in the Vesuvian areas in which Sant'Anastasia is part, an element of the fragile territory.

Fragility must be understood as the predisposition of a territory to change its state in a radical way following multiple disruptive events. In the case of Sant'Anastasia (as well as the whole Vesuvian crown), it is both a constitutive feature of the territory and therefore an original state (e.g., seismic, hydrogeological and volcanic hazards and risks), and an artificial destabilizing state, that can be the result of a design action, consciously or not. In this second meaning, the state of fragility is an onset state, being the result of a process of moving away from a state of balance and resistance, which involves the affirmation of a state of degradation (high rate of soil consumption, often uncontrolled, followed by a high demographic density).

The soil element under study is a resource to be preserved, subjected to hydrogeological risk and anthropogenic impacts due to the presence of a strong and invasive built environment. The anthropogenic pressure due to economic and social activities increases the vulnerability of the territory and the soil, confirmed by data on the transformation of the soil, especially in protected areas. The transformation of the soil can undergo a U-turn if Sant'Anastasia applies the concept of resilience, triggering a change thanks to which the "consumed" soil becomes a "useful surface" to make concrete re-adaptive tools of the territory.

The surface of man-made soil of the municipal area is 33%, placing itself in a range of medium-high values, while the value of the percentage of urban and productive areas of the municipal area decreases slightly, equal to 22%. Variations in UAA between 2000 and 2010 are −46%, representing a great loss of free surface for the city of Sant'Anastasia. The difference between the woodiness index of 15% and the percentage of urban and productive areas of the municipal area of 22% is remarkable. The municipal area is part of the Vesuvius National Park and includes three Natura2000 areas. The percentage of surface area of the protected area out of the total municipal area is very high compared to the falling surfaces of the Amalfi

area and the Sorrento coast, but has a slightly lower value for some areas falling within the Vesuvius National Park. The municipal territory has a low percentage of protected area, and observing the cartography, among the municipalities falling within the Vesuvius National Park, it is one of the municipalities with the lowest value. The elements of the territory of Sant'Anastasia undoubtedly represent elements of a heritage cultural to preserve. Soil sensitivity is part of the protection of SPA and SCI areas. The surface of the municipality of Sant'Anastasia falling within the Natura 2000 SIC and SPA areas is 564.02 ha with a percentage of 31.4% of the total municipal area. The SPA is included in the area of competence of the Vesuvius National Park. The total extension of the "Vesuvio and Monte Somma" SPA is 6250.61 ha, and the area involved amounts to 371.53 ha, equal to about 19.75% of the municipal area of Sant'Anastasia.

The study of the characteristics of Sant'Anastasia concerned economic-social, territorial, environmental, and productive themes. For the purpose of defining the sustainability objectives or environmental sustainability for the city of Sant'Anastasia, the regulatory and programmatic framework is defined at different planning levels used as a reference. During the elaboration of the municipal urban plan of Sant'Anastasia, we focused on the contents of environmental, economic and social sustainability, giving importance to the development and protection of the soil of Monte Somma and Vesuvius, from agricultural product's point of view, naturalistic (pathways)—landscape (panorama) as well as the mitigation of the risks that the naturalistic system can suffer due to hydrogeological and volcanic risk.

The information obtained from the sixth agricultural census (ISTAT, 2010) describes the agricultural status of Land area, Utilised Agricultural Area (UAA) and Total Surface Area (TSA) by municipality and for Sant'Anastasia the Utilised Agricultural Area (UAA) is of 862.26 ha, the Total Surface Area (TSA) is 1279.28 ha, and the rate UAA/TSA of 45.96%. The agricultural area is mainly used for agricultural woody crops, with a use of 317.9 ha. The "unused agricultural area and other areas" has 122 agricultural units with a use of 24.4 ha.

A better understanding of the quality aspects of the municipality is provided by the SWOT analysis (Fig. 2) that explores the main strong aspects and risks of the territory in order to propose strategic and mitigation measures. Among the mitigation measures, there are certainly those for volcanic and seismic risk and the city of Sant'Anastasia is more exposed to volcanic risk than to seismic risk.

The SWOT analysis was the first step of the qualitative analysis. The zoning action has set two types of areas: transformable and non-transformable, also in relation to future actions to be considered in soil monitoring, revealing some considerable reflection regarding the hydrogeological risk. Non-transformable areas are characterized by: "high" and "very high" environmental values of the Environmental Protection Charter of the Plan for the protection of soil and water resources, or areas covered by forests.

The "Extraordinary Plan for the removal of the situations to higher hydrogeological risk", elaborated in emergency way by River Basin Authorities, foresaw the perimeter of the only areas R3 (high risk) and R4 (very high risk) relatively to the "Landslide Risk" and to the "Flood Risk" (Regione Campania, 2015).

Most areas of the municipality are exposed to hydrogeological risks. The border areas between the slopes of the Vesuvius National Park and the municipal territory (historical center, urban area, peri-urban area, suburban area) are more subject to landslide hazards P1, landslide risk R2-R1, hydraulic risk R3-R4.

In general, however, the municipality of S. Anastasia has been identified risk areas classified as R4 (very high risk) and R3 (high risk).

For this assessment, specific and characteristic criteria of the individual factors and territorial components were used. The initial analysis study made it possible to show the fragility of the territory. The Vesuvius Emergency Plan drawn up by the National Civil Protection in 2001 (Protezione Civile, 2019), subsequently updated in 2007, 2013, and 2019, identifies the municipalities most exposed defining the area "Red Zone" of which the municipality of Sant'Anastasia belongs. The Emergency Plan includes the municipalities surrounding Vesuvius. Regional Law 21/2003 has blocked the construction of new housing while providing for the start of long-term planning (but quickly effective) to reduce the population exposed to risk.

The seismic risk assessment, caused by the volcanic phenomenon, has been developed by the municipality of Sant'Anastasia. By performing several studies such as the geological and seismic study for the prevention of seismic risk, the analyses in June 2005 and June 2006 have resulted in Seismic Microzonation of the areas involved in the recovery project of the Old Town and areas of the town. After the demographic, production, and risk analyses, the territorial potential has been evaluated.

The assessment was constructed by combining risk factors with land use and valuable agricultural products, understood as negative externalities following a possible volcanic risk.

The municipality of Sant'Anastasia, thanks to its geographical position and fertile soil, allows the cultivation of grapes for the production of wines with the Controlled Designation of Origin (CDO, in Italian: DOC) and PDO denominations.

SECTOR	STRENGHTS	WEAKNESS	OPPORTUNITIES	THREATS
ANTHROPIC AND BUILT ENVIRNOMENT	increase in the index of availability of services in the household	increase of incidence of surface area of centres and inhabited areas	reduction of incidence of owner-occupied dwellings	increase of incidence of surface area of centres and inhabited areas
	increase of incidence of buildings in good state of preservation	decrease of potential for residential use	increase of potential for use of buildings	increase of average surface of occupied dwellings
	craftworks and valuable agricultural areas (apricots, wine) contributing to an increase in economic zones	increase of "square-metres-per occupant" value in occupied dwellings	potential of residential use in built-up areas	decrease of consistency of occupied historic dwellings
	religious pilgrimage for the rite of the Madonna at the sanctuary of Madonna dell'Arco		decreasing index of buildings expansion in population centres	increase of average age of recent housing stock
	nature trails in the Vesuvius National Park			
	architectural and cultural heritage in the area, and other sites of cultural interest			
SOCIAL AND DEMOGRAPHIC SECTOR	Population density decrease			increase of incidence of families in need of cares
	increase of incidece of employement in the tertiary sector outside trade			increase of index of underuse of dwellings
	increase of incidence of employement in high medium specialisation professions			
	increase of impact of employement in the agricultural sector			
	Housing crowing index			
NATURE, LANDSCAPE AND BIODIVERSITY	Natura 2000 network	anthropized soil level	low index of urbanised soil zones	volcanic risk
	Vesuvius National Park	low index of total agricultural area	high soil consumption as utilised agricultural area	hydrogeological risk
	high value of biodiversity	medium-low wooden index	medium percentage of land consumed over the total municipal area	natural areas with high volcanic risk
		medium-low percentage of surface area of protected area over total city area		

Fig. 2 SWOT analysis, elaboration of D'Auria and Di Ruocco

"The areas of wine" cover almost the entire area of the Vesuvian crown, incorporating Natura 2000 areas and the Vesuvius National Park, which are affected by hydrogeological risk R1, R2, R3, R4 and landslide risk R2-R1. Moreover, like the other municipalities of the Vesuvian area, the whole territory of Sant'Anastasia, and especially its "areas of wine", is affected by very important landslide risks (see Fig. 3) and by significative hydrogeological risks in lowland areas (see Fig. 4).

The strategic objectives aim at reducing housing deprivation and reducing the exposure of the population to environmental and anthropogenic risk factors, as well as the protection of the natural heritage and biodiversity (Balena et al., 2014; Torre et al., 2017).

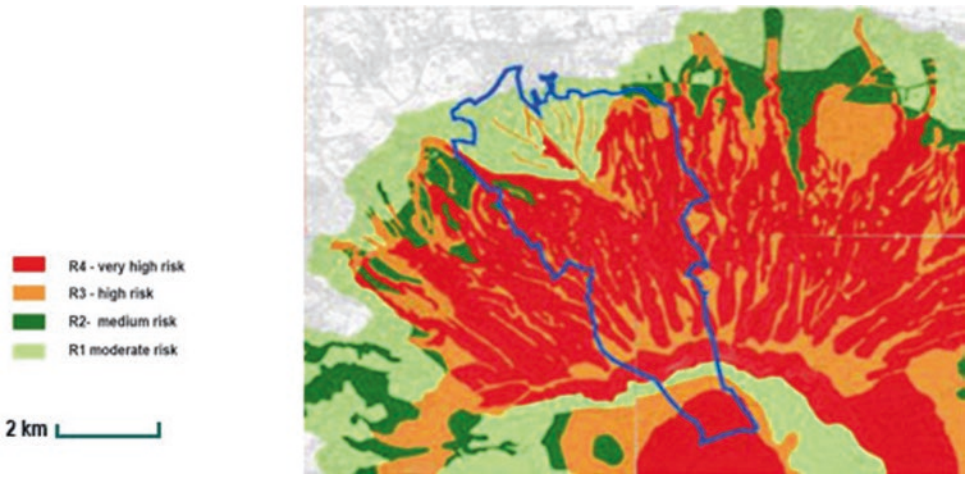

Fig. 3 Landslide risk. Elaborated by I. Di Ruocco

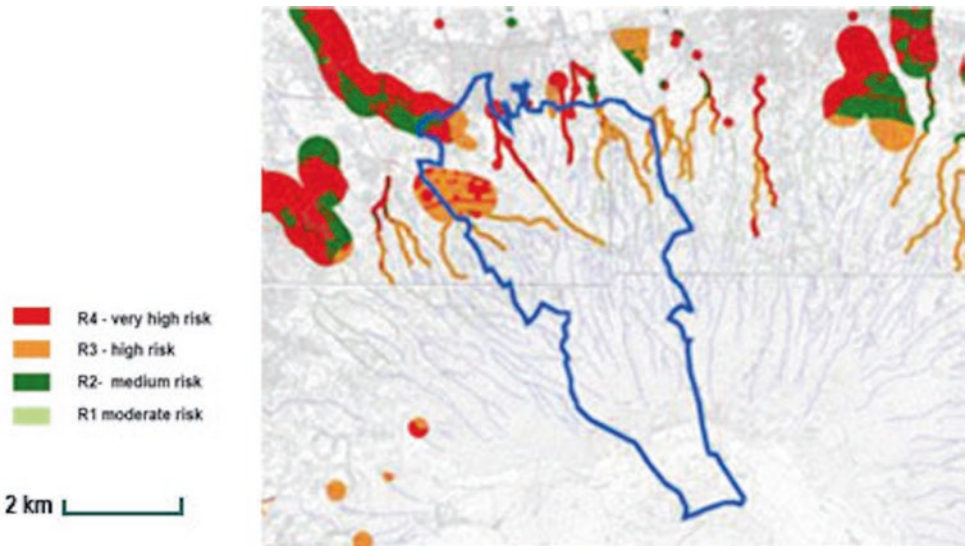

Fig. 4 Hydrogeological risk. Elaborated by I. Di Ruocco

3.2 Strategic Environmental Assessment of Urban Development

VNP is one of the knowledgeable sources on environmental issues examined for the Sant'Anastasia case study. In order to assess the coherence analysis among the superordinate plans in the relationship between the city and the VNP, a comparison was made between the VNP's objectives, among which are the conservation of plant or animal species, scenic and recreational values, natural processes, and the use of management or environmental restoration techniques that can restore the lost integration between man and the environment. This last aspect is a resource that has undergone a decline in recent years, due to the inclusion of variables such as land consumption and building growth that have made the balanced system of man and nature unstable.

The Plan is structured according to an "Objectives-Strategies-Actions" (OSA), identified by the municipal administration. The objectives of the plan are as follows:

- Ob. 1—Overcoming the "block" condition induced by the legislation on the red zone with promotion and requalification measures.
- Ob. 2—Develop/redevelop new/existing poles for equipment and services.
- Ob. 3—Regenerate the production sector.
- Ob. 4—Redevelop escape routes and promote infrastructural reform.
- Ob. 5—Protection and enhancement of historic centers and "farms".
- Ob. 6—Rationalization of the settlement system.

Each objective is divided into strategies (not reported here for the sake of brevity) to which operational actions are associated, which are the subject of the environmental compatibility assessment.

The Environmental Report has been drafted toward an "integrated decision-making process" perspective (Fusco Girard et al., 2014; Torrieri & Batà, 2017).

The procedure of Strategic Environmental Assessment in the formation of the plan is an essential prerequisite for ensuring coordination and consistency between the objectives of sectoral policies with those of territorial planning and is also one of the greatest challenges in order to achieve an authentic integration between the environmental, social, cultural, and economic issues (Mondini, 2009). In this perspective, integration represents a privileged means of increasing the effectiveness of the evaluation in the decision-making process (Patassini, 2006).

An early reflection on the significance of the impacts is provided by a mapping of the territory in order to the areas of greatest environmental value, agronomic, and landscape sensitivity, to verify which of these are actually solicited, so as to allow in the identification phase of the mitigation measures/compensation to consider only those in a state of excessive coercion or directly solicited by the specific actions in progress or foreseen by the general planning.

We have to consider that any human action has as a consequence an impact on the territory: what matters is to understand if this impact acts on a local scale or on a large area; if it is slight or significant; and finally, if it is positive or negative.

It is necessary to proceed with a weighting of the impacts, considering both the potential effects and the values of target resources. In fact, the target resources of the impacts do not have all the same importance, and if you want to reach a reliable and formalized impact budget, it may be appropriate and necessary to carry out a weighting of the estimated impacts. This weighting, in particular, is necessary when it is not acceptable in a homogeneous way the impacts of similar value but on scarce and valuable resources rather than modest value and abundant. The attribution of weights is an operation that can be highly discretionary and must therefore take place in a clearly specified way and retraceable. In the case in question, it was decided to carry out the weighting proposing an evolution of the weight attribution methodologies for environmental assessment in existing literature (Janssen, 1992; Zeppetella et al., 1992) using judgment schemes of the value of resources and of the weight of predefined effects.

The assessment of the size of the environmental consequences has been carried out by preliminary defining the parameter "P_e" (potential effect), which in turn consists of the following two parameters:

1. The scale ("*S*") of the activity that determines an impact or its extension.
   - Punctual (*P*) or areal (*A*) actions have been attributed a weight equal to '1'.
   - Widespread (*W*) or linear (*L*) actions have been attributed a weight equal to '2'.
2. The magnitude ("*M*"), that is the largeness of the impact.
   - Slight effects have been attributed a weight equal to '1'.
   - Significant effects have been attributed a weight equal to '2'.
   - Very significant effects have been attributed a weight of '4'.

The aforementioned weights have a positive or negative direction depending on the direction of the effect.

Global weight of the potential effects is therefore determined by the following product (1):

$$P_e = M \times S \tag{1}$$

To determine the value of the actual impact "*I*", it will be necessary to multiply "P_e" by the value (*V*) attributed to the resources requested by plan actions.

In fact, environmental resources have been given an additional weight (from '1' to '5'), based on their value depending on the combination of the following factors:

- Rare/common.
- Renewable/non-renewable.
- Strategic/non-strategic.

So, you will have (2):

$$I = P_e \times V \tag{2}$$

In brief, we can consider an impact as a vector, to define which it is necessary to know: direction (value of the environmental components), intensity (magnitude and scale of the potential effects of the plan actions), and direction (positive or negative) of the potential effects of the plan actions.

The difference between "effect" and "impact" is not merely nominalistic, but stems from a reasoning similar to that which leads to the distinction between "dangerousness" and "risk". Therefore, the environmental effect means the potential damage or benefit that a plan action could cause to the environment; by environmental impact, on the other hand, we mean the consequences deriving from the environmental effect on environmental factors and components,

RESOURCES / POTENTIAL EFFECTS	magnitude	scale	WEIGHTS	common/renewable/non-strategic	common/non-renewable/non-strategic common/renewable/strategic	rare/renewable/non-strategic common/non-renewable/strategic	rare/renewable/strategic rare/non-renewable/non-strategic	rare/non-renewable/strategic
				1	2	3	4	5
Negative very relevant W/L	-4	2	-8	-8	-16	-24	-32	-40
Negative very relevant P/A	-4	1	-4	-4	-8	-12	-16	-20
Negative relevant W/L	-2	2	-4	-4	-8	-12	-16	-20
Negative relevant P/A	-2	1	-2	-2	-4	-6	-8	-10
Slightly negative W/L	-1	2	-2	-2	-4	-6	-8	-10
Slightly negative P/A	-1	1	-1	-1	-2	-3	-4	-5
Slightly positive P/A	1	1	1	1	2	3	4	5
Slightly positive W/L	1	2	2	2	4	6	8	10
Positive relevant P/A	2	1	2	2	4	6	8	10
Positive relevant W/L	2	2	4	4	8	12	16	20
Positive very relevant P/A	4	1	4	4	8	12	16	20
Positive very relevant W/L	4	2	8	8	16	24	32	40

Fig. 5 Framework matrix for the attribution of weights to impacts. Elaborated by A. D'Auria

or on the whole of environmental resources, based on their value (which in turn depends on their vulnerability and resilience).

In Fig. 5, the matrix of impact factor for the attribution of weights between effects and impacts.

The Plan Actions, subject to an assessment of "environmental compatibility" (Senes & Toccolini, 1998), can be divided into two different and complementary types:

1. Spatial/localization actions, functional to give localization specificity to the plan strategies.
2. Regulatory actions, functional to define the rules and conditions for implementing the plan choices.

Only spatial/localization actions, which have a direct territorial impact, and not regulatory/normative actions, which lead to programmatic provisions, were considered.

The evaluation phase was divided into two successive stages: first a quantitative evaluation and then a qualitative one.

For the quantitative assessment, a frequency analysis was used, which indicates which action actually impacts on a sensitive area from a naturalistic, agronomic, or landscape point of view. To this end, the areas identified by the soil study, the landscape units, the ecological network, and the Central Campania Basin Authority were surveyed (Ruiz Pereira et al., 2021).

This frequency analysis only measures the presence ('1') or not ('0') of an impact of each action on each sensitive area, without providing us with qualitative indications, which will be examined in the next phase. That is, it is an analysis rather than an evaluation, since it does not provide for the attribution of weights. From this first step, it is clear that some actions are pervasive (e.g.: actions related to objective '4'). It is equally interesting to see how some areas are more impacted than others, regardless of their level of environmental sensitivity.

Therefore, each share was classified according to the scale using the appropriate values, assigning a weight '1' to the "punctual" ('*P*') or "areal" ('*A*') actions, while a double

coefficient was attributed, equal to '2' to large-area actions ("widespread"—'*W*' and "linear"—'*L*' actions).

In addition, a direction has been attributed to the intensity of impact, according to this scheme:

- Very significant negative = —
- Significant negative = –
- Slight negative = -
- Slight positive = +
- Relevant positive = ++
- Very relevant positive = +++.

On the basis of the attribution of weights to each action, based on the characteristics of each of them, a correspondence matrix was then constructed between the plan actions and the sensitive areas, as previously carried out for the frequency analysis, but this time also with the attribution of values.

This assessment made possible to identify the most impacting actions on sensitive areas.

Unlike the frequency matrix, the total values have been reported exclusively for the actions, and represent the cumulative impacts of each action, i.e., the impacts (positive or negative, direct or indirect, long and short term) deriving from the actions in each area sensitive, each of which may not be significant when considered separately.

Subsequently, a summary of the results was made, in which, through a distribution in classes, the actions were classified, in order to assign specific mitigation measures to the actions, based on their level of impact on resources.

The columns "impact frequencies" and "cumulative impact values" show the totals of the previous tables. The "negative impacts" column shows only the negative values of the cumulative impacts. A subdivision into classes was made for these values, with three classes of values, in order to identify three categories of mitigation measures:

1. The actions falling within the first class require mild mitigation/compensation measures or in any case non-binding recommendations.
2. The actions falling into the second class require significant and binding mitigation/compensation measures.
3. Actions falling within the third class require very significant and binding mitigation/compensation measures.

For all the forecasts of the Plan which, through the evaluation matrix, highlight a negative effect (certain or possible) in sensitive areas from an environmental, agronomic, and/or landscape point of view, with respect to each specific environmental component, data sheets have been drawn up analytical in which the reasons that led to the assessment are explained and in-depth, where necessary, the corresponding mitigation and possibly compensation actions proposed are identified and their level of cogency is defined with respect to the possibility of implementing the related policy/action of Urban Plan.

Starting from the analysis of the impacts, therefore, the appropriate actions have been identified in the sheets aimed at mitigating and/or overcoming the potentially negative impact of the action considered.

The evaluations, therefore, follow an operational approach aimed at increasing, where possible, the degree of environmental and territorial sustainability of the policy/action considered.

Starting from the results of the evaluations, three classes/types of specific compensation measures have been identified:

1. Mild mitigation/compensation measures or in any case non-binding recommendations.
2. Relevant and mandatory mitigation/compensation measures.
3. Very significant and mandatory mitigation/compensation measures.

To these, there are other general measures, to be applied to pursue the sustainability of the Urban Plan.

They are:

- Compensating eco-account.
- Prevention and reduction of impacts on the water cycle and on land consumption.
- Filter woodlands.
- Complementary planning tools (Green areas plan, Urban sustainable mobility plan, Plan for the Elimination of Architectural Barriers, Action Plan for Sustainable Energy and Climate).

4 Conclusions: Planning and Environmental Assessment in Protected Areas

The territory analyzed, the municipality of Sant'Anastasia and the Vesuvian area are emblematic examples, as suggested by the proposed analysis, in which characteristics and potential, highlighted by the SWOT, intersect in a context of high vulnerability. The analysis of the socio-demographic characteristics shows that inside the Vesuvian Park live 551,837 inhabitants, making the case study The Vesuvius National Park is an example of ambiguity and duality, since it embodies nature and risks patterns, in detail anthropic risk and natural risk, and the duality pattern is represented by natural and anthropic landscapes. As shown in the weight analysis and SWOT, the demographic impact is one of the pressure elements that gravitate around the

Natural Park of Vesuvius, and thus, biodiversity and natural values have to coexist with urban expansion, aggravated by phenomena of illegal building. The volcanic risk collects the negative impact of natural hazards impacting biodiversity, by making the whole areas extremely vulnerable, and subjects to the destructive risk of the volcano Vesuvio.

The object of study representing by Sant'Anastasia town is a place, like others in the Vesuvian area, where many different elements are added together and which produce contrasting and sometimes negative effects. Undoubtedly, the actions proposed after the analysis of the environment bring out the criticality of union between development policies and conservation policies of protected areas and natural parks.

In a very urbanized territory as the case study of Sant'Anastasia, the conservation policies of protected areas must allow a balance between the built environment and the natural park, not limiting the park with a physical perimeter, but allowing activities in all sustainability within, maintaining a relationship between man and nature. The conservation of the parks must be included in the planning phases, making the economic and social policies which interact with the environmental ones, between settlement phenomena and the protection of biodiversity (D'Auria et al., 2018).

Planning protected areas, while maintaining its peculiar characteristics of specialty, must be understood as planning effectively integrated with all other forms of planning (territorial, urban, landscape, and basin). To this end, the recognition of a strategic or structural aspect, and an operational one, is fundamental, namely between the intangibility of values and the questionability of the political choices with which these values must be safeguarded and valued, that is, between irreversible choices and reversible and therefore negotiable choices (Gambino, 1991).

According to the European Union document relating to the elaboration of the *Schéma de Développement de l'Espace Communitaire* (Faludi, 2004), concerning the policies for territorial development in Europe, protected areas, as territories of important ecological value, exercises an important social function that is expressed in the conservation of the natural environment. Protected areas have an environmental, landscape, and ecological value. However, any constraints and restrictions on development must not penalize the population by compromising their living conditions. Rather, ecological interventions should be enhanced, including through appropriate fiscal measures: conservation of nature can be achieved by providing for compensatory, protective, regulatory, and safeguard measures in planning actions. Therefore, the planning of parks and protected areas—and their territorial context—must aim at active conservation and a form of dynamic management of resources, associating the regulation and safeguard measures with those of incentive and promotion, with particular reference to agricultural use of soils and the development of increasingly advanced and sustainable forms of eco-tourism.

In this sense, the very concept of "environmental compatibility" could be reductive if it refers exclusively to the phase of mitigation of impacts, but it should instead be conceived in a logic of "territorial coherence" of land use transformation interventions.

The assessment of environmental and territorial resources is therefore configured as an indispensable and fundamental moment in the planning process of protected areas, with a view to verifying the sustainability of the choices made (Calafati & Mazzoni, 2002).

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Empirical Analysis of the Impacts of the Refugee Influxes on Amman Urban Characteristics

Dana M. A. Hamdan and Antonino Di Raimo

Abstract

In 2020, more than 80 million people have been recognized as forcibly displaced, and Refugees represent about 35% of that. Jordan has one of the highest number of refugees in relation to its population, which is due to multiple influxes of refugees to the country since the late 19th C until today. These people settle either in refugee camps or in urban areas. The sudden mass migration to the capital city Amman has caused massive pressure on the city's infrastructures and urban fabrics and resulted in uncontrolled urban expansion. Meanwhile, refugee camps in the city and in several other areas have outlived the crisis that produced them and have turned into urban areas with substandard living conditions. They are often excluded from all development plans. The poor/lack of planning policies which were developed by foreign consultants, have led to unbalanced concentration of investment between the newer and older parts of the city, and the densification of informal settlements in eastern Amman. Current research mainly discusses the urban expansion in Amman from Satellite perspective and quantitative population growth, with little understanding of the street level of these urban changes. Therefore, this research analysis the impact of the refugee crisis on the urban characteristics of Amman. First, five neighborhoods have been identified as examples of areas that developed post-every refugee movement. These areas are: The historic town (19th and early 20th C), Al Wehdat camp (established in 1955), Al Ashrafeyeh (1950s–1960s), Al Rawabi (1970s–1980s), and Khalda (1994 –Now). Second, empirical observation through site visits is used to analyze and compare the urban characteristics of each of these neighborhoods. The findings of this research provide insights into the urban trends in Amman, which can be used to assist effective future planning policies, as well as assist further research on the environmental quality of different urban typologies. The theoretical implications add to the body of research on relationship between immigration and urban production.

Keywords

Informal settlements · Morphology · Urbanization · Urban human scale · Migration · Heritage mobility

1 Introduction

The issue of forcibly displaced people is growing worldwide, where the United Nations High Commissioner for Refugees (UNHCR) estimates that there are more than 80 million forcibly displaced people in 2020. Globally, refugee makes up 35% of the total forcibly displaced people (UNHCR, 2020). Jordan has the second-highest number of refugees to its population. Preceded only by its neighbor, Lebanon (The UN Refugee Agency, 2021). As a result of the various refugee movements to the country, the population of Amman city—the capital of Jordan—have almost doubled during the last 10 years (United Nations Population Division, 2020). Moreover, most of the refugees in Amman live in urban areas as opposite to camps. Meanwhile, camps have turned into permanent settlements that are integrated with the urban area on one hand and drove the rapid urbanization of other areas in the city (Fishman, 2014; Saidan et al., 2017). Therefore, it is to be expected that the city's urban infrastructure is straining to keep up with its exponential population growth. While on the other hand, the infrastructures in the refugee camps are lacking due to their

D. M. A. Hamdan (✉)
Lecturer at the University of Brighton School of Architecture, Technology and Engineering, Brighton, United Kingdom
e-mail: d.hamdan@brighton.ac.uk

A. Di Raimo
Reader in Architecture at the University of Portsmouth School of Architecture, Portsmouth, United Kingdom

A. L. Pisello et al. (eds.), *Building Resilient and Healthy Cities: A Guide to Environmental Sustainability and Well-being*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-031-33863-2_13

expected "temporariness," which have lasted decades in several cases (Martin et al., 2020).

The sudden population growth by these refugees of different cultural and economic backgrounds, as well as the time period in which they immigrated to Amman, have created extreme urban morphological variations in Amman urban fabric. From densities of more than 75,000–100,000 km^2 in the informal urban refugee camps, to newer developments of densities less than 1000 km^2 (DoS, 2019). These variations in the urban form are reflected on access to services and economic status of the residents, contributing to the socioeconomic polarization between eastern (older) and western (newer) Amman (Potter et al., 2009). The issue has been escalated by the poor planning policies for the city since the 1950s, which were mainly developed by foreign consultants with poor understanding of the local context. These plans failed to address that the urban structure is a product of the cultural and social process (Lai et al., 2018), which have rendered many of these policies unapplicable to Amman (Beauregard & Marpillero-Colomina, 2011; Saad & Amr, 2015). Meanwhile, current research mainly discusses the urban expansion in Amman from Satellite perspective and quantitative population growth, with little attempts to understand the street level of these urban changes, and reflect on the historical, social, economic, and environmental variables that created these urban typologies within the city.

Therefore, the main question of this research is to understand what is the impact of the refugee crisis on the urban characteristics of Amman? To answer this question, the research objectives are to first identify the main refugee movements and the socioeconomic conditions of their migration to Amman, and the resultant urban expansion of areas from each of these refugee movements. And second, to analyze the urban characteristics in example neighborhoods that were generated following every refugee movement. To achieve the first objective, systematic literature review is used to identify the main refugee and immigration movements to Amman and the resultant impacts on population and urban expansion. This, alongside the GIS maps released by the Royal Jordanian Geographic Center of Amman, has been used to identify five main zones that have developed following every major immigration influx. The second objective is achieved through empirical observation during site visits which was recorded through photography. Analysis of the urban characteristics of each of these zones is conducted, which are the building average plot size, number of floors, external materials, street function, access types, and street widths.

The research output aims to assist future research to analyze the impact of heritage mobility on architecture and urban form in Jordan. Moreover, the analysis of the urban characteristics in Amman will be used for future study on analyzing the relationship between the urban characteristics and microclimate conditions in Amman (Hamdan & de Oliveira, 2019; Melnik, 2019). On a wider scale, the research aims to contribute to our understanding of urban trends in Amman to assist effective future planning policies, as well as understanding the relationship between immigration and urban production in general.

2 Pre-urban Amman: From a Roman Town to the Capital of Transjordan

The first archeological evidence in Amman dates to the Paleolithic age between 1.8 million and 16,000 BC. Evidence of the occupation of Amman from pottery Neolithic period was found in Amman Citadel (Jabal El-Qalaa), a hill at the center of modern Amman, which is one of the seven hills that formed the original town (Khawaldah, 2016). The L-shaped hill was fortified during the Bronze Age and became the capital of the Kingdom of Ammon during the Iron age (around 1000 BC). The town was known as Rabath Ammon, Rabath meaning "the Capital," from which the modern name Amman was derived (Melnik, 2019). Modern form of the historic downtown of Amman has been largely influenced by the Roman period (63 BC-AD 324). The Roman Theater in downtown Amman and the adjacent Odeon bounds the Hashemite Plaza from the south and east. Fast-forward 1800 years after it was built, the Some of the Roman amphitheater stones has been used to build the Circassian refugees' homes in the late 19th C. It also served as a shelter for the Palestinian refugees in 1948 (Hanania, 2014).

The Area, along with the rest of the levant region, has been a subject of struggle between several Islamic eras and the crusaders, until the Ottoman Empire took control of the region in the 16th Century up to its defeat in world war I. The region of trans-Jordan was not of main interest for the Ottomans to be developed; it did not present a major opportunity for revenue or development (Hamed-Troyansky, 2017; Kazziha, 1972). Consequently, the town was mostly abandoned until the second half of the nineteenth century with the construction of Al Hijazi Railway. The main interest the Ottoman had in the area was that it was a route of pilgrimage to the holy city of Mecca and Medina for the Islamic annual Haj ritual, which takes few months a year. The establishment of Al Hijaz Railway, along with the Circassians refugees, has placed the first stone in the revitalization of Amman town and increasing its regional importance to later become the capital of Jordan.

Since then, Amman have witnessed several influxes of refugees, started with Palestinian refugee's post 1948 and post 1967, then migration of Jordanians and Palestinian workers from the gulf countries post the first Gulf War in

1991, followed by Iraq refugees post 2003s Gulf War, and finally the Syrian refugees in 2011. Each refugee era caused population expansion that resulted in rapid urbanization (Ana & Gibson, 2015; Hamd, 2016). Moreover, each of these eras also brought new socioeconomic changes that resulted in extreme urban morphological variations in Amman urban fabric (Ababsa et al., 2011; Abu-Ghozalah, 2007).

Several factors impacted the uncontrolled urban expansion of the city and the failure of planning policies. In city shaped (Kostof, 1991), the author emphasizes the importance of pre-urban landownership patterns on cities evolution. In Amman, this has been especially critical due the land being 95% privately owned (Ana & Hamd, 2016). Moreover, these development plans since the 1950s to 1980s were developed by foreign consultant who lacked understanding of socioeconomic factors within the city, and the subsequent development urban plans from the 1990s and early 2000s were oriented around foreign investments (Abu-Ghozalah, 2007; Meaton & Alnsour, 2012; Melnik, 2019; Saad & Amr, 2015). These investments were directed toward western Amman, which presented a blank canvas in comparison with older Amman that was challenging with its high densities, informal and formal economy, and organic form. Consequently, this has created a growing polarization between eastern and western sides of Amman.

3 Research Methods

The main method used in this research has been empirical observation and analysis during site visits in summer 2020 and 2021. Five neighborhoods have been visited to Amman from different refugee/immigration eras to record the urban characteristics of each of them. These sites were identified using systematic literature review and through data provided by IFPO Atlas of Jordan with the Royal Jordanian Geographic Center (2009), which has been updated using Ordnance Survey maps and NextGIS Data to show 2020 urban areas of Amman (NEXTGIS Amman, 2020) See Fig. 1. Literature review has also been used to reflect the social/cultural conditions that were associated with every immigration influx, which contributed to these urban characteristics. Moreover, the GIS maps of each of the five neighborhoods have been obtained from AmmanGate in the form of shapefile (Ammancitygis, 2021), and previewed using ArcGIS Pro.

Figure 1a shows the main refugee movements to Amman, and Fig. 1b shows the five study areas. The five sites are first, the historic town (Al Balad). It has Roman origins but dates most of its current form to late 19th and early 20th C following the Circassian refugees' settlement in Amman. To understand the urban extent and form prior to the first Palestinian refugee movement in 1948, archival

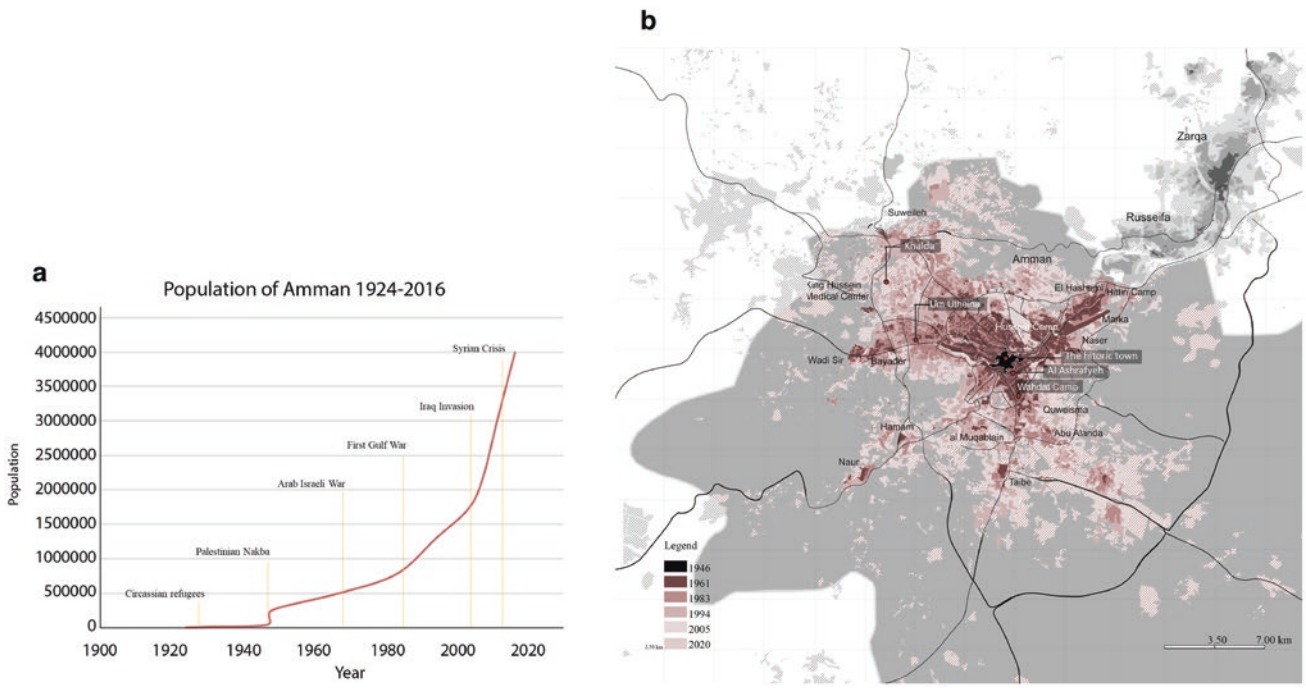


Fig. 1 **a** Population increase in Amman following refugee movements. Data is from (Ababsa, 2013; Al-Bakri et al., 2013; United Nations Population Division, 2020). **b** The corresponding expansion of refugee movements to Amman between 1946 and 2020. Five sites that represent a sample from every expansion period are highlighted, which are: The historic town, Al Balad, (late 19th C to early 20th C). Al Wehdat camp (1955). Al Ashrafeyeh (1950s–1960s). Al Rawabi (1970s–1980s). Khalda (1990s-2010s)

map of the town was reviewed (Fig. 3), which was obtained from the Bodleian Library Archive (Great Britain Army Middle East Drawing Reproduction, 1947). The second site is Al Wehdat refugee camp, which is located 2 km away from the center of the historic town and was formed in 1955 by the United Nations following 1948 Palestinian Nakba. The camp has taken an urban permanent form today and is physically integrated with the surrounding urban area. Third is Al Ashrafeyeh neighborhood, which developed between Al Wehdat camp and the historic town, by Palestinian families who left that camp and bought land around it. This area represents an example of 1950s–1960s expansion of Amman, which currently represent "Eastern Amman," an acronym for the poorer and more informal part of the city (Potter et al., 2009). The Third zone is Al Rawabi, which is an example of 1970s and early 1980s development. This time period witnessed uncontrolled expansion due to the income generated by the Jordanian and Palestinian workers in the Gulf countries, who were investing money back in Jordan in the form of apartment buildings. Finally, Khalda neighborhood (1994–2005) is an example of western Amman expansion, which started following the gulf war with the return of Jordanian and Palestinian workers to Amman, where 500,000 workers returned and resettled in Amman (Abu-Ghozalah, 2007; Swaidan & Nica, 2002).

