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VOLUME 1

SPATIALIZING WASTE MANAGEMENT STRATEGIES: THE 3R4UB EXPERIENCE

Edited by
Gabriella Esposito De Vita,
Marina Rigillo

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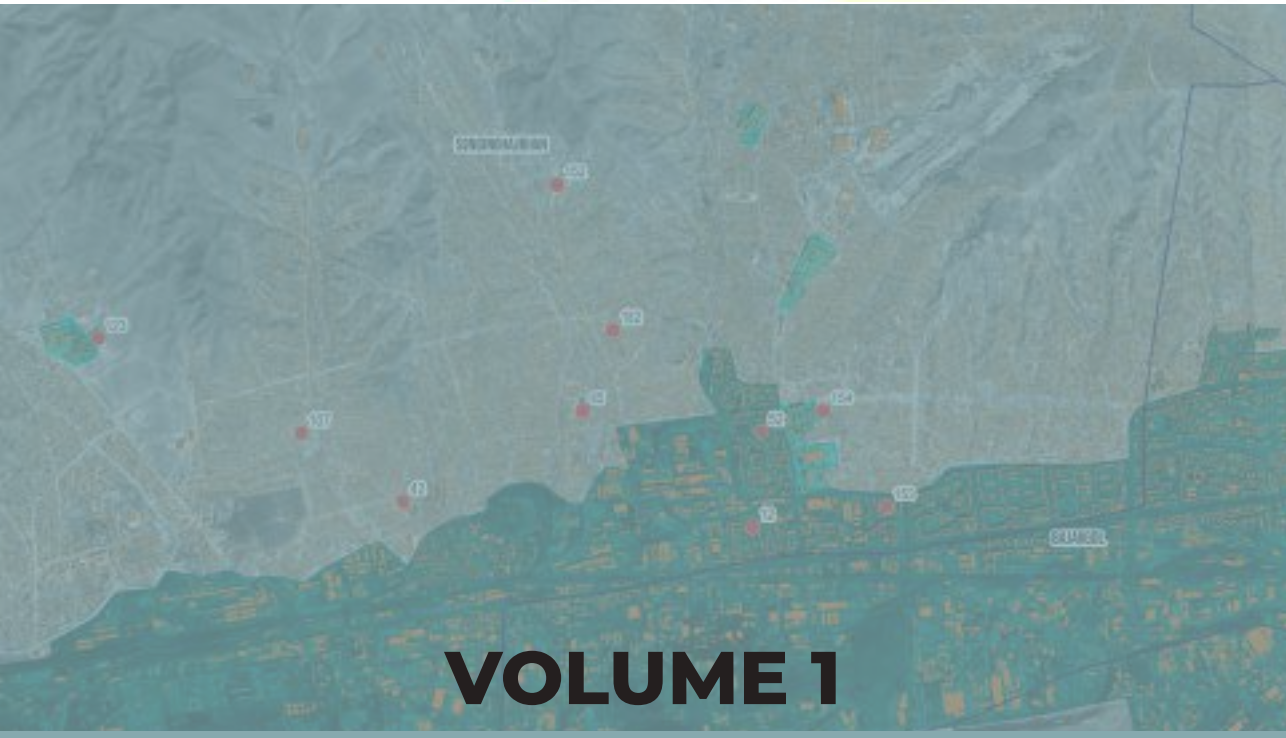

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We would like to share the book with the CNR IRISS director Paolo Landri and the former directors Alfonso Morvillo and Massimo Clemente who supported the project throughout its challenging and rewarding phases. Our heartfelt thanks go to Fabrizio Canonico, the project's Technical Coordinator, for his unwavering commitment.

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SUMMARY

00 Enabling strategies within international cooperation programs: the 3R4UB rationale

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Current environmental challenges invite us to deeply revise policies, governance models, and resource management toolkits pushing towards a more circular approach. Notably, circular waste management is one of the pillars of responsible and foresighted planning for territorial sustainability as well as a key part of the Sustainable Development Goals (SDGs) matching both social innovation and environmental objectives. In this framework, the "3Rs for a sustainable use of natural resources in Ulaanbaatar" (3R4UB) aims at developing and transferring a site-specific sustainable approach to urban solid waste management, focusing on providing effective opportunities for developing circular supply chains in the target area of the Mongolian capital city by providing Ulaanbaatar Municipality with a co-designed masterplan for urban waste management.

3Rs4UB aligns with the European Union's framework and specifically with the SWITCH Asia Program, enhancing environmental awareness by adapting collaborative tools for civic engagement and capacity building in so developing both research advances and international cooperation. The SWITCH Asia program promotes sustainable consumption and production (SCP) with the aim to "support the transition of Asia, the Middle-East and the Pacific to a low-carbon, resource-efficient and circular economy while promoting sustainable production and consumption patterns, and greener supply chains between these regions and Europe"[1]. The program aims

1 Through its 2019 EU Green Deal and Global Gateway, the EU has further committed to supporting the transition of countries to a low-carbon, resource-efficient and circular economy. This has also strengthened the knowledge basis and momentum of the programme in supporting Asian countries' SCP com-

to improve the environmental performance of products throughout their life cycle, it stimulates demand for better products and production technologies, and it helps consumers make informed choices. The Programme, launched in 2007, helps 24 countries across Asia to tackle global challenges regarding the side environmental effects of the rapid economic growth such as increased use of natural resources, growing greenhouse gas emissions and larger waste streams[2].

Under these umbrella concepts, the 3R4UB rationale is rooted in the idea that research-based projects can act as enabling strategies, creating new knowledge while at the same time delivering tangible outcomes for local communities. According to the aims of the EU SWITCH Asia funding program, a combination of research, knowledge transfer, training, and civic engagement activities has been designed and put in practice to enhance capacity building and local empowerment towards sustainable development goals. The three pillars of this site-specific approach cover social awareness dimensions, circular economy aspects and a tangible pilot to trigger a snowball effect in Ulaanbaatar.

This peculiar sociotechnical approach to the waste management plan and treatment plant is rooted on the co-design approach developed by the CNR IRISS research group throughout years of experience on different scales and multiple territorial contexts. According to this background, the social component of the technological flow has been delivered through fieldwork, local engagement and mutual learning with the communities involved.

The research focused on the spatialization of resources/waste flows in the formal and informal settlements of Ulaanbaatar, while also considering cultural traditions, social structures, and community habits, in terms of a purposely designed combination of spatial planning, governance modelling, and capacity building activities. Enhancing technical knowledge, integrating the multilayer structure of the waste management technical

mitments as part of SDG 12 and the Paris Agreement. Cfr. https://www.switch-asia.eu/switch-asia/who-we-are/

2 Since its launch, about 143 projects have been funded across a wide range of sectors including energy efficiency in industrial plants and houses, agri-food and fishing sectors, textiles and leather, tourism, logistics and freight. These have been implemented by over 500 Asian and European partners and some 100 private sector associates, which indirectly benefitted up to 80,000 MSMEs. The evidence from the projects feeds into dialogues with national and regional governments and other stakeholders, strengthening the implementation of sustainable production and consumption policies. Cfr. https://international-partnerships.ec.europa.eu/policies/programming/programmes/switch-asia_en

organization within the urban master-planning, and supporting the development of a collaborative approach in rising and spreading environmental awareness are the main tasks the research group planned with the local institutional partners.

In fact, the project rationale has been designed for providing effective research outputs and for generating demonstrable impacts on the target territory, namely an engagement campaign with the schools and the educational communities, a participated pilot project for testing the capacity in waste collection and management. Furthermore, the project worked at improving local technical governance by devising the city's waste management masterplan with specific technical guidelines, and policy recommendations.