The analysis aims to understand the refugee influence on Amman, which can be used to reflect on the relationship between informality, immigration, and host cities. By understanding some of the urban physical characteristics, the research can be a starting point for future research to understand the impacts of urban form and scale on the environmental quality in Amman (Hamdan & de Oliveira, 2019). Moreover, this research can help contribute to our understanding about how cities transform, the relationship between immigration/refuge and urban transformation, and reflect on social–cultural variables as means of urban structure production. As well as understand the relationship between informal settlements and urban production, where it is estimated that more than 1 billion people live in informal settlements around the world as means of affordable housing (Dovey et al., 2020),

3.1 Analysis and Data Limitation

Buildings average plot size, number of floors, external materials, along with streets hierarchy and function have been photographed during site visits. And comparison of the main features between the areas have been recorded in Table 1. The streets' levels are analyzed using four hierarchal orders: Main, secondary, tertiary and allies (Micara et al., 2016). This model of hierarchy was used after initial site visits, where the street functions and scale could be grouped in for categories in each of the five sites. Measurements of the street widths are determined using Openstreet maps and Shapefile obtained from AmmanGateway of the map of Amman, which has been viewed in ArcGIS pro. However, due to the high density in Al Wehdat refugee camp and Al Ashrafeyeh, satellite data is not accurate or do not show the small passages/allies with the neighborhood. Therefore, the width of these paths has been estimated during site visit through the perception of standard object. Consequently, some inaccuracy in measurement is expected.

This research is concerned with the analyses of the current state of these five urban areas in Amman. The aim is to observe how these different urban typologies differ from each other and reflect on the socioeconomic conditions that led to their formation and contributed to their current form. The research does not attempt to trace the morphological changes of each of these five areas in Amman since their formation until now. It documents the urban characteristics they have in 2020–2021, which would be relevant for future planning policies and research.

4 Refugee Movements and Main Expansion Areas of Amman

This research compares the different urban characteristics of five neighborhoods in Amman. These five neighborhoods represent examples of areas that have been generated during and after different major influxes of refugees/immigrants to Amman. Each of these influxes has been associated with different social and economic conditions that created different scales and typologies in the urban realm. The output of the research can contribute to the planning policies and future development plans of Amman by first, reflecting on the socioeconomic variables that led to the current urban patterns, and second, by documenting some of the main urban characteristics in different areas in the city. Figure 1a shows the refugee installments and the population growth of Amman and Fig. 1b displays a map of Amman urban expansion between 1946 and 2020.

4.1 Trans-Jordan and the Initial Urbanization of Amman Town: Circassian Refugees 1878–1914

4.1.1 Socioeconomic Conditions During the Circassian Immigration

The foundation of modern Amman traces its form to the immigration of Circassia refugees to pre-urban Amman.

Table 1 Characteristics of five neighborhoods in Amman

					
Criteria	Historic town (19th and early 20th C)	Al Wehdat refugee camp (1955)	Al Ashrafeyeh (1950s-1960s)	Al Rawabi (1970s-1980s)	Khalda (2005-now)
Average building area (m^2)	1920s–1940s: 100–150 m^2. Newer apartment blocks: 250–300 m^2	Unit size as provided by UNRWA: 100 m^2	175 m^2	320 m^2	290 m^2
Building number of floors	1–2 floors (1920s and 1930s) 3–4 apartment blocks (1980s-now)	1–3 floors commercial/mixed-use area	3–5 floors	4–7 floors	2 floors in residential zones 3–5 in commercial zone
Main building types	Single-family houses and apartment buildings Live/work buildings Detached buildings	Apartments blocks Live/work buildings Attached units from three sides	Apartment's buildings Live/work buildings Attached and detached buildings	Mainly large apartments buildings Detached buildings	Mainly single-family houses and villas. Also, apartment buildings and town houses Detached buildings
Formal or informal settlements	Mainly formal. Some informal in the market allies and tertiary roads	Informal settlements	Formal in the main streets, informal in the allies	Formal	Formal
Building finishing materials	Limestone cladding, painted plaster	Exposed concrete hollow brick and concrete (CMU), exposed plaster, paint, limestone cladding near the main roads	Exposed CMU, limestone cladding facing the main and secondary streets, paint, exposed plaster in the allies	Limestone cladding, paint, artificial stone cladding, metal cladding, curtain walls	Limestone cladding, artificial stone cladding, metal cladding, curtain walls
Primary street width, function, and main accessibility	10–12 m (25 m in the expanded plaza) Mixed use, mainly commercial Car access and pedestrian	8–9 m Mixed use, mainly commercial Car access and pedestrian	10–12 m Mixed use Car access and pedestrian	20–25 m Single use, mainly commercial Mainly car access	25–30 Single use Mainly car access
Secondary street width, function, and main accessibility	7–8 m Mixed use Car access and pedestrian	6 m Mixed use, mainly commercial Limited car access, mainly pedestrian	7–8 m Mixed use Car access and pedestrian	12–15 m Mixed use, mainly residential Car access	15–17 m Residential Car access
Tertiary street width, function, and main accessibility	4–5 m Residential Car access	2.5–4 m Mixed use, mainly residential. live/work relationship Some limited car access	4–5 m Mixed use, mainly residential. live/work relationship Limited car access, often cull de sacs	7–9 m Residential Car access	4–6 m Residential Car access
Alley width, function, and main accessibility	2–3 Residential Some limited car access	1–1.8 m Residential Pedestrian only	2–3 m Residential Mainly pedestrian. Partial car access/informal parking space. Several Allies are in the form of staircases due to steep topography	3–6 m Residential Car access	2–4 m. Mainly leftovers between buildings offsets

Since coming under the Ottoman rule in 1516, Jordan was recognized as southern Vilat Al Sham (southern Levant). Its location at the edge of the empire did not form a priority for Constantinople. Therefore, its administration was left for Valis Damascus (Hamed-Troyansky, 2017; Kazziha, 1972).

The lack of governing by the Ottomans had allowed the southern tribes from the Arabian Peninsula to migrate and take control of the lands, raiding the villages and towns, which drove the local population out toward the West Bank (west of Jordanian River, Palestine). This has left the town of Amman abandoned, as well as several agricultural villages in the northwest of Jordan. The trans-Jordan area was left to deterioration until the second part of the nineteenth century. The construction of Al Hijaz railway has brought semi-rural and semi-urban life back to the area again (Melnik, 2019). Moreover, that period witnessed the first refugee movement to Amman from the Circassians, whom had been displaced to Amman as a result of the Russian-Ottoman wars (Hamed-Troyansky, 2017).

The Circassian refugees have settled around what is now Amman city center because of water resources, which are the Amman springs and Ras Al Ayn. This had caused Ottoman Amman to become a subject of conflict between the different Circassian groups among themselves, as well as the local Bedouin population, over water resources and the land around them. The Circassian refugees arrived in three installments at different times. The earlier arrivals claimed the most fertile land around the water resources in the valley. They have arrived at Amman after the Russo-Ottoman war and settled in the Roman theater and around it and build their houses from its stones. The second refugee installment arrived between 1880 and 1892, which are the Kabardine and Abzakh Circassians (Ahl Amman). These represented the core population of the town. The last Circassian refugees, the Kabardine, arrived in 1902. They immigrated from Russia and settled near Amman springs (Ras Al Ayn NH) (Hamed-Troyansky, 2017), which is currently the area adjacent to the Al Wehdat refugee camp that was founded in 1955.

The immigration of Circassians to Amman was one of the main factors that led to revitalization of the town. The land was given to them by the ottomans, which led to the establishment of the first municipal council in Amman 1907 (Al Rawashdeh & Saleh, 2006). These lands were previously uncultivated, but still claimed by the local community. One of the aims of the government was to generate income from natural areas and from non-tax-paying communities, by transferring it to Circassian refugees (Muhajirs). This resulted in competition among the local community to register their land in the newly established land registry, which meant they had to pay full taxes, and abide by the usufruct rights. On the other hand, the opening of Al Hijazi railway between Damascus and Amman in 1903 encouraged Palestinian and Syrian traders to invest in the town. All these factors contributed to the revitalization of the town and paving the way for it to be the capital of Jordan (Hamed-Troyansky, 2017; Hanania, 2014).

By the end of WWI, Transjordan became a British mandate. Settlements where mainly at the current downtown area (El Balad) and occupied an area of 0.321 km^2, north and east of the Roman Amphitheater (Al Rawashdeh & Saleh, 2006). In 1928 Amman became officially the capital of Transjordan with a population of 10,500 people. Figure 2 shows Amman town in the 1920s, where the main economic activity was agriculture with growing commercial activity (Matson, 1932). Prince Abdullah I, who was dictated as the Prince of Trans-Jordan by the British mandate, had to gain the support of the tribes in the region as well as the Circassians to support his legitimacy. By that time 95% of the current Amman area has been privately owned (Ana & Hamd, 2016). Since the government owned a small portion of the land, the subsequent urban development plans

Fig. 2 Amman downtown during the 1920s, around the Roman amphitheater (Matson, 1932). The town location in the valley ensured access to water resources, which promoted agricultural activity. This revitalization attracted traders to the town

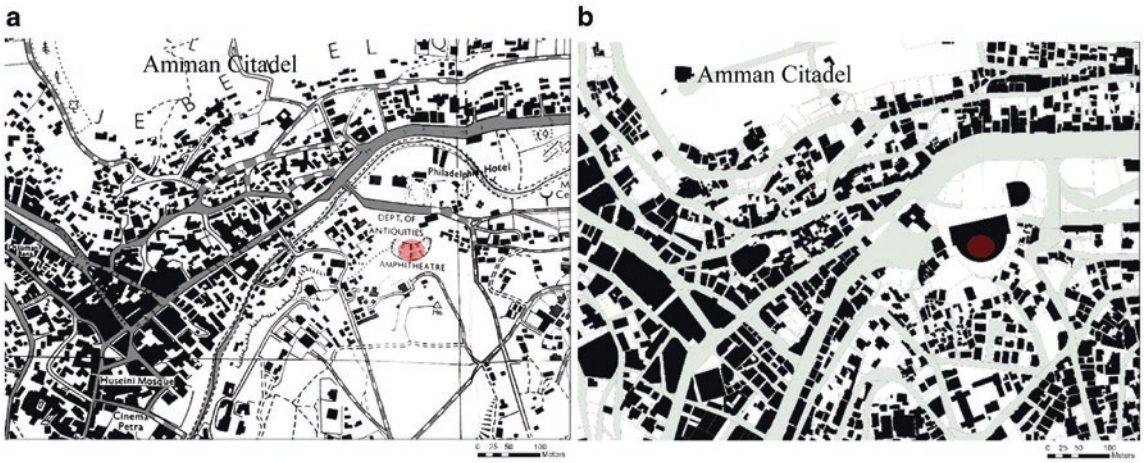


Fig. 3 **a** Amman downtown in 1947, before the first Palestinian refugee movement. Most buildings were built on the flat part of the valley, and commercial activity was centered around the main roads (*Transjordan Town Plans: (Amman. [cartographic Material]*, 1947). **b** shows the same part in 2021 (Ammancitygis, 2021)

for Amman struggled to achieve their goals over the mainly private lands.

By 1947, Amman town was becoming a commercial center with agricultural activities. In 1948, the formation of the Israeli state in Palestine have resulted in masses of refugees being displaced to Amman. Some refugees settled in the two refugee camps in Amman, which has formed about 2 km from the town center. Meanwhile other more well-off refugees settled in the town. Both of those groups have contributed to the expansion of the city, forming what is now known as eastern Amman. Figure 3a shows part of Amman historic town plan in 1947, and Fig. 3b shows the same part of Amman in 2021. The commercial activity expanded by the immigration of Palestinian into the town, until it completely replaced the agricultural activity. Figure 4a shows a view from the Citadel toward the Roman theater, south, in the early 1950s, and Fig. 4b in 2021. The expansion of Amman around the refugee camps and around the downtown has connected them together and created urban characteristics that are a gradient between them. These characteristics will be discussed more in Sects. 4.2 and 4.3.

4.1.2 Urban Characteristics of the Amman Historic Town

As the town transformed from agricultural to commercial activity, the semi-rural single-family houses that were built in the late 19th and early 20th C behind the commercial roads have been either replaced or converted into commercial buildings as the market expanded. While the commercial buildings facing the main and secondary streets has mostly been preserved since they already served a commercial function. As can be seen in the plans in Figs. 4 and 5, the main roads have been preserved, while more secondary streets have been added and expanded. Meanwhile, areas in the historic town that were not part of the main market in the valley, like Alweibdeh and Rainbow Street, have maintained more of their early 1900s buildings, especially in the tertiary streets and allies. These areas are being now featured as attractions in Amman, with artist displaying elements of the local and global heritage on wall morals, and trendy cafes adopting classical Levant style (Fig. 7). However, even in the non-commercial zone in the valley, most buildings facing main streets have been replaced with modern apartment or commercial buildings, which is to maximize the profit out of these main accesses. See Fig. 6.

Most of these newer buildings maintained a similar plot scale to the original ones, which mainly relates to the land-ownership of the land, topography, and road restrictions. These restrictions have prevented mega structures from being developed unlike the uncontrolled expansion in western Amman in the 1970s and 1980s. Moreover, more efforts are being put in place by heritage groups to preserve their urban and architectural characteristics (Dilworth, 2017; Melnik, 2019; Page, 2012). Table 1 summarizes the main urban characteristics of the historic town in comparison with other areas in Amman.

4.2 The Era of Refugee Camps in Amman: The First Palestinian Refugee Wave in 1948

4.2.1 Socioeconomic Conditions During the First Palestinian Refugee Wave

The formation of Israeli state in 1948 has resulted in 700,000 Palestinian refugees, 500,000 of which were placed in Jordan. By 1950, 36,000 refugees have been displaced to

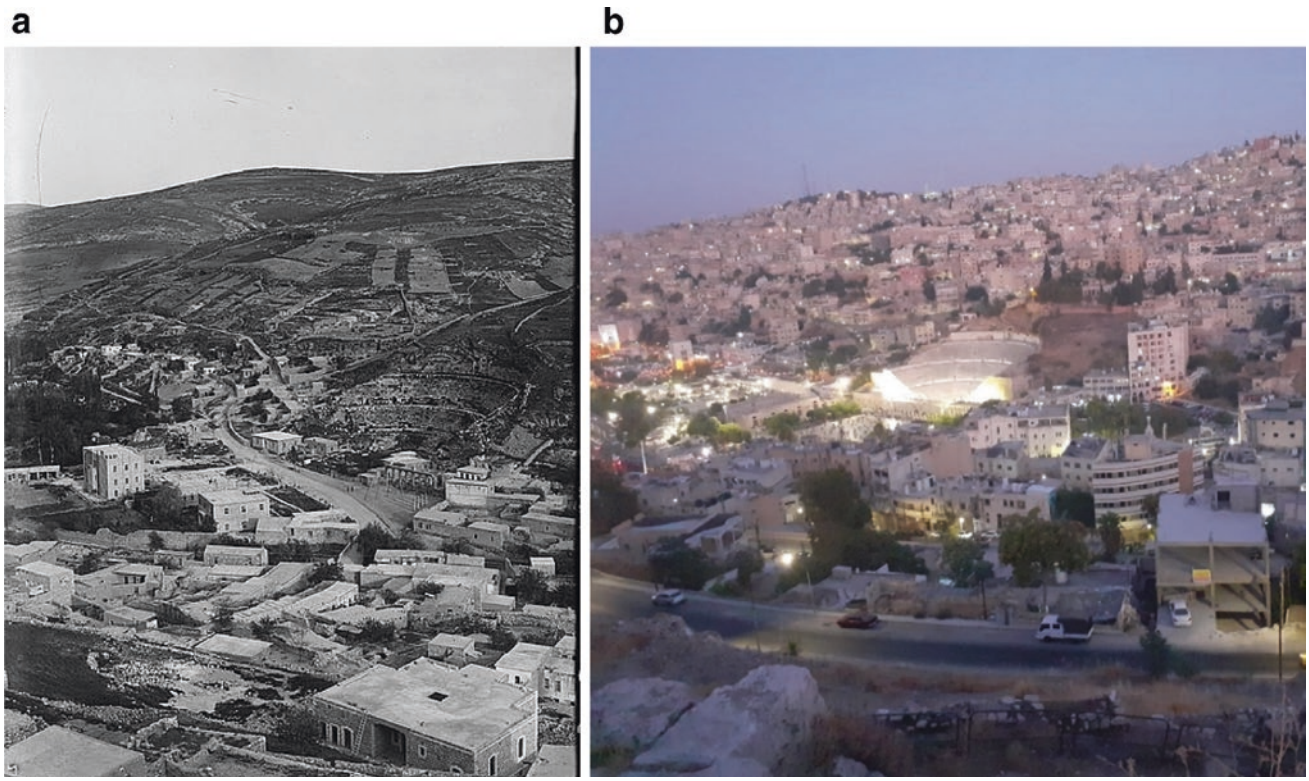


Fig. 4 A view from Amman Citadel toward the historic downtown, south. **a** is in 1920s (Matson, 1920), and **b** in 2020 (author own photograph). The land function has changed from agricultural and simple commercial activity into a main commercial center and one of the highest-density residential areas in Amman. Historically mainly the valley was used, but the population explosion resulted in urbanization of the steep topography

Fig. 5 Amman historic town: Main Road in the valley, next to the Roman Amphitheater

Amman (Hanania, 2014). Most of the refugees, especially ones from rural areas who just lost their farming land, settled in five refugee camps in Jordan close to town centers (Khawaldah, 2016), two of which in Amman, which are Al Hussein camp (established in 1952) and Al Wehdat camp (established in 1955). All these camps have turned into a lifelong temporary–permanent settlements, which take an urban form and represent an integral part of their current cities. In Amman, most of the camps residents were rural Palestinians who had just lost their farming land in 1948 Nakba and with it all their capita. They had no skills outside of farming. Meanwhile, urban Palestinians, have moved to the towns and carried their trades with them (Hanania, 2014). Eventually, a market started to emerge in the camps through trading with the aids provided by the United Nations (Gharaibeh, 2019). The markets evolved and today

Fig. 6 Amman historic town. **a** Main street in Alweibdeh. Modern apartment buildings replacing the single-family houses in main streets. **b** Secondary branch in Rainbow Street, which maintained more of early 20th C features. Preserving its features has allowed it to be promoted as an attraction in Amman

Fig. 7 Amman historic town. **a** and **b** Tertiary streets in Al Balad. **c** An Alley in Alweibdeh showing local artists. **d** Alley connecting the citadel with Al Balad. These allies preserved their original scale and function

form one of the main commercial zones in Eastern Amman. Figures 8 and 9 show the market which occupies most of the main and secondary streets in the camp.

4.2.2 Urban Characteristics of Al Wehdat Camp

Upon visiting Al Wehdat refugee camp near the historic town of Amman, there is no demarking point of where the camp ends and the city starts. The camp was officially recognized/founded by the UNRWA in 1955. It had an initial population of 5000 and an area of 0.48 km^2 (UNRWA, 2021). It took 10 years to change the camp from tents into more permanent construction, as refugees refused to accept their new surroundings and the loss of their land (Alnsour & Meaton, 2014). Today, the population is estimated to be 118,000 and still occupy the same official area. This area is surrounded by mixed-use buildings with a busy market on the street level. Entering the urban camp, there is a gradual transition of quality of buildings, and the street scales decrease the deeper you move inside. Moreover, the presence of street sellers "Bastat" become more dominant in the internal market, making navigating the streets even on foot challenging. Figure 8 shows the marketplace, and Fig. 19 shows a map of Al Wehdat, where the blend between the camp and the city is visible from an urban perspective.

The layout of the camp was originally placed by the UNRWA in 1955. Every family has been given a 100 m^2 "unit" or "Wehda" for their tent when the camp was formed. As the crisis prolonged and the tents were slowly replaced with permeant structure, the growing refugee families expanded to the limits of their plots with no consideration for setback. This has left most units surrounded from three sides and created windowless rooms. As the horizontal expansion reached its limits, and permeant roofs became allowed in the camps, where previously it was illegal (Alnsour & Meaton, 2014). The units started to expand vertically, with three floors being the maximum allowed

number of floors. Evidence of this generational vertical expansion can be observed throughout the camp; see Fig. 9. This incremental architecture property is a common feature among informal settlements, where the adaptions priorities immediate actions and needs over the end results (Dovey et al., 2020). Consequently, it is to be expected that building quality, finishing materials, and floor heights vary between different levels. Moreover, special violations, to outside the allocated plots became a common feature, especially for vertical circulation; see Figs. 9 and 10.

The buildings in the camps are done with cheap materials and low standards due to the low income of the refugee families (Alnsour & Meaton, 2014). Most buildings appear to have an exposed rough plaster coating or single coat of painting. Some buildings have stone cladding, especially near the commercial roads in the camp. Despite the longevity of the camps, most families are not investing in improving the quality of their settlements (Kamalipour & Dovey, 2020). In their study of housing quality in Al Baqaa camp, the authors found that this partly due to low economic abilities, and partly reflects the refusal to acknowledge the camp as their permanent home (Alnsour & Meaton, 2014). It can also be due to their lack of ownership of their housing units, where they have no legal claim over it. This is because Al Wehdat camp is built on rented private land by the UNRWA, where the lease is for 99 years. Despite that, there is a market of buying, exchanging, and renting the units. This form of informal real-estate market has no legal basis. Meaning that the only claim the buyers have over their property is an informal documentation of transfer of ownership that is acknowledged by the local community. Nevertheless, the representative from the Palestinian Affairs assured that the government and UNRWA turn a blind eye on these activities (Al-Husseini, 2011).

The main streets in the camp are at the perimeter. These streets are wider and regarded as having more value due to their direct accessibility from the foot traffic outside the camp as well having car accessibility. They are manly commercial

Fig. 8 **a** Main Street in Al Wehdat perimeter. Car accessibility is limited due to street sellers. **b** Secondary street. The deeper inside the camp the more spatial violations are seen, where street sellers overtake the sides of the roads as an extension of their stores

Fig. 9 Tertiary streets. The ground floor is sometimes used as a workshop or a store, like in **a** and **b**. **b** and **c** Shows limited car accessibility due to spatial violations, like the external staircases that were added when upper floors were built

Fig. 10 Allies in Al Wehdat camp

buildings that leads to the main market inside the camp. The streets of the internal market are narrower than the perimeter ones, but have a main commercial function, and are mainly accessed on foot despite being wide enough for car access. This is due to informal sellers "Bastat," who block the roads with their carts and kiosks (Fig. 8). Secondary streets are connected by tertiary ones, which can be about 3–4 m wide. The closer tertiary ends to secondary streets have live–work relationship, where workshops occupy the ground floor, and upper floors are used as residential. They are mainly foot passages, with some limited car accessibility. The width of these streets would have allowed car access, but external staircases and benches "Atabat" from the buildings limited that (Fig. 9). Finally, Allies form a network of passages within the camp. They are mainly used by the residents of the block and can be as narrow as less than 1 m. They provide access and offer some daylight to the otherwise completely locked housing units (Fig. 10). Table 1 summarizes the properties of each of these street levels. Despite every unit being allocated a plot size of 100 m^2, the spatial violations and lack of regulations for setbacks have made the entirety of each plot being completely built-up. This made the unites attached to each other forming large impermeable blocks. Some internal passages might not appear in the map due to overhangs in the upper floors. See Fig. 19 for the solid and void map of Al Wehdat.

4.3 The Expansion of Amman Town into a City: The Gradient of Urbanization Between the Camp and the City 1950s–1960s

4.3.1 Socioeconomic Conditions During 1950s–1960s Amman

The Area of Amman expanded from 2.4 km^2 in 1947 (Potter et al., 2009) to 4.123 km^2 in 1948 (Khawaldah, 2016). Refugee influxes kept moving to Amman and by 1952 the population reached 108,000 (Hacker, cited in Khawaldah (2016)), increasing from 30,000 in the 1940s, which more than tripled in the following 15 years (Khawaldah, 2016). 1952 census states that 29% of Amman's population was living in tents, and 8% in caves (Abu-Dayyeh, 2004). Moreover, the international relief agencies support, along with the new emerging informal economy with refugees' migration, has attracted internal migration from rural areas to Amman. This resulted in a growth rate of 9.6% in the 1950s, in comparison with 4% in the rest of Jordan (Khawaldah, 2016).

This growth pattern continued that by 1959, the Amman Municipality estimated the Amman's population at 175,000 (Hanania, 2014), which is more than 80% increase since pre-Palestinian migration. As the economic status of some of the refugees improved, they started purchasing land outside the refugee camps in the city, which gradually connected with the growing town center. These areas mainly developed in the 1950s and early 1960s (Ababsa et al., 2011). Additionally, the 1967 Arab-Israeli war added to the accelerating expansion of the city, causing the population to reach half a million (Khawaldah, 2016).

Two plans were developed by foreign consultants in attempt to control the urban expansion of Amman: 1955 development plan, and 1966 Town and country planning act. Both plans failed to address the growing issues of lack of transportation, services, job opportunities, and leisure places. They imposed drastic development proposals that lacked understanding of the local context and land ownership patterns (Beauregard & Marpillero-Colomina, 2011; Saad & Amr, 2015). Moreover, the Arab–Israeli war led to redirecting the funds away from the development plans. Meanwhile, the lack for regional planning led to most investments being focused on Amman, causing over concentration of services in comparison with the rest of the country. It is estimated that 70% of services were allocated in Amman, while it had 40% of Jordan's population. This became one of the factors that accelerated internal migration from rural areas and other cities to Amman (Alnsour & Meaton, 2014; Hanania, 2014).

4.3.2 Urban Characteristics of Al Ashrafeyeh

Moving outside Al Wehdat refugee camp to Al Ashrafeyeh, which is one of the main areas that have emerged between the refugee camp and the historic town center during the 1950s and 1960s, the streets start to become wider, and building finishing materials starts to gradually improve and the building sizes increase. Primary, secondary, and tertiary streets, as well as allies, are wider than in the camp, as well as the average plot size, which is 175 m^2 in comparison 100 m^2 in the camp. The streets scale is more comparable with the historic town center, but the average unit

Fig. 11 Two photographs are taken from the same building. **a** is facing the main street, showing formal buildings following the street regulations and with some finishing materials on the building facades. **b** photo shows the back view to the allies, displaying characteristics of informal settlements

size is smaller. Figure 19 shows Al Ashrafeyeh morphology in comparison with the other neighborhoods from other eras in Amman, and Table 1 summarizes the main features.

This emerging gradient scale between the center and camp, as well as the gradual improvement in building materials quality from the camps, can reflect some economic improvements of refugees. It can also be due to their ability to legally own their homes, unlike in the camp. Additionally, it indicates some planning regulations by the municipality. Although these regulations were not fully in place and were mainly imposed on the main roads, leaving internal allies a subject for informal settlements. Figure 11a shows a photograph taken from building facing a main street in Al Ashrafeyeh, while Fig. 11b shows the view from the backside of the same building. Features of informality such as incremental architecture and poor materials can be seen facing the back streets, which a similar typology and scale to the camps. Meanwhile, the façade facing the main and secondary streets is more regulated and resembles and scale and typology of the historic town. As for commercial activity, it takes place in the main and secondary streets (Fig. 12), while tertiary roads are often steep paths connecting larger roads together and have car accessibility (Fig. 13). Meanwhile, allies in these areas are mainly pedestrian with some limited parking space sometimes. They are often staircases between buildings connecting with secondary roads to adjust to the steep slopes. See Fig. 13.

4.4 Globalization of Amman: Urban Expansion by Gulf Workers 1970s–1989

4.4.1 Socioeconomic Conditions During 1970s–1980s Amman

The 1970s witnessed wide unplanned urban expansion in all directions in Amman. By 1987 Its area reached 350 km^2, with a population of 960,000 (Abu-Ghozalah, 2007). This population growth was partially due to Palestinian and Lebanese refugees after 1975 (Khawaldah, 2016). However, the massive urbanization movement was mainly induced by the Jordanian and Palestinian workers in the Gulf countries, who immigrated to the oil-rich regions during that time period and occupied mainly white-collar jobs (Harrigan et al., 2006). These workers have invested back in Amman, where it is estimated that income from gulf countries increased from 550 million in the 1970s to 1.3 billion during 1980s. The main form investment these immigrant workers did in Amman was in the building sector (Beauregard & Marpillero-Colomina, 2011). The foreign income, alongside the lack of regional planning, has resulted in an uncontrolled, fast urbanization of the city.

This time frame is when expansion toward western Amman started. See Fig. 1b. The western part of Amman, and generally the northwestern part of Jordan, includes the main areas with rainfed lands. It is the region of the main forest cover and agricultural areas in the city (Abu Hammad, 2017). Which meant that the urban expansion was happening over the forest and farming land. Amman attempted to control this expansion over agricultural land through the Down Zoning approach. The approach was developed in the US during the 1920s to protect open spaces. The adopted strategy entails limiting the allowed density to built-up ration on agricultural land. In other words, it permits lands to be sold only as larger plot sizes, which limits the affordability to buy such lands and therefore limits the urbanization over them. However, the main impact of this approach was that it reduced prices of rural areas and increase prices of urban ones. Moreover, it decreased affordability of housing for low- and middle-income groups- which increased the spread to informal settlements in eastern Amman (Alnsour, 2016). In 1979, the Building Regulations Ordinance was established. The main

Fig. 12 Secondary roads also have mixed-use activities, with live-work relationship in the same building. Buildings facing secondary roads are of better conditions than the ones facing the tertiary roads and allies

Fig. 13 **a** Tertiary Street in Al Ashrafeyeh, **b** and **c** Allies. They have similar characteristics to the refugee camps, but slightly larger scale

aims of the regulations were to control land use, improve quality of buildings through establishing regulations regarding occupancy ration to plot size, ventilation spaces, and building heights. The regulations had a positive impact on providing some control over urbanization.

The relative political autonomy of the era, along with the prominence of western planning ideologies, and abundance social welfare systems due to foreign income of the gulf workers, have contributed to the introduction of international style to Amman. Globalization in urban areas that developed during the 1970s and 1980s is prominent, where it replaced the elements local architectural style of the levant that was still prevailing (Abu-Ghozalah, 2007; Melnik, 2019). Gird-distributed, large apartment buildings became the dominant form of urbanization, and features of local architecture such as arched windows, and façade

proportions were abandoned. Moreover, the use of imported building materials started to have a share of the building market, although most apartment buildings still used the local natural limestone for external cladding (Al Nassar et al., 2020; Dahabreh, 2020) Fig. 15.

4.4.2 Urban Characteristics of Al Rawabi

Figure 19 shows the urban morphology of Al Rawabi, which was developed between 1970s and early 1980s. The scale of the plots is larger than all the previous eras in the city, with an average of 320 m^2. See Fig. 19. Multi-story apartment blocks became the most common building typology. This is due to Jordanian and Palestinians workers in the gulf, who invested in apartment building in the 1970s and 1980s (Abu-Ghozalah, 2007). It was seen as a form of retirement plan by these immigrant workers and fulfilled the housing demand in the city due to the continued refugee movement and internal migration. Moreover, the Down Zoning approach has prevented smaller plots from being sold in western Amman. This has contributed to larger building plots and higher number of floors than was previously common in Amman, which is to maximize the possible profit of the increasing land prices. Moreover, the presence of higher buildings increased during that period (Abu-Ghozalah, 2007). In Al Rawabi neighborhood, seven floors are the most common in the main streets which are mainly commercial, whereas in the historic town and Al Ashrafeyeh three to four floors are the most common for commercial streets. See Fig. 14.

These buildings construction quality improved from the refugee camps and the areas that emerged between the center and camps. This can be related to 1979 Building Regulations Ordinance, as well as to the improve economic situation of the immigrants' workers. Additionally, the ventilation spaces as well as the availability of open spaces have improved. However, the lack of details in the regulation of construction materials resulted in increase of energy consumption (Meaton & Alnsour, 2012). The globalization influences led to the street scales becoming larger than any of the previous periods, with car accessibility being provided in all street levels. Commercial activities became centered in the main roads, with some on the secondary ones; see Fig. 14. Tertiary roads have little to no pedestrian pavements, and allies are less common due to the shallow schemes, where most buildings are accessed through secondary roads, Fig. 15. The single-use urban schemes, along with the large-scale streets that are car-oriented, have contributed to reducing pedestrian activity. People workplace became further away from their living place. And with no coherent public transportation plan in place, car numbers continued to increase in the following years, magnifying the traffic, energy, and pollution issues in the city (Abu-Dayyeh, 2004; Melnik, 2019).

4.5 Polarization of Amman: Western Amman Expansion Following the Gulf Wars in 1994 and 2003, and Current Trends.

4.5.1 Socioeconomic Conditions Following the Gulf Wars

The economic boom during the 1970s and early 1980s started to slow down after the international collapse of oil prices in 1983. This has decreased the demand on Jordanian and Palestinian workers in the oil-rich gulf countries, where it is estimated that 20% of Jordan population was working in the Gulf countries during that time (Swaidan & Nica, 2002). The relative economic prosperity came into a crashing point when King Hussein of Jordan decided to cut all political ties with the west bank in Palestine at the end of 1988, which is following conflicting policies with the Palestinian Liberation Organization (PLO). This had caused panic among the Palestinians, especially the 1967 refugees who still had

Fig. 14 Main and secondary streets in Al Rawabi

Fig. 15 Tertiary streets and allies in Al Rawabi

strong family ties with the occupied west Bank. These Palestinians "Control the bulk of wealth in Jordan economy," which, by early 1989, caused large capital flight out of the country. This was one of the main contributing factors that led to the crash of Dinar value in 1989, to less than 50% of its value the year before (Harrigan et al., 2006).

The financial and population crisis worsened after the first gulf war in 1991, which led to the displacement of 400 thousand Palestinian and Jordanian workers from Al Kuwait. This has increased Amman population to 1.3 million, more than 50% increase since 1979 (Al Rawashdeh & Saleh, 2006). Unemployment increased from 4.5% in 1980 to 19.2% in 1992 (Swaidan & Nica, 2002). And income from the gulf states decrease from 1.3 billion dollars in 1980s, to 164 million in 1991 (Ana & Hamd, 2016). As a result, it is expected that any development plans were put on hold. The first gulf war put pressure on infrastructure, increased land value, reduced the affordability of housing to middle- and low-income groups, and increased the presence of high-rise buildings (Abu-Ghozalah, 2007). All these factors contributed to the densification of informal settlements in eastern Amman, that in 1992, Housing and urban development corporation (HUDC) was founded to control informal settlements. It gave permission to divide large land into smaller plots with soft loans from the government. 170 projects started to provide affordable housing. They incorporated 42,000 houses and targeted 400,000 inhabitants. An example is Abu Nuseir New Town. It has capacity of 70,000 people and include 8700 houses of different sizes. However, one of the main project downfalls is that it has been allocating a long distance from economic activity (Alnsour, 2016).

The failure of these strategies to properly address affordable housing issue and limit informal settlements is rooted in the lack of cohesive planning, which accelerated the issue of centralization of services and work opportunities (Alnsour, 2016). These plans were still put on place by foreign consultants who lacked street-level understanding of the local communities. Placing these affordable housing projects away from urban centers, with no plans to encourage investments and create job opportunities close to them, have rendered these projects unsuccessful to address the issue of informal settlements and densification of the city. Most seekers of affordable housing are low-income groups who rely on informal economic activities and blue-collar jobs, which are dependent on the urban activities in the city (James et al., 2014). These groups represent the largest portion of the population (UNDP, 2015). Moreover, it failed to address the social structure of Jordanian families, where they tend to live near their families. Therefore, reallocating them away from their work and social groups was insufficient to address their needs (Alnsour, 2016; Ana & Hamd, 2016).

Another impact of the first gulf war is that it started to increase the gap between different income groups in Jordan. The displaced Palestinian and Jordanian gulf workers. Despite being unemployed initially, the immigrant workers still had a higher average capital and assets than the local workers. Adding to that the start of immigration of Iraqis to Jordan following the Shia uprising, who come from an oil-rich country with a level of income that is incompatible with Jordanians agricultural and simple industrial activity. These groups need for housing, and exposure to globalization in the gulf state, directed them to develop new areas in western Amman. The newly developed areas are of different urban grain, architectural properties, and quality than what Amman has been used to. The globalization of Amman has started to attract foreign investment, and the city marketing strategy became directed toward tourism in the 1990s (Abu-Ghozalah, 2007). All these factors contributed to increasing land values and pushed the urban sprawl to western Amman. It started to create an economic and social polarization between the older eastern parts of the city, and newly emerging, globalized western side.

The invasion of Iraq in 2003 was the yield point for Amman. The city's physical and social structures were permanently changed. Almost half million Iraqi refugees have moved to the city by 2007 (Jawad & Yahya, 2013), increasing its population by 25% within 3 years. Their large numbers required widely expanding the urban areas, where in 2004, new urban boundaries were set for the city (Ababsa, 2013; Potter et al., 2009). However, where the Iraqi refugee large numbers stretched the urban fabric, their financial abilities changed its texture. Iraqi were a different kind of refugees- wealthy ones. Their financial ability to purchase lands and construct and rent affluent houses resulted in sharply increasing the prices of real estates (Sassoon, 2009, p. 55). Suddenly, the local population must compete with a level of income that is not acquiesced with the internal economy. As a sequence, socioeconomic polarization between eastern Amman became a defining feature of the city.

Iraqi immigration also increased foreign gulf estate investment in Amman. Several governmental projects have been privatized, increasing the urban growth rate. By 2007, land prices have doubled, especially in western Amman, in comparison with late 1990s and early 2000s (Abu-Ghozalah, 2007). However, in the absence of cohesive regional planning and regulations, this foreign investment was direct toward the service sector to accommodate the new population needs, relying on foreign income. It was not accommodated with industrial expansion, leading to an increase in import rates (Alshoubaki, 2017; Obalade, 2012). In other words, the main target in urban development projects has been the more affluent layer of society in western Amman, with foreign assets. Meanwhile, the ability of lower socioeconomic groups to attain these services decreased due to lack of investment in the production sector.

4.5.2 Urban Characteristics in Khalda

Understanding the globalization factors is essential to understand the emergence of the low-density urban grain in western Amman. Moreover, Gulf investors in western Amman are more exposed to globalized architecture, an USA planning models of zoning and car-orient urban scales (Al Rabady & Abu-Khafajah, 2015). This can be observed in the wide street scales of areas developed in the 1990s and 2000s, in comparison with the rest of Amman; see Fig. 19. Car accessibility is granted in all street levels, creating shallow schemes that are divided by wide roads. Figure 16 display main and secondary streets in Khalda. Meanwhile, allies are mostly leftover space between houses (Fig. 17b). Like in 1970s and 1980s development, single-use streets as opposed to mixed are more prominent. This, alongside the low density, ha reduced the foot traffic, which made walking in these zones is more for leisure than a mean of transportation. Moreover, the higher land prices means that only the affluent layer of society can afford living in there. Building regulations in these areas limit the allowed built-up area of the land and number of floors (Ababsa et al., 2011). As a result, the main architectural typology is single-family homes and villas of two floors; see Figs. 17 and 18. Meanwhile, apartment blocks are less prominent than in 1970s and 1980s zones and are mainly seen in commercial roads only.

5 Discussion

The aim of this research has been to analyze the impacts of the refugee influxes on urban morphological characteristics, which can be used as guidance for future development plans and policy recommendations. Refugees settled in urban areas as well as refugee camps and brought up different socioeconomic conditions that impacted the urban form. Five main urban expansion zones have been identified, which have evolved in response to different migration movements into the city from late 19th C until today. These zones have been identified using mapping data from the Atlas of Jordan with the Royal Jordanian Geographic Center, along with literature review of the forced migration movements to Amman. Consequently, five sites have been selected from each of these zones as a sample to understand the urban characteristics of each of them.

Figure 19 shows the five selected sites solid and void maps. Larger plot sizes can be seen in Al Rawabi and Khalda, which are in western Amman, in comparison with the other areas which are part of eastern Amman. The sites photographs and maps display clear differences in density, average buildings plot size, materials, and average number of floors between the five expansion zones. As well differences in streets' widths, function, and accessibility (pedestrian or cars). Contextualizing these characteristics is essential in order to understand their implications on the built environment quality in the city, as well as assisting future research in studying the environmental implications of these urban characteristics. These environmental implications include energy consumption and impacts on the microclimate and related urban heat island effect (Hamdan & de Oliveira, 2019; Melnik, 2019).

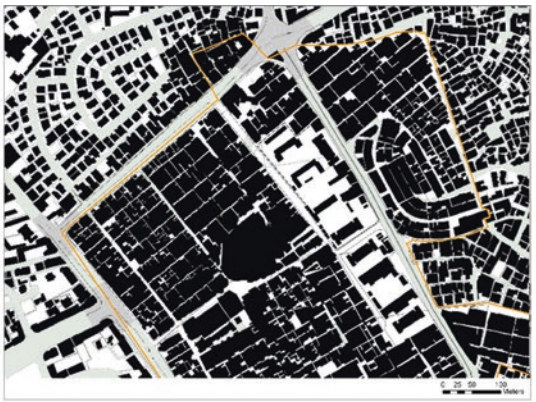
The historic town originated in the valley around water resources and followed the natural lines of the topography. The scale of the roads and buildings is like other historic towns and cities in the levant region. The main activity in the late 19th and early 20th C was agricultural, with a growing main market in the main street. The market grew as more refugees moved to Amman, and the urban function completely replaced the rural one. These urban areas main

Fig. 16 **a** Main streets in Khalda. Multiple lanes in both directions servicing low-density houses, and the large setbacks from the streets contribute to less commercial activity. **b** Secondary streets. Mainly residential with low-density, single-family houses/villas of two floors

Fig. 17 **a** Tertiary Street in Khalda. They have on-street parking and provide access to the houses that are not facing secondary or main streets. **b** An ally in Khalda. They are mainly left-over spaces between the setbacks of building

Fig. 18 Another form of allies in Khalda. Sometimes they provide shortcuts and connectivity between different tertiary roads, but do not provide main entry to the houses

Amman historic downtown valley region: revitalized in the late 19th C and early 20th



Al Wehdat refugee camp: Founded officially in 1955. The orange line marks the camp official area

Al Ashrafeyeh: Emerged between the town center and Al Wehdat refugee camp between 1950s and 1960s.

Al Rawabi: Rapid urban expansion caused by the income from Jordanian workers in the Gulf countries (1970s and 1980s).

Khalda: 1990s-2020 low-density expansion induced by the first and second gulf wars and continues to expand.

Fig. 19 Solid and void maps of five neighborhoods in Amman developed in response to five refugee/immigration influxes to Amman

features include human-scale design and mixed-use schemes. The mixed use was largely represented through the live-work relationship in buildings, where people have their shop/workshop on the ground floor and live on the upper floors.

This typology of live-work buildings was replicated in the nearby Al Wehdat refugee camps, which originated 2 km from the town center following the 1948 Palestinian Nakba. Al Wehdat is characterized by very high density due to lack of open and ventilation spaces, as well as poor construction materials, which have negative impacts on the quality of the built environment. This is especially true in the allies, where gaps between buildings can be as small as 1 m. The small

scale was a result of the socioeconomic activities of the camp residents. It does not follow the rest of the regulations in Amman seeing as camp main plots were allocated by the UNRWA in the 1950s and are still legally under its responsibility. The conditions that created this small urban scale are not ideal. They are the result of the need to maximize the living space under political exclusion and restrictions. Despite that, the pedestrian-oriented commercial area in the main, secondary, and tertiary streets of the camp, can offer a positive example of a human-oriented scale that offers all needs within walking distance. Additionally, the self-shaded urban form, because of the narrow canyon ratio (building height to street width ratio) of the street, can have positive impacts on the microclimate in comparison with wider canyons (Hamdan & de Oliveira, 2019).

Al Ashrafeyeh is an example of a neighborhood that emerged between the refugee camp and the town center in Amman. The streets scale offers more ventilation for the housing units than the Al Wehdat, even in the allies. And building conditions, especially in the main streets, are of better quality than the camps but is generally more deteriorated than the historic town area like Al Balad and Alweibdeh. This is probably historically due to the downtown area being occupied with more affluent layer of refugees and merchants, in comparison with areas that emerged later between the camps and the town. The street scales/canyon ratio is comparable to the town center and allows for car accessibility in main, secondary, and most tertiary streets, with major pedestrian movement. While allies are still mainly pedestrian-oriented only. This human-scale urban character is related to first, the time period that they emerged in, where the use of cars was still relatively small (Al Rabady & Abu-Khafajah, 2015). Second, it is related to the live-work relationship in the neighborhoods, where most people worked near or in the same building that they lived in. On the other hand, the desire to be near the town center and water resources have evoked the development of Al Ashrafeyeh and similar areas on the steep topography surrounding the downtown. This has made al Ashrafeyeh less walkable than the downtown, despite having similar street scales and mixed-use functions.

Newer developments in western Amman, like in Khalda and Al Rawabi, generally have better building finishing material quality than the eastern Amman, like in the downtown, Al Ashrafeyeh, and Al Wehdat camp. Also, there are more open and ventilation spaces. However, the large distances between buildings, wide streets, and single-use zoning reduces their walkability and pedestrian activities. They are more car-dependent which has implications on the city's congestion, energy consumption, and pollution. Khaleda's low density makes dependency on cars even higher than in the 1970s–1980s development, which despite having large buildings setbacks, compensated density with the number of floors. This low-density sprawl over western Amman is devastating for the countries limited green cover, where most rainfed lands and forest cover is in the western and northwestern part of Jordan (Abu Hammad, 2017). Moreover, wider canyon ratio can have negative implications on the microclimate on outdoor spaces due to lack of shading in summer, which also can increase the buildings energy consumption. However, it can also be positive in terms of allowing for wind passive cooling. This trade-off between wind cooling through allowing wind passing, and cooling through shading, is dependent on the context and requires further research (Hamdan & de Oliveira, 2019).

6 Conclusions

This study set out to understand the impacts of the refugee and immigration movements on the urban characteristics of Amman. The research used literature review to review the socioeconomic conditions of each era, and site visits to empirically assess and photograph the urban characteristics. Additionally, site maps were used to analyze and compare the urban grain scale between the five sites. The aim of the present research was to determine the current urban trends in Amman in order to assist in effective future planning policies for the city. This comes as a response to several plans since the 1950s, which failed to address the rapid urbanization, the reduction of agricultural land, the infrastructural pressure, the uneven concentration of services, and the lack of open space and recreational needs. Previous research has highlighted that the failure of these plans can be attributed to the lack of understanding of the local context, where plans have been mostly developed by foreign consultants, as well as failure to address the urban structure as a product of cultural and social processes.

Amman urban form and characteristics have been a result of the several forced migration movements to the city. Urbanization of Amman started in the valley around water resources and following the flat lines of the steep topography. This revitalization of the town was induced by Circassian refugees in the late 19th and early 20th. 1948 The Palestinian Nakba in 1948 caused rapid urbanization on the steep sided of the hills around the valley. The expansion was concentric to the town center, which was a growing commercial zone. This has attracted Urban Palestinian refugees into the town, who carried on with their trades. Correspondingly, the town density started to increase, transforming the economic activity of the town from simple commercial and agricultural, into a main commercial center in the Levant region. Meanwhile, rural Palestinian refugees whose capita was tied with their land, settled in the refugee camps around Jordan, including Al Wehdat refugee camp which is 2 km away from the town center. As new

generations were born into the camps, horizontal expansion reached its limit over any possible open space, and vertical expansion proceeded, with a maximum of three floors being allowed. Evidence of this generational growth can be seen in the form of incremental architecture all over the camp, with external staircases to connect with the upper floors.

As the economic situation of some of the refugees improved, they started purchasing land outside the camps, causing concentric growth around the camp. This has connected the camp with the growing town center. The emerging areas between the town center and camp, like Al Ashrafeyeh, had combined characteristics of both the camp and the town center. On one hand, the streets widths canyon/ratio is like the historic town, and most buildings facing the main and secondary streets followed had formal urbanism features, which is an indicator of some of the building regulations being put in place. They also have finishing materials like natural limestone and paint. On the other hand, buildings in the allies of al Ashrafeyeh have informal settlements characteristics, like the camps, such as incremental architecture and lack of/poor finishing materials.

Furthermore, in the 1970s and 1980s, Jordan became a main exporter of skilled and semi-skilled workers to the oil-rich gulf countries. This has marked the start of globalization process in Amman. Jordanian and Palestinian gulf workers invested their earnings in the gulf countries back in Jordan. This was mainly directed to the real-estate market, with the growing need for housing with the refugee influxes to Jordan following the Arab–Israeli war. It has marked the beginning of urbanization of western Amman. Large Apartment block became the dominant building form to accommodate the growing population needs. The car-dependent schemes have been carried out throughout western Amman in the 1990s and 2000s developments. These areas were largely influenced by the gulf wars. The return of Palestinian and Jordanian created another wave of urban expansion in western Amman, where these returned immigrants/refugees have brought large capita with them, which is much higher than the level of local economy. It was followed by the Iraqi refugee's movement to Amman following 2003s gulf war, who settled in Amman and caused a sharp increase in properties value due to their high level of income coming from an oil-rich country. Single-family houses/and villas became prevalent in these new areas in western Amman, like in Khalda. This has attracted foreign investments to western Amman, which added to the social, economic, and services polarization between the eastern and western parts of the city.

Overall, Western Amman urban areas, like Khalda and Al Rawabi, have better building quality and open spaces and attract foreign investments due to the higher average income of the residents. It is also due to the ease of developing large projects in the open lands. However, the large streets and buildings setbacks, and single-use developments are increasing car dependency in the city and reducing foot traffic. Moreover, the low-density sprawl over the limited green cover is causing environmental destruction and increasing the pressure on the city's infrastructure. Additionally, this concentration of investment in western Amman is increasing the socioeconomic gap between the eastern and western parts of the city. Meanwhile, while the eastern part of the city, especially inside and close to the refugee camp, lack open and ventilation spaces, it provides human-scale design. Moreover, the mixed-use design feature of eastern Amman reduces car dependency and increases the possibility of local economic activity that is dependent on foot traffic.

Future urban policies should aim to direct more investment toward 1950s–1960s zones in specific, and eastern Amman in general. This is to create more economic balance between the two parts. Moreover, any affordable housing project should aim to integrate mixed-use features and work with the local community to transfer their economic activities into the affordable housing zones, rather than force them to transport. Additionally, more efforts should aim to improve the quality of the informal settlements, like repurpose some areas and turn them into open green spaces. As well as aiming to direct some investment to create wider job opportunities near these zones. They present several advantageous economic and urban features. Therefore, working to improve them can be more effective and economical than treating them as issues to be erased and relocate their inhabitants.

Policies should also limit urban sprawl in the western part and densify existing areas instead of developing new zones. Moreover, re-introducing the human-scale design that is seen in eastern Amman, while maintaining more open green spaces, can help in pedestrianization of western neighborhoods. It can also help increase the local economic activity over dependency on large-scale, foreign investment projects. Finally, the research is part of a series of studies investigating the multiple levels of impacts of refugees and migration on urban characteristics and performance, as well as heritage mobility. Part of the research findings will be used to investigate the environmental thermal quality of different areas in Amman. These outputs can be used to develop targeted interventions and recommendations for this specific context, with potential for expansion to wider contexts.

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The Innovative Housing Models for Green Architecture: Come-Back of the Garden-Cities First Known as Bank-Houses in Istanbul

Hülya Coskun

Abstract

This research focuses on garden-cities in Istanbul, first developed as a new, innovative housing models in the world, later planned in context of sustainability, green architecture, and recently with the pandemic, COVID-19. In the beginning of the twentieth century, E. Howard's book of *Garden-cities of To-morrow* and his idealized garden-city models became a worldwide phenomenon. First with the climate change concerns, and later the recent pandemic COVID-19 people began to question the old planning theories and doctrines and the city and metropolitan life model which was imposed throughout the twentieth century. Nowadays, with the increasing awareness of sustainability and green architecture, also planning with the renewed interest, this old rhetoric, E. Howard's garden-city models have recently made a come-back as a research object after the recent pandemic. The original English garden-city models and its derivatives in Europe were known as *cité-jardins*, in France, and *Garten-stadts*, in Germany, also known as bank-houses in Istanbul, Türkiye. These housing models were transferred to Istanbul via European, French, and Italian architects later were designed and developed uniquely for Istanbul. Characteristically various models of French *cité-jardins* (garden-cities) developed for Istanbul by Henri Prost a French architect-urbanist who was affiliated the French urbanism school were searched. Until 2000s, the garden city housing models and its derivatives in the post-Prost period known and developed as bank-houses as a version of his *cité-jardins* later implemented by Turkish architects on the Asian-Anatolian side; Kadıköy, Acıbadem, Koşuyolu and European Side; Levent, Yeşilköy, districts were revealed. After the 2000s, some new and innovative housing models appealing the old, English style countryside living originated from garden-cities were planned out of the city. In the 2020s, with the recent pandemic the old, Welwyn garden-city concept come-back first in England, later influenced the world and Istanbul. As original garden-city, this model first known as bank-houses emerged and evolved as healthy houses concept planned in green areas with the pandemic specifically for Istanbul were examined.

Keywords

Istanbul · Bank-houses · Garden-cities · Green architecture · Housing · Sustainability

1 Introduction

This research examined the garden-cities and their come-back as an old rhetoric helped to build a new and sustainable relationship between dwellers and city presented an updated study after the recent pandemic COVID-19, in the world and in Istanbul. With the global warming, climate-change and particularly the recent pandemic, we have witnessed the come-back of the twentieth century's urbanism theories and doctrines. The climate crisis since the late twentieth century and recent coronavirus created and imposed new lifestyle and housing, and urban planning principles in cities and even new ideologies and theories. We confronted unprecedented urban scenarios and the changing world dynamics altered the city planning and housing design and model parameters that are known to us so far. Reflected in the cities, this unforeseen radical change might be a long-term and permanent process that spans a longer period. If we explain in the other words even,

H. Coskun (✉)
MSGSU, Mimar Sinan Fine Arts University, Faculty of Architecture, Istanbul, Turkey
e-mail: her_222@yahoo.com

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we have not confronted the worst incident and circumstances yet (Gates, 2021).

Even though, the newly emerging significant conditions in the cities, the people first underestimated, the consequences of the recent pandemic COVID-19 having vast influences beyond the expected. During the public regulations imposed in the cities such as social distance and isolation effected the social life and psychology of population who clustered in their homes long days and months which enhanced to influences of pandemic. Also, the pandemic emphasized and made more visible the unhealthy living conditions in cities which was not noticed previously. First the climate issues and later the pandemic process have been unexpected and transformative outcomes on cities and led to rapid, and radical changes in people's lifestyles, housing ideas and models. Global warming, and COVID-19 have forced cities to take new and urgent measures, and some major cities like New York, London, Paris, also Istanbul used the pandemic to forge ahead with crutial urban plannings.

The post-metropolitan life and escape from the city centers with its growing population and urgency with the problems by climate—change came to the fore even more after COVID-19 as an inevitable new idea. Indeed, living in the city centers has always been monopolized by the upper class as a privileged living style previously. However, due to recent closure, the people had to clustered in their multistory apartments for long months without stepping out as well as the craved living in green areas, and healthy lifestyle in rural. Hence, especially, after the coronavirus the people started to look for new living styles and housing models longing for the green areas and forests. They began to question the metropolitan life established on the car dependency model which was imposed us with the twentieth century's urban living norms. Thus, especially, after the recent pandemic, the idea of living a healthy lifestyle in the less dense and greener areas or near towns has emerged again instead of crowded city centers among the people.

The ideas once seen as solutions to the climate issues in the 1980s, were accelerated, especially after the coronavirus, the search for a more green, healthier, car-free and comfortable lifestyle emerged in American States, England, Europe, in the world as well as the in Türkiye. The people first time facing to a pandemic nearly later a century confronted to the dramatic effects and we witnessed the shrunk of America's biggest cities which led the people moving elsewhere (Vox, 2022). Thus, this newly developed circumstance has driven escape from big cities to the less-density suburbia or vicinity of small towns (Wall Street Journal, 2021). In the context of the global warm the densely urbanization and the uncontrolled human settlements not only emerged as a threat after the COVID-19, but the big cities where the carbon emission achieved a peak, have also now become a threat to human health. The recent pandemic worsened the living and working conditions and forced to people to make permanent and radical changes. The pandemic not only changed housing demands and models but also working conditions and we witnessed the birth of the new remote and hybrid working models. Hence, the big cities and metropoles which were known their popularity before pandemic that offered sumptuous living, and working in high-rise buildings around the chic cafes and shopping areas, now seem to lose their old appeal after that.

In recent years, the architects have had to adopt new, and innovative housing models in response to climate change which was described as the main problem of the world today; however, housing issues and the recent need altering housing models became more significant after the COVID-19, pandemic. In this context, after the coronavirus, the idea of innovative housing design, the garden-cities have recently made a come-back, and the old garden-city models have become a research object focused to create new, and innovative models aimed to plan the green and sustainable architecture. The preliminary examples of this new idea came to the agenda as an old rhetoric and pioneering project, the renewal of E. Howard's Welwyn, in England, which became a symbolic model of garden-cities (Fig. 1). A recent article published in England referred to old Welwyn town designed as a garden-city by E. Howard in the beginning of the twentieth century, it was stated that the city will be renewed as the center of point after COVID-19 (Hertslife, 2021). Furthermore, it was also stated that in this article there was a resurgence of interest in the ethos of the garden-city models and the type of neigborhood, and community advocated by E. Howard prompted the problems of metropolitan and regional development also in accordance with the importance of sustainability in government policy (Schuyler, 2002). The Welwyn Garden City was described by The Times news paper that a world-famous modern new town developed as an experiment in community planning and Hatfield created by sporadic buildings in the open country and Welwyn, made the New Towns Act possible, just as Hatfield, by its imperfection made it necessary (The Times, 1948, p. 5).

However, COVID-19 was not the only reason for this rapid and radical change idea to search for new housing and living models in the green, sunny areas, but also the searching for car-free, zero carbon emission, quiet and calm neighbourhoods, housing shortage, rising housing prices and the expensive cost of living in the big cities played a significant role. Searching for new and healthy living styles delivered the return houses like E. Howard's garden-city models, but also car-free notion with new pedestrian and bicycle ways reminiscent of the ideas of the old garden-cities were reinstated in this new arrangement.

Fig. 1 The specific Garden-city model first designed by E. Howard, in Welwyn, England. Photo, Hertslife (2021)

Likewise the come-back of the garden-cities Welwyn, also, Paris Mayor A. Hidalgo put into effect the most ambitious plan *ville de quart d'heure* (15 mins city) as another alternative solution to the garden-city planning ideas for Paris in the scope of measures taken for the sustainable plan as well as the COVID-19, pandemic. (Financial Times, 2017). Therefore, they specified and developed some new and innovative regulations based to pandemic that they could not even realize with climate change yet, with coronovirus.

Furthermore, as an another idea and reason the houses with gardens it was thought to originally derived from Kropotkin's old notion that low-income people will cultivate their own vegetables, to achieve clean food and environment since the beginning of the twentieth century (Ragon, 1986, p. 19). The pandemic has already become the initiator of a rapid change process with an acceleration that increases the awareness of these innovative ideas that are slowly developing together with the climate crisis.

With the climate change and COVID-19, we have seen the failure of existing urbanism theories and discourse of the twentieth century and the car depended urban ideas. New developments from this century were centered in this study within the context of ideological, and intellectual debates that formed the background of housing, and human discussions. With renewed interest, and as an object of research, rethinking the existing city planning, and housing design questioning the negative impacts of the physical environment that were created by cities built for cars rather than human or environmental concerns. This was realized in reaction to both the practices of CIAM, *Congres Internationaux d'architecture Modern* (International Congress of Modern Architecture) and modern architectural doctrines in the mid of the twentieth century. It was also a reflection of the necessity of discussing of background such questions as "What is the housing design?", and "How will houses be designed in the future in the context of the sustainability and green design, and architecture"? The pandemic has emerged as a shocking way and notion changed and transformed the cities, people's living, and even working style, system, housing design and plannings very short period.

In recent years, garden-city models have become a research object both on theoretically and practically to create a sustainable model. In the theoretical context, the issue of producing characteristics of the doctrines of sustainable urban planning on innovative housing models was questioned in an article that referred to French urbanist Françoise Choay who constituted primary classifications as a pioneer these discourse and ideas (Choay, 1965).

The idea of designing a more livable environment with sustainable concerns focused on primarily nature, and human needs, as well as the housing problematic was first stated at the Rio Conference, in 1992, and later at the Istanbul Conference, in 1996. After these series of conferences, the idea of searching for housing models that comply with the manifestations and meet the requirements of green architecture, and sustainable design became significant.

The searching new lifestyle, particularly after the COVID-19 led to rethink on the garden-cities, as well-known housing models presented as modern, airy and sunny living areas outside the city since in the beginning of the twentieth century. The coronavirus which now affects the world is changing the priorities in the housing sector

as well, and the need for quiet, peaceful, healthy and spacious residences has started to increase. Recently, Turkish contractors founded a health board to determine the new specifications for changing housing demands of the people after the pandemic and they created specific housing design term healthy city-housing, in Istanbul (Hürriyet, 2021). Turkish, private contractors explained that new housing plannings consisted like houses with gardens or with larger balconies and terraces with green have became one of the indispensable criteria for residences, also the interest in horizontal buildings instead of multi-story, in Türkiye. Additionally, they explained that this idea help to establish a new and sustainable relationship between urban dwellers, and urban areas (United Nations, 2021). Recently, they initiated a new urban agenda planning garden-cities with 90% green areas and described that the COVID-19 period as a second milestone after the 1999s earthquake. Therefore, in the housing planning the use of more green elements and gardens in housing models appeared as an indication that come-back of the garden-city concept.

Although E. Howard's and R. Unwin's garden-city models have been referenced in many studies so far, as a significant future model for green architecture, and sustainable design, there have been few researches on garden-cities in Istanbul. This study addressed this research gap and presented updated research including the period, especially after the recent pandemic by examining housing planning and evolution of the garden-cities in Istanbul, as a case-study to specify the main problematic.

The Methodology

The first part of the research focused on the first half of the twentieth century and garden-cities in Europe. Garden-cities were known as *cité-jardins*, in France, *Garten-stadts*, in Germany, and also known as French version, *cité-jardins* its various derivatives were developed and mostly known as bank-houses in Istanbul. First developed by E. Howard this model and its derivatives was later transferred to Istanbul by European, French, and Italian architects.

The original version of E. Howard's garden-cities were developed, and designed uniquely for Istanbul; as *cité-jardins* (garden-cities), *cité-parcs* (park-cities), and *cité-satellites* (satellite-cities) by French architect-planner Henri Prost, and later implemented by Italian architect-planner Luigi Piccinato and Turkish architects. In the early twentieth century, as an first generation, French architect-urbanist Henri Prost, who was affiliated with the *l'Ecole Française* (French urbanism school), later thaught lectures in *ESA*, *l'Ecole Spéciale d'Architecture* (Architectural School in Paris) constituted characteristically various housing models referred to E. Howard and R. Unwin plannings (Figs. 2 and 3). Some derivatives of these housing models

Fig. 2 R. Unwin's English garden-city model, from H. Prost's Urbanism lectures, *ESA l) ESA, l'EcoleSpècìale*, Paris. Plan, IFA Archives, Paris

Fig. 3 H. Prost, and his colleagues *cité-jardins* Models Site-Plan in ESA, *l'Ecole Speciale*, Paris. Plan, IFA, Archives, Paris

in the post-Prost period known as bank-house projects were developed by Turkish architects and implemented by Bank and Municipality partnership construtions system on the Asian Side (Anatolian) districts; Kadıköy, Acıbadem, Koşuyolu, and European Side districts; Levent, Yeşilköy, etc., were examined.

In the second part of the research, including newer versions of the garden-city models were examined, focusing on the second half of the twentieth century to the post-2000s. After the 2000s, new, and modern versions of the old garden-cities were first planned in Istanbul due to increasing awareness, and re-interest in green architecture, and living plea in the countryside. These models directly taken and transferred from old, English garden-city models appeared outside of the city and fringes on the far northern axis of both European, and Asian-Anatolian sides, in regions such as Kemerburgaz, Sarıyer, and Kurtköy, as an English-originated "country" themed projects aimed at modern, sumptous rural lifestyles. Finally, after the COVID-19 pandemic old, garden-cities come-back with the newly changed idea living in the green areas in the out of the city centers. These constitute the first examples of green planning, in accordance with the development of housing models for the future were examined.

In this research, new, and innovative housing planning models, and typologies in city planning in Istanbul were considered as case studies on the content of the methodology. Although there have been numerous researches on garden-cities, this research will be the first which was scrutinizing of origins of garden-cities and it's evaluation as well as the very recent update after the coronavirus in the city of Istanbul.

2 Towards Healthy and Livable Housing Planning: Sustainability and Green Architecture

Since the twenty-first century, the cities, and their inhabitants have faced new, and unexpected circumstances with the rapidly developing urban agenda in the last few decades first after the 1990s, climate-change issues and very recently, in the 2020s, COVID-19. Indeed, in the beginning of the twenty-first century, the urban planning world freed itself from the old explanatory models whose limits that we know today extensively (Paquot, 2013, p. 122). Once again very recently the planning dynamics of cities radically have evolved, and it has created new design paradigms concentrated on new, innovative urban, and housing planning (Coskun, 2021a).

Nowadays, the majority of the world's human population began to live in mega-cities where they became uninhabitable places with the uncontrolable migration, and urban sprawl to the suburbia, green areas, and even forest. With this radical change in living conditions, United Nation was declared that in 2008, the global urban demographical structure due to outnumbered rural settlements, by 2025, it is expected that two-thirds of the world population will be living in urban areas (Habitat III, 2016).

Today, the problems experienced in the cities have become significant all over the world and forced the urban planners and administrators to take some instant plans, and precautions. Addressing the problems experienced in the cities recently, and facing an increasingly immobile international community of nations, the mayors of Paris, Sydney, Tokyo, and Cape Town taken some measures even boasted in the *Financial Times* in January 2020, with the boldest ideas, and crucial plans for a sustainable future of the low carbon city and COVID-19 (Hidalgo et al., 2017, p. 2). However, put into effect some implementations with significant decisions in cities having such a vast population as substantial issues like migration and housing was still as the main problematic.

Aside from the other cities as a mega-city Istanbul also has problems that induced arose from unplanned, and uncontrolled urbanization process, as well as the housing issues due to inner migration first initiated in the 1970s, and today, continued with transnational migrations. Nowadays, newly emerged innovative plannings such as sustainability, green design, green urbanism, and eco-planning became significant. Searching for new planning methods has recently become the subject of renewed interest and requirement in Istanbul, specifically after the late pandemic.

By the 1990s, the issue of global warming became the major environmental concern through the efforts of some activists. The first "Earth-Summit" was held related to concerns about climate change, and creating a more livable environment in Rio de Janeiro, Brazil, by United Nations. These worldwide conferences, and debates were focused on sustainability which would be later formulated in Istanbul as Agenda 21 (Pérouse, 2014, p. 230). Thus, living styles in cities began to be questioned again, the center of the critics searched for a healthier, and more livable urban environment, through green architectural designs was emerged. In addition, the idea of desirability of living in the city centers commenced to change after the 1980s, and the urban population in the cities began to sprawl and settle outside the city borders.

2.1 The Declaration of 1996, Climate Conference, Istanbul, in the Context of the City's Planning

Recently, Istanbul has become one of the leading mega-cities in the world, with the nearly a country size population

of 15 million according to the late World Bank Reports. Indeed, a serious housing problem first revealed in the city due to initiation of massive inner migrations by the workers in the 1970s. The uncontrolled planning implementations by the Democrat Party in the 1960s, later with the 1980s liberal policies the illegal houses increased led to the deterioration of the housing problem.

After the first "Earth-Summit" in 1992, in the context of Agenda 21, the next Conference would be held in Istanbul in 1996. This conference was seen as the turning point emphasizing issues of İstanbul city once again related to the necessity of taking some measures referred to sustainable city and the Agenda 21.

In 1996, Climate-Summit, in Istanbul, Türkiye, emphasized the importance of the declaration once again. It was mainly stated that in the reports and notes; "Habitat Conference in Istanbul, moved into the twenty-first century and presented a positive vision of sustainable human settlements, a sense of hope for our common future and building a world where everyone has to right to live in a safe home with the promise of a decent life of dignity, good health, safety, happiness and hope) also Conference ideally focused on the human needs and human beings were at the center of concerns for sustainable development on the basis an action plan as implemented in the Habitat Agenda". (United Nations, 1996)

Furthermore; besides centered on the human, also the this Conference emphasized the right to adequate housing for everyone, in order to sustain the global environment improve the quality of living in our human settlements, and sustainable patterns of production, consumption, transportation, and settlements development pollution prevention, respect for the ecosystems and the preservation of opportunities for future generations. After the 2000s, some new, and innovative projects have come to the city's planning agenda, to find solutions to the problems of the city that emerged with migrations and the transformation of the city.

Following the Istanbul Climate Conference, 1996, the studies were mostly concentrated on to searching innovative solutions to the problems of the world's cities. In 2010, about 14 years after the 1996, Istanbul Conference the Istanbul Municipality implemented some actions on innovative settlements that met the requirements of the last meeting.

Today, regarding the recent Agenda 21, Istanbul aimed to divided the city into five specific regions, in the context of sustainable ideas including Zeytinburnu district next to the Historic Peninsula in the west. Even though willing to take some action against the Climate-change, some further steps have yet to be taken by the institutions such as Government, and the Municipality when considering these specified regions in the scope of the Istanbul, Agenda 21.

3 The Come-Back of Garden-Cities the Search for New, and Innovative Housing Models

After the 1980s, the idea of innovative housing design-focused again on the garden-cities as an old concept with a renewed interest in the context of green, and sustainable architecture and urban planning. Since the environmental turn in the 1970s (the considered that the garden-cities back in the twentieth century even earlier), both explicit and implicit green city concept made obligated to reduce the environmental impact of urban settings have been part of urban policies around the world (Müller and Mattisek, 2018; Bauer and Melosi, 2012; Bernhard et al., 2012).

In 1969, Reyner Banham pioneered a new idea and technology, based on human needs, considered that the environmental problems is an integral part of the discipline of architecture. Previously, no historian or architect before him so systematically explored this specific problematic and its impact of environmental engineering, as well as the services on the design of buildings (Howard, 2008b; Banham, 1969). Later, with the growing interest on green urbanism and the idea the first verison of this model surfaced via Ebenezer Howard's, book, in 1902 entitled as *Garden Cities of To-morrow*, in the context of the political, and social agenda has recently made a come-back (Lehmann, 2011, p. 243).

In addition to recent come-back of garden-cities it is referred that new and innovative housing settlements will be re-planned in the context of garden-cities, also with possible some renewings in the near future. Like Welwyn city which was designed as garden-city originally by E. Howard at the beginning of the twentieth century, in England, has become the center of the point of this newly revived idea. The issue of renewal of this old town has come to the agenda recently due to the an idea improvement of the environment to create more livable places, made them vibrant place to everyone and for humans, pedestrians, and cyclists with the awareness of the recent COVID-19 (Smith, 2021, p. 4) (Fig. 1).

In the late years, architects, and planners needed to rethink on the city planning, and housing models when questioning the negative impacts of the physical environment which was built for cars not for humans as a reaction to the over-confidence in the technique of the 1960s, and to the practices of CIAM, *Congres Internatianux d'Architecture Modern* (International Modern Architectural Congress) and the modern architectural doctrines.

Towards the end of the twentieth century, with the further development of housing, and urban planning the old ideas based on modernism has entered a new process of change with the recent design discourse such

as sustainability, and green architecture, have been significant since the 1980s. This change have also emphasized that the end of the sovereignity of architecture and city planning in the twentieth century. Recently, with the twenty-first century, new, and innovative models that could not be foreseen previously in the twentieth century have come to back the recent urban, and housing planning agenda.

3.1 The Early Garden-City Models Transferred to the Istanbul From France, and Italy

In the early twentieth century, E. Howard's English garden-cities which were first planned in out of the cities in green areas were appeared as ideal houses that were beneficial for human life, and health, with gardens and direct sunlight (Howard, 2008a, p. 99). Indeed, these sunny, airy settlements out of the cities was recognized as early examples of today's green, and sustainable design theories and discourse in architecture and urban planning.

E. Howard's, R. Unwin's original garden-city models, transferred from England, and became widely known in Paris, France, as *cité-jardins* (garden-cities) modern housing plannings. In the beginning of the twentieth century) these housing models were first restricted by *Le Musée-Sociale* (Social Museum) was known as a think tank institution (Doğrusöz, 1981), also as a regulatory, and controlling mechanism in Paris city planning (Horne, 2002, p. 233). Later, these houses were approved by the *Le Foundation del'Association des Cité-Jardins* (The Council of garden-cities) advocates by French architects, Benoit Lévy, and George Riesler who implemented outside Paris *banlieues* (suburbs) as some modern *cités-jardins* (garden-cities) (Sellier, 1998, p. 23–24).

The housing models and typologies between the two world wars were various spectrum in Europe and in France (from Le Corbusier's CIAM model to the Henri Sellier, Eugene Beaudoine, who planned *cité-jardins* in Paris *banlieue*s for mostly the mid-income, and low-income families) (Coskun, 2017, p. 130). In the 1950s, Paris city developed with *les grand-ensembles* (large-scale settlements), HLM's, and some competitions were held for the construction of these large-scale housing settlements houses (Baratucci, 2006, p. 61). During the World War II, *les grand-ensembles* (large-scale settlements), HLMs, as *Habitat Louer à Moyen* (Medium Rent Houses) were planned around the city of Paris, providing financial resources by private charity groups and foundations (Stébé, 1998). When the French architect-urbanist H. Prost prepared, Paris Master plan, *Plan d'Aménegament de la Region Parisienne* the city's surrounding was already planned with the *cité-jardins* (garden-cities) from periphery to the outside of the city with a advanced transportation network (Bruant, 2011, p. 269).

Paris city *banlieues* were planned specifying class of the people which defined as East–west or North–south *banlieues* (suburbs), known as *cité-jardins* (garden-cities) by the prominent architects-planners. The East–west *banlieues* model were designed for wealthier segment of people by the architects like were; Le Corbusier, and A. Lurçat (Figs. 4 and 5). According to Le Corbusier these *cité-jardin*s (garden-houses) in the suburbs had ideal life, divided

Fig. 4 Andre Lurçat, Modern *Cité-jardins*, Along Sen River, Paris, East–West *Banlieue*s. Photo, Anonym

Fig. 5 *Cité-jardins*, Cité De La Muette, Paris, E. Bedoune. Sellier, Une Cite pour Tous, Paris, 1998, p. 203

by the plots; 300–400 m2 or 500 m2 as well as the with a small cultiveted garden. These people called as *les banlieusards* (residents in *les banlieues*-suburbs), were lived *villas to pavillions* (residences with gardens), and *cités-ouvrières* (workers-dwellings) as long as their socio-economic conditions allowed (Le Corbusier, 1980, p. 194).

European architect-planners played an important role in the planning of İstanbul since the beginning of the twentieth century, including early models of the garden-city settlements and their recent derivatives. The garden-cities as earlier innovative housing models first spread from England to Europe; France, Germany, Italy, and later they transferred to the İstanbul via French and Italian architects.

3.2 Until 2000s, The Early Models of Garden-Cities in Istanbul Developed as Bank-Houses

- French Architect-Urbanist Henri Prost's Early 20th Century Istanbul Plannings

Before arriving in Istanbul, Henri Prost had a profound knowledge about the European originated housing models as a member of the French *Le Musée-Sociale* (Social Museum) an Institution that previously drew attention to the urban problems of Paris city (Rabinow, 1991, p. 269). He focused on such models with a pragmatic planning strategy to solve the housing problem in Istanbul (Doğrusöz, 2016). H. Prost's Istanbul Master Plans (Prost, 1949, 2008) included some new housing areas that addressed the housing problematic in the city. In the 1950s, housing models, and typologies ranging from single blocks to the building-blocks to the *cités-jardins* (garden-cities) transferred originally from France according to H. Prost's Master Plans, and plan-notes (Coskun, 2021b). H. Prost planned some *cité-jardins* (garden-cities) in the green areas in the mid of the Historical Peninsula, along the Bayrampaşa Stream with small gardens for the families of workers which were suitable for the urbanism ideas of the era (Bilsel, 2010b, p. 143).