These ambitious objectives have been reached thanks to the composition and expertise of the 3R4UB partnership. The consortium is composed of CNR (leading partner), Metellia Servizi S.r.l., Municipality of Ulaanbaatar (UB City) and Fresh Water Resources and Nature Conservation Center (FWRNCC). As CNR[3] is the largest public research institution in Italy, the IRISS Institute hosts researchers from different backgrounds: urban and regional planners, experts in international law, economists and sociologists. These disciplines are intertwined within the specific expertise of Metellia for designing a collaborative design approach with the Mongolian side, in order to plan shared territorial transformations, social inclusion and urban regeneration.

This book is a set of 3 publications developed to share the results of project and enhance the awareness regarding the opportunities of a circular waste management4[4]. Following the

3 CNR was founded on 18 November 1923. Its mission is to perform research in its own Institutes, to promote innovation and competitiveness of the national industrial system, to promote the internationalization of the national research system, to provide technologies and solutions to emerging public and private needs, to advise Government and other public bodies, and to contribute to the qualification of human resources.

4 Cookbook: THE 3Rs FOR SUSTAINABLE USE OF NATURAL RESOURCES IN ULAANBAATAR. Giannini Editore, Naples, 2025. ISBN: 9788869065064 | e-book ISBN: 9788869065071. Edited by Marina Rigillo and Gabriella Esposito. Printed in Naples by Officine Grafiche Francesco Giannini e Figli S.p.A., October 2025.

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Volume 2: SOCIAL INNOVATION TOWARDS ENVIRONMENTAL CHALLENGES: COLLABORATIVE APPROACHES TO WASTE MANAGEMENT. Giannini Editore, Naples, 2025. ISBN: 9878869065101| e-book ISBN: 9788869065118. Edited by Marina Rigillo and Ga-

publication of the 3R4UB Cookbook, a sort of "recipe book" aimed at transferring the project methodology and the results achieved, this volume focuses on the spatial dimensions of the project, integrating the different sectorial technical solutions within a system approach to the 3Rs. The third volume mainly focuses on the social impacts of the educational programs combined with the civic engagement initiative.

The present book, reports the specificity of the Ulaanbaatar mapping program depicted to recognize the different urban contexts. Mapping program highlights the specific characteristics of the different urban patterns, city's stratification and the settlement typologies (Chapter 1). Such a critical perspective feeds the Spatially Informed Waste Management (UBSIWM) framework integrating multilayer datasets and qualitative data into a coherent GIS-based tool. As research output, an interpretative thematic atlas has been designed to test the actual potentialities of the UBSIWM approach in terms of a replicable framework for transitional urban contexts where formal planning struggles to engage with informality and rapid demographic change. Chapter 2 introduces the masterplan for waste management. This latter was co-designed with the Mongolian partners by applying a systemic planning approach to detect the specific needs of the Ulaanbaatar neighbourhoods: differences in building typologies, population densities, and accessibilities have been considered within the masterplan. This latter has also been paired with a capacity building program, including training to UBCity officials, community engagement and analysis of best practices as described in Chapter 3. The dialogue with Mongolian universities and the involvement of scholars and students from the University of Naples Federico II gave to the research group the opportunity to explore innovative solutions to enhance the potentiality of a circular approach: circular hubs for the waste management cycles have been designed in order to involve local communities in a daily circular experience (Chapter 4).

The visual survey concludes the book. Photographs made by Francesco Sammarco during his fieldworks in Mongolia offers original perspectives of UBCity, its inhabitants, and its habits.

briella Esposito. Printed in Naples by Officine Grafiche Francesco Giannini e Figli S.p.A., October 2025.

CHAPTER 01

Mapping Ulaan Bataar: urban pattern in a critical perspective

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Abstract

This chapter critically examines the methodological trajectory and empirical outcomes of the Ulaanbaatar Spatially-Informed Waste Management (UBSIWM) framework in the 3R4UB project. The research advances a multi-scalar, spatially explicit understanding of waste governance by integrating heterogeneous datasets into a coherent GIS-based geodatabase and producing an interpretative thematic atlas. Methodologically, the study highlights the dual function of GIS as both an analytical instrument - capable of revealing spatial discontinuities, infrastructural deficits, and accessibility patterns - and a socio-technical device that mediates knowledge between experts, public institutions, and civil society. The development of an interactive StoryMap served as a narrative infrastructure, transforming spatial evidence into a shared platform for dialogue and collective learning. Findings suggest that the UBSIWM approach contributes to current debates on sustainable waste management, data spatialisation, and urban narrative, offering a replicable framework for transitional urban contexts where formal planning struggles to engage with informality and rapid demographic change.

Keywords

Sustainable waste management, Data spatialisation, Urban narrative, GIS

1. Introduction

In the context of escalating global environmental challenges, the shift towards a circular economy (CE) has emerged as a priority for both scholars and policymakers seeking to reconcile economic growth with planetary limits (Sharma et al., 2021), considering the earth as the third actor in the ecological and territorial transition (Perrone, Marchigiani, Esposito De Vita, & Rossi, 2021). Within this paradigm, sustainable waste management is no longer a technical end-of-pipe solution but a cornerstone of spatial planning aimed at fostering responsible, resilient, and resource-efficient urban systems (Memon, 2010; Gurjar & Gaur, 2022). The 3R4UB project – "The 3Rs for a Sustainable Use of Natural Resources in Ulaanbaatar" – positions itself within this global discourse, focusing on Mongolia's rapidly transforming capital city as a testbed for innovation in waste governance.

Funded under the European SWITCH-Asia programme, the project seeks to develop and transfer an integrated, spatially informed model of municipal solid waste management (MSWM) that embeds the principles of reduce, reuse, recycle (3Rs) and fosters collaborative participation between public authorities, local communities, and educational institutions (Esposito De Vita et al., 2023). This entails moving beyond the traditional linear "produce–consume–dispose" model towards regenerative cycles of resource use, privileging material recovery, waste minimisation, and long-term sustainability (Adami & Schiavon, 2021).

A distinctive feature of the 3R4UB approach is its emphasis on spatial mapping as both an analytical and participatory device. By employing Geographic Information Systems (GIS), the project enables a granular reading of waste flows and infrastructural gaps, supporting the design of targeted interventions and optimised collection routes (Singh, 2019; Sakshi et al., 2023). The resulting geospatial data are not treated merely as static information layers but are narratively reassembled through ArcGIS StoryMaps, producing a multi-scalar, interactive representation of the city's waste dynamics.

Within this overarching framework, the CNR research group identified three main objectives:

- to map settlement functions in relation to Ulaanbaatar's Waste Master Plan, distinguishing between the planned city, the

spontaneous city, and the city in transition;

- to influence residents' behaviour through education by involving students, teachers, and families as key agents of change;
- to identify ecological–settlement "assembly mechanisms" starting from the spatial reading of the urban fabric.

GIS emerges as an indispensable tool in this process, offering a platform to visualise spatial inequities, locate intervention priorities, and design neighbourhood-scale eco-hubs that function as nodes for waste separation and recycling. By combining quantitative data (e.g., waste volumes, infrastructure distribution) with qualitative evidence (photographic reportage, storytelling from school campaigns), the 3R4UB project constructs a layered narrative (Perkins, 2008; Graham & Zook, 2015) of urban metabolism that is both analytically robust and socially meaningful.

Ulaanbaatar (UB), Mongolia's capital and largest city, provides a paradigmatic case for exploring transitional urban dynamics. Home to approximately 1.77 million residents, nearly half of the country's population, UB is simultaneously Mongolia's cultural, industrial, and financial heart and a city grappling with severe planning and environmental challenges (Karthe et al., 2022). Its geographic location in the Tuul River valley at 1,300 m elevation – combined with one of the harshest climates of any world capital – intensifies its infrastructural vulnerabilities, particularly in heating, transportation, and air quality management.

Founded in 1639 as a nomadic Buddhist monastic center, UB changed location 29 times before settling permanently in 1778. The city's modern identity was consolidated in 1924, renamed Ulaanbaatar and designated the capital of the newly established Mongolian People's Republic. Beginning in the 1950s, Soviet-style master plans initiated the transformation of UB's spatial and social fabric, replacing traditional ger districts, sprawling across Ulaanbaatar's flatlands, valleys, and hillsides (Miller, 2013), with prefabricated housing blocks, constructing the road network, and centralising services.

The 1954 master plan projected growth to 125,000 residents by 1974, yet migration from rural areas consistently exceeded forecasts: the population had already reached 180,000 by 1960.

Subsequent plans in 1961, 1975, and 1986 sought to control growth through satellite cities and migration limits but were repeatedly overtaken by demographic reality. The post-1990 democratic transition marked a turning point: as state controls loosened and herders faced economic hardship, massive rural-to-urban migration accelerated, fuelling the expansion of informal settlements (Park et al., 2019).

Today, Ulaanbaatar can be conceptualised as a tripartite urban organism (Sammarco et al., 2025):

- The Planned City represents the Soviet legacy, characterised by grid layouts, multi-storey apartment blocks, and centralised infrastructure for heating, transport, and waste collection.
- The Spontaneous City consists of the informal ger districts, sprawling across the periphery and hillsides, where residents live in traditional portable dwellings often without sewerage, paved roads, or central heating.
- The City in Transition denotes hybrid zones where new infrastructure (roads, schools, high-rise apartments) is emerging but remains fragmented and uneven, reflecting the tension between formalisation and informality.

This tripartition is not only a morphological classification but also a socio-political lens through which to interpret disparities in service access, environmental risk, and governance capacity. The ger districts, in particular, epitomise the coexistence of modernity and tradition: while many households have electricity and private cars, they still rely on coal-fired stoves, contributing to severe winter air pollution – one of UB's most pressing public health crises.

The accelerated expansion of Ulaanbaatar over the past three decades has profoundly reshaped the city's spatial and social fabric. Its built-up area has grown nearly fourfold - from 10,730 hectares in 1990 to more than 39,000 hectares by 2020 (Bolormaa et al., 2019) - a pace of growth that has placed severe pressure on infrastructure and municipal services. Much of this expansion has occurred in an unplanned and informal manner, giving rise to sprawling ger districts that now host more than half of the city's population. These informal settlements, while emblematic of Mongolia's nomadic tradition, often lack the most basic urban services, including sewage systems, paved

roads, and reliable waste collection, generating fragmented governance (Duurenbayar, 2016). The resulting landscape is a patchwork of well-serviced Soviet-era neighbourhoods and extensive areas of infrastructural deficit, where residents rely on coal-fired stoves, pit latrines, and informal waste disposal practices.

These infrastructural shortcomings intersect with severe environmental challenges. The city's valley location, combined with its long, harsh winters, traps emissions from domestic stoves, heat-only boilers, and coal-fired power plants, leading to some of the highest levels of winter air pollution recorded worldwide. The situation is further aggravated by UB's rapidly motorising society: public transport coverage remains limited and irregular, prompting a surge in private car ownership that intensifies congestion, contributes to greenhouse gas emissions, and strains a road network originally designed for a much smaller population. Waste management, too, suffers from systemic inefficiencies. Collection services are uneven, treatment infrastructure is insufficient, and the city remains heavily dependent on landfilling, with illegal dumping sites proliferating on its peripheries. These combined pressures compromise not only environmental quality but also public health and social equity, threatening the long-term liveability of the city.

Governance challenges amplify these problems. Regulatory frameworks are fragmented and enforcement is weak, as evidenced by the fact that less than one-third (29.6%) of the targets set in the 2013 master plan were successfully implemented (Karthe et al., 2022). The recently approved seventh master plan (2025–2040) represents an attempt to correct decades of uncoordinated development by promoting decentralisation, expanding green infrastructure, and reimagining mobility systems in line with sustainable and climate-resilient urban models. However, the plan's success will depend on the ability to operationalise its ambitious goals through precise, spatially informed strategies capable of bridging the gap between vision and implementation (Sammarco et al., 2025).

It is precisely in this context of complexity and fragmentation that the 3R4UB project introduces the Ulaanbaatar Spatially-Informed Waste Management (UBSIWM) approach, positioning spatial analysis as both a methodological framework and a political instrument. Rather than treating mapping as a neutral

technical exercise, the project employs it as a critical means of making urban dynamics legible and actionable. By integrating demographic data, infrastructural networks, and waste generation patterns, GIS enables a multi-scalar diagnosis of the city's urban metabolism, revealing disparities between the planned city, the spontaneous city, and the city in transition. This spatial intelligence highlights precisely where interventions—whether in infrastructure, collection routes, or public services—are most urgently needed.

Beyond diagnosis, the layering of spatial data supports scenario-building exercises, allowing planners to model alternative configurations for waste collection, treatment, and recycling. Potential locations for neighbourhood-scale eco-hubs, transfer stations, or decentralised waste treatment facilities can be evaluated in terms of accessibility, service coverage, and environmental impact. In this way, GIS becomes a decision-support tool that can guide policy towards more efficient, equitable, and locally adapted solutions.

A central innovation of the UBSIWM approach lies in its commitment to participatory engagement. The visual outputs of the spatial analysis - interactive maps, thematic layers, and ArcGIS StoryMaps - are designed to be intelligible not only to technical experts but also to citizens and community groups. This accessibility facilitates dialogue, fosters co-production of knowledge (Turnhout et al., 2020), and strengthens collective ownership of the solutions being proposed. Crucially, the integration of qualitative storytelling, including photographic documentation and narratives from school-based awareness campaigns, ensures that the data are grounded in lived experience rather than presented as abstract statistics. This narrative dimension resonates with the principles of urban narrative mapping (Perkins, 2008), turning the spatial analysis into a shared cultural resource capable of shifting perceptions - from seeing waste as a nuisance to recognising it as a potential resource.

Ultimately, the spatial reading provided by UBSIWM is not simply descriptive but strategic, offering a framework through which Ulaanbaatar can align its waste governance with broader global sustainability agendas such as SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). By embedding spa-

tial intelligence into the core of municipal planning, the 3R4UB project does more than address immediate operational issues: it lays the foundation for a replicable, GIS-enabled model of sustainable waste management that could inform similar efforts in other transitional or rapidly urbanising cities across the Global South and post-socialist regions.

2. Ulaanbaatar Spatially-Informed Waste Management (UBSIWM): methodological approach

Building on the historical and spatial reconstruction of Ulaanbaatar presented in the previous section, the research developed within the 3R4UB project introduces a methodological approach specifically designed to address the city's complex urban dynamics through collaborative and spatialised waste management strategies. The Ulaanbaatar Spatially-Informed Waste Management (UBSIWM) framework was conceived as both a technical and a relational device: while relying on geospatial tools, it also sought to foster dialogue between institutions, communities, and schools. Its key concept lies in the integration of collaborative GIS - understood as the coupling of geospatial tools with group spatial decision-making and public participation, from classic PPGIS frameworks to today's web- and real-time collaborative environments (Balram & Dragićević, 2006; Jankowski, 2006; Sieber, 2006; Kahila-Tani et al., 2019; Sun et al., 2016; Yaqin et al., 2022) – and the co-production[1] of knowledge, where mapping becomes not only a means of data processing but also a catalyst for participation, civic engagement, and place-based governance. In this sense, GIS is embedded in a broader effort of citizen science (Vohland et al., 2021), conceived as a platform for empowering local actors and producing shared knowledge to inform sustainable waste management.