- *Cité-Jardins* (Garden-Cities) Developed by H. Prost for Istanbul as Bank-Houses

In the early twentieth century, derived from E. Howard's original and innovative ideas the *cité-jardins* (garden-cities) after the Paris were planned for Istanbul city's outskirts, in green areas or in woods planning a sunny, healthy life-style for low-income people or retirees. Indeed, planning new houses was not on the agenda of a newly established Turkish Republic on that era having economical difficulties which was emerged in the inter war years. Also, Türkiye was lack of some advanced housing construction institutions like developed countries; the French HBMs, *Habitat Bon Marché* (Social-Rental Housing), HLM, *Habitat Louer à Moyen* (Medium Rent Houses) (Merlin, 1991, p. 30; Stébé, 1998, p. 74) as well as the other institutions; banks, municipalities etc., and *Le Credit Fonciere* (An Institution Supply Credit for Houses) which produced houses for low-income people in France supported by social insurance as an institution for HBM with the economical aid (Guerrand, 2010, p. 292). The bank-municipality model was first developed in Istanbul as a model of housing production likewise the French-originated HBM and HLM version known also *grand-ensembles* (large-scale developments) (Cohen, 2010, p. 51) (Figs. 4 and 5). The other model was the cooperative model based on the German

Fig. 6 The bank-houses planned as garden-cities in 1960s, Yapı-Kredi Bank, Kadıköy, Koşuyolu, Asian (Anatolian) and later European, and other districts in Istanbul. Photos, left R. S., 2009 and U. Dogrusöz and IFA Archives

housing construction system [*Garten-stadt* or *Siedlung* (garden-city) in Germany known as GEHAG] realized mostly in the capital city Ankara (Tekeli, 2011; Akcan, 2006, p. 51). However, this model was never applied and implemented in Istanbul. H. Prost's the "multiple housing models and proposals" for Istanbul were the "property-housing" model targeted the middle-income group, also applied similarly in France between two world wars. In Türkiye, the development of the banking system also allowed the emergence of the "middle-class" bank-housing model. The origin of the H. Prost's "middle-class" housing models should be sought in housing finance systems developed with the Turkish banking system. Some French-model of *cité-jardins* (garden-cities) were known as bank-house projects after the thisbuilding model was first implemented in the Levent region, the European side, Istanbul. Uncommonly, the housing model of the first Bank project was inspired by Le Corbusier's block design explained by French architect-urbanist H. Prost, and his close colleague Aron Angel in 1949. Later, the project was handed over and redesigned by Turkish architects K. A. Aru, and R. Gorbon. Later in the European Side, these housing models developed on the Asian (Anatolian) Side), in Kadıköy, Acıbadem, Koşuyolu districts, etc. After H. Prost left the city, in the 1950s–1960s (the Levent model previously planned by him) as "bank-houses" were built with a new method of housing planning in Levent district, by *Istanbul Imar Limited* (A Government Housing Construction Company) established at the end of 1946, in partnership with Istanbul Municipality and Emlak Bank (Tekeli, 2013, p. 449). The bank-houses were known as specifically by some bank names and brands which were realized their construction: İşbank houses, Yapı-Kredi bank-houses, Emlak bank-houses, etc. (Fig. 6). Garden-city settlements were widely built in post-Prost era some of them developed as middle-class houses typomorphologically in the Asian (Anatolian) Side. In the late 1960s, with the abandoning of social based policies housing production left the private sector and Istanbul's housing construction have evolved into completely a privatized different system form the social housing since then.

- *Cité-Parcs* (Park-cities), Developed by H. Prost as a Unique Model for Picturesque Bosphorus, Istanbul

In the Bosphorus Heights of Istanbul by architect-urbanist H. Prost planned some *cité-parcs* (park-cities) in the slope of Bosphorus in order to save the groves which were been neglected for many years (Bilsel, 2010a, p. 369). Although, based to the old urban planning principles of E. Howard, and R. Unwin's, England, Letchword, etc. *Cité-jardins* (garden-cities) this housingmodel reflects some differences that were developed as another version of garden-cities like *cité-parcs* (park-cities) designed uniquely for Istanbul groves. *Cité-parcs* (park-cities) planned as less-density areas to refrain from harming the picturesque integrity of green areas in the Bosphorus Heights where they located.

- *Cité-Satellites* Planned by Italian Architect Luigi Piccinatoas Post-Howard Generation on the West Axis, Istanbul

First envisioned in Istanbul's, 10 years Master plans, by French architect-urbanist Henri Prost's c*ité-satellites* (satellite-cities) later developed, and implemented by Italian architect-planner Luigi Piccinato as a post-Howard generation (of garden-cities) he followed the old, rhetoric who realized some urban planning in London with the big-scale city projects and garden-cities. L. Piccinato was collaborated a Turkish architect E. Menteşe in the Ataköy region planned a project according to newly established bank-housing system, by Emlak Bank. Later, the Italian architect-urbanist was appointed to the head of the Istanbul planning office after the H. Prost, and he prepared a macro-city plan by expanding and moved the city's boundaries with the newly planned *cité-satellites* (satellite-cities) (İller Bankası, 1972) (Fig. 8). The project planned first in the European side, along the newly specified city's western axis ~12,000 residences and 60,000 inhabitants (Malussardi, 1993, p. 48) (Fig. 8). In the 1970s, with the new Bosphorus Bridge, European, and

Fig. 7 Bosphorus Bridge, Istanbul, today. *Cité-parcs* were planned uniquely by H. Prost in the 1940s, to protect groves on Bosphorus heights. Today, Bosphorus with uncontrolled houses. Photo, Trthaber

Fig. 8 Ataköy, Istanbul, Today. Planned as first *cité-satellites* (Satellite-cities), by Italian architect, Luigi Piccinato with bank-houses system, by Emlak Bank. Left, Habertürk, Right, *Arkitekt* 1958, N. 02, p. 290

Asian (Anatolian) Sides connected with a new transportation network first time (Fig. 7) the new *banlieues* (the suburbs) were planned as bank-houses in previously vacant and unreachable green areas. After the 1970–1980s, housing problematic of Istanbul was emerged with massive inner workers migrations just after the industrialization finally evolved more chaotic period. The city continued to sprawl with new *banlieues* (the suburbs) connected by the new railways both European, and Asian (Anatolian) Side along the city's east–west axis from in Asian (Anatolian) Side from Kadıköy to Pendik and in European Side from Eminönü to Bakırköy districts. In the 1960s, to find a solution to the housing problem, schematically prepared garden-cities for the middle-class hastily planned after the French architect-urbanist H. Prost the outskirts of the city suburbs based on the creation of new Turkish middle-class as a physical reflection of policies economically and socially (Akpınar, 2010, p. 183).

3.3 After the 2000s, Developing Modern English Garden-Cities in Istanbul Countryside

Nowadays, from the early twentieth century still stimulate great re-interest in the world E. Howard's garden-cities have also previously planned, as an exemplary model for new, innovative sustainable, and green planning.

Furthermore, between 1990s–2000s, the original old, English garden-city models was previously became popular out of the Istanbul city, in the green areas as a new and innovative housing plannings and introducing a new English style country living. Although, in the 1950s, first transformed, and developed as a model for bank-houses, later in the 2000s, again with the increasing re-interests these garden-city models, were transferred directly from originally from English country lifestyle model in Istanbul.

In the 2000s, these garden-city models which evoke and the temptation of the English lifestyle in the countryside planned along the new northern development axis of Istanbul city towards the outside of the central regions, especially to the Northern woods, and green areas as large-scale residential projects, and settlements.

These original English garden-city settlements were planned in the wide green areas as English countryside theme housing models directly inspired from England, with large-scale housing projects such as; Kemer Country, AlarkoAlkent, Orman-evleri (Wood-houses), İstanbul and Istanbul, etc., and as well as the Asian (Anatolian) Side; Ömerli Kasaba (Town) project, Beykoz Houses, etc. (Figs. 9, 10, 11, and 12).

As a one of the 1990s, modern Turkish English garden-cities model Kemer Country was planned as residential, and social facility area located in Göktürk neighbourhood in the northern part of the Istanbul (Figs. 9 and 10). In this residential area, the garden-city concept was created for the first time in 1986, similar to today's sustainable housing design model by the group of people who aimed to English country-style life out of the city. This modern version of old garden-city model appealing the high-income people designed around the wide green areas, and consisted of large golfing areas in the northern forest of the Istanbul city. This settlement also included, a hotel, a club house, horse farm, sports facilities, and it currently has a population approaching 4,000 people.

With the sustainability, and green design concept in the architecture and planning attracted attention at that time when innovative projects emerged in the world, these projects could not appeal to the majority population as presented an isolated lifestyle outside the city in Istanbul. However, this lifestyle and housing plannings which were previously criticized as far from the city, and facilities like shopping areas have unexpectedly become popular, after the recent pandemic, and the interest by the people who wanted to live outside of the city and residences with gardens, in the green areas has increased rapidly.

3.4 2020s, Istanbul, Rising Demand of the Garden-City Models After the Recent Pandemic

In the 2020s, in post-Pandemic period, after the COVID-19 and searching new lifestyle, led to come-back garden-cities again, which were presented as modern, airy, green and sunny living models outside the city at the beginning of the twentieth century. The coronavirus which now effected

Fig. 9 2000s, modern garden-cities, Kemer-Country, Kemerburgaz, Istanbul. Photo, Kemer Country website

Fig. 10 2000s, modern garden-cities, Kemer Country Golf-areas, Kemerburgaz, Istanbul. Photo, Kemer Country website

Fig. 11 2000s, modern garden-cities, Alarko, Alkent, Büyükçekmece, Istanbul. Photo, Alarko.com.tr website

the world is changing the priority of choice in the housing sector as well, and the need for residences with gardens or with more green areas. The specific effects of pandemic particularly in Istanbul city, and in Türkiye were even more diverse and multifaceted. Aside from pandemics, the consequences of global warming and sustainability concerns have not yet created an awareness, the pandemic has made this issue even more significant, and visible.

With the pandemic as a new problematic of the world cities as well as the İstanbul made some radical changes in people's living and working styles reflecting the housing demand including people who mostly living in multi-story apartments, (approximately five-six storys) concrete blocks or building-blocks. The pandemic public measurements during the pandemic such as social distance and long-term isolation led social

Fig. 12 2000s, modern garden-cities, Casaba, Project, Anatolian Side, Istanbul. Photo, Casaba.com.tr website

and psychological effects on the populations who clustered in these high-rise concrete blocks. Similar to the American cities, people in Istanbul especially those who preferred the hybrid or remote works from distance began to escape from the city centers and from the big cities towards near small towns like: Kocaeli, Tekirdağ, etc. Therefore, many houses were sold in Tekirdağ a close town to Istanbul and its population started to increase rapidly (Trthaber, 2022). The people who had to remain in the city began to look for houses with gardens including additional office rooms that will be convenient for their hybrite or remote working schedule which emerged after the pandemic while living in outside the city or near small towns.

Due to the effects of the pandemic's which led to a rapid change people's demand on living style and housing ideas, Turkish private sector contractors established a new health board to determine the radically altered housing model by the people's recent requiest. In the 2020s, according to the recent requirement of Turkish clients, the garden-city concept comes to the fore again and the houses with gardens, large green balconies, and expanded terraces with green elements have become one of the indispensable criteria for residences first in Istanbul, later in all Türkiye (Habertürk, 2020). They explained that the housing construction and planning period after the COVID-19, is a second treshold after the 1999 earthquake they had to re-regulated the housing, and construction. The housing projects began to plan similar similar to the garden-cities with 90% green areas, indicating that the come-back of the old garden-cities and its similar forms or low-rise multi-story blocks..

Therefore, in the 2020s, after the recent COVID-19 pandemic, the new specific concept determined as *saglıklı-evler* (healthy housing) were emerged specified the houses with garden or green terraces in the green areas as a newly entered term in the housing terminology first in Istanbul, Türkiye. Also, matched the ideas of United Nations' declaration to sustain a sustainable relationship between urban dwellers and urban areas, increasing the land value emphasizing the more livable and healthy house for everybody. The healthy houses concept include gardens or three, or four story low-rise blocks with wide green balconies and expanded green terraces started to planned in the outside of the city in airy, sunny and green areas with the recently launched new projects in Istanbul's European side, Levent, and Asian Side, Çekmeköy regions, etc. (Internethaber, 2022) (Figs. 13 and 14). Indeed, in the mid of the 20th century, garden-cities, previously known as bank-houses, were in demand as a housing model for the upper-middle people and incomers in Istanbul. The first garden-city model was introduced by French architects for many years since the beginning of the twentieth century, before the some modern versions of this model were planned in 2000s. Therefore, in the 2000s, these housing models with the re-interest of high-income people were planned as sumptuous green ghettos for Turkish *bourgeoise* people located near green areas in Istanbul. Today, with the effect of the pandemic, COVID-19 the demand for garden-city houses have come-back, increased considerably spreading throughout society's all segments as affordable houses (Tables 1 and 2).

The recent pandemic, COVID-19 made a considerable change and led to the spread of garden-city models to lower-income people and even to all income groups throughout all segment of the society. It is noteworthy that even TOKİ, a state construction company have preferred more horizontal architecture instead of high-rise housing blocks and they initiated planning more garden-cities and neighbourhoods in the green areas in their recent projects. However, in large-scale projects, aimed at a mixed planning model instead of the settlements consisting entirely of houses with gardens in the past, it is also planned as mixed or generally low-rise horizontal settlements.

Fig. 13 2020s, the post-pandemics, a healthy-city concept, newly launched with low-story %90 green areas Modern Houses inspired from garden-cities, Asian (Anatolian) Side, Çekmeköy, Istanbul. Photo, Dapyapı.com.tr website

Fig. 14 2020s, the post-pandemics, a healthy-city, newly launched modern garden-cities with 90% green areas, European Side, Levent, Istanbul. Photo, Dapyapı.com.tr website

Table 1 Planning process of the Istanbul city through the years

Dates	Istanbul city planners	Plans	Region
1935–1950	Henri Prost Plan	Modernization plan	European and Asian Side Mainly
1950–1960	Luigi Piccinato	Metropolitan plan	Out of the Historical City Area
1970–1999 Inner migration problem	Increasing Illegal Housing	Blocks and Apartments, Legal and Illegal Houses	All City; Bosphorus Heights, Suburbans
After 2000s	Future planning of the city, etc	Future projects; eco-cities, garden-cities, etc	City's outskirts, green areas
After 2020s	Future Planning of the city, etc	Garden-cities, Healthy-cities (after Covid-19)	City's outskirts, green areas

Table 2 Early-mid-20th-century housing projects

Dates	Planner	Origin	Regions	Bank-houses; garden-city models and typologies
1935–1949	Henri Prost	French *Cité-jardins*	Bank-Houses; Anatolian Side; Kadıköy, Acıbadem, Koşuyolu, etc. Bosphorus Heights	*Cité-jardins* (garden-cities), And *Cité-parcs* (park-cities)
1950–1960s	Luigi Piccinato	French *Cité-satellites*	West Axis, Ataköy	*Cité-Satellites* (Satellite-cities)
After 2000–2020s	Various	English Garden-cities	Northern Regions of Both, European-Anatolian sides	2000s Garden-cities and Healthy-Cities, etc

4 Conclusion

This research examined the garden-cities and their recent come-back after the pandemic COVID-19, in the world and in the example of Istanbul, Türkiye particularly. After the recent pandemic, the information is reached that and sheds light on an updated development and evolution of garden-cities and their derivatives from the beginning of the twentieth century to the present day.

E. Howard's garden-cities which have been modelled for many time as housing projects since the twentieth century recently come-back, and today this housing model still continue to influence world today and will be significant example for future housing designs. Since the 1980s this model has also come to the fore in the context of green architecture, and sustainable city planning, with the climate change issues, and recently, unexpectedly this housing model has gained more importance with the COVID-19.

Furthermore, a recent article mentioned and heighlighted that the come-back of the garden-cities concept and renewement of the old Welwyn town, in England. The town which was designed originally by E. Howard a in the beginning of the twentieth century will be renewed as a centre of the point again as a much-improved environment for pedestrians, and cyclists in the context of the COVID-19. Additionally, the article also referred that the garden-cities as innovative settlements that will be planned and developed possibly in the context of a future model.

In this study, E. Howard's English garden-cities that were first transferred, and designed by French architect-urbanist Henri Prost in Istanbul, after the 1950s, planned and known as bank-houses, later in the 1990s-2000s as modern versions of these garden-cities planned again out of the city appealing as modern English countryside living, finally, in the 2020s, today as a new and innovative housing this model made a recent come-back after the COVID-19 were examined.

Emphasized the modern living style of that time E. Howard's, old English garden-city housing models and its 1940s–1950s French derivatives first emerged in France as *cité-jardins* (garden-cities) and later they were transferred and planned by French architect-urbanist H. Prost, and implemented after his leaving in Istanbul. These houses were mostly known as bank-houses for mid-income people, and retirees planned in the newly developed Asian (Anatolian) Side and European Side *banlieues* (suburbs). Also in the 1990s–2000s, modern settlements based and taken from originally planned English

garden-cities' outside the city as an example of new and innovative housing planning were examined.

Although the early garden-cities in the beginning of the twentieth century as the first-period projects were not directly taken from the original English model, they transferred via France to Istanbul indirectly and were developed by French architects-urbanists. The modern garden-cities after the 2000s, as the latest period projects, were known as some implementations of English-originated garden-city projects in the city.

The different and various versions of garden-city models were previously designed by French architect-urbanist H. Prost with an innovative approach in the green areas as *cité-jardins* (garden-cities), especially in accordance to preserving the groves, and woods of picturesque Bosphorus Heights, in Istanbul as well as the planned as *cité-parcs* (park-cities).

Indeed, while the original garden-city models focused on a specific model, new models of French architect-urbanist H. Prost in Istanbul such as *cité-parcs* were developed uniquely in accordance with the natural characteristics of the city. Likewise the bank houses as originally designed *cité-jardin*s also *cité-parcs* are specific models were planned as unique to Bosphorus Heights, in Istanbul, and never planned in France, and other countries as well.

Today, the garden-cities, previously known as bank-houses planned for upper or mid-class houses, in Istanbul, have evolved into a different path, and with the influences of the pandemic, COVID-19 the demand for these houses considerably has spread throughout the society's all segments. Although the first garden-city model has been known by first introduced by French architects-urbanists for many years since the beginning of the twentieth century, many modern versions were planned in the 2000s, for high-income people near green areas in Istanbul.

Recent COVID-19 have led to garden-city models spread and more achievable for the lower-income people once monopolized by high-income people and even for all income groups throughout the society. It also changed the provision of the Turkish constructors, private or governmental side likewise the TOKİ, a state construction company have guided their plannings and preferred more horizontal architecture instead of high-rise housing blocks also initiated planning more garden-cities and neighbourhoods in the green areas in recent projects.

In conclusion, in the context of this research, it was found that some of the old originally well known garden-city models and its derivatives developed in the other countries such as France like; *cité-jardins* (garden-cities), *cité-parcs* (park-cities), or *cité-satellites* (satellite-cities) uniquely were developed for Istanbul, such as planning of bank-houses, *cité-parcs* (park-cities) and these models never designed and known elsewhere in the world. Furthermore, these housing models come-back with the recent pandemic COVID-19 due to people's changing life-style and housing demand they will continue to influence even future housing planning for Istanbul or for other cities in the world.

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Measuring to Evaluate Alternatives: The Carbon Footprint Calculator for Urban Planning of the Community of Madrid

Alexandra Delgado, Roberto Álvarez and Fernando Beltrán

Abstract

This work is oriented to analyse the carbon footprint calculator for urban planning developed by the authors funded by the Community of Madrid. The starting point is the evolution of urban planning related to environmental problems that have resulted in current situation. Now it is needed to plan cities in a context of climate crisis. Planning with climate change criteria is especially important in the Community of Madrid, a hotspot of urban growth at the European level with a very unique dynamic, near doubling the artificial surfaces from 1990 to 2018, in less than 30 years, and without regional planning. The carbon footprint calculator consists of an assessment of the uses and activities to be developed in future planning that generate greenhouse gas emissions, as well as changes in land use that affect the soil's sink capacity. Mitigation strategies (as self-generation capacity by renewable energies) are analysed for assessment and quantification where data is available. The carbon footprint calculator includes the derived and influential activities that should be included in the application for the approval of urban planning instruments, within the ordinary or simplified strategic environmental assessment procedures, in relation to the potential environmental impacts in terms of climate change. The carbon footprint calculator could help to measure different urban planning alternatives (alternative 0, no transformation and others) for the urban development or transformation, as in the application of a planning proposal is shown. Consequently, thanks to carbon footprint calculator it is possible to choose the lowest carbon emissions alternative among several and to make visible the crucial aspects that generate the most emissions at an early stage of urban development as it is a masterplan.

Keywords

Carbon footprint · Calculator · Urban planning · Community of Madrid · Alternatives

1 Introduction

This research introduces the tool for calculating greenhouse gas (GHG) emissions generated by urban planning in the Community of Madrid with the aim of establishing itself as a comprehensive and synthetic instrument for quantifying these emissions. This tool has been developed at the request of the Subdirectorate General for Strategic Environmental Assessment and Sustainable Development of the Community of Madrid. The calculator is an example of the incorporation of measurable scientific criteria in decision-making in the current context of climate crisis (Álvarez et al., 2022).

This instrument includes the derived and influential activities that should be included in the application for the initiation of urban planning instruments, within the ordinary strategic environmental assessment procedure, in relation to the potential environmental impacts in terms of climate change, in accordance with Article 18 of Law 21/2013, of 9 December, on environmental assessment.

It also involves a proposal of the information to be included in the application for the initiation of urban planning instruments subject to ordinary strategic environmental assessment, for masterplans for the entire municipality, or simplified, for masterplans for a specific area of the

A. Delgado (✉)
Architecture Department, Higher Polytechnic School of University Nebrija, Madrid, Spain
e-mail: adelgado@nebrija.es

R. Álvarez · F. Beltrán
Engineering Department, Higher Polytechnic School of University Nebrija, Madrid, Spain

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municipality that includes urban design, in terms of climate change.

In simple words, carbon footprint is defined as the environmental indicator that aims to reflect all greenhouse gases emitted by direct or indirect effects of human actions, events or products. The calculator concept is a tool that allows the users to estimate the greenhouse gas emissions associated with the activities of humans in a country, a region, an organisation, etc., considering both direct and indirect greenhouse gas emissions from electricity consumption.

A wide spectrum of environmental urban planning calculation tools currently exists, tools that help their users to address GHG emission and climate change mitigation. But the one here presented is specifically developed for calculation of GHG in the territorial reality of the region of Madrid, just from urban planning stage, and it has the capacity to work simultaneously at both the regional and local scale levels, or to capture both building performance and transportation impacts.

In practice, this means providing scientific and technical advice on the assessment of climate change in urban planning administrative processing in the Community of Madrid.

This scientific research shows the purpose and justification of the tool by showing the singularities of the development model of the geographical area of the Community of Madrid, where the calculation is circumscribed.

It also specifies the methodological aspects of the calculation both in its general approach to energy consumption, mobility, water consumption and waste treatment, the sink effect of soils that varies with changes in land use resulting from planning and, finally, the strategies for mitigating greenhouse gas emissions and their valuation.

In this way, the role of the tool is analysed with several alternatives of a masterplan in order to assess planning and to be able to select the most suitable one with the lowest carbon footprint. But also in making visible which planning decisions have the greatest effect on reducing greenhouse gas emissions and are therefore the most suitable way to plan and transform to the goal of a low-carbon city. Measuring development in such important aspects as the carbon footprint helps us to make decisions of particular relevance in urban planning, the effects of which are very long term if not irreversible.

2 The Specificity of the Case of the Community of Madrid

The Metropolitan Region of Madrid has been a hotspot of urban growth at European level with a very unique dynamic. As a result, the Community of Madrid has almost doubled the artificial surfaces from 1990 to 2018 in less than 30 years (Fig. 1), so the processes of urban expansion have been very important for the region. It must be underlined that the region has got no land-use planning, only plans for municipalities.

The Community of Madrid is the only region in Spain that does not have spatial planning tools approved, i.e., a plan for the entire region or at the subregional level.

This means that territorial transformations, such as the creation of a new neighbourhood, are decided in each municipal plan or modifications to it, without a regional framework, although the impact in such a conurbation region is regional, especially in topics as mobility.

Therefore, the transformation of the region has been decided on a plan-by-plan basis (sectoral, such as communications and municipal infrastructures) and not with a vision of the whole and of the interrelationships between areas, which in practice means a lack of control over the development as a whole. This also influences climate change in a specific way through induced mobility and through the occupation of the territory and the sealing of soils caused by artificialisation.

Added to this is the territorial impact of the development model and the specific weight of metropolitan mobility in the Madrid Region as a whole, which is much greater than in other Spanish regions (Fig. 2). It has a very important centre-periphery mobility, which has varied through the different conformations of the metropolitan fabric, in a first wave during the developmentalist period and (1940–1975) in a second wave in recent decades (especially during the "prodigious decade" 1997–2008). This configuration and development pattern implies high levels of energy consumption and greenhouse gas emissions for the region (Delgado, 2012).

In the Spanish context, there are currently some tools for calculating greenhouse gas emissions in urban planning in different regions (Sobrino, 2017; Iraegui and González, 2017; Gobierno Vasco, 2017). These tools are of great interest but need to be adapted and adjusted to the Madrid context in order to estimate or weight key aspects for the reality of the Community of Madrid, such as the aforementioned, metropolitan mobility and the loss of land due to urban development. These mentioned aspects (mobility and the loss of land) have been improved in the methodology of the tool is presented and the justification for the development of a calculator is its specificity for the region of Madrid, with the biggest metropolitan area of the country including Madrid the second city in Europe, after Berlin, in one municipality.

This tool aims to offer an instrument for measuring the carbon footprint with a tool to assess urban planning adapted as close as possible to the reality of Madrid. This is of interest so that any plan that will be presented, of growth, of transformation, can be evaluated in order to make a

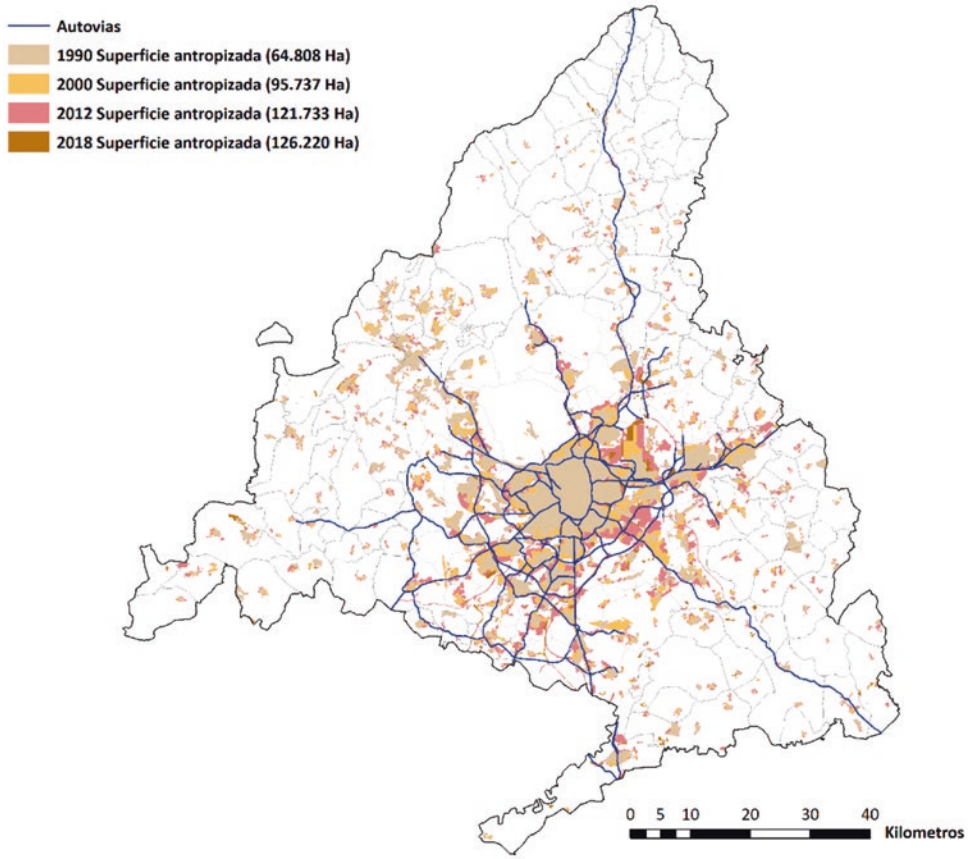

Fig. 1 Evolution of anthropisation in the Autonomous Community of Madrid (Córdoba and Álvarez, 2020, p. 23) based on CORINE Land Cover data (1990, 2000, 2012, and 2018)

better decision, in terms of its position, in terms of its density, in terms of its parameters in relation to its impact on climate change.

In this way, although there is still a lack of regional planning, it is possible to analyse an impact that affects the whole (and globally), such as climate change. It is possible to visualise how urban transformation decisions in one area or municipality are related to the whole and can influence the urban model and, therefore, the development model. Specifically measuring the carbon footprint of an area or territory involves characterising it in terms of its energy consumption and land use.

The need for the application of sustainable urban planning in the Community of Madrid is crucial because of the scale and population of the region and the fact that it has become a centre of accumulation and consumption (Méndez, 2007) which, through its development model, has had an impact on climate change.

3 Method

The main stumbling block in establishing a methodology for calculating the emissions associated with urban planning at such an early stage is undoubtedly the lack of information or certainty. The main stumbling block in establishing a methodology for calculating the emissions associated with urban planning, such an early stage, is undoubtedly the lack of information or certainty.

In planning at this level, the detail is not known, but only the allocation and areas assigned land to certain uses, but only that. The implications of this for the calculation are first to recognise that only an approximation will be possible and secondly that it will be necessary to use sources of statistical information.

The methodology here explained is a continuation of previous research works released between the years 2015 and 2019 by Roberto Álvarez Fernández and Sergio Zubelzu Mínguez (Zubelzu and Álvarez, 2015; Zubelzu et al., 2015; Álvarez et al., 2017; Álvarez, 2019; Álvarez and Giménez, 2019) which have led to the development of a tool for calculating greenhouse gas emissions specific to the Community of Madrid. There is no any other existing assessment methods for calculating carbon footprint from urban planning stage applied to Madrid region.

These previous reference works established the pillars on which the methodology applied in this new research are based and expanded them to include some more aspects.

The methodology followed for the development of this tool consists of analysing the uses and activities to be

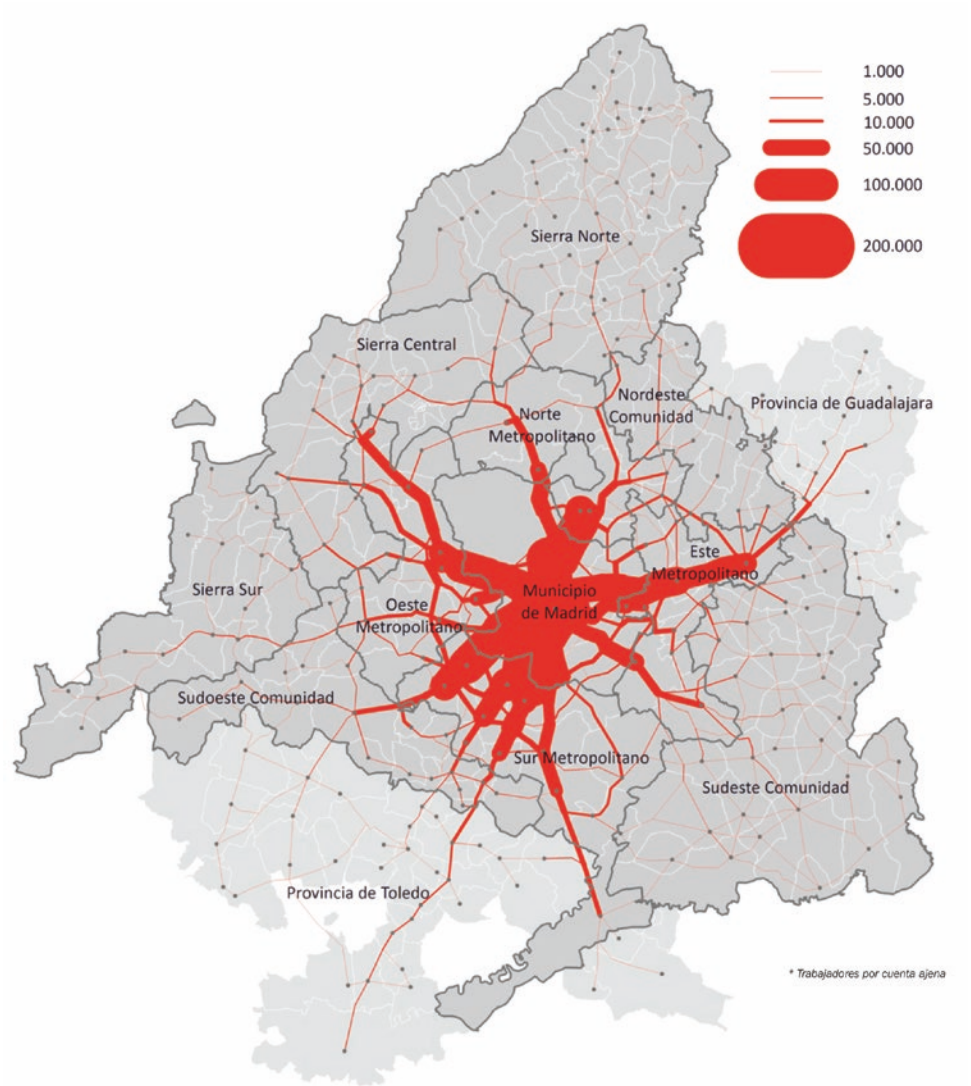

Fig. 2 Inter-municipal flow of workers in the Community of Madrid (2016) (Community of Madrid, 2017a)

developed in future planning that generates emissions, as well as changes in land use that affect the soil's sink capacity. Finally, mitigation strategies are analysed for assessment and quantification where data is available.

In terms of greenhouse gas emissions from energy consumption, emission sources are characterised, consumption is quantified and emission factors are obtained in order to calculate greenhouse gas emissions.

The general theoretical framework for calculation involves defining the cause of emissions around which to orient the calculation process. Thus, making appropriate simplifications, planning should define the land-use pattern and the associated GHG emissions. This requires characterising the emission sources, quantifying consumptions and emission factors and finally calculating the emissions. See an example of emissions from drinking water consumption (Fig. 3).

In the case of calculating the carbon sink of soils, the difference in tCO_2eq capture between the initial and final situation due to the urban transformation under review is calculated. Emissions saved by mitigation are also calculated, when data are available and depending on the type of strategy followed, with this aspect being treated differently.

To sum up, the methodology focuses on the following main stages:

- The land-use distribution, including a preliminary assessment.
- Structuring the calculation of greenhouse gas emissions based on land use.
- The definition of the key factors that affect the calculation of greenhouse gas emissions for each type of land use.
- The relevant aspects of mitigation, adaptation and carbon sequestration.

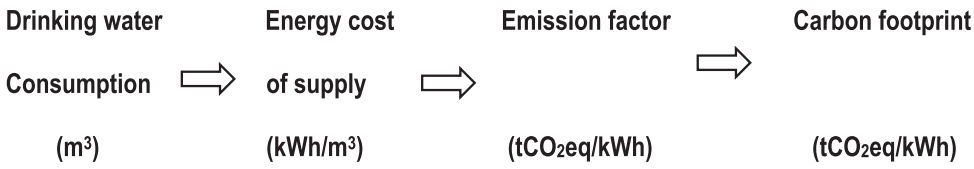

Fig. 3 Emissions from drinking water consumption

3.1 Land-Use Distribution: Initial Balance

This represents the starting point and a key action for GHG calculation. It is an overview, a first approach that allows to know the magnitude of the problem to be analysed and a preliminary approach for the evaluators to obtain an overall idea of the urban planning foreseen for a geographical area. At this stage of the study, the general data of the urban development to be analysed are defined. One of them is, for example, the household size for the planned development [average household size 2.5 persons by the source: Instituto Nacional de Estadística (INE),[1] the figure has remained constant since 2018]. On the other hand, the geographical location of the municipality where the land is situated, the definition of the current and future (planned) land uses must be detailed at this stage, specifying the type of use foreseen, together with the assigned surface areas. It is worth highlighting the introduction of the concept undeveloped land for those soils that do not have pre-existence or that are not going to be developed.

3.2 Structure for GHG Calculation

The general structure for calculating the carbon footprint derives from the distribution of the land according to the different possible uses. These possible uses of the land and buildings with reference to the National Classification of Economic Activities (CNAE) are the following: residential, tertiary, facilities and industrial use.

In addition, GHG emissions from street lighting and irrigation of public green areas and landscaped open spaces should be included. A distinction must be made between the two categories, even if they have vegetation cover, since public green areas are public and constitute their own plots, while landscaped open spaces are private and occur on plots with other uses.

3.3 Key Factors of GHG Generation for Each Type of Land Use

Efforts to calculate GHG emissions depend on understanding the sources and quantities of these gases. The proposed calculation method is based on two previous research works:

- Zubelzu, S., Álvarez, R., & Hernández, A. (2015). Methodology to calculate the carbon footprint of household land use in the urban planning stage. *Land Use Policy*, 48, 223–235
- Zubelzu, S., & Álvarez, R. (2015). Urban planning and industry in Spain: A novel methodology for calculating industrial carbon footprints. *Energy Policy*, 83, 57–68.

The tool represents a simplified representation of collecting data for analysing that tries to encompass all emissions generated by human activity into four emission factors. This consumption-based activities cause a carbon footprint that is persistent over time, being possible to evaluated and quantified and their evolution over time or after the application of mitigation measures can be seen.

For each one of the aforementioned land uses, the greenhouse gas emissions are calculated on the basis that they are generated by energy consumption as a result of different actors:

- Air-conditioning and domestic hot water (DHW) and the rest of the activities.
- Consumption derived from the water cycle.
- Solid waste treatment.
- Mobility.

In the following sections, they will be addressed each of them separately. The four key factors are equally important. The applied methodology evaluates and aggregates the emissions from the different sources and the weight of the key factors contribute differently in every alternative depending of the features, but their weight on the total does not need to be weighted.

[1] Available at: https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736176952&menu=ultiDatos&idp=1254735572981.

3.3.1 Energy Consumption: Air-Conditioning and DHW and the Rest of Activities

Energy consumption can be calculated according to the particularities of each land use. A distinction can be made between a first level of influence that corresponds to the consumption and energy for air-conditioning and domestic hot water and the second level of influence that represents the energy consumption for the performance of other activities. In the first level, energy consumption can be established by means of the energy certification label of the projected building, taking into account the particularities of each land use (Fernández-Herguedas, 2016; Zabalza et al., 2010) established by the Spanish Institute for Energy Diversification and Savings (IDAE). In turn, it is considered that the electrical energy network serves household appliances, lighting and air-conditioning, while heating and hot water are supplied by natural gas. On the other hand, the calculation can also be carried out by applying the technical building code, allowing the percentages of gas and electricity to be distributed in different ways.

On the second level, energy consumption must be estimated for the performance of the activities carried out in each land use, which will be different in each one, both in terms of the quantities and the type of fuel used. The values for the consumption of energy of this second level in the residential, industrial, tertiary and facilities (schools, medical centres, etc.) sectors are obtained from various sources (Sech-Spahousec, 2011; Hernández Sánchez, 2012; Mertens, 2013; Zubelzu and Álvarez, 2015, 2016; INE—National Statistical Institute, 2017; Díaz Martín, 2018).

3.3.2 Consumptions Derived From the Water Cycle

The average annual water consumption for different land uses can be obtained from several sources of information (Community of Madrid, 1984; INE—National Statistical Institute, 2006, 2016; IDAE, 2010; López-Jiménez et al., 2017; Ferrer et al., 2017), either on the basis of square metres built or per inhabitant. Once these consumptions are known, the relationship with emissions is obtained through the energy cost that represents the energy of the water cycle. This will include the processes of adduction, distribution, sewerage, purification and regeneration. This factor relates to the energy required in kWh per cubic metre of water supplied (IDAE, 2010) and, together with the emission factor of the electricity mix in Spain averaged over the last 5 years (Oficina Catalana del Cambio Climático, 2013) makes it possible to calculate the carbon footprint of water consumption.

3.3.3 Solid Waste Treatment

Municipal waste includes waste from the cleaning of public roads, green areas, recreational areas and beaches; furniture, electrical and electronic equipment, clothing, batteries, household goods and abandoned vehicles; waste and rubble from minor works and home repairs. It also includes commercial waste, defined as waste generated by retail and wholesale trade, hotels and restaurants, bars, markets, offices and services. In addition, for management purposes, waste generated by industry, which is considered to be similar to municipal waste, has been considered to be comparable to this waste.

Direct and indirect emissions from the complete management process are included: collection and transport, transfer plants, pre-treatment plants, final treatment plants and final disposal of the waste. In addition, a differentiation is made between the possibility of selective collection and non-separate collection.

The generation of the different types of waste by each land use and the corresponding greenhouse gas emissions can be calculated from data obtained from various sources (Zubelzu et al., 2015; INE—National Statistical Institute, 2016, 2017; Community of Madrid, 2016, 2017b).

3.3.4 Mobility

In order to determine the carbon emissions associated with the mobility, it would be necessary to know the data related with the number of trips (journeys) generated as a result of the activities in each land use planned in that area. A part of this information can be extracted from surveys, as the Community of Madrid Mobility Survey (Community of Madrid, 2018) and other publications (Hernández et al., 2008; Tejada, 2018; Martínez Palencia et al., 2016; Álvarez and Giménez, 2019; Álvarez, 2019; Community of Madrid, 2020), but it will therefore be necessary to combine the available statistical data with additional research techniques in order to complete the estimation of emissions. The information is complemented with the application of the Theory of Gravitational Modelling (Zubelzu et al., 2011; Zubelzu et al., 2015; Álvarez et al., 2017). It has been applied with the objective of estimating the distribution of movements and the distances travelled, which allow estimating the distribution of trips from a population (origin-i) to a set of destinations-j by weighting different alternatives and establishing the so-called degree of attraction (DoA). This is a factor that depends on the mass (inhabitants) of the different destinations (Mj) and the corresponding distances separating them from the origin, which in turn represent the distances to be travelled (dij). This information makes it is possible to estimate the distribution of the number of outbound vehicle journeys from a starting town (i) to the different destinations (j), and thus the total mileage travelled.

In the case of private vehicles, the statistical analysis of the percentage composition of the vehicle fleet (diesel and petrol) in the Community of Madrid is obtained from the General Directorate of Traffic (DGT) and the estimated

fossil fuel consumption of the different vehicle models is provided (Zubelzu et al., 2015; Álvarez, 2019; Álvarez and Giménez, 2019). This makes it is possible to estimate both, fuel consumption and greenhouse gas emissions.

At the same time, the emissions of public transport journeys are evaluated using the emission factors of these vehicles, means of transport per kilometre and passenger (Oficina Catalana del Cambio Climático, 2013). Mobility of heavy-duty vehicles and vans in the industrial and tertiary sectors is estimated through the number of such vehicles (trucks and vans) per surface area and averaged number of kilometres travelled (Oficina Catalana del Cambio Climático, 2013; Community of Madrid, 2019, 2020).

Residential Land Use: Degree of Attraction Calculation

To determine this parameter as a property of a destination town, it is necessary to apply the Theory of Gravitational Modelling that, in its maximum simplification, considers that the number of movements generated at an origin (point being studied) and attracted to a set of destinations are directly proportional to population of destination and inversely proportional to the distance between both points (origin and destination). This simplification is necessary when exists a large number of municipalities (179 in the Community of Madrid), each of which could be either origin and/or a destination. The steps to be followed to make this calculation are summarised as follows:

Step 1: Construction of distance matrix (D): This is a square matrix with a number of rows and columns equal to the destination towns. Each element dij represents the distance from origin (i) to destination (j),

Step 2: Construction of the mass matrix (M): This matrix is composed by the number of inhabitants of each municipality. It is a single column matrix where each element (M1j) represents (for j = 1–179) the population (mass) of each municipality.

Step 3: Determination of the force of attraction (FoA) and construction of the matrix of forces of attractions (F). It is a square matrix. Each element (Fij) is obtained as a result of the application of the Gravitational Law Equation (Eq. 1), where K is a value that allows to emphasise the importance of a destiny for different (work, commercial, or recreational among others) reasons. In the case of existing a decentralised model where densely populated areas coexist with larger, less populated areas, the force of attraction depends mostly on population and distance factors and the value of the parameter "K" is considered equal to all the municipalities.

$$FoA_{ij=}K * \frac{Mj}{d_{ij}^2} \quad (1)$$

Step 4: Calculation of the percentage of trips of each destination. Once constructed the FoA matrix, it is easy to see that elements of each file represents the capacity of attraction of each destination j to the origin I. By summing up all the values in a row and using that value as a divisor for the elements in that row, it can obtained the different percentages of trips that each destination j attracts from each origin.

This procedure needs to know the total number of trips leaving the municipality under study. This information is obtained through the mobility surveys. In the case of Community of Madrid, it is estimated that, for a residential use, a value of 0.46 motor vehicle trips per resident (Community of Madrid, 2018).

This information allows to determine how many vehicles are driven from each origin to the 178 possible destinies. As the information of the distances is compiled in matrix D, it is possible to calculate the number of kilometres driven. Besides it is necessary to establish a set of representative vehicle models to extract the GHG emissions per km driven. Statistics from Spanish Directorate General of Traffic (DGT) allow knowing the percentage of petrol and diesel cars (10.939.069 patrol and 1.3510.143 diesel in Spain). Once it has been established the distance and it is determined the fuel, it is a final calculation left: determine the GHG emissions per km of the different types of vehicles. In this sense, three representative consumption values for patrol and three for diesel are selected by using statistical procedures (Álvarez, 2019; Álvarez and Giménez, 2019) and it is possible to construct the procedure for determining the emissions.

There is an additional variable to consider in the model, and it is represented by domestic traffic. In municipalities as the one considered here the interior movements have much less importance than the exterior ones, and that is why the outer movements can be considered of an estimated of 5% of the traffic for each of the sections of the road network (Mínguez, 2011).

Mobility in Tertiary, Industrial and Facilities Uses

In the case of emissions by trucks and vans including heavy duty for the different land uses. The first step is to determine the number of trips per built area. In the case of Community of Madrid and under normal conditions, this information is based on empirical studies (Community of Madrid, 2020); frequently generation rates used in traffic are:

Commercial (tertiary): 0.04 trips/built m^2 (15% heavy-duty vehicles);
Industrial: 0.014 trips/built m^2 (80% heavy-duty vehicles);
Facilities: 0.016 trips/built m^2;

3.4 Key Factors for GHG Mitigation and Capture

The second issue is to take into account permeable soil, CO_2 fixation in the initial and final state. It is known that soil is a scarce and non-renewable resource. Preserving permeable soil, especially with vegetation cover, improves the CO_2 sink function. In this way, it is possible to prioritise whether an alternative is more rigorous and maintains areas with trees with a certain function as a sink, compared to another that does not take this into account.

It also includes a section on measures that are not quantified but which it was important to evaluate positively in a carbon footprint report that will accompany urban planning in its environmental processing. To this end, there are free fields for introducing mitigation and adaptation measures beyond those that can be quantitatively assessed today. Also for new measures that may emerge in future.

Such free texts can be recharging points, inclusion of a heat network, or self-generation capacity by renewable energies, among others.

Then it is in this very positive and currently so often quoted concept of the 15-min city (Moreno et al., 2021). In the event that these mitigation and adaptation measures can be measured, these values are introduced and reduce the carbon footprint. In any case, even if the reduction is not known, it is important to the action and the effort that is being made, for example, to choose between two alternatives, is positively valued.

In the case of the alternatives shown as case studies, self-sufficiency has been assessed, which implies significant variations on business-as-usual case study.

Finally, it is important to underline that at this stage of the urban planning the uncertainty is total, as only the distribution of land according to its use has been carried out with its key factors and the mitigation and captures measures proposed. Therefore, the tool serves to make approximations that will have the usefulness of allowing a comparison between two or more urban development solutions.

4 Results: Application for Selection Alternatives in a Case Study in Sector 11B, Alcalá de Henares, Community of Madrid

For testing the tool, a number of alternatives for the development of a sector that has already been developed, Sector 11B in Alcalá de Henares (Madri) are set out below, changing some criteria to look at the impact they have on the generation of GHG emissions (Fig. 4).

4.1 Alternative 1: Business-as-Usual

A sector of 27.27 ha located in Alcalá de Henares (Community of Madrid), 193,751 of inhabitants and 87.99 km^2. This is a neighbourhood already developed, and its features have been considered. In this case with energy certification B for buildings, as a minimum for new buildings (Fig. 5).

This alternative has got 6.774 tCO_2eq, and the majority of emissions from the planned urban development by sources and uses of Alternative 1 belong to Residential Use (53%), but with less intensity that the built-up surface that represents (71%). Mobility stands out, being the highest of all the emissions generated, because 59% of GHG emissions corresponds to the mobility generated, without considering emissions from land-use change.

In the case of this location (the original one), the average distance of trips is set at 5.28 km and the percentage of trips for the sector being 53.81%.

The second biggest source is energy consumption (without considering air-conditioning and DHW, the third source) with 19%. The land cover changes suppose the emission of 110 tCO_2eq.

4.2 Alternative 2.1: Masterplan with Energy Certification a for Buildings

This alternative is equal to the first one but considering an energy certification A for buildings.

This alternative has got 6.312 tCO_2eq, 7% less than alternative 1. In alternative 2.1, the residential use is the source of the majority of emissions, with 50.47%. The most significant emission in this use belongs to mobility, with 63%, and energy consumption increases up 21% (Fig. 6).

4.3 Alternative 2.2: Masterplan with 0 Emissions for Air-Conditioning and Domestic Hot Water (DHW)

This alternative is equal to the first one but considering no energy consumption for air-conditioning and domestic hot water (DHW).

This alternative has got 6.063 tCO_2eq, 11% less than alternative 1. In alternative 2.2, it can be seen some changes. The predominant emissions are still from residential use but with a lower percentage of total emissions, 49.32%. By far the highest emission within this use belongs to mobility (67%), followed by energy consumption.

In alternative 2.2, the air-conditioning and DHW emissions are 0 while in alternative 2.1, 193 tCO_2eq, approximately 6% of the total emissions (Fig. 7).

Fig. 4 Municipalities for location in alternatives 1, 2, 3, 4 (Alcalá de Henares), 5 (Madrid) and 6 (San Martín de Valdeiglesias) for showing the weight of location by population size and size of the municipality in the generation of GHG

4.4 Alternative 3: Masterplan with 100% Renewable or Self-Production

This alternative includes self-consumption emissions (consumption of energy with other uses of electricity) that suppose a cut of 1,278 tCO_2eq, without energy consumption, that are 19% of total emissions, with a total of 5.496 tCO_2eq, as seen in Fig. 8.

In case it is considered to be zero emissions, then the values for air-conditioning and DHW, energy consumption, public lighting and irrigation of green and public areas would be zero.

If we also include air-conditioning and DHW, public lighting and irrigation of green and public areas the emissions avoided are 2,079 tCO_2eq, 30% of total.

If it could prove this self-consumption energy emissions are really with 100% renewable energy without emissions, the cut of emissions is very important. Between one in five or one in three emissions could be avoided with 100% renewable emissions, depending on the emissions cut. Mobility, water consumption and waste treatment and management are not included in any case.

4.5 Alternative 4: Masterplan with Tertiary Use Instead Residential Use

This alternative is equal to the first one but considering there is no residential use, and the use surface for residential in alternative 1 is considered as tertiary.

This alternative has got 16.146 tCO_2eq, 238% more than alternative 1, and the alternative with the highest amount of emissions (Fig. 9).

In this case, the tertiary sector is the source of the majority of emissions, with 90% of total emissions. The most significant emissions in this use are mobility with 52% followed by energy consumption with 37%.

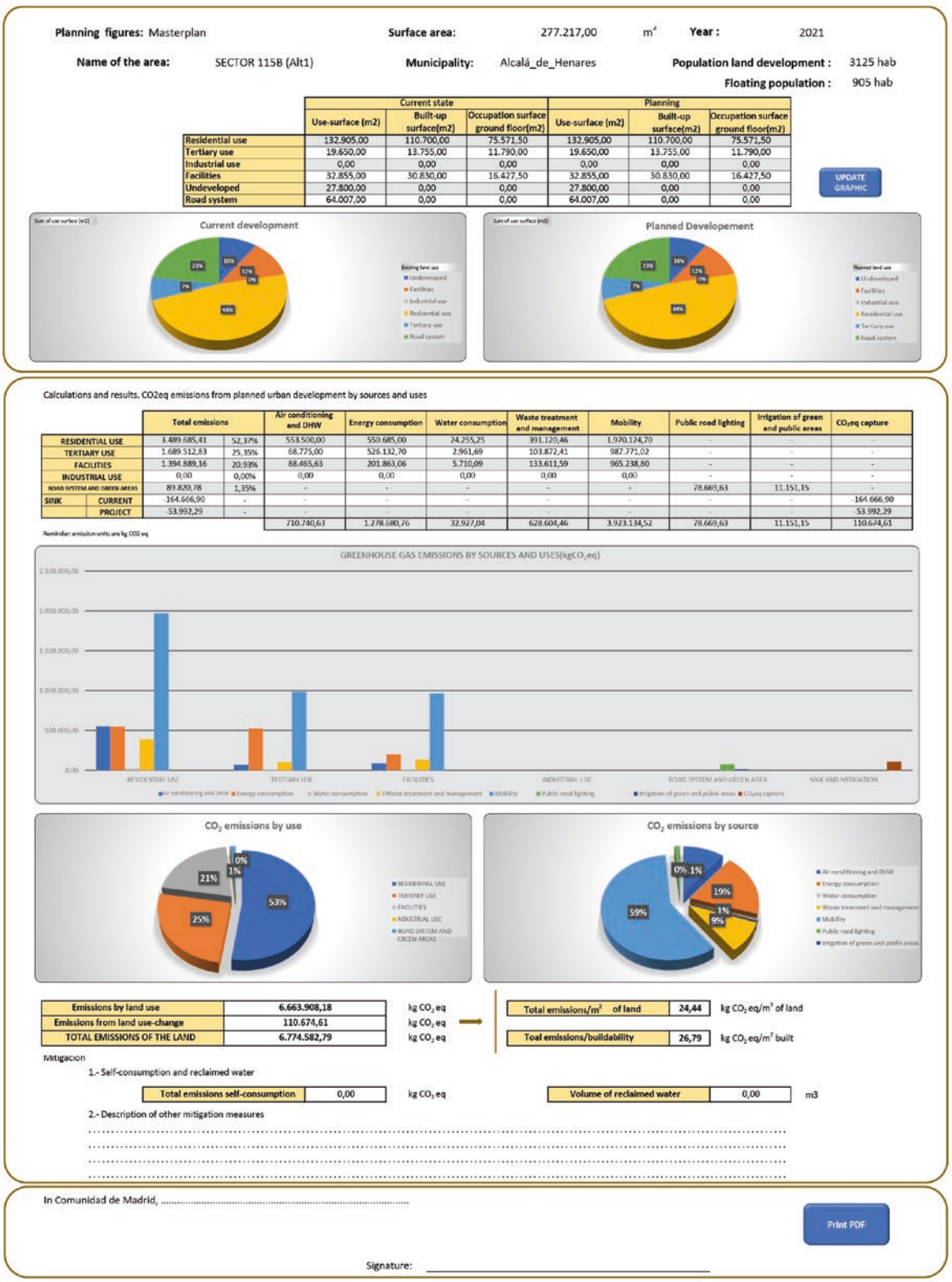

Fig. 5 Sector 11B Alcalá de Henares Alternative 1: report carbon footprint urban planning

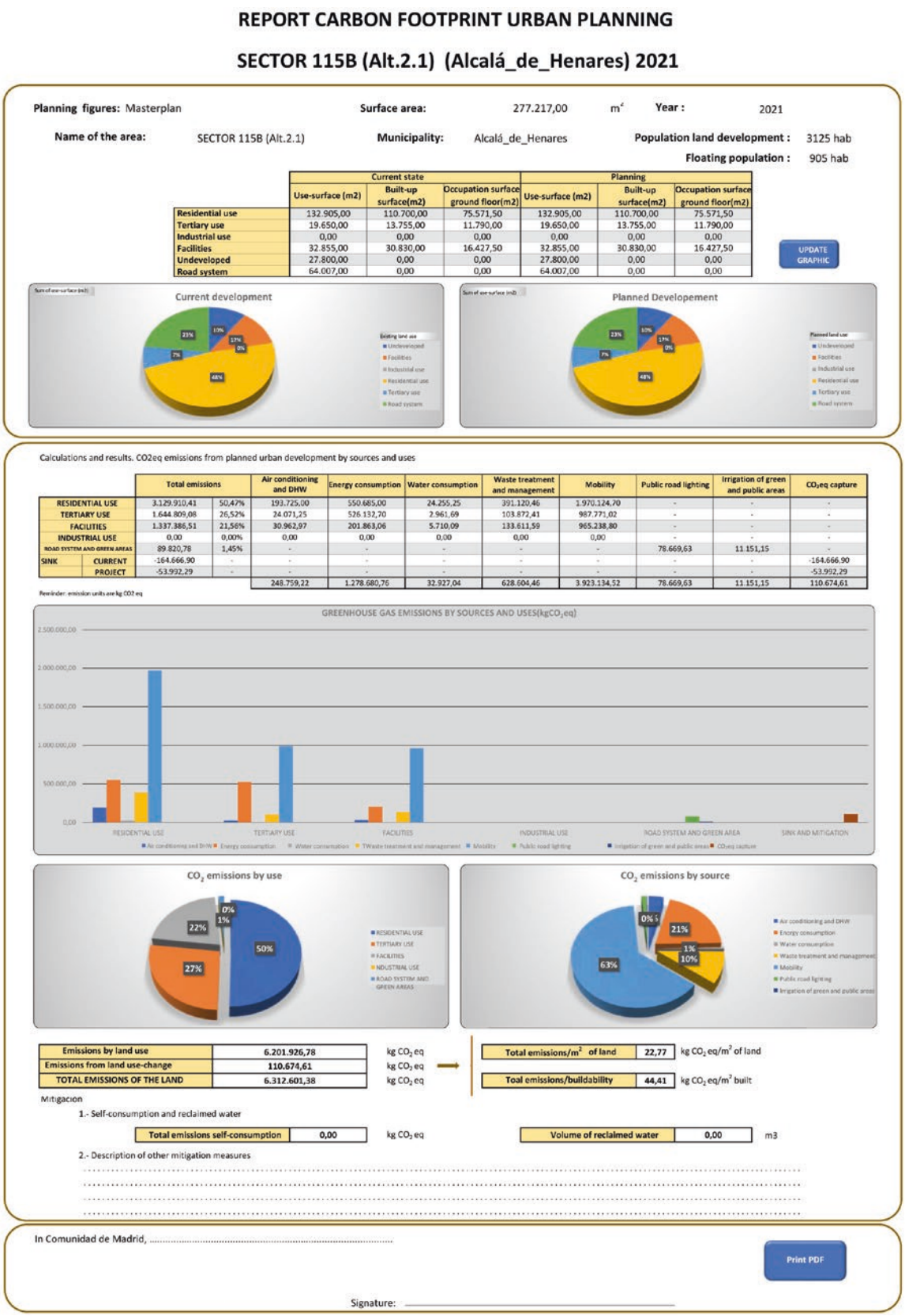

Fig. 6 Sector 11B Alcalá de Henares Alternative 2.1: report carbon footprint urban planning

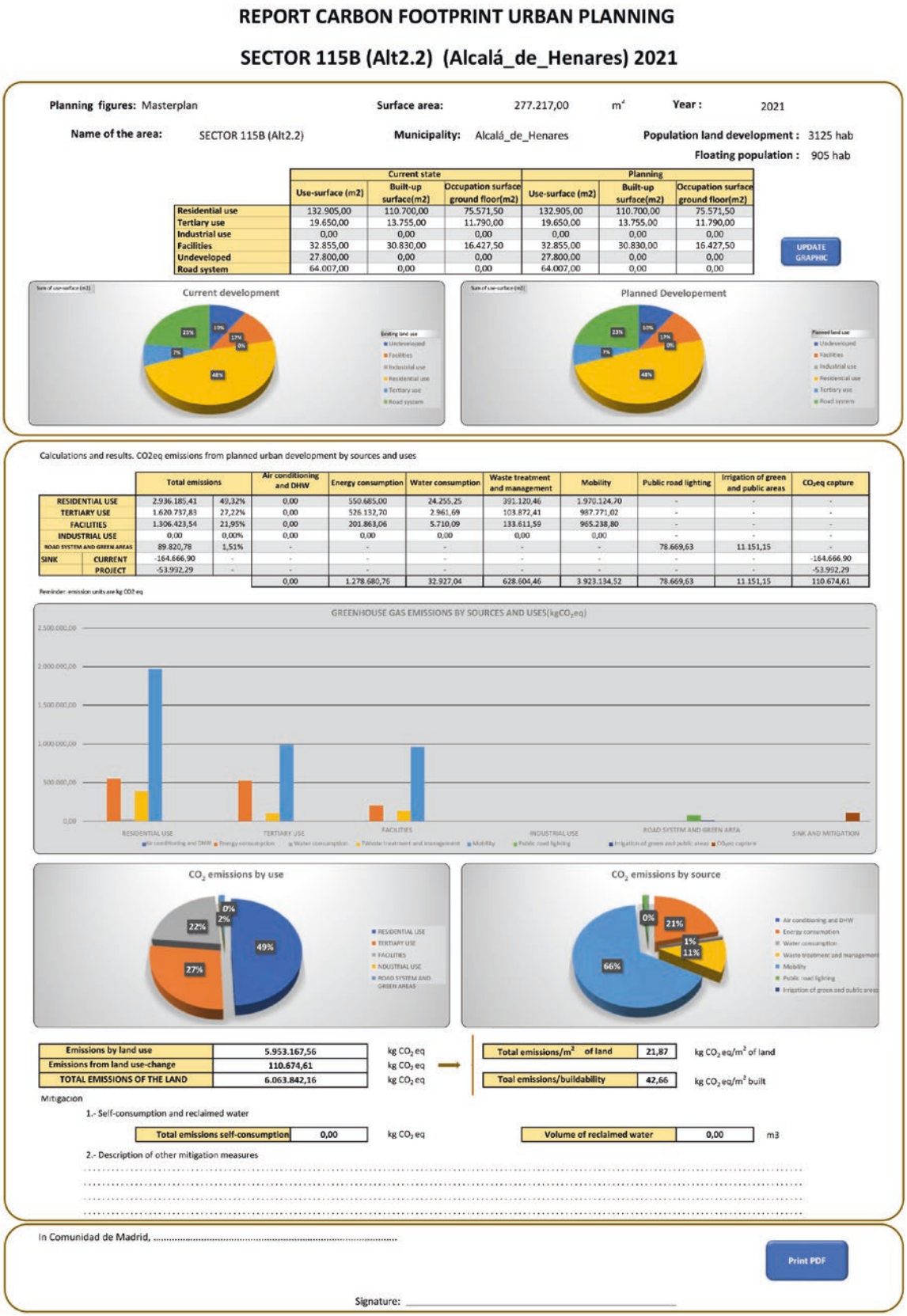

Fig. 7 Sector 11B Alcalá de Henares Alternative 2.2: report carbon footprint urban planning

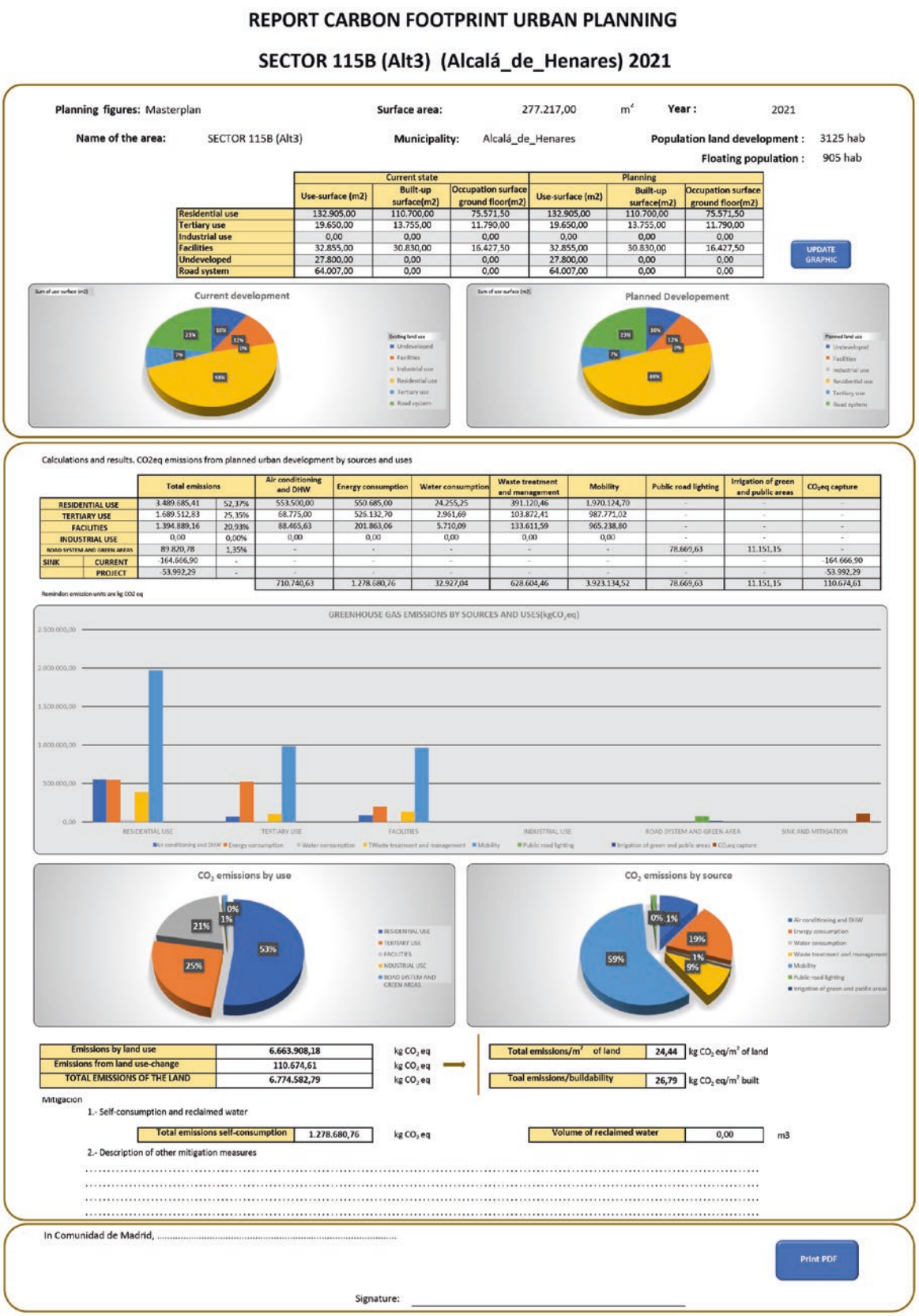

Fig. 8 Sector 11B Alcalá de Henares Alternative 3: report carbon footprint urban planning

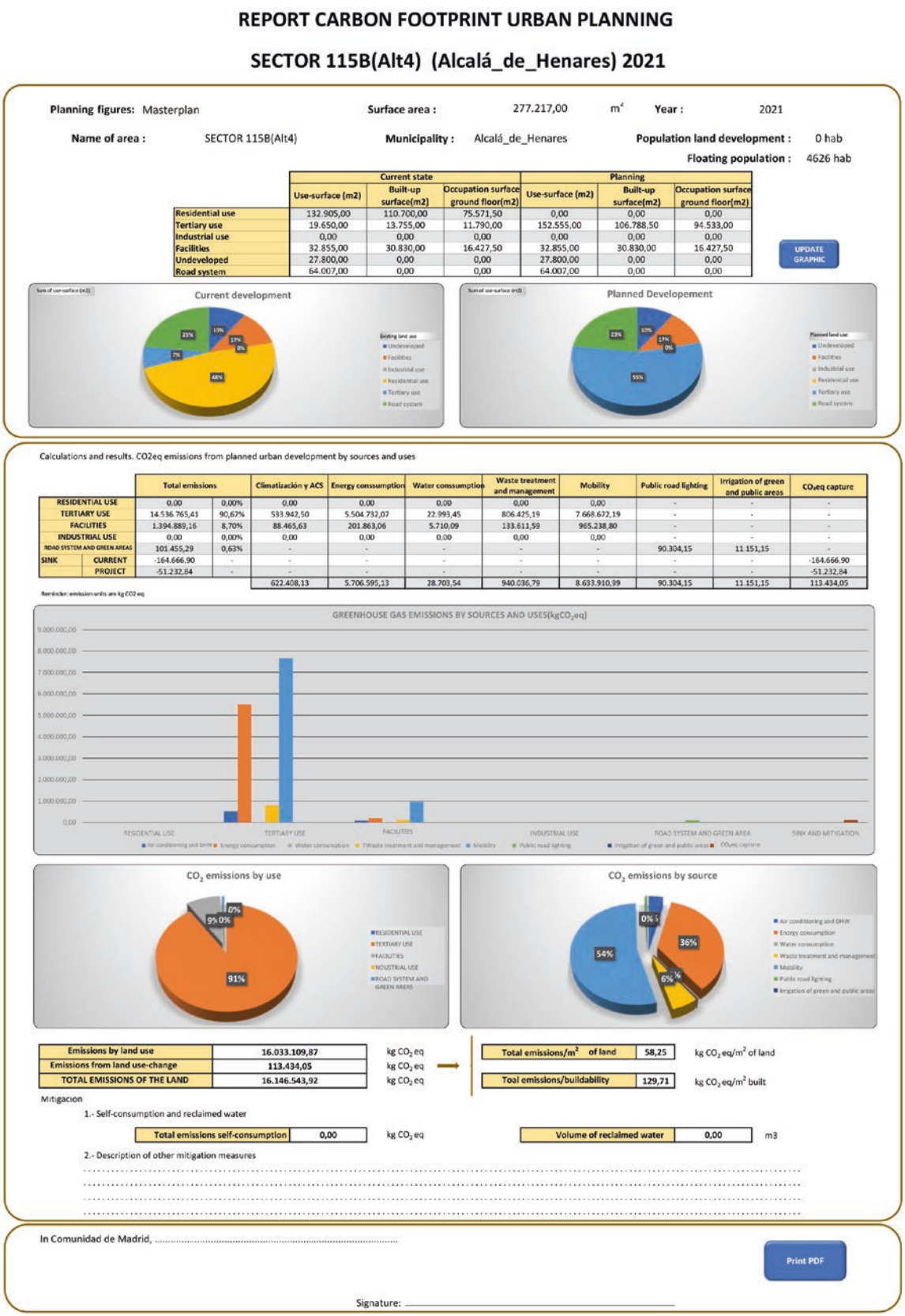

Fig. 9 Sector 11B Alcalá de Henares Alternative 4: report carbon footprint urban planning

It is clear that in the tertiary use, the mobility of people going to work is more important as the energy consumption inside the buildings. In any case, energy consumption in this alternative 4 is 446% higher in alternative 1.

4.6 Alternative 5: Business-as-Usual with Location in Madrid City

This alternative is equal to the first one but moving the masterplan to Madrid City, with 3,223 million of inhabitants and 604.3 km^2.

This alternative has got 8.748 tCO_2eq, 29% more than alternative 1 (Fig. 10).

It does not have much impact on emissions, with residential use once again being the main part, with 44.94%, where the highest emission belongs to mobility that increases up 68%.

In the case of alternative 5, the average distance of trips is set at 13.88 km and the percentage of trips for the sector being 72.28%. This means that it is a municipality where internal movements are predominant but which, due to its large size, ultimately involves a greater number of emissions than alternative 1.

4.7 Alternative 6: Business-As-Usual with Location in the Municipality of San Martín de Valdeiglesias

This alternative is equal to the first one but moving the masterplan to a municipality in the border of Community of Madrid, with 8.318 inhabitants and 115.5 km^2.

This alternative has got 12,525 tCO_2eq, 84% more than alternative 1 (Fig. 11).

In this alternative, the predominant emissions are by far those from residential use, with 77.29%, and mainly by mobility.

In the case of alternative 6, the average distance of trips is set at 6.06 km and the percentage of trips for the sector being 15.17%, which means that there is a strong commuting to other municipalities and its location far from more populated municipalities.

As a conclusion of the results, it can be seen than mobility is the first source of GHG emissions in the alternatives.

Furthermore, it can be seen that the alternative that generates the most mobility of all is alternative 6 because of commuting (9,588 tCO_2eq), and after this, alternative 4 with tertiary use (8,633 tCO_2eq).

The alternative 4 with mainly tertiary use, is the one with the highest amount of GHG emissions of all, because of the high amount of emissions of mobility, as said, and the greatest weight in other kind of energy consumption (38%).

The use of renewable energy could avoid an important amount of emissions, in the studied alternative 3, between one in five to one in three GHG emissions.

The emissions of land-use change are around 2% in the alternative with more intensity, alternative 3, but they are important for the irreversibility of the process.

5 Conclusions

There is a climate crisis which means that all plans and programmes must be measured in terms of how much they will affect climate change, and for then, it is necessary to have tools. Therefore, this environmental awareness, this change in the discipline's criteria, which it has been seen today, responds to the fact that urban planning can be at the service of ecology in the search for impact reduction, such as climate change.

Planning operates between thresholds or maximums. It is not a project that materialises the next day. Planning shows scenarios that are shaped, in the case of development planning with urban design. It has to be understood that with regard to climate change it is needed to quantify the effects, 1.5 or 2 degrees of temperature increase scenario. But the causes are not always quantified, and this quantification does not always help us to make decisions. Then, there is a need to measure in order to evaluate, as in the alternatives showed. And for this, the concept of carbon footprint introduces the set of GHGs emitted as a direct or indirect effects of an activity. In the case of a plan of the activity, it will host when it is in operation.

With the carbon footprint, the impact of climate change is observed and specific data is available to evaluate development alternatives in terms of climate change. It is necessary to understand that instruments that provide better, more rigorous, contrasted and comparable information will help us to make better decisions. This means making data on the carbon footprint impact of urban development plans visible, so that they can be included in the public agenda. With better data and the best data available at any given time, citizens can know and make decisions.

For all these reasons, it is considered the carbon footprint calculator for Community of Madrid could be useful for urban planning decision-making. Its data can be revised when it is updated, new methods could be more realistic for the region or when better data becomes available. But what is also important is the structuring of the factors affecting the carbon footprint and the visibility of the effects.

The carbon footprint calculator structures, simplifies and makes visible processes and their relative impact on climate change actions when the planning being assessed is under load for the specific case of the Community of Madrid.

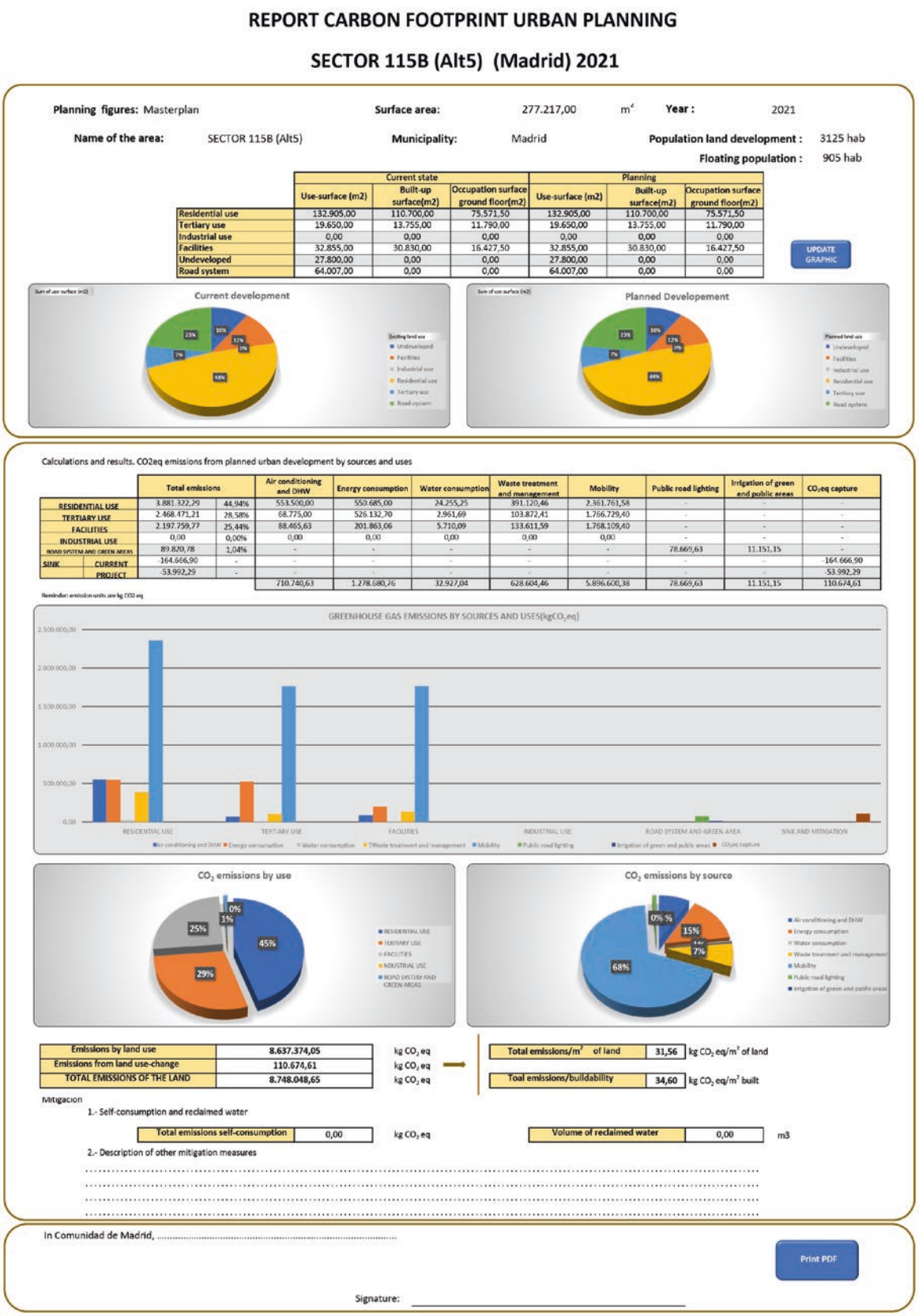

Fig. 10 Sector 11B Alcalá de Henares Alternative 5: report carbon footprint urban planning

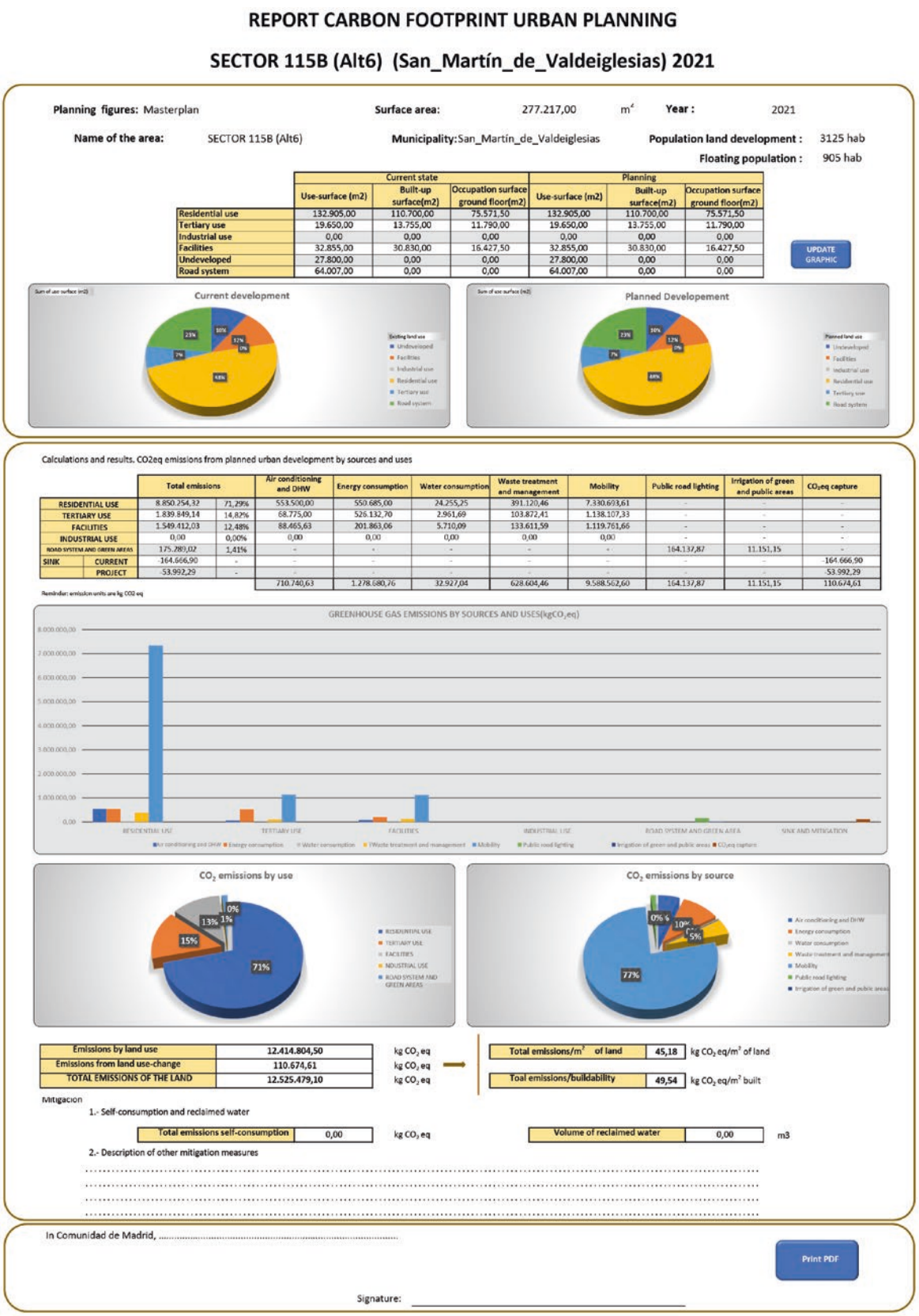

Fig. 11 Sector 11B Alcalá de Henares Alternative 6: report carbon footprint urban planning

Therefore, a dynamic region like Community of Madrid has the support of a tool to assess plans whose effects are very long term. In this way, information is provided for discussion, but also for sharing, with the ultimate objective of influencing administrative decisions and the general interest.