The UBSIWM approach was framed within the broader tradition of action research and participatory spatial planning (Healey, 2003; Chambers, 2006; Turnhout et al., 2020). By involving local communities, schools, and institutional actors in data collection, interpretation, and restitution, the methodology aimed at generating a multivocal reading of the territory, activating new

1 The term co-production here follows Turnhout et al. (2020), indicating a collaborative process of knowledge creation that involves researchers, local institutions, and citizens in shaping both data and interpretation.

alliances between space, knowledge, and decision-making. To orient this process, the Sustainable Development Goals defined by the United Nations were adopted as guiding references, with particular attention to four macro-objectives most relevant to Ulaanbaatar's context: SDG 8 on decent work and economic growth, SDG 11 on sustainable cities and communities, SDG 12 on responsible consumption and production, and SDG 13 on climate action. These goals informed the construction of location criteria, the definition of spatial priorities, and the design of communication and training content later conveyed through the StoryMap platform.

The methodological framework (Fig. 1) was supported by a broad preliminary analysis of heterogeneous data, including official statistics from the National Statistics Office (NSO) of Mongolia and the Ulaanbaatar Statistical Yearbook, remote sensing and satellite data, field surveys, and photographic documentation. Additional layers of information came from technical reports produced by international cooperation agencies such as the Asian Development Bank (ADB), the Japan International Cooperation Agency (JICA), and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), together with contributions from local NGOs engaged in promoting waste separation and environmental awareness in marginal districts (Oppido, Ragozino & Esposito De Vita, 2023). All this material was systematised within a GeoDB GIS environment, enabling the superimposition of multiple thematic layers and their interpretation according to circularity criteria.

The operational path unfolded in three main phases, closely interconnected and progressively oriented toward action. Each phase not only responded to a technical need but also carried a strong symbolic and relational value, progressively strengthening the link between data, governance, and participation.

The first phase (definition of objectives and location criteria) was dedicated to clarifying the strategic assumptions of the plan and setting the foundation for subsequent actions. Three objectives were prioritised in alignment with the research topics of UBSIWM: (1) identifying ecological–settlement assembly mechanisms to ground waste strategies in the urban fabric (sustainable waste management); (2) mapping settlement functions in relation to the Waste Master Plan, distinguishing between planned, spontaneous, and transitional areas (data spa-

tialization); (3) building integrated spatial stories to transform data into shared narratives for dialogue and governance (urban narrative). Beyond their operational value, these objectives established a political horizon: a model of waste management that was not only more efficient but also more equitable and participatory. The elaboration of location criteria was particularly crucial, as it defined the parameters through which the suitability of different areas for new facilities or interventions could be assessed. These criteria combined quantitative indicators (population density, waste production rates, accessibility of infrastructures) with qualitative dimensions (social vulnerability, local practices, community willingness to engage). In this way, the first phase did not merely set technical targets but laid the groundwork for a governance model rooted in inclusiveness and accountability.

The second phase (operational mapping and selection of pilot areas) translated the objectives into practice through the construction of project actions and operational mapping. Three pilot areas were identified within the Ulaanbaatar masterplan for their morphological and functional heterogeneity, and for the different incidence of waste-related phenomena they presented. Each area offered a different laboratory of urban conditions: the planned city with its structured but ageing infrastructure, the spontaneous ger districts with their informal dynamics and infrastructural deficits, and the transitional areas where new development meets informality. In these zones, field surveys and visual narratives were carried out to reconstruct aggregate waste flows at the neighbourhood scale. This spatialised analysis made it possible to identify optimal sites for new eco-hubs[2], conceived as neighbourhood-level collection points that could improve efficiency while remaining accessible to the communities they serve. At the same time, a participatory awareness strategy was launched, starting with schools. These institutions were not only practical nodes for waste collection but also cultural nodes, capable of disseminating sustainable practices to students, families, and local communities. The integration of spatial analysis with participation, guided by principles of collaborative geodesy and inclusive planning practices (Fraser et al., 2006), turned the pilot areas into living laboratories where

2 By eco-hubs we refer to decentralized neighborhood-level waste collection and processing nodes designed to facilitate sorting, awareness, and community engagement around circular waste practices.

technical solutions and civic engagement were tested together.

The third phase focused on the restitution and interpretation of results, a moment as crucial as the analytical steps that preceded it. Here, data spatialisation was transformed into a process of collective storytelling. Thematic maps were developed to illustrate the actual state of waste in the three pilot areas, the distribution of existing plants, the structure of mobility networks, the localisation of potential eco-hubs, the mapping of stakeholders (industries, micro-enterprises, NGOs), and the role of schools engaged in awareness campaigns. These cartographic outputs were not intended as static descriptions but as interpretative devices, capable of guiding decision-making and structuring dialogue among stakeholders. Alongside the maps, photographic reportage played a decisive role: by visually narrating the material and social conditions of the neighbourhoods, it enriched the spatial data with human stories and contextual detail. The restitution was completed by the development of an interactive StoryMap platform on ArcGIS, which integrated maps, images, and texts into a dynamic environment accessible to both specialists and the wider public. This final step marked the shift from technical data to visual storytelling, reinforcing the communicative and pedagogical function of the project and demonstrating how spatial tools can become platforms for knowledge-sharing, capacity building, and participatory governance.

Taken together, these three phases illustrate the innovative scope of UBSIWM. By progressively linking strategic objectives, spatial analysis, and narrative restitution, the methodology transformed GIS from a technical tool into a relational infrastructure capable of supporting collaborative planning and strengthening the cultural and political legitimacy of waste management strategies in Ulaanbaatar. The process revealed how maps, far from being neutral artefacts, can operate as tools for governance and participation, aligning scientific evidence, community engagement, and policy decisions within a shared framework for sustainable urban development. In this environment, the data are also made readable to non-specialist audiences, reinforcing the communicative and pedagogical function of the project. This integration between technical data and visual storytelling draws inspiration from the principles of urban narrative mapping (Perkins, 2008) and the experiences of urban data storytelling (Graham & Zook, 2015), which are ca-

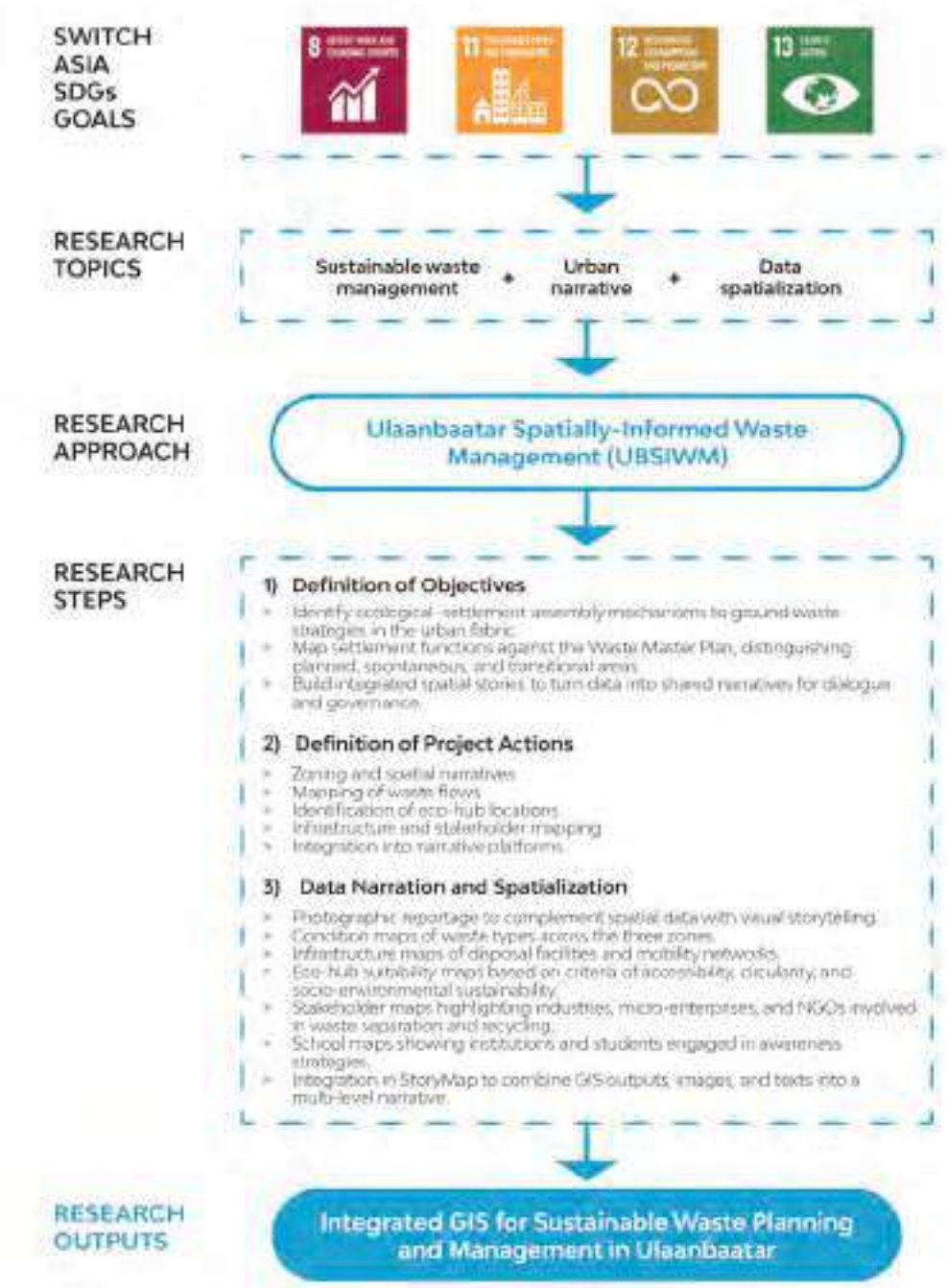

Fig. 1 - Ulaanbaatar Spatially-Informed Waste Management (UBSIWM) (author elaboration)

pable of rendering the complexity of local dynamics through a dialogic synthesis between different but interdependent forms of knowledge.

3. Results

Among the most relevant results achieved by the research, and completing the methodological path described in the previous chapter, a key role was given to the design of a narrative device capable of rendering not only the spatial complexity of the analysed phenomena but also the cultural, social, and symbolic dimensions that characterise the different forms of settlement in Ulaanbaatar. The choice to work with a StoryMap developed on the ArcGIS platform was guided precisely by this ambition: to go beyond the limits of conventional cartographic representation and to construct an interactive storyboard, where numerical data, images, textual narratives, and interpretative layers converge in a single environment. In this way, the StoryMap does not merely display information but enables a multi-level and shared reading of the urban context, integrating spatial analysis with forms of communication accessible to both experts and non-specialist audiences (Gurjar & Gaur, 2022; Sakshi et al., 2023).

The construction of this narrative platform was grounded in a comprehensive geodatabase compiled from multiple sources. Core information was drawn from official open-access datasets, such as those provided by the National Statistics Office of Mongolia (NSO)[3], the Ulaanbaatar City Master Plan[4] , and various public environmental databases[5].

3 See: National Statistics Office of Mongolia (NSO), official statistical data and reports available at: https://www.nso.mn [Accessed April 14, 2025].

4 See: JICA – Japan International Cooperation Agency (2009), The Study on City Master Plan and Urban Development Program of Ulaanbaatar City (UBMPS), Final Report. Available at: https://openjicareport.jica.go.jp/pdf/11937166_01.pdf [Accessed April 14, 2025].

5 Publicly accessible environmental data sources include: the UNEP WESR Climate Change Country Profile for Mongolia https://wesr-cca.unepgrid.ch/cca/mongolia/climate-change; the citizen-driven air quality monitoring platform Breathe Mongolia https://www.breathemongolia.org; the World Bank Environmental Indicators for Mongolia available on HDX https://data.humdata.org/dataset/world-bank-environment-indicators-for-mongolia; and the Asian Development Bank's Environmental Monitoring Reports for Ulaanbaatar infrastructure projects https://www.adb.org/sites/default/files/project-documents/45007/45007-004-emr-en_2.pdf.

To enrich and cross-check these materials, additional datasets were provided by research groups from partner universities in Ulaanbaatar[6], allowing the inclusion of more detailed and context-specific layers. All the collected data underwent a process of organisation and refinement within the QGIS environment, selected as the main processing tool for its capacity to ensure interoperability, traceability, and open access. As emphasised by Gurjar and Gaur (2022), the adoption of open-source solutions is crucial to guarantee that spatial data management remains transparent, reproducible, and available for further use by local institutions and communities.

Working through a cartographic narrative made it possible to highlight the profound heterogeneities that define Ulaanbaatar as a true "city within a city." The capital is articulated into markedly different urban fabrics: compact high-density districts rooted in planned development; extensive ger settlements, where social cohesion is strong but infrastructure is limited; and transitional areas, where new urban fragments overlap with incomplete service networks. Rendering this mosaic required an approach able to combine statistical evidence, field observations, and qualitative insights into a unified spatial framework.

A significant step in this direction was the construction of a collaborative GIS designed to support sustainable waste planning and management. This system integrates multi-source and multi-scalar data, producing thematic maps that portray both settlement distribution and waste streams in detail. As underlined by Sakshi et al. (2023), such cartographies establish a solid information base for developing targeted and place-specific interventions, aligning waste management strategies with the actual morphology of the territory.

The interpretative value of the system lies in the possibility to overlay different thematic layers - from demographic density and waste generation to transport networks, accessibility, and social vulnerabilities. This cross-analysis highlights the most fragile areas of the city, particularly the peripheral ger districts, where limited infrastructural provision combines with high exposure to environmental risks. Through this spatial synthesis, the maps do not merely describe problems but also indicate operational responses, suggesting where efficiency can be increased and sustainability improved.

AREA	DISTRICT	CITIZEN	WASTE (no ash) ton/year
1	Baganuur + Bagahangai + Bayanzurh + Nalaih	462.560	107.379
2	Bayangol + Han Uul + Suhbaatar	595.841	138.319
3	Chingeltei + Songinohairhan	509.600	118.299
		1.568.000	363.996

Table 1 - Definition of the collection project assumption. Procapite-Territory Subdivision (3R4UB)

Equally relevant is the narrative dimension of the mapping process. The maps were not conceived as static images but as decision-support frameworks capable of articulating the interrelations among spatial, social, and infrastructural dynamics. They encourage a multi-perspective reading of Ulaanbaatar and provide stakeholders with visual evidence to evaluate priorities and design strategies. At the same time, the communicative form of the StoryMap strengthens dialogue and accessibility: the results can be understood not only by specialists but also by local communities, fostering engagement and shared responsibility. By combining analytical precision with communicative clarity, the cartographic narrative becomes a tool for constructing forms of planning that are at once better informed, more inclusive, and more conscious of the city's complexity.

The sequence of thematic maps reflects this orientation.

The first (Fig. 2), cross-references demographic distribution with waste generation and disposal flows, identifying the areas of greatest environmental and social concern. The underlying data (Tab. 1) derive from the Master Plan and from open-access statistical sources, including the national portal and the City Population platform[7].

Scaling down, in order to observe more closely the areas where schools were directly involved in the project, a set of focused maps was elaborated.