It should be stressed that this type of tool does not replace spatial planning, nor does it replace planning itself. Rather, they provide it with information and complement it by showing the factor of the development model in climate change when urban planning is in charge.

The current moment is a time of transition in which there are many uncertainties. Added to this is the fact that planning is an early stage of design in which projects have not yet developed their guidelines and therefore carries with it certain uncertainties.

It must take advantage of this confluence of early design stage so that the urban futures will have the lowest carbon footprint impact.

Acknowledgements To Mariano Oliveros, for his interest and ideas, and to Elena Román for her help.

Appendix

Alternatives Reports

In this appendix are the full reports of the evaluated alternatives showing the options in relation to the data or variables as well as associated greenhouse gas emissions.

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Potential Benefits of Application of Green Roofs on Buildings of Communist Period: Tirana Case Study

Anna Yunitsyna and Ardian Laçi

Abstract

This research proposes the application of green roofs to the flat terraces of residential buildings, commercial buildings, and public-owned buildings in the city of Tirana. Green roofs have proven that they can offer ecological, innovative, and sustainable solutions. Application of green roofs provides multiple such as reduction of CO_2 in the atmosphere and on-site, management of rainwater runoff, reduction of noise pollution, addition of green areas, and reduction of urban heat air islands and brings a positive contribution to urban agriculture, recreation, flora, and fauna. Green roofs demand higher installation cost rather than conventional ones, but they prove to be more cost-effective and economical in the long run. As a case study, two buildings of the communist period built in one of the most urbanized areas of Tirana have been selected. The study examines the type of construction and the capacities that these buildings have to support different types of green roofs. Green roofs are classified according to the density of vegetation, applied technological solutions, and components used in construction. The long-term benefits of each roof type are compared with the cost of application, and based on the analysis, the most appropriate one is selected.

Keywords

Green roof · Intensive and extensive green roofs · Pollution reduction · Rainwater management · Sustainable design · Vegetation

1 Introduction

Tirana is being built currently without the implementation of building codes, and it needs a lot of intervention and innovative ideas to make it a modern and efficient city. Tirana ranks as the most polluted city in Europe which at the end of 2020, scored 81.11 points in the air pollution index compiled by Numbeo (2020) agency. Consequently, the air quality is very low. Numerous problems are also encountered with rainwater management, lack of recreational and green spaces as well as effect of urban heat island by rising temperatures by 4–5 °C from reflecting built surfaces. Application of the green roofs over existing buildings could serve as a sustainable long-term solution, which can improve the quality of life. Although there are some sustainable and ecological projects in Tirana, their impact is still negligible in the improvement of the overall urban microclimate. The result would be more noticeable if the application of green roofs is done over the existing buildings.

Sustainable design seems to be the main focus in the field of long-term construction. The use of green roofs provide a sustainable solution which can resolve some of the urban problems. Green roofs are the upper surfaces of objects that are completely or partially covered with plants. Green roofs include various types of vegetation, starting from the low grass and plants to the shrubs, bushes, and even some trees (She & Pang, 2010). An important addition could be the possibility to use the green roof as vegetable garden. The rooftops occupy the considerable area of the city which is not used daily and does not contain any activity. These surfaces can be considered as a great opportunity for solving the vital problems of the city.

This research aims to find a sustainable and long-term solution for the green roofs taking into account the types of building structures and to provide a cost-benefit analysis for the selected roof types. The first stage of the research is related to the site selection and the analysis of its urban

A. Yunitsyna (✉) · A. Laçi
Epoka University, Rruga Tirana-Rinas, Km 12, 1039 Tirana, Albania
e-mail: ayunitsyna@epoka.edu.al

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parameters. The site has been selected at one of the most urbanized areas of Tirana, and it is facing problems with the quality and the amount of public space, occasional flooding, and uncontrolled urbanization. The site analysis includes the identification of buildings with the greater potential for the application of the green roofs. The selection of the two buildings is based on their construction period, the footprint area, and the building height. From the central archive are taken all the drawings such as plans, sections, and facades of both buildings. The buildings have been 3D modeled, reproducing all the structural elements of the existing buildings, and the plans were redrawn. At the second stage, structural analysis of the buildings is carried out to find out the load-bearing capabilities of the flat roofs. Based on the load-bearing capacity, potentially applicable green roof systems have been introduced and cost analysis of their application has been performed. Vegetation analysis is based on the selection of the flora that is present in the district of Tirana. In addition, the cost analysis of required materials was performed based on the market prices. One of the priorities of this research is to find out more economically feasible and easily applicable urban-scale solution for the existing buildings. After the comparative analysis, the general evaluation of the benefits for each type of green roof is done through a comparative rating.

2 Classification of the Green Roofs and Major Benefits of Use

The basic components of a green roof are waterproof layer of the roof deck, root barrier, drainage membrane, filter layer or geotextile fabric, substrate or growing medium and vegetation (Allnutt et al., 2011). All of these layers have a primary function of protecting them from water, pests, and other organisms and also serve as very good insulators for protection against weathering and energy loss inside the building.

By the amount and type of vegetation green roofs are categorized into two main categories: intensive green roofs and extensive green roofs. Extensive roofs are suitable for the large areas, they are simple to design and install, don't require irrigation and the build-up height is 50–150 mm. Due to the lightweight, they do not require highly reinforced structures or special reinforcement systems. Also because of short vegetation and low weight it is possible to apply them even on the steep slopes. With build-up height of 150–1,500 mm, intensive roofs require highly durable structures since they can accommodate the wide range of plants and trees, combine hard and softscape, and create gardens, which are similar to the natural ones. Intensive roofs have costly start-up costs and require regular irrigation and maintenance, but they become more profitable after a long period of use and have good thermal insulation properties (Cath et al., 2007). Intensive green roof creates a load of 180–500 kg/m^2. Extensive green roofs are relatively light at 60–150 kg/m^2 (Cascone, 2019). The height of the roof is about 120–250 mm and the weight of 120–200 kg/m^2 (Raji et al., 2015). Extensive and semi-intense green roofs consist of almost the same materials due to the same typology they have. Since the semi-intense green roofs have higher weight and higher substrate level, the quality of the materials should be better and should have a longer lifespan. Also, the water capacity is higher and requires a proper drainage system to drain the water during storms in order to avoid the flooding of the roof. Extensive green roofs are the most popular types for the implementation due to the lower thickness of the roof layer, but the capacities of the intensive green roofs are higher in terms of the building energy balance, biodiversity, rainwater mitigation, and the urban heat island mitigation (Nguyen et al., 2022). Semi-intensive green roofs stand in-between of the two previous types. Reduction of the thickness of the green roof is the main challenge, but in the hot climate it may increase the overall temperature of the substrate and negatively affect the plants resistance (Savi et al., 2016).

Modular green roofs are systems that can be easily applied and in a very short time over a large area. The important layer for the modular system is the water isolation. Several types of insulators, such as bitumen or liquid insulators, can be used for this process. Green roof modular systems don't need the protection membrane from the plant roots and the water drainage layer, because the container or modular box performs this function. Modular systems don't require the filter layer since the drainage openings of modular boxes are positioned higher than the base of the box, and this creates the storage of moisture in the substrate and makes the plants more resistant during droughts. It also excludes the need for irrigation of planted vegetation. Built-up layer system consists of three or more layers. The main differences between the extensive green roof and semi-intensive green roof systems is the substrate layer and the water drainage system. Due to the construction properties, modular roofs have the big capacity in reduction of rainwater runoff (Korol & Shushunova, 2016).

Biodiverse green roofs are also known as brown roofs. The effects of construction and urbanization damage the biodiversity and habitat of many species, causing losses in the enrichment of biodiversity. Biodiverse roofs create living conditions for different species and attract insects such as bees which also help in the process of pollinating flowers (Hui & Chan, 2011). Blue-green roofs are a combination of green roofs and blue roofs and serve to store rainwater and make it usable for building purposes. These types of roofs reduce water consumption in buildings where they are applied, mitigate the heat island effect, and reduce

electricity consumption in the building. Bio-solar green roofs include the photovoltaic panels installed over the green roofs. These types of roofs manage to produce clean energy and reduce the electricity consumption. Bio-solar green roofs are suitable mainly for the buildings with large area and loaded activity (Larsen et al., 2020).

Green roofs can provide multiple benefits, such as better rainwater management, air purification, enrichment of biodiversity, reduction of energy spends of building, reduction of urban heat island effect (Shafique et al., 2018). Green roofs offer a series of positive and beneficial effects on reducing temperatures during the summer in urban areas. Summer surface temperatures in the urban areas are on average 7–9 °C warmer, than in the surrounding rural areas, which have forest and vegetation cover. During the summer day, the temperature of the roof can rise to 50–90 °C (Arabi et al., 2015). The temperature of street surfaces and pavements is 27–50 °C hotter than the ambient air temperatures. However, surfaces that remain shaded or wet did not deviate far from the air temperatures (Berdahl & Bretz, 1997). The study conducted in Greece shows that green roof serve as good insulator to prevent the overheating. The indoor summer building temperatures are 0.6 °C cooler for the buildings with the green roofs, and the cooling loads are 11% reduced (Sfakianaki et al., 2009). Another study strengthens this case more by comparing black and green roofs. The green roof has the lowest heat loss rate and the black roof has the highest heat loss rate, and the difference between the black and green roofs is roughly 37% (Gaffin, 2010). Green roofs demonstrate the high ability in reduction of the fluctuations of the roof temperature during the summer time. The differences of the conventional roof daily temperature reach 20–48.5 °C, while for the green roof this parameter is just 5–11.3 °C (Maiolo et al., 2020). The comparative research on the thermal performance of the different types of green roofs conducted in Portugal shows that the extensive roofs have 2.8 times higher cooling energy demand than the semi-intensive roofs and 5.9 times higher than the intensive roof (Silva et al., 2016). Green roofs have greater contribution into the lowering of the energy balance of buildings with the lower number of floors, since the energy savings are the highest for the apartments, which are located directly under the roof. The cooling and heating loads can be 16% and 5% lower consequently with the implementation of the green roofs (Theodoridou et al., 2017). For the single-story building application the green roof causes 19% deduction of the annual energy consumption (Peñalvo-López et al., 2020). The implementation of the simple roof lawn in the conditions of Rome, Italy caused the 30% decrease of the heating demands and 51% of the cooling demands in comparison with the conventional roof (Evangelisti et al., 2020).

Another benefit, that green roofs provide for cities with the poor water drainage systems, is the management of rainwater runoff from building and the loading of the exhaust pipes. Annual reductions of runoff of green roofs with 8 cm deep media have been reported as 38–54% (Miller, 1998). A medium depth of 6.5 cm can retain 40% of the rain from a single 50 mm storm (Scholz-Barth, 2001). The capacity of water retention is limited by several factors, such as geographical position, the slope of the green roof, the thickness of the soil layer and its composition, the type of vegetation applied, and the surface area of the green roof. Palla et al. (2008) report that the green roof may be used as a medium to control the storm waters in Mediterranean climate with the average retain of the 85% of the water volume. Paço et al. (2019) propose to select the local drought-resisting plants and to combine the mosses and the vascular plants, which can use the retained water. The slope of the green roof directly affects the acceleration or deceleration of the water circulation, which accumulates in the drainage system. Vegetation type has an impact on the water retention capacity of the green roof since different plants increase the evaporation capacity of the collected water and slow down the flow of rainwater. The surface of the green roof affects due to the density and weight that rainwater causes, this increases the intensity of water circulation and reduces the water retention capacity. The secondary factors having the smaller impact on water retention are the type of materials used and the selection of the drainage system. According to a study conducted for different types of green roofs based on the thickness of their composition (5, 10, 20, 40, 60, and 80 cm), the average capacity of water retention ranges from 55 to 75% (Metselaar, 2012). For the 6-cm-thick extensive green roofs water retention can reach 30–57% (Neto et al., 2014), and for the semi-intensive green roofs with 20 cm thickness, it is about 85% (Palla et al., 2010), and for the extensive roofs from 39 to 43% (Wong & Jim, 2014). Despite on the fact, that intensive green roofs have thicker soil layer and denser and diverse vegetation than the semi-intensive roofs; the semi-intensive green roofs have better performance in managing rainwater, due to the large weight of water stored in the intensive green roofs.

Green roofs are used for the air purification. They can clean the air by lowering temperatures, removing pollutants directly from the air, and preventing additional air pollution (U.S. Environmental Protection Agency, 2018). A study conducted in Michigan and Maryland demonstrated that green roofs covered with low vegetation or sedum species with the height of 2.5–12.7 cm managed to sequestrate ~162 g of CO_2 per square meter (Getter et al., 2009). In Amman green roof demonstrated annual 3.68% reduction of the CO_2 emissions in comparison with the traditional one (Abdin et al., 2018). According to another study conducted

on the effect, that green roofs have on environment, the results revealed that green roof system could induce up to 33.8% savings in terms of the combined cost reduction and environmental values (Li & Babcock, 2014). Green roofs demonstrate 84.71% less CO_2 emissions during their life cycle (Nadeeshani et al., 2021). Extensive green roofs have CO_2 payback time about 5.8–15.9 years (Kuronuma et al., 2018). Given the fact that the green roof layers contain polymers, in the long term the pollution caused during the production of components is balanced by the pollutants, which are gathered by plants (Bianchini & Hewage, 2012). Green roofs have a positive impact on increasing biodiversity and attracting the different species mainly in urban areas where the cities have deformed and displaced it. The sedums, herbs, grasses, or host plants create the habitat for the birds, butterflies, and insects. Green roofs may include the use of wood cavities, rocks, various types of substrates, sand, tiles, bricks, or nests for birds. In Mediterranean areas, the arbutus plants are more preferable than the sage plants since they can overcome better the drought climate (Raimondo et al., 2015).

The economic factor should be considered, because the green roofs have a higher initial cost than other roofs and require the periodical maintenance. If the public benefits are added into the assessment, the lifecycle cost of the green roofs can be retrieved in most of the markets (Feng & Kasun, 2018). The application of the appropriate modern technology is considered to be the main factor of economic green roof (Philippi, 2006). Application of the green roof can also increase the property value and gain more space for the residents. Green roofs extend the service life of the roof materials. With the increase of the green roof area, the cost of its application per square meter is decreased. For multifamily residential buildings with high number of floors, the share of costs can reach 0.4% of total construction costs of the building (Pfoser & Dierks, 2018). An experimental study from China demonstrates the overall ecological benefit of $3.37 per square meter of roof and the 10 years of the investments return (Cai et al., 2019).

3 Methodology of the Research

The study is organized in a several steps since it requires to perform the several analyses and to collect the data from different sources. At the first stage of the data collection, the following steps are done:

- Site selection in one of the most urbanized areas of Tirana, which has constant problems with the quality of space, growing density, pollution, and noise.
- The site analysis includes the identification of buildings with the flat roofs, which can be potentially converted into the green roofs.
- Selection of the two buildings of the most prevalent building typology in order to examine their load-bearing capacities.
- Redrawing of the plans, sections, and facades of the buildings based on the documents from the central archive.
- Modeling the 3D models includes all the structural properties of the existing buildings.

At the second stage, the structural analysis was performed including:

- Structural analysis of the buildings in order to find out the load-bearing capacities of the flat roofs.
- Comparison of potentially applicable green roof systems and cost analysis of their application.
- The analysis of the general benefits of green roofs has been carried out, referring to previous studies and articles.
- Vegetation analysis of plants, which typical for the Tirana region.
- Proposal of the new activities that green roofs can offer and evaluation of the potential social impact.

As the conclusion, this research aims to find more economically feasible and easily applicable green roof solution for the flat roofs of the existing buildings.

4 Analysis of the Case Studies

4.1 Selection of the Apartment Blocks

The site is located between the two main streets of Tirana, Kavaja Street and Durres Street and between the Skanderbeg Square and Reshit Petrela Street. The total area of it is 417,340 m^2. The site has been selected as one of the most urbanized areas of Tirana, which has problems, such as repeating flooding of the roads during the heavy rains, lack of greenery, high density, variety of the commercial activities, and lack of public recreational spaces.

The selected includes residential, commercial, educational, religious, cultural and governmental buildings. The higher buildings are located at the main streets. The buildings from communist period are constructed using the load-bearing brick walls, and the recent ones are built using the post and beam system. During the communist period, the urbanization was controlled and main blocks of residential

buildings were constructed along the Durres Street, such as "Blloku Partizani" and "Blloku 21." The satellite image elaborated using QGIS (Fig. 1) shows all the buildings which potentially can support a green roof. The buildings with pitched roofs and low-story buildings are excluded from the selection because of the low load-bearing capacity. The map is provided by the State Authority for GeoSpatial Information (ASIG) of Albania (ASIG, 2020). The functions of the selected buildings are mainly residential and office buildings. The total approximate area of buildings with flat roofs is 65,558 m^2 which is 16% of the total site area. The two buildings selected for analysis have the roof area greater than 500 m^2, a height of more than five floors and are built during the communist period. The building floor plans (Fig. 2) are extracted from the documents found in the State Archive of Construction (AQTN).

Case study 1 is the Partizani building, which belongs to a residential block located in front of State University of Civil Engineering. The Partizani building is a five-story residential building which was built using the brick retaining walls in 1968. It has a 515 m^2 footprint area. Case study 2 is the 12C building located at Adem Jashari Plazza. The building is a four-story residential building which was built using the brick retaining walls in 1958, and it has a 598 m^2 footprint area.

The slabs of the Case 1 are composed of horizontal beams, which support the weight and transfer it to the retaining walls. Analysis of ceilings was performed by analyzing each of the beams and applying it to the entire sole. The following section (Fig. 3) presents the typology of Partizani building slabs. The building has five types of slabs with the same structure and concrete grade, but with differences in the amount of reinforcement steel and slab proportions. Knowing the surfaces, the grade of concrete, the dimensions of the slabs, and the amount of iron, the maximum-resistant moment is found. Then the resistance moment of each slab is converted into a force. The ultimate load (UL) is needed to calculate the loads which have an impact on the structure: Dead Load (DL) = Concrete + Brick = 0.225*1.4, Live Load (LL) = 0.256*1.6

Fig. 1 Selected site and buildings which are suitable for the green roof installation (adopted by author from Google via QGIS)

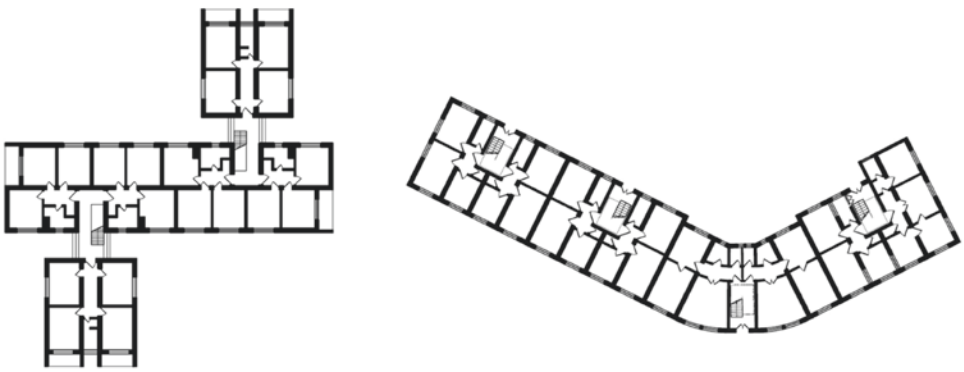

Fig. 2 Ground floor plan of Partizani Building (left) and Building 12C (right)

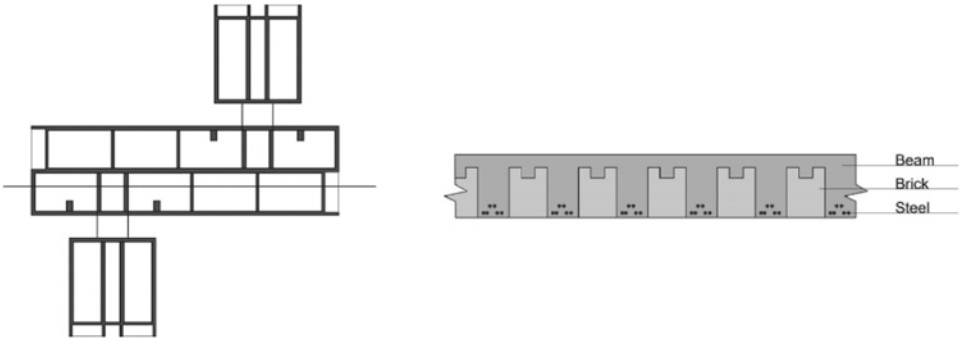

Fig. 3 Structural plan of Partizani building (left) and slab section (right)

Table 1 Structural plan of Partizani building

	Slab 1	Slab 2	Slab 3	Slab 4	Slab 5
Maximum resistant moment (KN)	3.26	3.70	1.99	1.52	0.75
Force (KN/m^2)	1.3	1.5	1.37	3.07	1.47
Allowed load (KN/m^2)	0.593	0.783	0.985	2.323	0.749
Permissible load (KN/m^2)	2.8	3.9	4.79	8.35	3.5
Maximum weight (KN/m^2)	2.1	2.9	3.6	6.25	2.6

from where the UL = DL + LL (1.4*0.225 + 1.6*0.256) = 0.717 kn/m. To find the allowable weight for meter on each beam is subtracted from the converted force F the ultimate load (F-UL) for each slab. Knowing the allowed load per square meter, the permissible load for each slab is found by multiplying the Allowed Load * Span Length * Number of the beams. Once the total permissible load for each slab is found, it can be converted into the permissible load per square meter for each slab by dividing the total permissible load of the slabs to the respective slab surfaces. From the permissible load is subtracted the tolerance of 25% of the total load-bearing capacity of the slab, which results in the maximum weight, that can be applied on each slab per square meter (Table 1).

The ceilings of the Case 2 building are built with the prefabricated soles. Due to the lack of data on the grade of concrete used for fabricated panels, a structural comparison with the Case 1 building is made. Figure 4 shows the structural plan of the building and the type of slab based on the drawings from the Central Construction Archive of Tirana.

The calculations are done for the slab with the largest area. Slab has a steel surface of 9,344.64 mm^2, which is divided by the area of the ceiling (9.6 m*3.65 m) to find the surface of the steel per square meter, which is 266.68 mm^2 per square meter. It's assumed that the slabs of the Case 2 building can support a weight greater than any of the slabs of the Case 1 building, due to the higher steel content. Referring to this data, it can be assumed that the slabs of the Case 2 can support any green roof that can be supported by the slabs of the Case 1 building.

4.2 Evaluation of the Supported Green Roof Types

For the application of green roofs, several important factors should be considered such as water insulation, thermal insulation, barrier for plant roots to prevent damage of the water insulation layer and layers to preserve moisture and minerals inside the soil to feed vegetation. Referring to the green roofs classification (Raji et al., 2015) (Table 2), the most suitable green roofs to be applied in the two analyzed cases are: modular green roofs, extensive green roofs, and semi-intensive green roofs. Intensive green roofs can't be applied in any of the cases, due to their heavy weight.

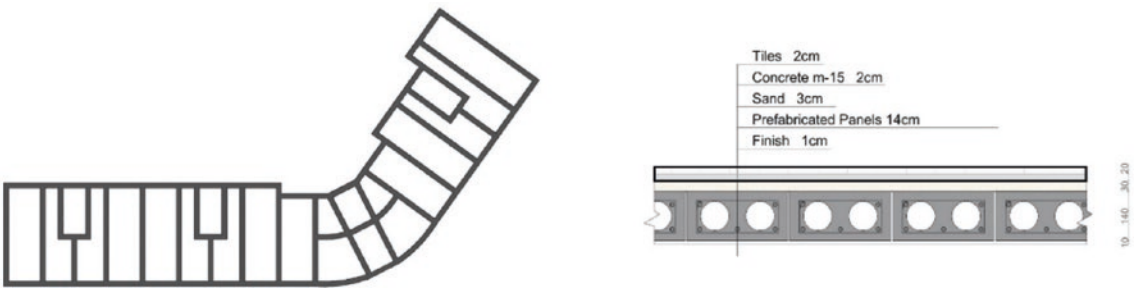

Fig. 4 Structural plan of 12C building (left) and slab section (right)

Modular green roofs, extensive and semi-intensive roofs do not require irrigation under normal conditions. In cases where the drought lasts too long and there is no rainfall, all types of the green roofs are recommended to be irrigated. Since modular and extensive green roofs have limitations in vegetation typology due to the dimensions that these roofs have, their need for the maintenance is minimal, while for the semi-intensive green roofs the maintenance should be periodic. The height of green roofs is different for each type. The lower roofs are modular with a height of up to 9 cm, the extensive roofs are up to 20 cm, and semi-intensive are up to 25 cm. Modular green roofs are lighter because they are constructed using a compact box, which is easy to install, with the average weight of 64.5 kg/m^2. Extensive green roofs are also lightweight structures due to their low vegetation and substrate ranging from 80 to 125 kg/m^2. The weight of the semi-intensive green roofs varies from 120 to 200 kg/m^2.

Each slab of Case 1 and Case 2 buildings can support modular, extensive, and semi-intensive green roofs loads, but they can't support the intensive green roof load excepting the slab 4 of the Case 1 (Table 3). Due to the lack of capacity of most of the slabs, the green roofs which could be applied on site are modular, extensive, and semi-intensive green roofs.

4.3 Green Roof Materials and Cost Estimation

The three types green roofs have the similar layers of waterproof membrane, substrate, and vegetation, but the root barrier, drainage membrane, and the filter layer of the extensive and semi-intensive roofs are replaced by the modular boxes for the case of modular roofs. One of the main goals of green roofs is to reduce the costs of flat roofs and increase their lifespan. One of the biggest dilemmas for the green roofs is the high cost of application due to the use of a range of materials. Referring to the prices of the domestic market in Albania and the international market, it is possible to get an approximate value for the total cost of materials for each typology of the green roofs (Table 4). Research shows that modular green roofs have a higher cost in the market, but their lifespan is longer, and in case of damages, the boxes are easily replaceable without intervention in the whole structure of the roof.

4.4 Suggested Vegetation

The climate of Tirana is classified as a humid subtropical climate according to the Köppen classification. Based on the classification of the climate zones in Albania, Tirana is located in the field Mediterranean area. The summer months are hot and moderately humid/dry, while the winter months are cool and humid. The annual temperature is 14.8 °C in average, while the hottest month is August, when the temperature reaches 24.7 °C and the coolest month is January with 5.2 °C. The maximum precipitation occurs in November with 150 mm, while July scores as the driest month with just 33 mm of rainfalls (Climate-Data.org, 2022). Tirana ranks 8th among major European cities with the most sundials. It has a high level of solar radiation with ~2,400–2,600 h of sunshine per year (AEA, 2014). The city is located in the 9a Plant Hardiness Zone (Teqja et al., 2017), which can be characterized by a long summer season providing the long period for vegetation growing. The

Table 2 Classification of green roofs

Green roof types	Modular	Extensive (built-up)	Semi-intensive	Intensive
Irrigation	No	No	No	Regular
Maintenance	Minimal	Minimal	Periodic	Regular
Weight (kg/m^2)	64.5	60–150	120–200	180–500
Build-up height (mm)	60–90	60–200	120–250	150–1,500

Table 3 Supported roof types

	Case 1 Partizani building					Case 2 12C building		
	Slab 1	Slab 2	Slab 3	Slab 4	Slab 5	Slab 1	Slab 2	Slab 3
Modular	✓	✓	✓	✓	✓	✓	✓	✓
Extensive (built-up)	✓	✓	✓	✓	✓	✓	✓	✓
Semi-intensive	✓	✓	✓	✓	✓	✓	✓	✓
Intensive	✗	✗	✗	✓	✗	✗	✗	✗

Table 4 Green roof materials and estimated costs

	Modular (Lek/m^2)	Extensive (Lek/m^2)	Semi-intensive (Lek/m^2)
Waterproof membrane	320	320	320
Modular boxes	3,600	–	–
Root barrier	–	950	950
Drainage membrane	–	–	640
Filter layer	–	230	230
Substrate	150	150	280
Vegetation	30	30	1,800
Total material cost	3,300	2,320	4,220
Labor cost	400	1,200	1,200
Total cost	3,700	2,520	5,420

temperatures below zero are exceptional for Tirana climate, and the cultivated plants, such as vegetables, citrus and fruit trees, herbs and blossoming shrubs should be heat-tolerant. Green roofs of the Mediterranean area have low thickness, high usability, don't need the specific maintenance and may contribute to the passive cooling of the buildings. Tirana, although with a very urbanized urban center and lack of greenery, has suburbs rich in vegetation. To select local plants, that are applicable for the green roofs, the classification is based on their maximum height and on the lifespan. There should be used the types of plants, which provide a continuous surface and permanent greenery. Often the application plants require the maintenance, irrigation, and cutting. In general, the vegetation applied on modular green roofs and extensive green roofs should have a low height and require as little care as possible. It's more adequate to have plants with small roots resistant to drought and rapid growth spread. The most commonly used vegetation on modular and extensive green roofs belongs to the succulents family, as sedum, which has high resistance to drought. Sedums also minimize the water loss, which helps to increase the water retention of green roofs. There are selected the plants, which have an average length of less than 30 cm and a lifespan of more than 3 years. The local plants, that can potentially be applied to green roofs in Tirana, are *Thymus vulgaris*, *Teucrium polium*, *Trifolium pretense*, Coltsfoot, *Thymus serpyllum*, Oregano, Red Zorba Oregano, *Plantago major*, *Chamaemelum nobile*. A mix of succulents, such as sedum, requires less water, can resist in the difficult conditions of the open roof surface. CAM plants minimize water loss, helping with storm water management, while also offering the benefits of evapotranspiration (evaporating water from a plant by absorbing it through the roots and emitting it back out through the leaves as vapor) (Vegetal, 2013).

5 Discussion

One of the main benefits of green roofs is the delaying run-off peak of rainwater inflows and the reduction of the volume of rainwater discharge in the drainage system. The decrease in the volume of discharge occurs due to the ability of the vegetation layer and the soil to maintain a significant percentage amount of water, depending on the climatic factors and to restore it to the atmosphere through the evaporation phenomenon. This facilitates the central water discharge system as it significantly reduces the amount of water deposited in them during heavy rainfall. Both case study buildings have low-slope roofs of 3–5 degrees, so the water circulation coefficient is lower than in high-slope roofs, this slows down water flow and increases the capacity of water retention. Tirana's climatic conditions favor the application of semi-intensive green roofs, because Tirana has heavy and frequent rainfalls. The composition of green roof using the dense and diverse vegetation increases the capacity of evaporation of rainwater and reduces its flow in the drainage system.

Green roofs have high efficiency because the green layer exposed to sunlight enhances the evaporation process which brings a softening of temperatures, which in conjunction with the process of photosynthesis of vegetation absorbs energy from sunlight. The green roofs act as a cooling system by absorbing air energy and lowering temperatures. As the capacity of the green roof for water retention increases, so does the evaporation process, which results in a greater cooling efficiency. Green roofs, in addition to the positive impact they have on reducing the UHI effect on an urban scale, also play an important role in maintaining of the indoor temperature in the buildings. They serve as thermal insulation layer, contributing into the lowering of the temperatures during the summer and increasing during the winter. The massive application of the green roofs creates a local microclimatic zone, which reduces the use of energy for heating and cooling and increases the lifespan of the roof itself by protecting the materials from the sunrays.

Modular green roofs in contrast to built-in extensive green roofs, have higher moisture content, due to modular boxes which create a water collection at the bottom. The presence of water at the bottom of these boxes prolongs the process and amount of evaporation. The common geotextile layer below the soil layer serves for the longest possible storage of moisture. Semi-intense green roofs composed of a thicker layer of soil and a higher vegetation, which increase the water retention capacity, provides better shading effect, and gives the higher contribution into the process of air purification. The application of semi-intensive green roof gives better results for mitigating the urban heat island.

Fig. 5 Potential use of the green roof as cafeteria, meeting place, place for the social activities, resting area, or the herbs garden

Plants have the ability to improve air quality by absorbing pollutants or carbon dioxide and releasing oxygen. The impact that green roofs have on improving air circulation is related to the two main constituent layers of green vegetation and soil. Green roofs have an indirect impact on reducing pollution as they reduce the need for energy use. However, it is difficult to give accurate results in terms of evaluating the effects that green roofs can bring on air improvement. The impact of green roofs applied on a large global scale brings efficient results in improving the air and carbon sequestration. The measured PM10 concentration in Tirana was 124–127 $\mu g/m^3$, which is well above the EU limit value of 40 $\mu g/m^3$. Application of green roofs in the selected site may increase the air purification by 17%.

Green roofs may increase activity and liveliness on the terraces of residential buildings (Fig. 5). They give potential solutions for increasing communication of the residents and for improving the social life. Green roofs can be considered as a compensation to reclaim the ground space occupied by the buildings. Their application at the city scale can create a new ecological vision of the city. Green roofs offer opportunities to create playgrounds, adding space dedicated to children, and improving the social quality of the city. Their application should be done using all safety measures such as setting restrictive barriers, equipping with lighting at night, and placing retaining balustrades. Green roofs could be transformed into the cafés and restaurants and also can be used for family or social gatherings since of the most frequent activities of the citizens of Tirana is the consumption of coffee. They can serve as a place to organize small community performances, local meetings, political meetings, announcements, conversations. Semi-intensive green roofs can be planted with medicinal or aromatic plants that serve for daily use as spices in the kitchen, or teas with curative properties. Since Tirana is one of the sunniest cities in Europe, green roofs can be used for the sunbathing. Green roofs can also be used as relaxation spaces to spend free time, listen to music, read books, and meditate.

Despite on the all potential benefits, the application of the green roofs in Tirana currently is in not very common. The existing roofs are mainly the private initiatives, rather than the t result of the common policy. The green roofs can be used by the residents of the house, but they are not opened for the public. The roofs are equipped in a very simple way with the planting pots and boxes, which can be managed easily by the community (Fig. 6). In addition, the residents installed the benches and pergolas which make the place more comfortable. The roofs are also used as place for the solar water heaters, antennas, water tanks, and photovoltaic panels, which belong to the residents of the last floors. The green roofs in Tirana were widely used during the COVID-19 pandemic, when the residents were not allowed to get out of their homes, and therefore, they spend the time at the roof terraces. Currently, the demand is lower since the social life came closer to the pre-pandemic level and the citizens prefer to stay at the outdoor cafeterias and enjoy the music, social atmosphere, and food and drink services, which are provided there.

6 Conclusion

The evaluation of all three types of green roofs is done taking into account all the benefits they have. The result of the evaluation (Table 5) shows that application of semi-intensive green roof in our cases is more efficient and brings more benefits in a long term than other roofs that can be applied in these two cases.

Fig. 6. Existing green roofs in Tirana

Table 5 Green roofs performance (✓—poor, ✓✓—medium, ✓✓✓—good)

	Modular	Extensive	Semi-intensive
Cost of materials	✓✓	✓✓✓	✓
Cost of application	✓✓✓	✓✓	✓
Air pollution filtration	✓✓	✓	✓✓✓
Water retention	✓✓	✓	✓✓✓
Biodiversity	✓	✓	✓✓✓
Heat island reduction	✓✓	✓✓	✓✓✓
Recreational spaces	✓	✓✓	✓✓✓

Semi-intensive green roof gives better benefits in reducing of the level of pollution, has a greater capacity of water retention, is more efficient in terms of biodiversity, and has better capacities in reducing the UHI effect, but has higher material and application costs. Modular green roof has very good performance since it has a short installation time and good performance in water retention capacity, but poor performance in attracting the biodiversity and limitations for the organization of the recreational spaces. The extensive green roof has cheaper materials, but the benefits of modular and semi-intensive green roofs are higher.

The examined case studies show that residential buildings of the communist period have the ability to support three out of four main systems of green roofs, such as modular, extensive, and semi-intensive green roofs. Starting from the economic analysis, costs of the materials and the cost of the application, the total costs for each of green roof systems are estimated. The three selected systems of green roofs contribute positively in reduction of energy consumption for heating and cooling, in managements of the water flow, in extension of the roof lifespan. Lowering the level of pollution, lowering temperatures during the summer which further affects onto the local climate change, increase of green spaces, social, cultural, and lifestyle improvements are the features that make green roofs an efficient solution. One of the most important benefits is the displacement of the activities to the terraces of buildings, and this would make the city more diverse and more aesthetically pleasant.