The first of these, Fig. 3 – Ulaanbaatar's Three Urban Forms: Planned City, Spontaneous City, and City in Transition, offers a

7 See: The National Statistics Office of Mongolia – Open Data Portal https://www.1212.mn [Accessed April 14, 2025].

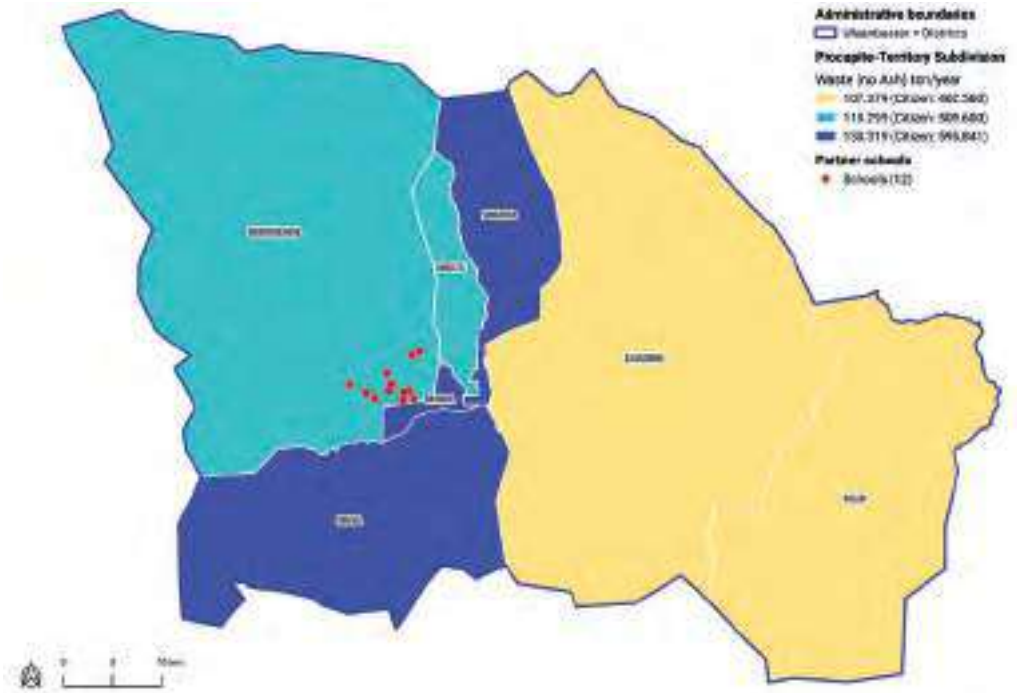

Fig. 2 - Mapping Waste per Capita and Educational Engagement in Ulaanbaatar's Districts

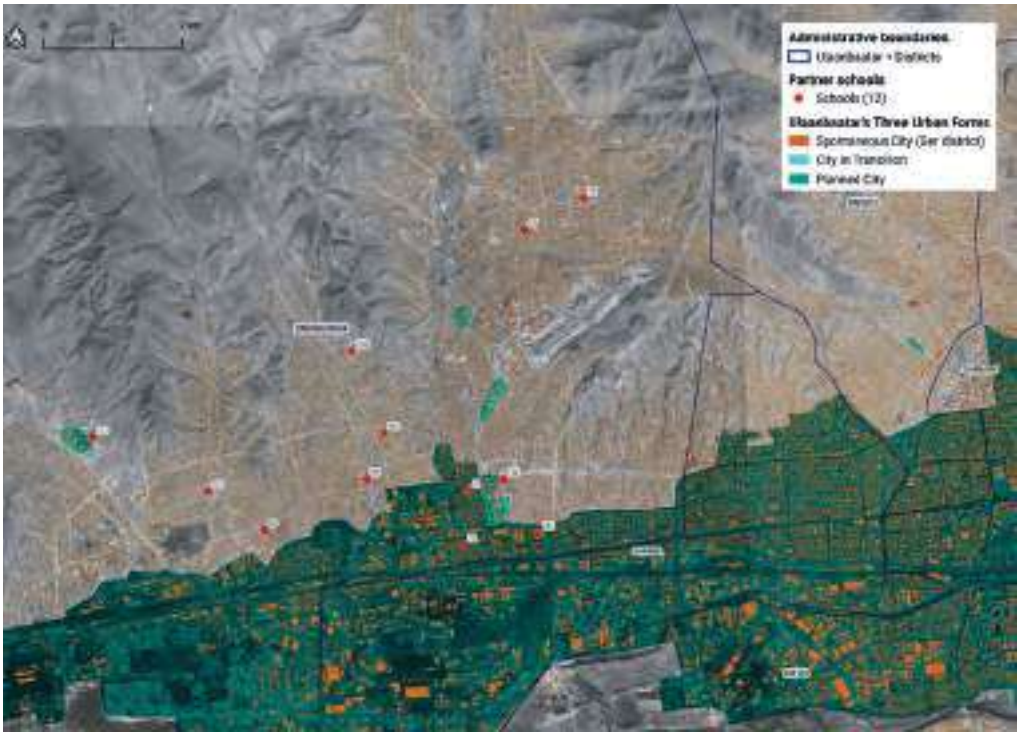

Fig. 3 - Ulaanbaatar's Three Urban Forms: Planned City, Spontaneous City, and City in Transition

comparative reading of the three major morphologies, combining fieldwork data with qualitative observations. It makes visible discontinuities in spatial organisation and unequal access to services, emphasising the sharp contrasts between formal, informal, and transitional fabrics.

An additional interpretative layer is provided by Fig. 4 – Mapping School Reachability and Urban Mobility: Student Distribution and 15-Min Walkable Areas, which depicts road-based public transport (routes, stations, stops), rail infrastructures, car parks, and airports, alongside accessibility zones defined by a fifteen-minute walking radius (Moreno, 2021). This analysis makes it possible to evaluate the integration of eco-hubs into existing networks and to test the coherence between infrastructure provision and collection strategies.

Further attention was directed to specialised land uses, represented in Fig. 5 – Mapping Specialised Enclosures and School Networks. Here, waste disposal plants, landfills, and other enclosed facilities are mapped against the settlement system, showing how they are integrated into the planned city and how transitional areas tend to expand around new infrastructures. Within this framework, the map also reveals the vast extension of one of the three main landfills[8] of the Mongolian capital, located at the edge of the ger districts (Byamba & Ishikawa, 2017). Its presence highlights not only the scale of the environmental challenge but also the spatial proximity between major waste facilities and the most vulnerable residential areas of Ulaanbaatar.

Complementing these infrastructural readings, Fig. 6 – Mapping Stakeholders in the Waste Management Chain shows the distribution and density of actors involved in recycling and community-based waste initiatives. The selected categories include recycling points, educational institutions, and community centres, often linked to NGOs. The combined use of point symbols and density mapping highlights clusters in the central districts and relative scarcity in the ger areas, offering a spatial perspective on governance networks and on the potential synergies among technical, institutional, and civic stakeholders in support of a more integrated waste management system.

8 Ulaanbaatar's municipal solid waste is mainly managed through three official landfill sites: Narangiin Enger (NEDS), Moringiin Davaa (MDDS), and Tsagaan Davaa (TsDDS), located at the periphery of the urban area. These facilities receive the vast majority of the city's solid waste and are cited as the core of Ulaanbaatar's disposal system (Byamba & Ishikawa, 2017).