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CFD Study Toward Eco-Economical Tall Residential Housing in the Mediterranean Climate

Menna Tallah A. Abo amo, Mohamed A. F. Mahdy and Walid F. Omar

Abstract

The concept "Design with Nature" has recently been promoted as the most effective solution to the global warming problem. Because there is limited natural-cross ventilation in the Mediterranean climate in Alexandria, Egypt, reliance on natural-stack ventilation in modern tall residential buildings is crucial. This research intends to rely on economical housing while maintaining thermal comfort within units. The research discusses the use of an atrium with evaporative cooling to direct the cool airflow toward tall buildings. The study uses CFD simulation with ANSYS Fluent to demonstrate and explain the concept. A centralized atrium with evaporative cooling applies to two different height cases: a five-story residential building and a ten-story residential building. The experiment simulates four variables: two air-exhaust opening positions, atrium width, and atrium shape. Each variable is assigned to a certain category. The results are presented through a comparison between the temperature and velocity contours of the proposed buildings. According to the findings, a centralized atrium with a rectangle shape in a ten-story residential building with an upper air exhaust vent provides an appropriate stack effect. Finally, in tall residential housing, the use of an atrium with an evaporative cooling system increases the effectiveness of natural-stack ventilation.

Keywords

Global warming issue · Surrounding environment · Stack ventilation · High-rise residential building · Mediterranean climate in Egypt

1 Introduction

Due to the rate of ozone reduction and the increase in greenhouse gases after 1980, climate change and global warming have become prevalent issues. According to the Meteorological Office, if we continue to emit greenhouse gases at current rates, by 2080 world average temperatures will climb by 3 °C over the 1961–1990 average and sea levels will be twice as high as they are now (Roaf et al., 2001). As a result, high heat and humidity pose energy and environmental challenges to all cities. As shown in Fig. 1, occupants rely on mechanical ventilation as an air-conditioner to achieve thermal comfort. Alexandria is the second-largest city in terms of population in Egypt, with 5.14 million residents as of 2017. Over the years 2008–2015, Alexandria's residential annual power usage increased significantly, growing at an average yearly rate of 5.7%. Because of its longitudinal design, the city's potential for growth is constrained by the Mediterranean Sea, Lake Maryut, and an agricultural area to the north, south, and southeast, respectively. Additionally, Alexandria City features the generally haphazard replacement of old buildings with new high-rise 15- to 20-floor building blocks surpassing the limits specified by the building code, in relatively narrow 6–7 m streets (Abdrabo et al., 2018). Its weather is characterized as Mediterranean, which is temperate, warm, and frequently very hot. Summer is a hot season, especially during the day but also at night. The continual development of cities with dense urban patterns results in a dramatic increase in building size in urban centers, increasing densities, building heights, collapsing infrastructure, and the heat emitted by large-scale human gatherings. The urban wind

M. T. A. Abo amo · M. A. F. Mahdy (✉) · W. F. Omar
Architecture Department, Faculty of Fine Arts, Alexandria University, Alexandria, Egypt
e-mail: mfouadmahdy@hotmail.com; mohamed.mahdy@alexu.edu.eg

M. A. F. Mahdy
College of Architectural Engineering and Design, Kingdom University, Riffa, Bahrain
e-mail: m.mahdy@ku.edu.bh

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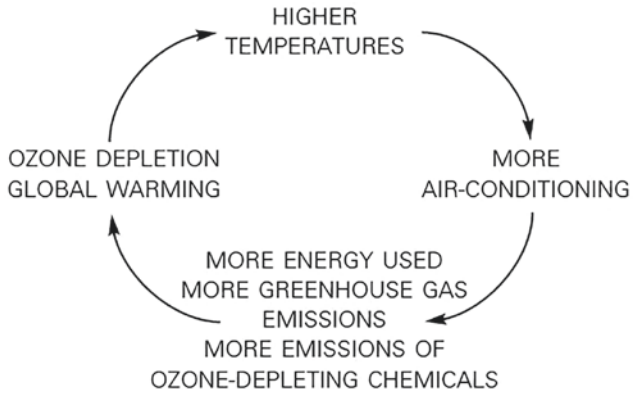


Fig. 1 Due to the greenhouse gas emissions, reliance on air-conditioners contributes to global warming (Roaf et al., 2001)

environment has deteriorated as a result of all of these factors. Furthermore, the height increases of Alexandria's residential buildings, without considering natural ventilation, lead to hot temperatures inside the rooms. In particular, natural cross-ventilation has restricted applicability as it is most effective when the temperature differential between the interior and exterior is at least 3°F (1.7 °C); otherwise, it has only a minor effect (Kwok & Grondzik, 2007). According to the National Center for Atmospheric Research (NCAR), the monthly maximum temperature in the summer (May–September) will be significantly higher by 2050 compared to the years 2007–2016 (Fig. 2). Therefore, it is necessary to implement methods compatible with economical housing to reduce electricity usage for cooling buildings.

Stack ventilation, also known as the stack effect, is a passive cooling method that relies on temperature differences between the interior and exterior of a building. Warm air rises and is replaced by cooler air when the temperature inside the building is higher than the outside temperature. It is effective, especially when the wind is not too strong and the weather is hot (Aflaki et al., 2015). By removing latent heat and directing cold air toward tall residential buildings, an atrium with an evaporative cooling system increases the effectiveness of stack ventilation. The No. 119 law of 2008 standardizes and specifies dimensions for atriums in residential buildings. The atrium's minimum dimensions are 2.5 m or 3 m, whichever is greater. The atrium must have a minimum area of 9 m^2 or a quarter of the height, whichever is greater. In order to provide enough airflow, these measurements must be considered while researching stack ventilation in tall residential buildings. Traditional atriums may be seen in the archaeological remains of a courtyard home at Ur, Mesopotamia, dating back to 3000 BC (Moosavi et al., 2014). It was later discovered that ancient Roman and Greek homes used a central courtyard. The atrium acts as an area for the residents of the building to socialize as well as offering the role of a climate modulator (Fig. 3). The Zeinab Khatoun House (1468) is divided into two sections: two-story and three-story (Mossad et al., 2016). All the spaces are enclosed by an inner courtyard or atrium, which allows for good ventilation in all areas. To minimize direct solar radiation, tall masses were placed in the west wing. Figure 4 shows how to change the internal pressure to provide more air circulation.

The research gap in Alexandria is that the temperature differences are insufficient to produce a suitable stack effect, and there are some months with high humidity. The main objectives of this study are to determine how to effectively use an atrium with an evaporative cooling system to create a suitable stack effect in economical residential housing in Alexandria and to establish the ideal atrium design parameters in this housing. So, this study looks into natural-stack ventilation in tall residential buildings using CFD simulation to direct cold air toward the units. It also looks into the relationship between urban canopy shading and the proportion of shaded places in a street canyon.

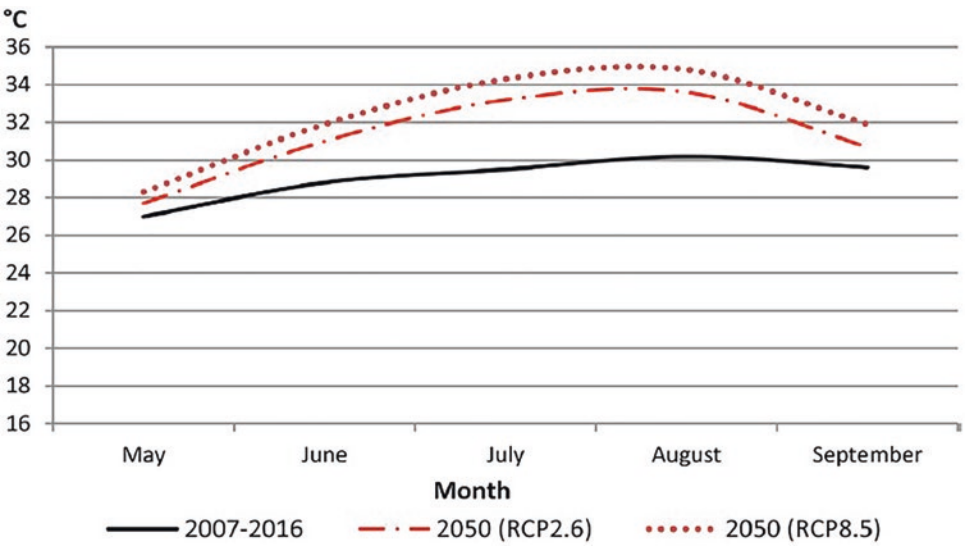


Fig. 2 Current and expected monthly maximum temperature in Alexandria (Abdrabo et al., 2018)

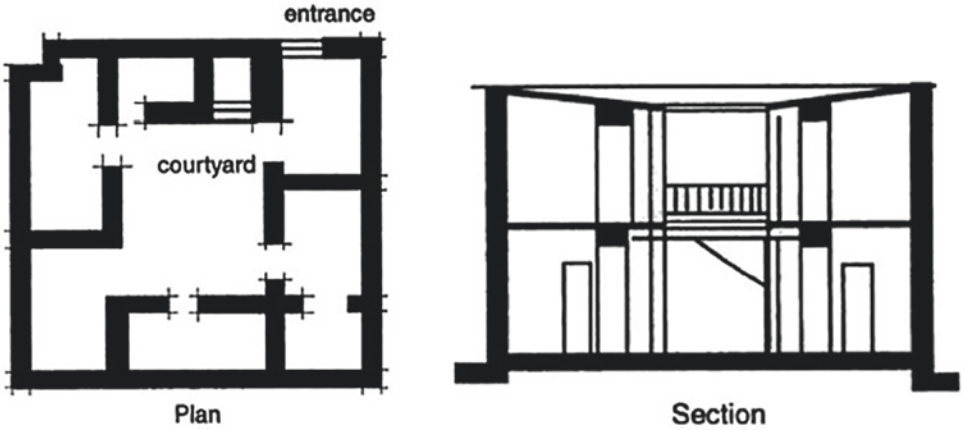


Fig. 3 Traditional atrium was discovered in the ruins of a home in Ur, Mesopotamia (Moosavi et al., 2014)

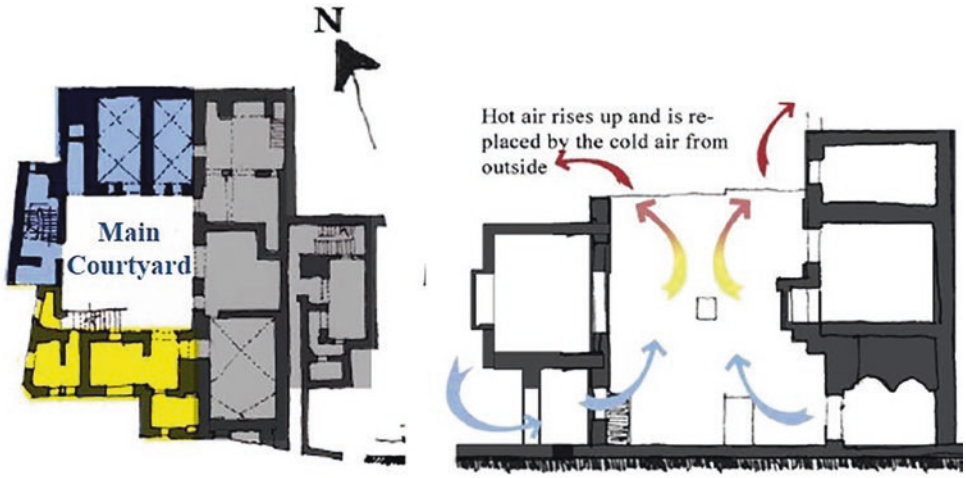


Fig. 4 In the courtyard of Zeinab Khatoun House, stack ventilation ensures proper airflow (Mossad et al., 2016)

2 Theory/Calculation

2.1 Tall (High-Rise) Residential Buildings

A number of blocks of high-rise structures will affect the airflow velocity and temperature in the street canyon (Shishegar, 2013). Regardless of whether the airflow is parallel or perpendicular to the canyon, the velocity of the airflow increases as the temperature drops. The urban canopy layer and the urban boundary layer are also present in the urban air areas. The average height of buildings is higher than the urban boundary layer. Due to the influence of solar radiation falling on building facades and the ground, the urban canopy layer blows hot air onto rooftops and into the spaces between buildings. On the other hand, the street canyon is filled with cold air due to trees and covered places. The air is forced to move vertically due to temperature differences, as shown in Fig. 5.

2.2 Atrium Integrated with Evaporative Cooling System

An atrium integrated with evaporative cooling is a low-tech system reliant on natural, simple, economical materials and acts as a passive solution. It promotes a "connection" notion between the residents and their buildings and between people and their surroundings. Before entering the tall residential building, evaporative cooling removes heat from the air. Stack ventilation produces an optimum airflow toward interior rooms due to temperature differences. In tall residential buildings, the atrium serves two purposes. It provides fresh air to interior spaces while also removing exhaust air from buildings (Fig. 6). To prevent Legionella bacteria, it recommends maintaining water temperatures under 20 °C and over 45 °C, avoiding low water flow, maintaining the system's cleanliness, and using water treatment techniques (Health and Safety Executive, 2013).

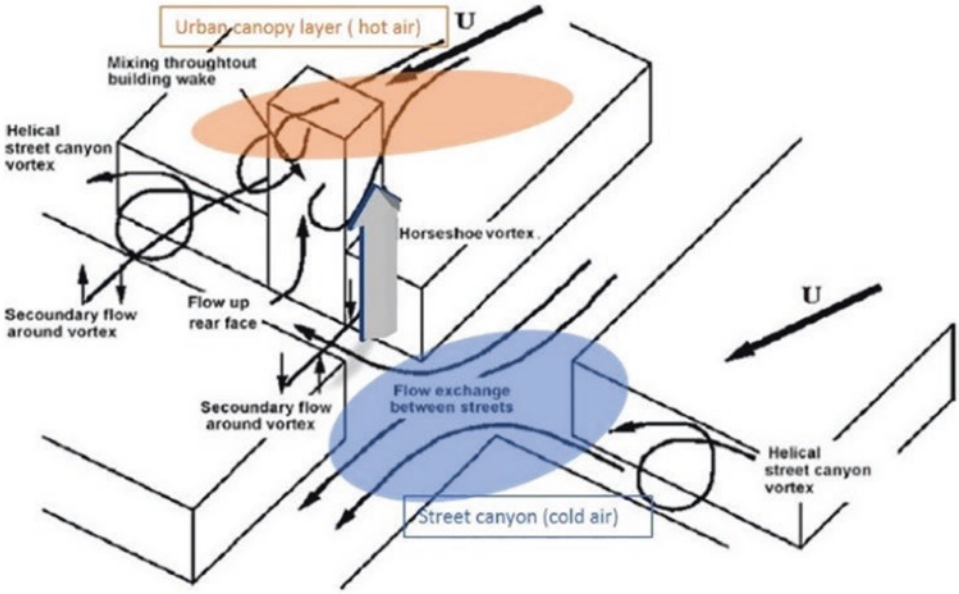


Fig. 5 Temperature differences are created by the interaction of the street canyon and the urban canopy layer, forcing air toward tall residential buildings, developed by the researcher from Shishegar (2013)

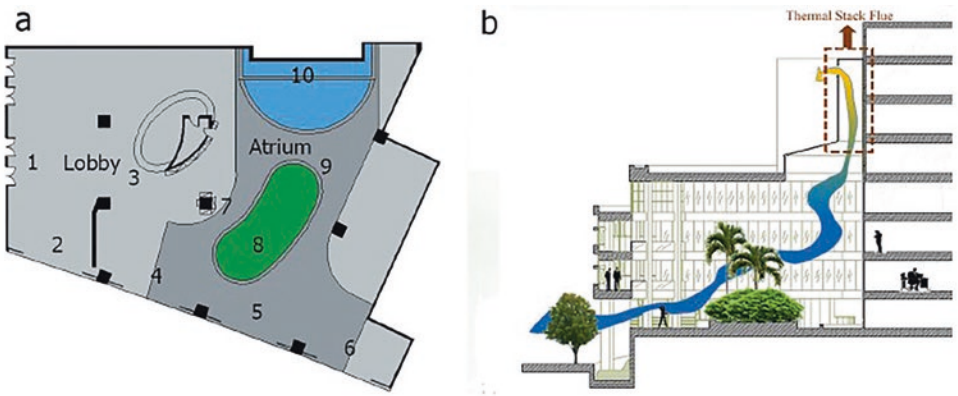


Fig. 6 Atrium (8) provides and exhausts air out of the building, while the pond (10) removes latent heat from the air before it enters the interior areas, developed by the researcher from (Moosavi et al., 2015)

3 Model of Study

Using CFD simulation, an atrium with evaporative cooling will be utilized in this case study to show and explain the concept. A centralized atrium was employed in the modeling buildings to enhance the stack effect inside tall residential buildings. From Moosavi et al. (2014), it is clear that external variables such as temperature, wind, and humidity affect atrium ventilation. Atrium criteria such as height, opening area, size, and form constitute the second element. This research aims to assess how to predict the rate and pattern of airflow within the atrium. The study is based on a multi-story residential building. ANSYS Fluent 2019 R1 is used to simulate the CFD results.

3.1 Modeling

There are four different comparison categories, as shown in Fig. 7. They will apply to two different height cases: a five-story residential building and a ten-story residential building. The centralized atrium plan in the first and second categories is positioned in the center of the master bedroom and living room with a width of 3 m, as shown in Fig. 8. The first category, a centralized atrium with an upper air exhaust opening, is seen in a 3D perspective and across the section in Fig. 9. CA1 refers to the ten-story residential building case model of the first category. CA1s refers to the short model case with five floors. Figure 10 shows the second category, a centralized atrium with air exhaust openings

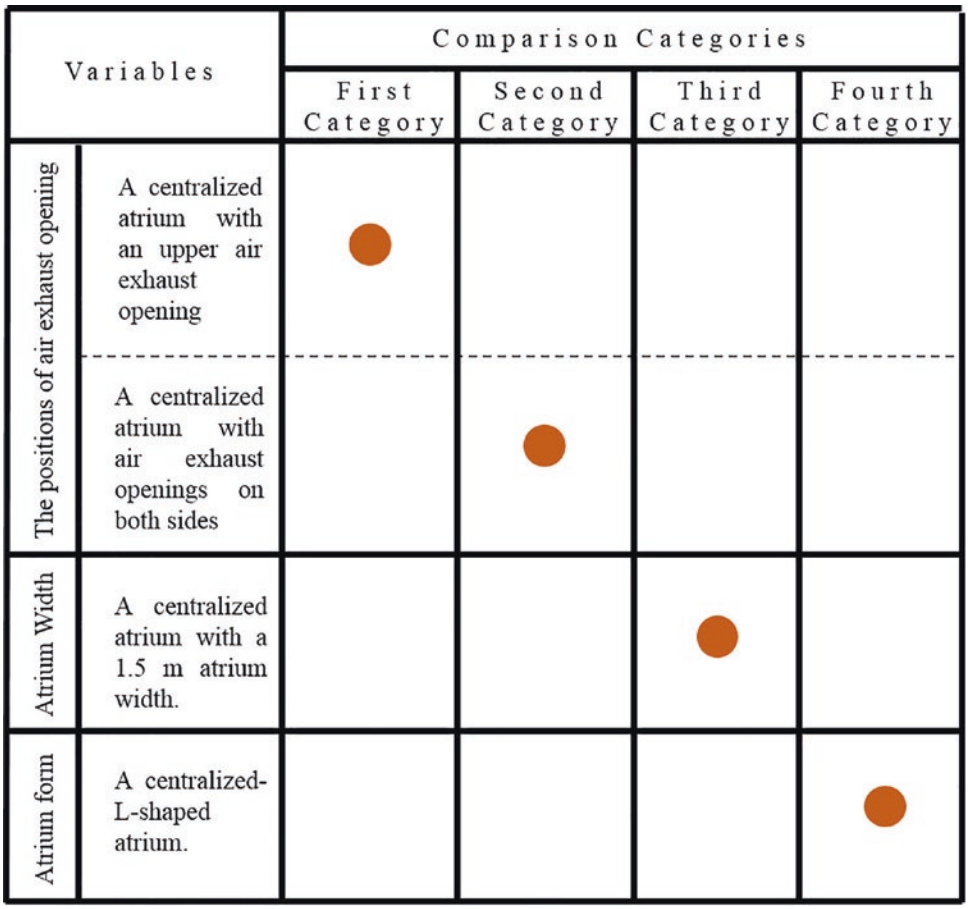


Fig. 7 There are four different comparison categories. Every category simulates one variable

on both sides, in a 3D perspective and across the section. CA2 refers to the first category's ten-story residential building model. CA2s refers to the five-story short model. The third category's centralized atrium plan, positioned between the master and living rooms, is 1.5 m wide and has an upper air exhaust opening, as indicated in Fig. 11. In the 3D perspective and section, Fig. 12 depicts the third category. The ten-story residential building model in the third category is referred to as CA3. CA3s refers to the five-story short model. The fourth category of the centralized atrium, as shown in Fig. 13, is an L-shaped plan with an upper air exhaust opening. In the 3D perspective and section illustrated in Fig. 14, the fourth category is visible. CA4 refers to the first category's ten-story residential building model. CA4s refers to the five-story short building.

3.2 Simulation

Mesh Models: The primary consideration in modeling airflow is the accuracy of the numerical solver for grids' generation. The numerical solver would perform the iterations for calculations from one cell to adjacent cells depending on the numerical models employed. In selecting a mesh type for the model, the setup time issue is significant. The mesh is created using face sizing with an element size type. Smaller values produce more divisions. A value of "0" tells the sizing control to revert to its default setting (ANSYS, 2010). In this simulation, the element size is set at 0.5 m. The results of fine meshes used in the comparison are shown in Figs. 15 and 16.

Boundary Condition: As stated in Fig. 17, the August weather data summary information is used as boundary conditions in CFD simulations. The outside temperature is 27 °C, with a humidity level of 71%. The air velocity is 4 m/s. The air, cooled by evaporative cooling, enters the master room through vents in all categories. The vents have a width of 1.20 m and a height of 0.5 m. The master bedroom's exhaust air is channeled out of the building through the centralized atrium, which serves as inlet 1. Inlet 1 is 21.8 °C on average. The centralized atriums also provide fresh air to the living rooms and remove exhaust air from the buildings. Two vents in the living room are stacked on top of each other. The vents are also 1.20 m * 0.5 m in size. The exhaust air from the living room enters as inlet 2 with an average temperature of 24.8 °C. The positions of inlet 1 and inlet 2 are shown in Fig. 13.

CFD Simulation Procedure: Using the CFD software ANSYS Fluent, the CFD turbulence model uses a K-epsilon

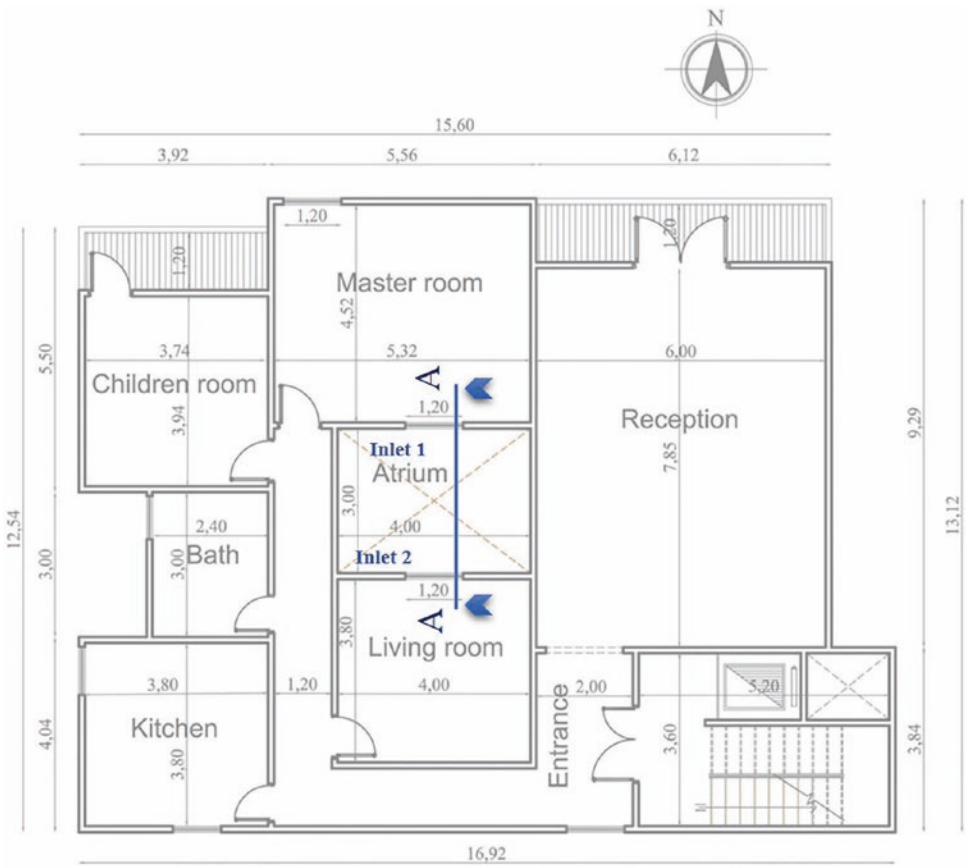


Fig. 8 First and second categories' centralized atrium plan is located in the master bedroom and living room center

modeling approach with a realizable model as the turbulence model and Species Transport as the specific model (Meroney, 2009). The CFD software solves the equations for the conservation of mass, momentum, and total energy with steady state. For spatial discretization, the pressure–velocity coupling scheme used is COUPLED, the pressure scheme is second order, and the momentum scheme is second-order upwind scheme. To achieve a solution, the iteration is based on the energy equation and standard initialization.

4 Result and Discussion

The centralized atriums provide fresh air and direct exhaust air out of the modeling building in all categories. As mentioned in the boundary condition, fresh air enters the master room after being cooled by one of the evaporative cooling systems, such as a pond or fountain. The exhaust air from the master bedroom is driven out of the building through a centralized atrium. The exhaust air is configured as an inlet 1 to the atrium in simulation, and its average temperature is 21.8 °C. A centralized atrium provides fresh air to the living room and removes exhaust air. The exhaust air from the living room is assigned to inlet 2 in the simulation. Its average temperature is 24.8 °C. Figures 18 and 19 show the velocity vector along the middle vertical planes and the temperature distribution along the Y–Z-axis in the middle of the X-axis for every category.

The modeling building in the first category has a centralized atrium with an upper air exhaust opening. In comparison with the CA1 atrium, the velocity vector demonstrates that the airflow is not evenly dispersed throughout the whole space of the CA1s atrium. Because the tall height causes larger temperature differences along the Y–Z-axis, the airflow in the CA1 atrium is better distributed. The highest velocity and maximum airflow are found in the CA1 and CA1s atriums on the ground floor. Furthermore, the airflow focuses on the outlet louvers as it is the only outlet in the atrium. The airflow in the upper corner of the CA1 atrium is minimized more than in the CA1s atrium. The modeling building in the second category includes a central atrium with air exhaust openings on both sides. Due to the CA2 atrium's height, the airflow is better spread across the entire space of the CA2 atrium as opposed to the CA2s atrium. In the CA2 atrium, temperature differences along the Y–Z-axis produce an acceptable stack effect. The ground floor level of the CA2 and CA2s atriums has the maximum velocity. In the top corner of each atrium, the airflow is reduced. Also, the exhaust air flows more

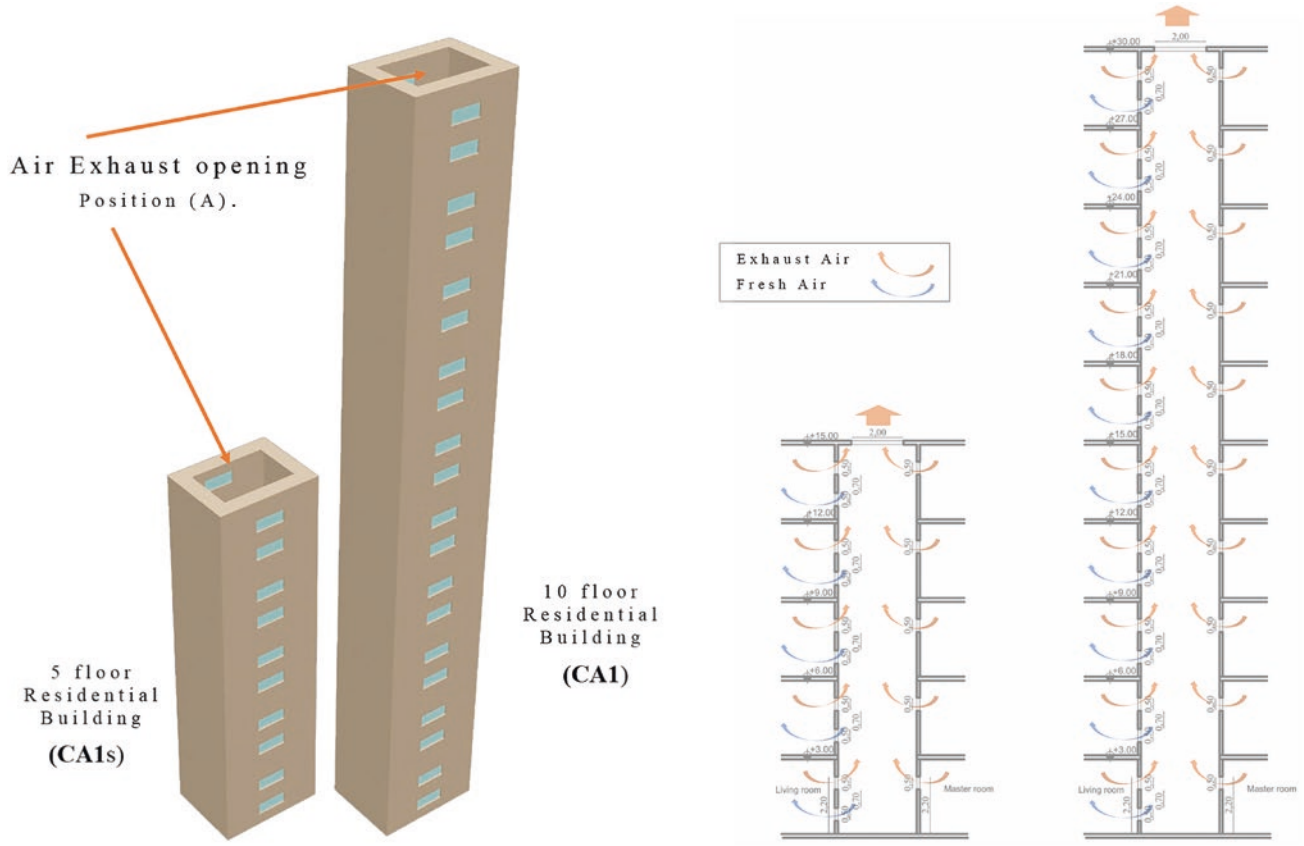


Fig. 9 First category, a centralized atrium with an upper air exhaust opening, is seen in a 3D perspective and across the section

toward the opening in the opposite wind direction. It directs exhaust air away from the building more effectively than a windward opening. Furthermore, stagnant air may be created in the CA2s atrium's top corner. The modeling building in the third category features a central atrium with an upper air exhaust with a width of 1.5 m and a length of 4 m. Based on the velocity vector, the airflow in the CA3s atrium is spread better across the space than in the CA3 atrium. In both atria, the peak velocity is seen on the ground floor. According to the temperature contour that describes temperature differences in the atrium, temperature differences along the Y–Z-axis in the CA3s atrium are larger than in the CA3 atrium. The narrow width of the CA3 atrium may make it difficult to guide exhaust air toward the upper opening. As previously stated, the role of CA3 and CA3s atriums is to provide fresh air while also removing exhaust air from the building. As a result, the narrow width of the CA3 atrium may not allow adequate airflow along the Y–Z-axis. The modeling building in the fourth category has a centralized L-shaped atrium. The airflow in the CA4 and CA4s atriums is not fully distributed for the velocity vector. In both atria, the peak velocity is seen on the ground floor. The airflow does not move through the whole L-shaped plan at the velocity contour of the CA4s atrium plan. In addition, airflow is reduced at the corner of the L-shaped CA4s atrium. The atrium is almost separated into two regions, as shown by the temperature contour. As a result, stagnant air could create in the atrium's corner. In addition, air may flow through the atrium's center.

The atrium is more clearly split into two parts at the temperature contour of the CA4 atrium. As a result, the air in the CA4 atrium may not flow properly. Also, stagnant air may accumulate at the corner of the atrium. Figure 20 shows the average surface temperature of the atrium wall in CA1, CA2, CA3, and CA4. W1 serves as the master bedroom wall. W2 is the living room wall. The average temperatures of W2 in CA4 are the highest compared to CA1, CA2, and CA3. In the CA4 model, the average temperature of W2 is around 23.28 °C on the eighth floor, which is the lowest figure. On all floors, the average temperatures of W1 in CA1 and CA2 are lower than CA3 and CA4. In the CA1 model, the average temperature of W2 is around 23.21 °C on the sixth floor, which is the highest figure. In the CA2 model, the average temperature of W2 is around 23° C on the first, fourth, fifth, and ninth floors. In the CA3 model, the average temperature of W2 exceeds 23 °C on the first, second, and eighth floors. In general, the wall surface average temperature is the best in the CA1 model. The

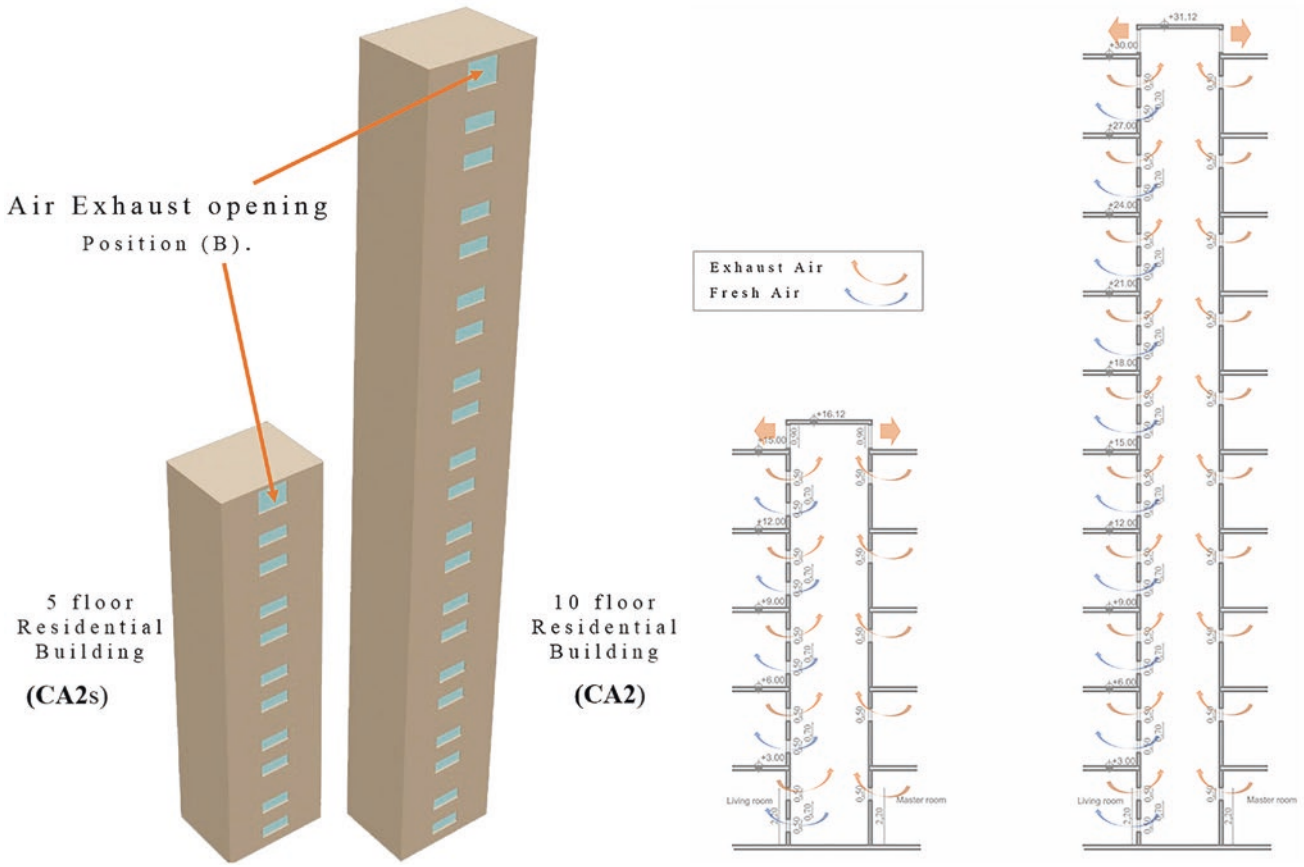


Fig. 10 Second category, a centralized atrium with air exhaust openings on both sides, is seen in a 3D perspective and across the section

temperature contour of the atrium (differences in temperature) on each floor in CA1, CA2, CA3, and CA4 is shown in Fig. 21. Figure 22 shows the atrium wall surface average temperature in CA1s, CA2s, CA3s, and CA4s. W1 serves as the wall of the master bedroom. W2 is the wall of the living room. On all floors, the average temperatures of W1 in CA1s and CA2s are lower than the temperatures in CA3s and CA4s. In the CA1s model, the average temperature of W2 exceeds 23 °C on the first and third floors. Furthermore, the average temperature of W2 exceeds 23 °C on the first and fifth floors in the CA2s model.

In the CA3s model, the average temperature of W2 is around 22.99 °C on the second floor, which is the lowest figure. In the (CA4s), the average temperature of W1 and W2 is the highest on the second floor. Figure 23 shows the temperature contour of the atrium on each floor in CA1s, CA2s, CA3s, and CA4s.

4.1 Interpreting Findings to Close a Research Gap

The airflow in the master bedroom is caused by temperature differences between the heated air within the room and fresh air, which is made chilly by evaporative cooling. The airflow is forced to go toward the direction of the atrium as a result. Stack ventilation works best in tall buildings because of the temperature differences between the lower and upper floors. The relationship between the atrium's height and width also has an impact on the airflow in the atrium vertically. Finally, if the parameters of the atrium are examined, an atrium with an evaporative cooling system is considered a suitable low-tech system in a tall residential building.