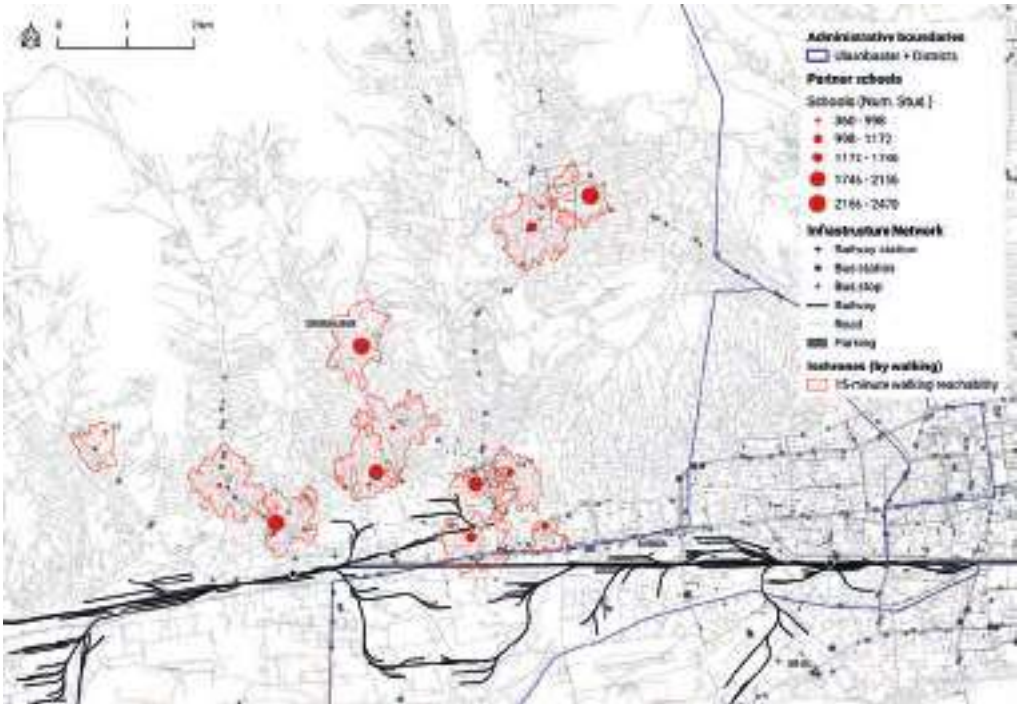

Fig. 4 - Mapping School Reachability and Urban Mobility: Student Distribution and 15-Min Walkable Areas

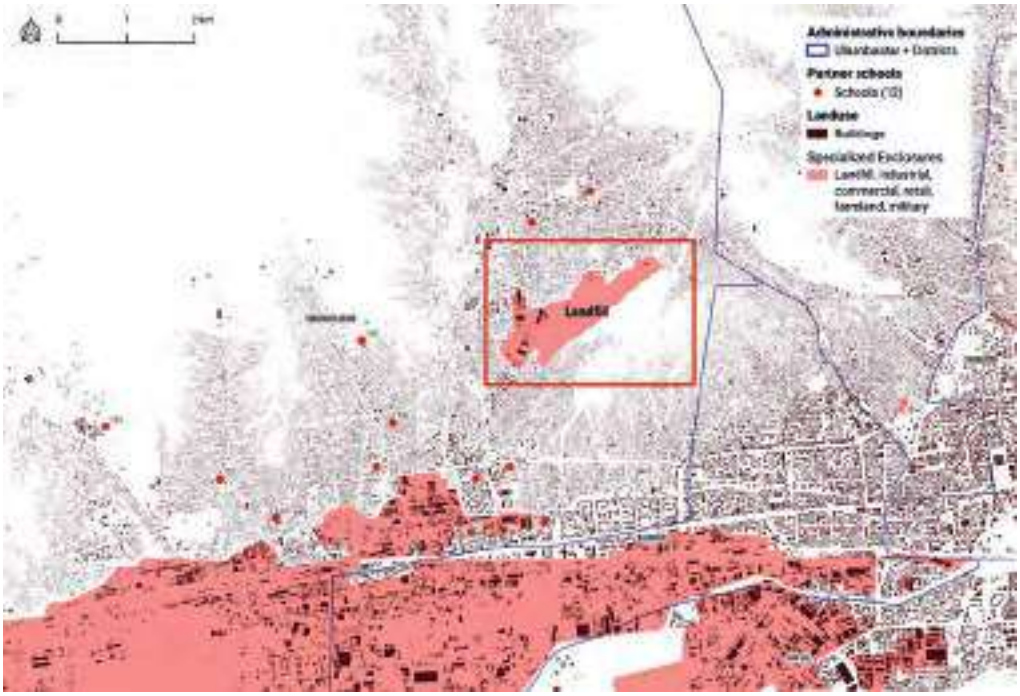

Fig. 5 - Mapping Specialised Enclosures and School Networks

Based on this comprehensive framework, the analysis culminates in Fig. 7 – Mapping Suitable Areas for New Eco-Hubs and Collection Points, which identifies three schools and their surrounding service areas as priority sites for the establishment of new eco-hubs. The selection was made through an overlay analysis that combined waste flow distribution, infrastructural accessibility, the presence of potential stakeholders, and the socio-environmental conditions of the three pilot zones. To these parameters, the evaluation added the extension of each school's service area and the number of enrolled students, ensuring that the choice reflected both technical efficiency and social impact.

The outcome highlights three schools, each located in a different urban form of Ulaanbaatar, to test the eco-hub model across highly diverse settlement contexts while also maximising the potential for community engagement and long-term sustainability. In the planned city, School No. 153 (Fig. 8) was selected for its strategic proximity to infrastructures and industrial stakeholders, and for its capacity to serve a large student

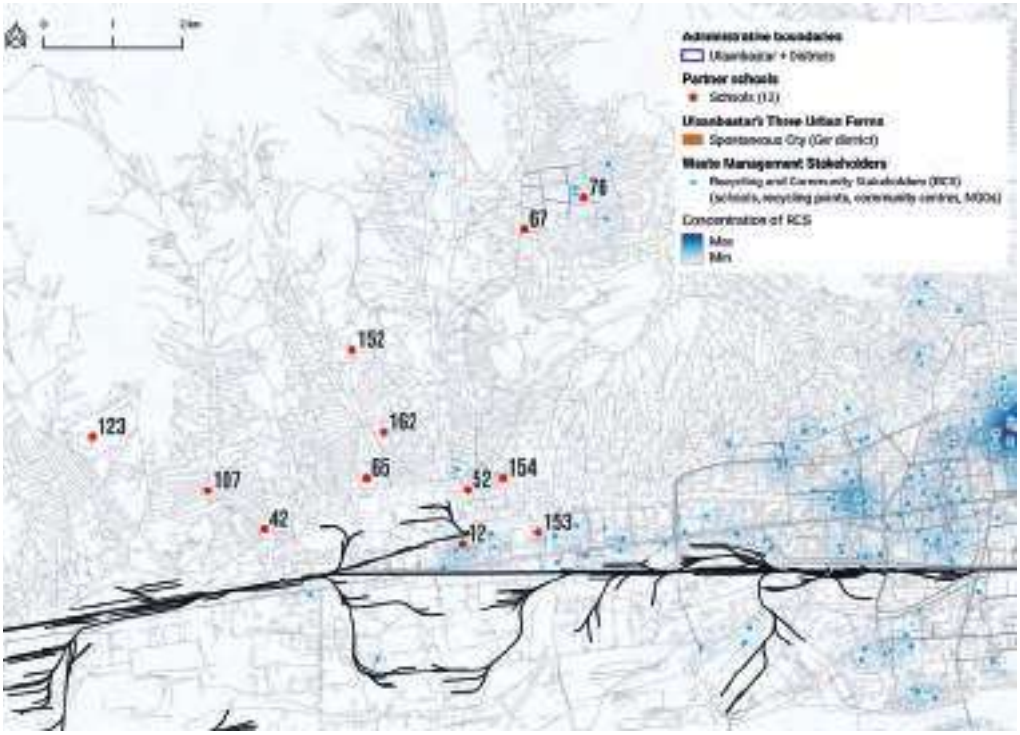

Fig. 6 - Mapping Stakeholders in the Waste Management Chain

population. In the city in transition, School No. 154 (Fig. 9) was identified at the interface between planned and spontaneous settlements, an area characterised by strong accessibility and the presence of multiple potential stakeholders.