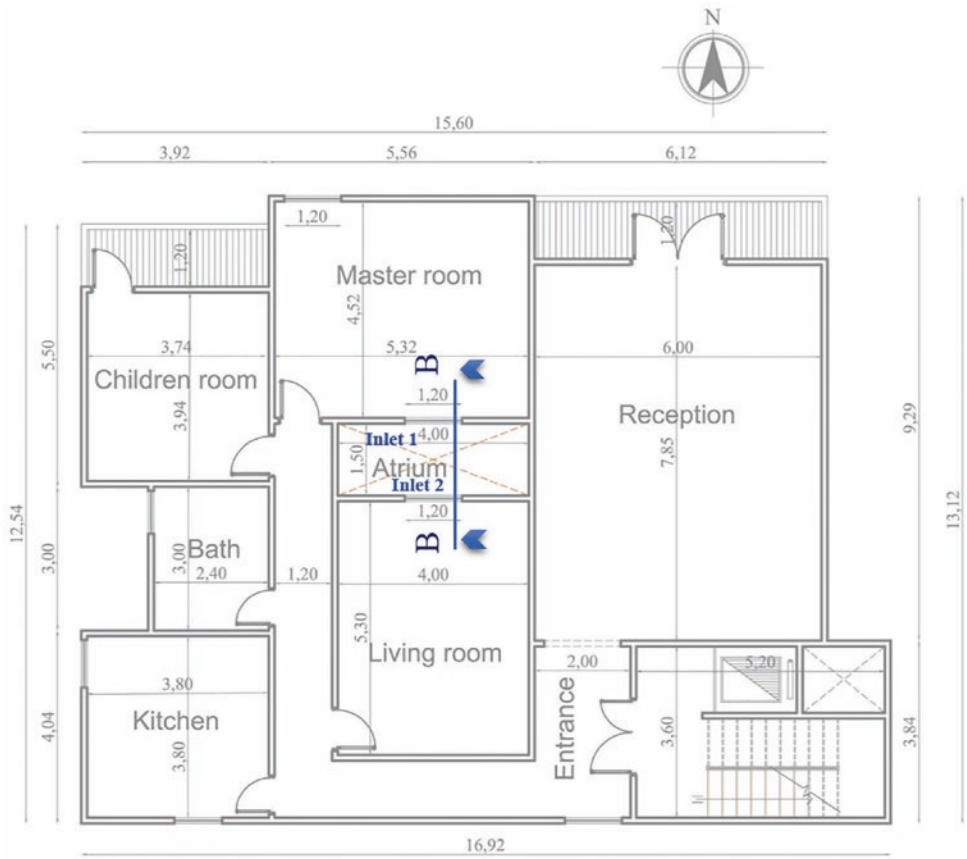


Fig. 11 Centralized atrium plan for the third category is 1.5 m wide

5 Conclusion

A low-tech solution for increasing the effectiveness of the stack effect is to implement an atrium with evaporative cooling. This technique relies on a fountain or pond to cool the air before it enters the building. The modeling buildings had a centralized atrium located between the master bedroom and the living room. Four variables were simulated using a CFD simulation to predict airflow rate and pattern. The variables were divided into two outlet opening positions, atrium width, and atrium shape.

In addition, the factors were applied to two different height cases: a five-story residential building and a ten-story residential building. A centralized atrium pushed the exhaust air from the master bedroom out of the building in all categories. The atrium provided fresh air to the living area while also removing exhaust air from the building. As shown in Fig. 24, five recommendations for atrium design are provided as a result of the experiment. First, the air exhaust opening's location at the top is appropriate for thoroughly distributing air along the Y–Z-axis (Fig. 24a). Second, the opening facing the opposite wind direction is ideal for venting the building's exhaust air (Fig. 24b). Third, the width-to-length ratio of the atrium is crucial for achieving a suitable stack effect (Fig. 24c). Fourth, the rectangular plan is preferable for the atrium with an L-shape plan because stagnant air can accumulate at the corner of the L-shape plan (Fig. 24d). Fifth, it is advised to utilize a centralized atrium with a rectangular form in a ten-story residential structure with an upper air exhaust entrance to achieve an acceptable stack effect (Fig. 24e).

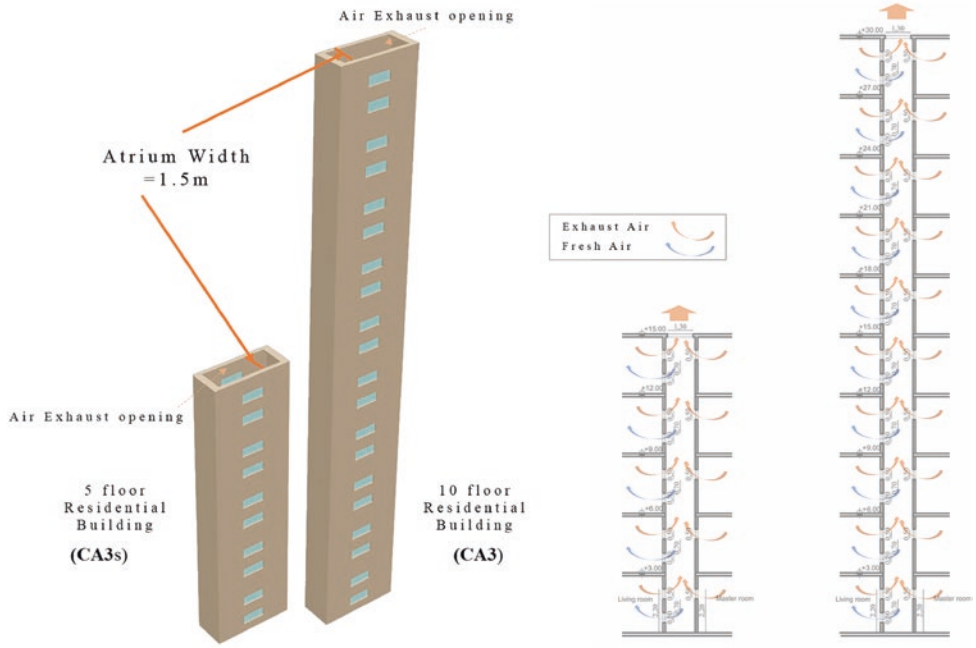


Fig. 12 Third category, a central atrium with a 1.5 m atrium width, is seen in a 3D perspective and across the section

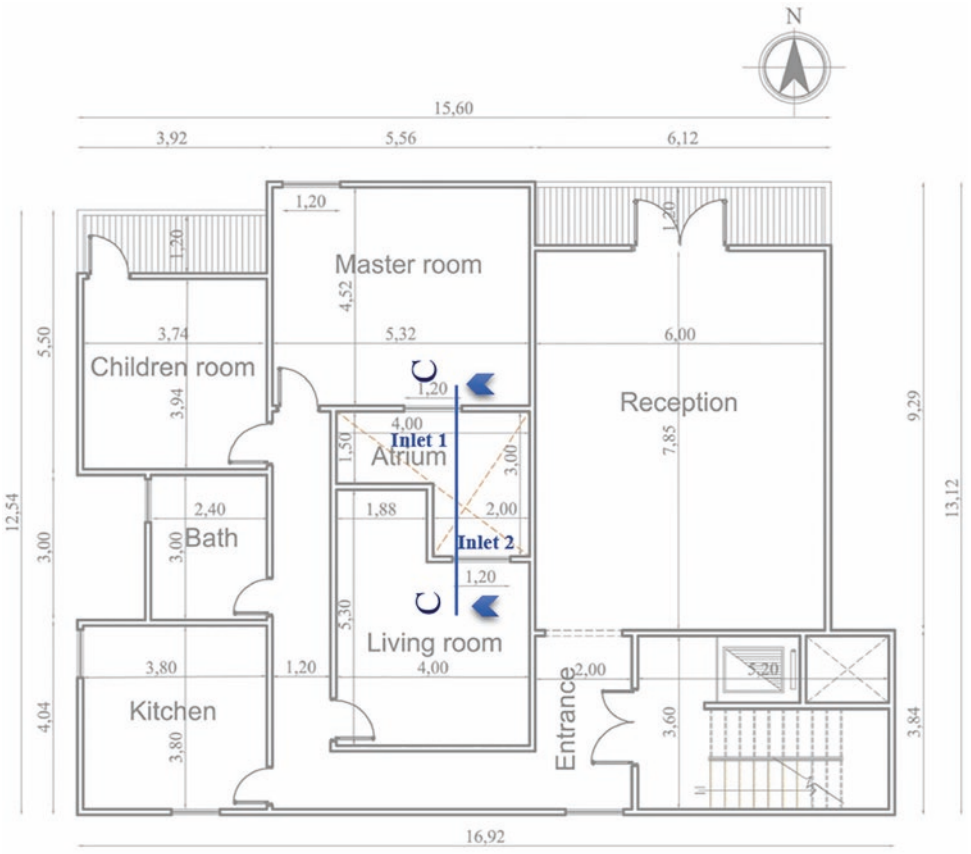


Fig. 13 Centralized atrium plan for the fourth category is L-shaped

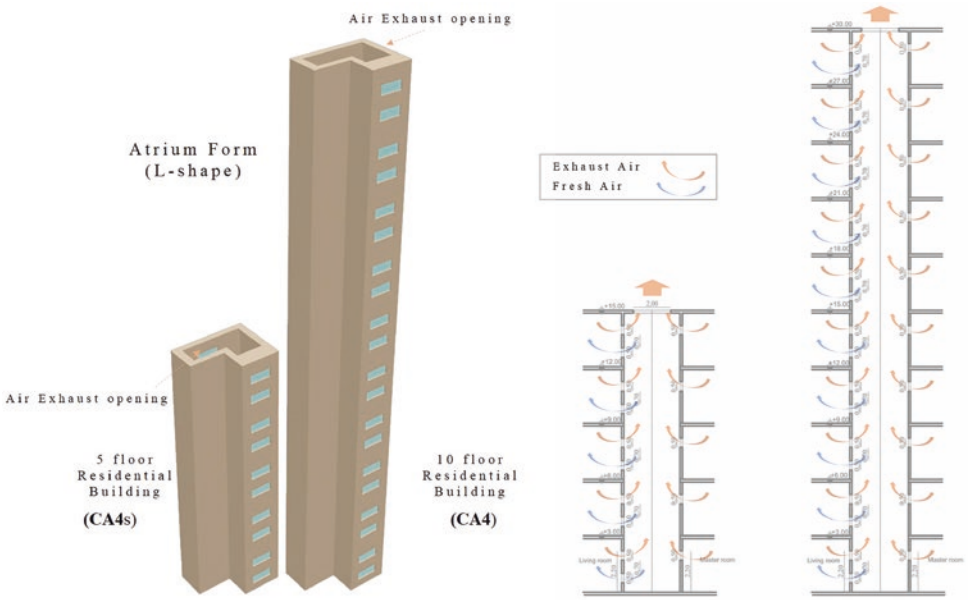


Fig. 14 Fourth category, a centralized-L-shaped atrium, is seen in a 3D perspective and across the section

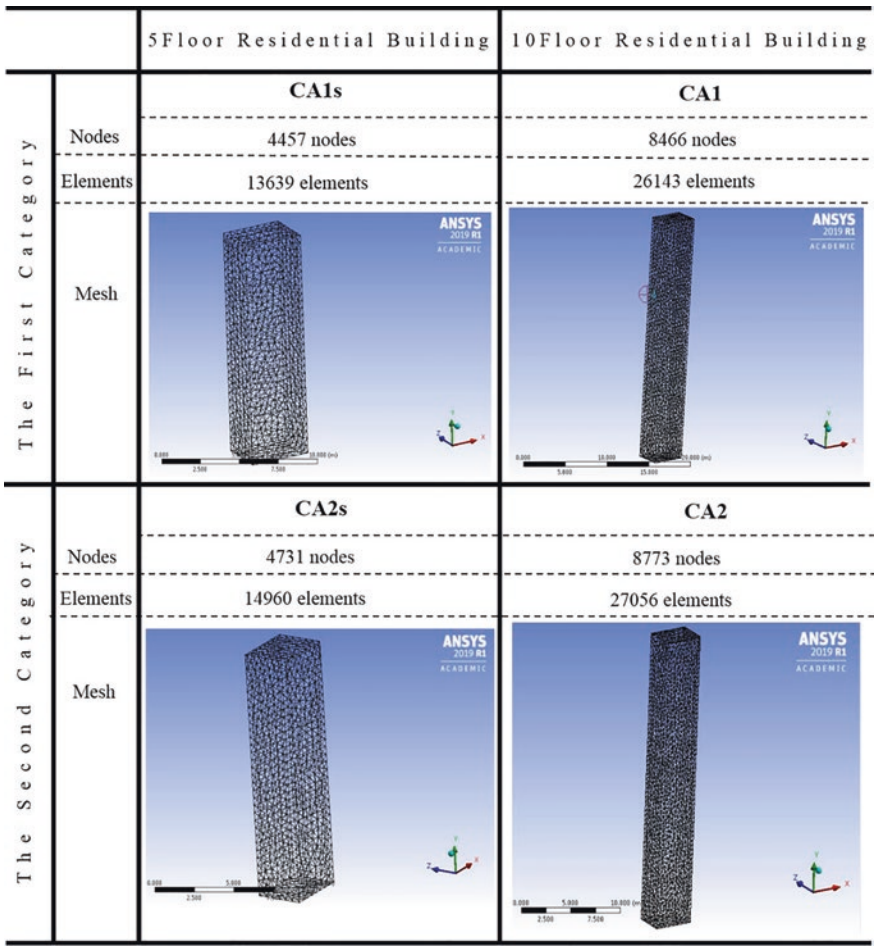


Fig. 15 Results of fine meshes are utilized to compare five- and ten-story buildings in the first and second categories

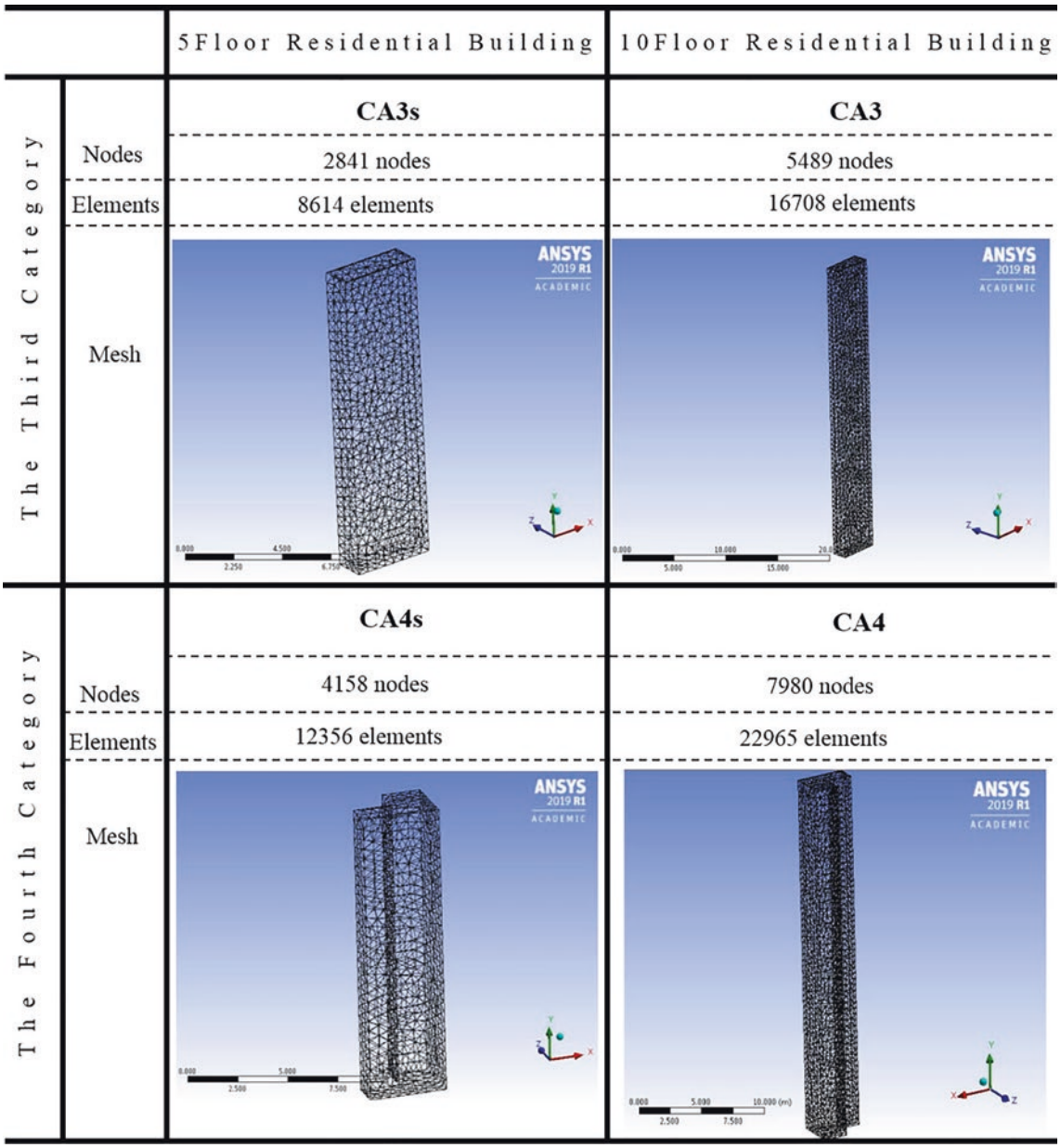


Fig. 16 Results of fine meshes are utilized to compare five- and ten-story buildings in the third and fourth categories

Fig. 17 August weather data information is used as the boundary conditions in CFD simulations

The boundary condition in CFD simulation	
Air Velocity	4 m/s
Outside temperature	27 °C
Relative Humidity	71%
Inlet Temperature (1)	21.8° C
Inlet Temperature (2)	24.8° C

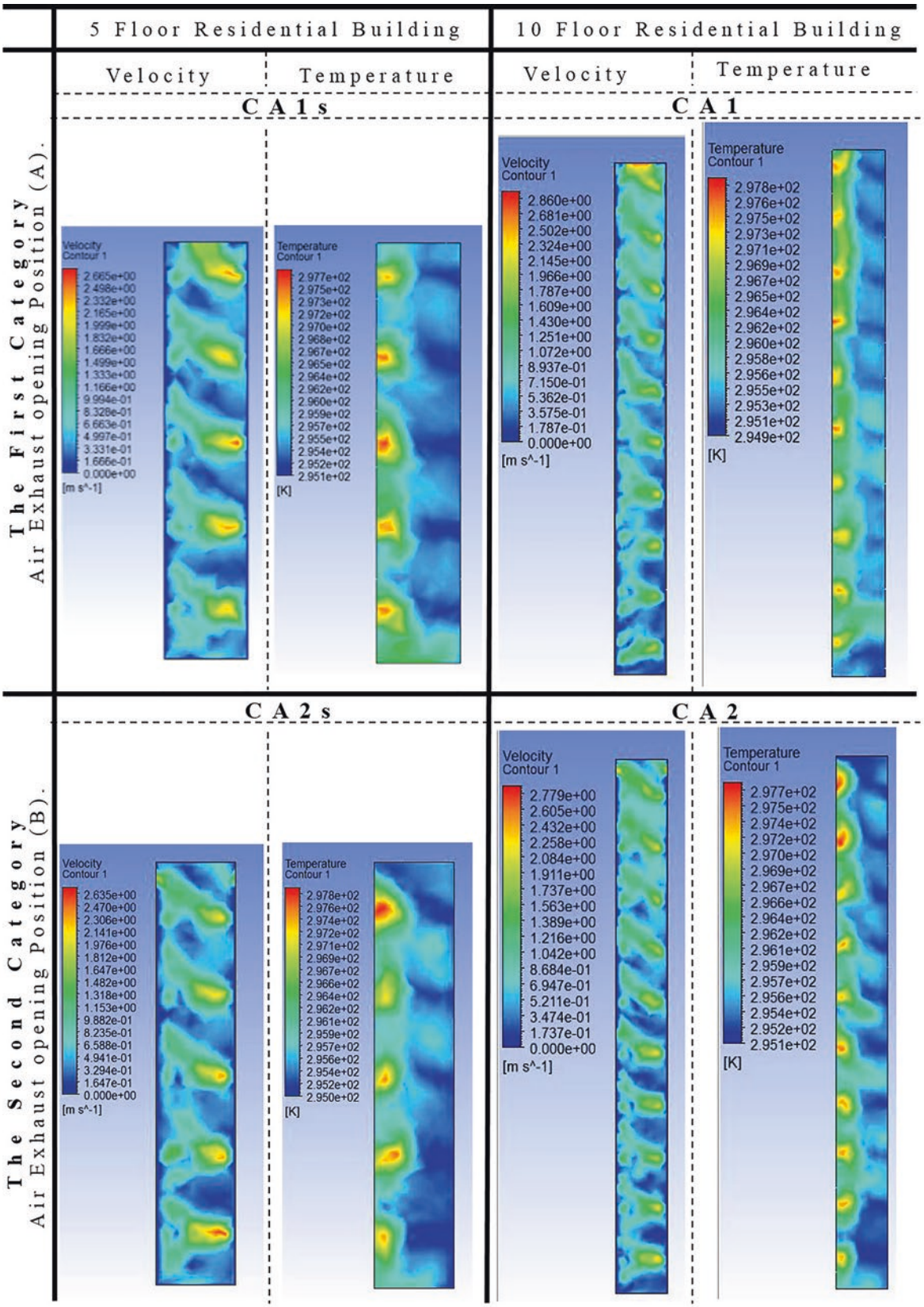


Fig. 18 Velocity vector and temperature distribution along the Y–Z-axis in the middle of the X-axis for the first and second categories

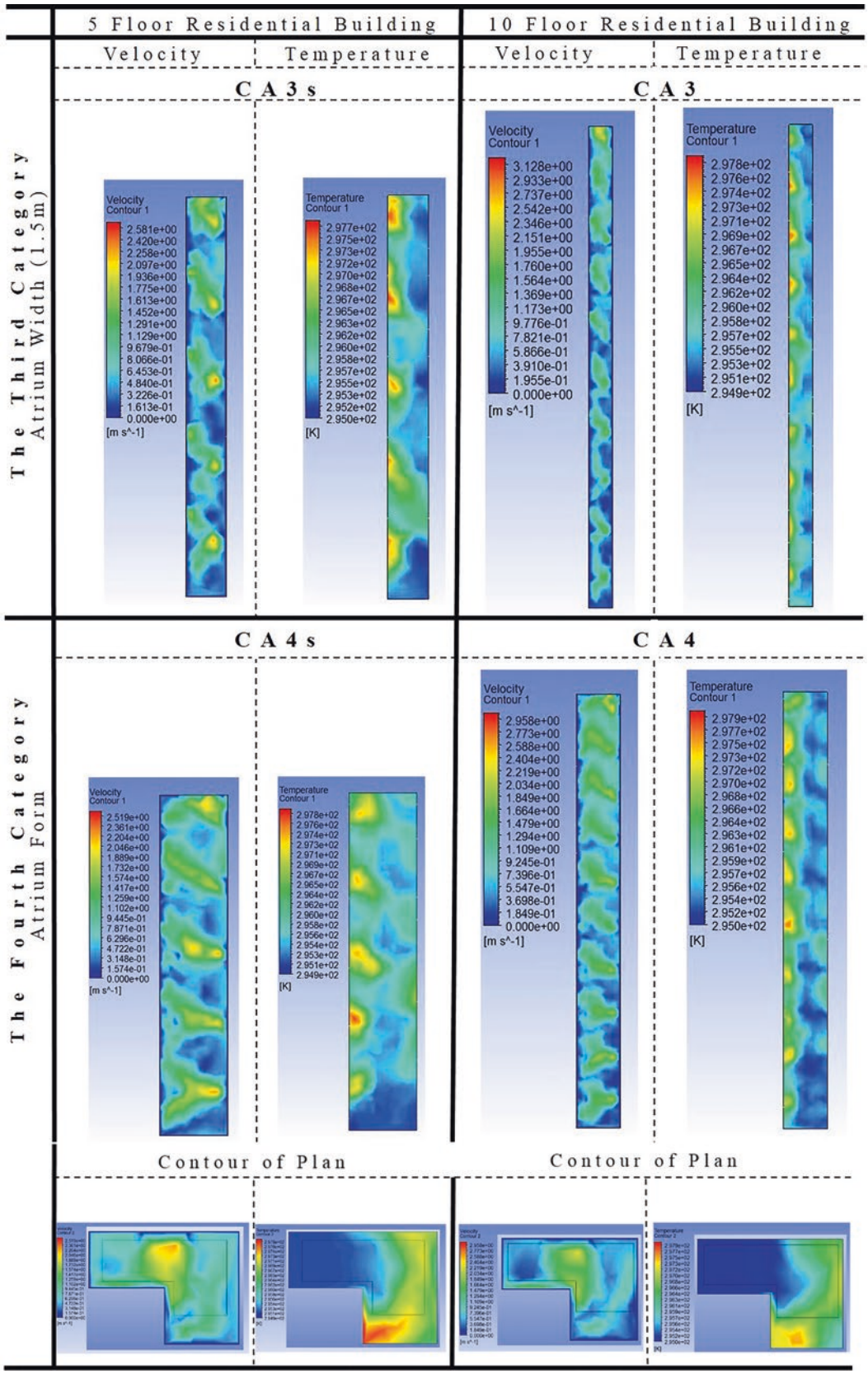
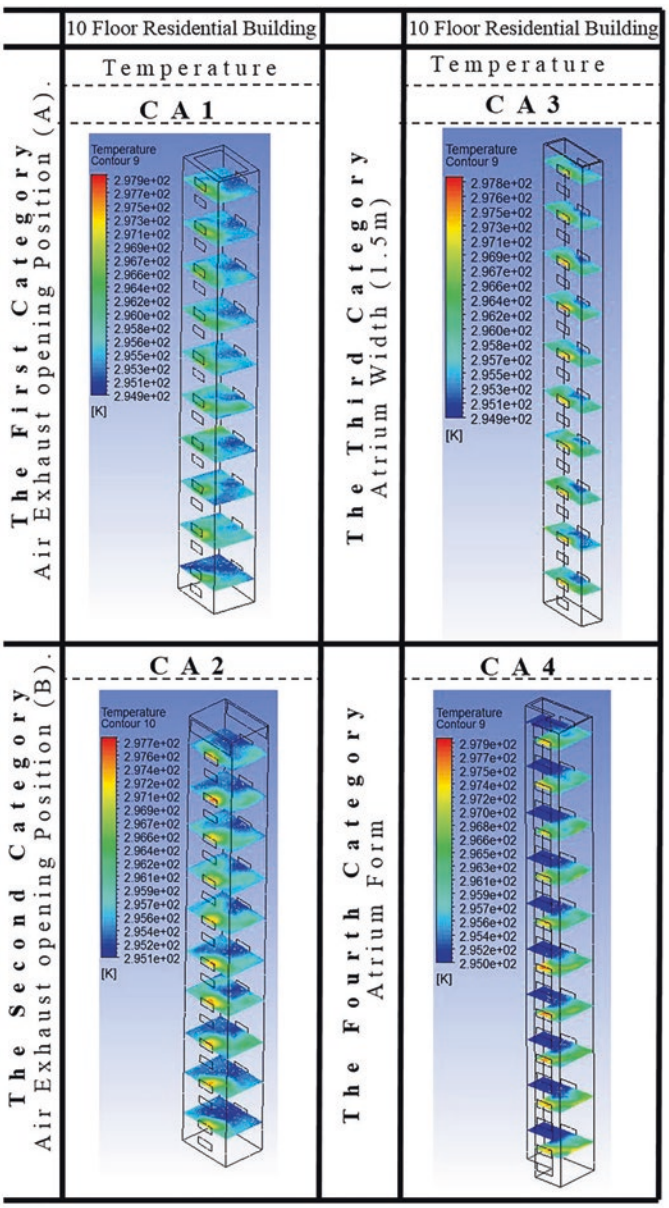


Fig. 19 Velocity vector and temperature distribution along the Y–Z-axis in the middle of the X-axis for the third and fourth categories

Fig. 20 Atrium wall surface average temperature in CA1, CA2, CA3, and CA4

Floor NO.	CA1		CA2		CA3		CA4	
	W1	W2	W1	W2	W1	W2	W1	W2
1	22.1	22.7	22.09	23	22.34	23.37	22.26	23.45
2	22.37	22.78	22.13	22.93	22.36	23.06	22.43	23.51
3	22.19	22.60	22.40	22.89	22.49	22.92	22.40	23.64
4	22.47	22.94	22.29	23	22.41	22.89	22.39	23.67
5	22.30	22.70	22.20	23	22.44	22.79	22.35	23.59
6	22.25	23.21	22.15	22.91	22.32	22.95	22.29	23.45
7	22.11	22.99	22.21	22.92	22.36	22.71	22.22	23.37
8	22.10	22.90	22.10	22.89	22.39	23.24	22.26	23.28
9	22.07	22.90	22.15	23	22.26	22.84	22.30	23.69
10	22.10	22.98	22.22	22.95	22.23	22.82	22.24	23.49

Fig. 21 Temperature contour of the atrium on each floor in CA1, CA2, CA3, and CA4



Floor NO.	CA1s		CA2s		CA3s		CA4s	
	W1	W2	W1	W2	W1	W2	W1	W2
1	22.30	23.16	22.12	23.07	22.34	23.21	22.31	23.45
2	22.20	22.83	22.13	22.90	22.35	22.99	22.69	23.77
3	22.15	23.06	22.24	22.95	22.32	23.12	22.36	23.70
4	22.10	22.91	22.21	22.93	22.32	23.21	22.33	23.35
5	22.30	22.80	22.28	23.10	22.33	23.14	22.28	23.24

Fig. 22 Atrium wall surface average temperature in CA1s, CA2s, CA3s, and CA4s

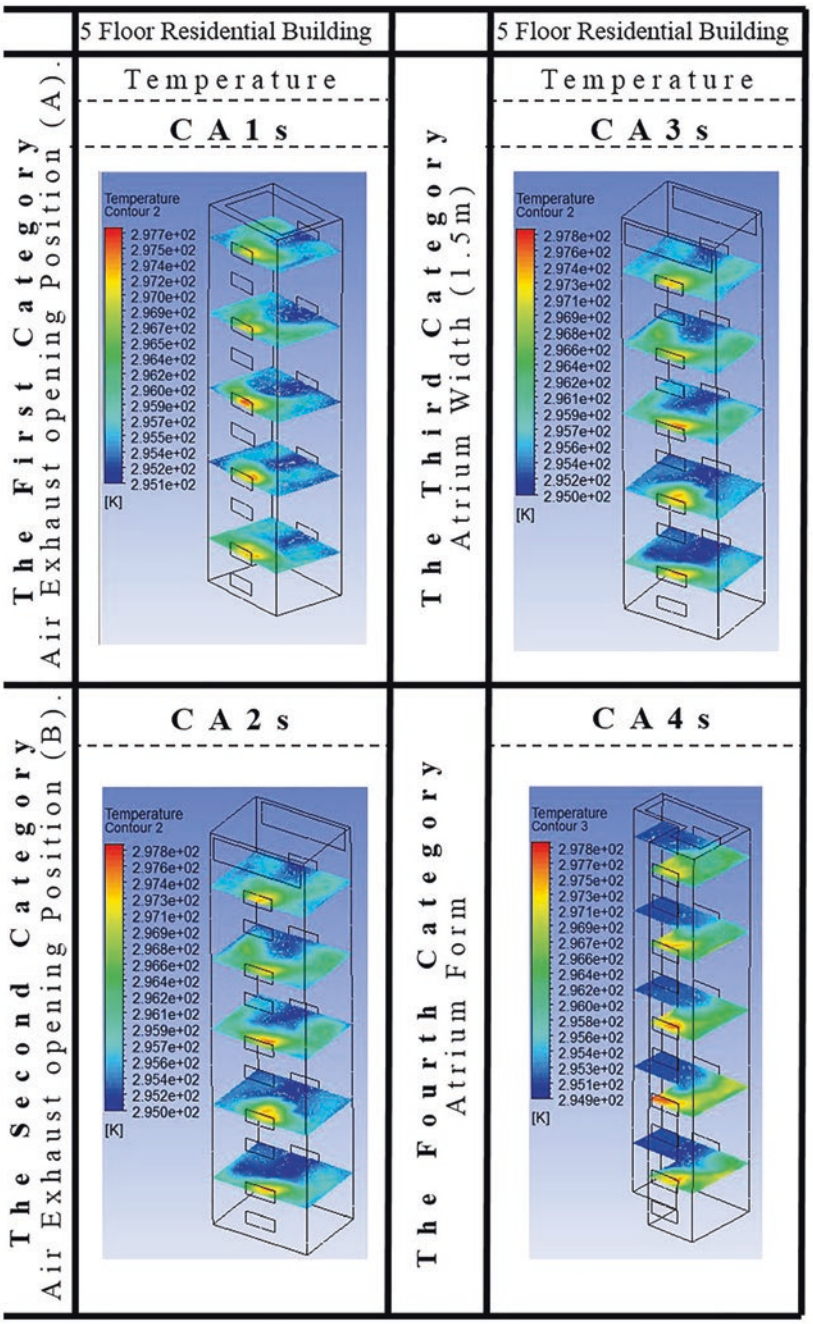


Fig. 23 Temperature contour of the atrium on each floor in CA1s, CA2s, CA3s, and CA4s

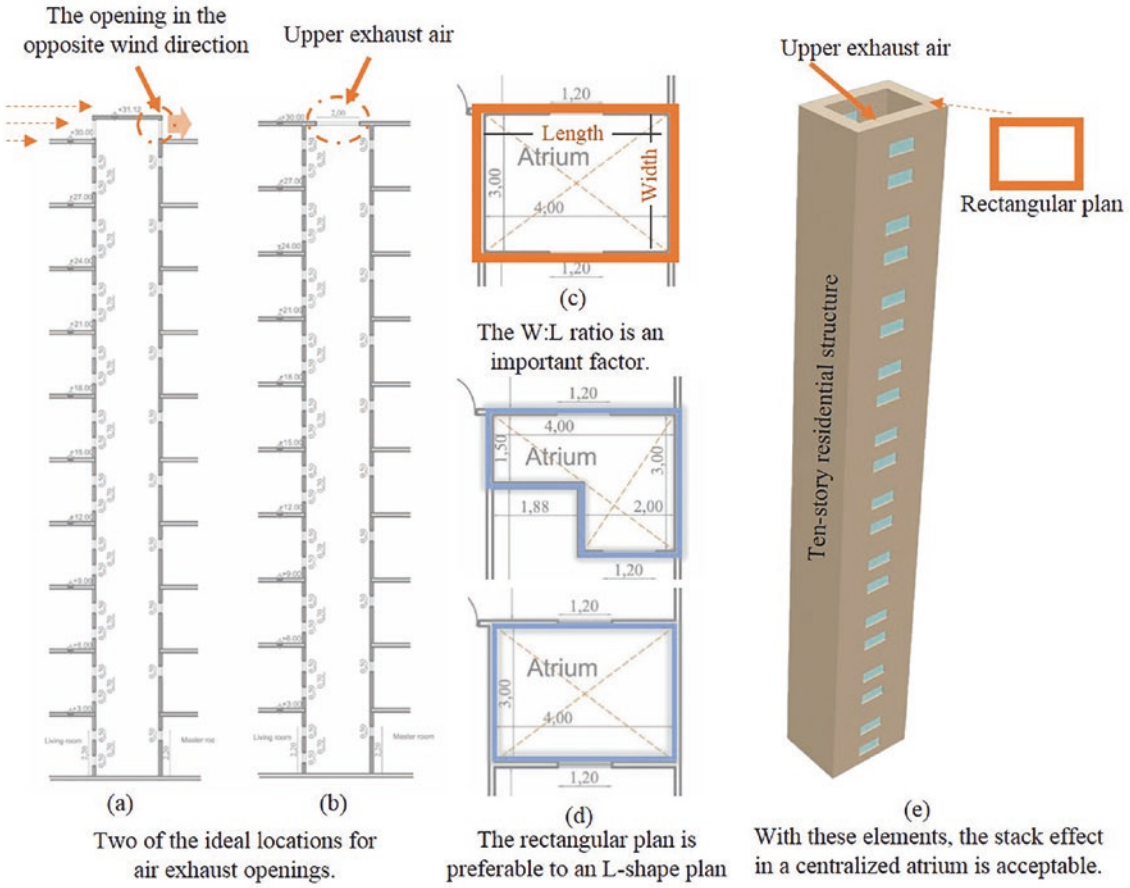


Fig. 24 Five recommendations for atrium design are provided as a result of the experiment

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Conclusion

In this comprehensive book, "Building Resilient and Healthy Cities: A Guide to Environmental Sustainability and Well-being," we have embarked on a journey to explore the critical role of greenery and nature-based solutions in urban areas. Through a series of thought-provoking chapters, we have scrutinized the multifaceted challenges posed by urbanization and the pressing need for environmental sustainability and societal well-being. Let us now synthesize the valuable insights gained from these chapters and critically assess the significance of integrating green solutions in our urban landscapes to combat energy poverty, mitigate urban overheating, and enhance the overall quality of urban life.

The initial chapters cast a spotlight on the foundation of our exploration. "Health and Environmental Resilience and Livability in Cities" underscored the indispensable link between health, environmental resilience, and urban livability. It set the stage for our subsequent chapters by emphasizing the pivotal role of urban planning in fostering well-being. "Greening the Local Solid Waste Management Through Community Participation" and "The Role of Waste Pickers in Solid Waste Management" delved into the intricacies of solid waste management, highlighting the potential for sustainability through community involvement.

As we advanced, "Air Pollution and Solid Waste" provided a stark reminder of the environmental challenges we face, emphasizing the urgency of green and resilient recovery strategies. "Generating a Design Concept of a Multi-regulation Biomimetic Envelope" introduced innovative concepts for improving comfort conditions in the built environment, emphasizing biomimicry and multiregulation as potential game-changers. Similarly, "The Role of Architectural Heritage" offered insights into architectural preservation's role in resilient urban planning, particularly in times of crisis such as lockdowns.

In the pursuit of reducing urban overheating, "Evaluating the Summertime Overheating Signature of Domestic Buildings" presented a methodological approach using synthetic temperature data to address a pressing issue. "Calm Space" explored the creation of inclusive and supportive outdoor areas, specifically tailored to benefit children with autism, underlining the importance of space design to address specific societal needs.

Part two of the book, "Principles of Green Urbanism and the Transformation to a Greener Sustainable Environment," shifted our focus to the principles of green urbanism. "Greenification of Dense Neighborhoods Through Pocket Parks" and "Guardians of Urban Public Spaces" introduced practical case studies that demonstrated the transformative potential of small green spaces and green markets in enhancing urban sustainability. "Environmental Assessment for Sustainable Land Use in Protected Landscapes" stressed the significance of preserving natural landscapes within urban settings, while "Empirical Analysis of the Impacts of the Refugee Influxes on Amman Urban Characteristics" addressed the critical issue of urban adaptation to demographic shifts.

"The Innovative Housing Models for Green Architecture" highlighted the resurgence of garden-cities, offering historical references with contemporary relevance. "Measuring to Evaluate Alternatives" and "Potential Benefits of Application of Green Roofs" delved into practical applications and assessments of green solutions in urban planning. Finally, "CFD Study Toward Eco-Economical Tall Residential Housing" examined cutting-edge research for eco-economical tall buildings in Mediterranean climates.

In conclusion, this book serves as an illuminating guide to the complex challenges and promising solutions in urban environmental sustainability and well-being. It underscores the vital importance of integrating greenery, nature-based solutions, and sustainable design principles into urban planning. However, it is crucial to recognize that the journey is far from over, and more work is needed to bridge the gap between theory and practice, exploring the complexities of urban development.

As we reflect on the chapters' content and their critical assessment, it is evident that green urbanism and sustainable development are not mere academic concepts but practical imperatives. The significance of greenery and nature-based solutions in close proximity to societal well-being, the fight against energy poverty, and the

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mitigation of urban overheating cannot be overstated. To build resilient and healthy cities, we must continue to explore, innovate, and apply the principles and strategies outlined in these chapters. As we look toward the future, it is essential to embrace a holistic, collaborative, and dynamic approach to urban development, one that prioritizes the well-being of current and future generations in the face of urban challenges. This book serves as a valuable compass for navigating this path to a greener, more sustainable, and healthier urban future.