Finally, in the spontaneous city, School No. 76 (Fig. 10) was chosen within a ger district, where infrastructural scarcity and socio-environmental vulnerability make the establishment of an eco-hub particularly relevant, with the additional aim of fostering environmental awareness among more fragile communities.

The cartographies compose a multilevel thematic atlas in which infrastructural, environmental, and socio-economic dimensions converge into a coherent framework. The maps are intended not only as descriptive outputs but as strategic instruments, supporting decision-making, stimulating dialogue among stakeholders, and enhancing collective awareness. Their integration into the StoryMap reinforces the communicative and pedagogical value of the research, while the structuring of the geodatabase in QGIS guarantees coherence and reproducibility. In this

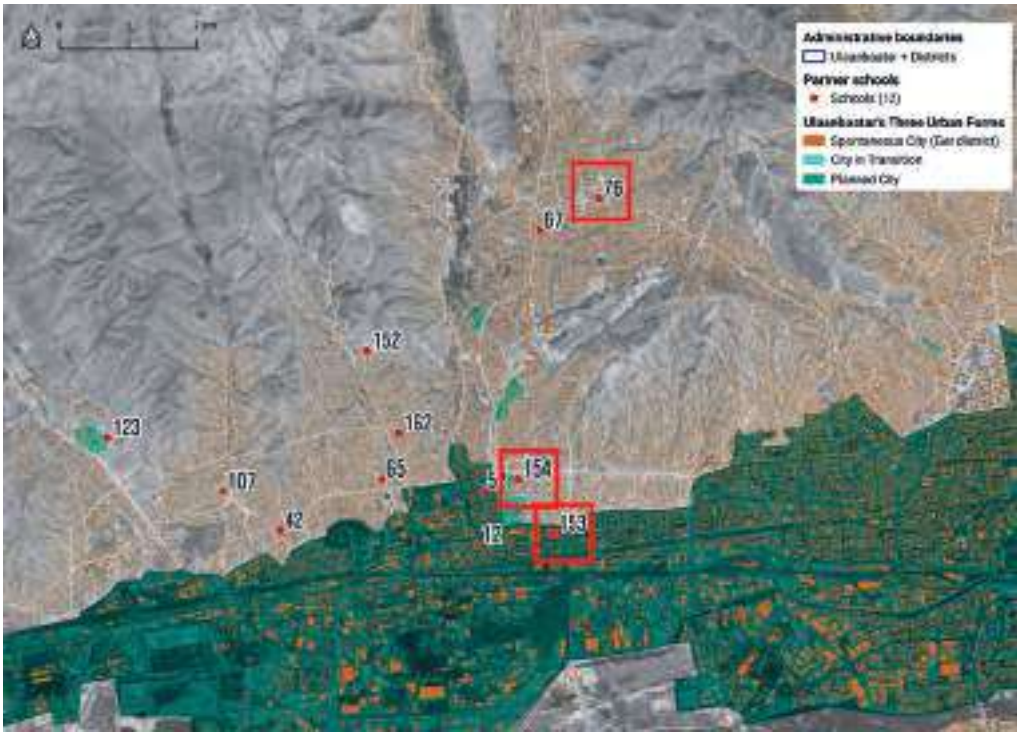

Fig. 7 - Mapping Suitable Areas for New Eco-Hubs and Collection Points

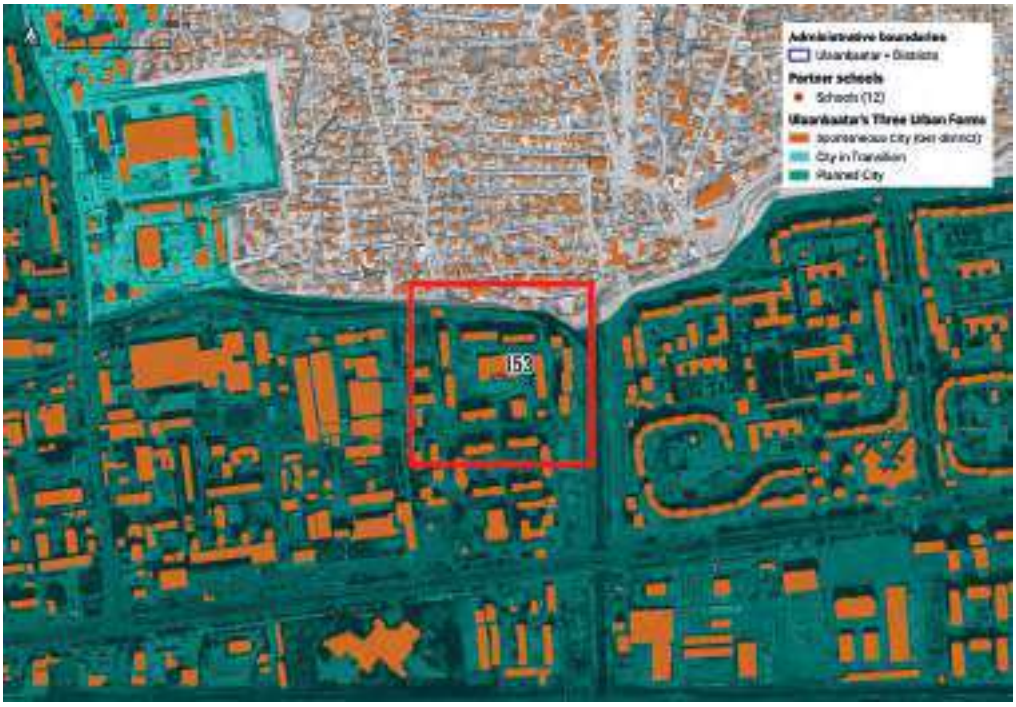

Fig. 8 - Mapping Suitable Eco-Hub Location in the Planned City

Fig. 9 - Mapping Suitable Eco-Hub Location in the City in Transition

Fig. 10 - Mapping Suitable Eco-Hub Location in the Spontaneous City (Ger District)

School (ID)	Urban form	Key selection criteria	Stakeholders in proximity	Service area & students
153	Planned City	High infrastructural accessibility; proximity to industrial areas; capacity for logistics	Industrial facilities, recycling points, community centres	Large service area; significant number of students
154	City in Transition	Interface between planned and spontaneous areas; strong connectivity; mixed urban functions	Recycling points, NGOs, public buildings	Medium-large service area; consistent student numbers
76	Spontaneous City (Ger district)	Addressing infrastructural gaps, location in a vulnerable area, and priority for awareness raising	Community stakeholders, NGOs, small-scale recycling initiatives	Smaller service area; moderate student population

Table 2 - Comparative overview of the three potential eco-hub locations in Ulaanbaatar

environment, interactive maps, photographic content, and explanatory texts converge to produce a representation that is at once analytical and experiential (Neofotistos et al., 2023).

The photographic reportage played a central role in this process. Documenting the everyday realities of the three pilot areas – landscapes of ger settlements, the materiality of waste, the infrastructures of collection and disposal – it added depth and context to the quantitative data. The images captured not only infrastructures and flows but also the gestures, spaces, and material conditions of urban life, turning data into lived experience and giving visibility to the human dimension of waste management. Integrated into the StoryMap, the photographs became narrative fragments within the larger cartographic framework, allowing viewers to engage emotionally as well as cognitively with the urban condition. The pilot activities in schools confirmed the potential of this integrated approach. Eco-hubs installed in educational institutions increased separate collection rates and expanded environmental awareness among students and their families. A waste management plan combining communication campaigns and participatory tools reached more than 25,000 students and their households. These awareness-raising initiatives proved decisive in promoting practices such as recycling and upcycling, which spread from the school environment into the wider community.

From the outset, the research followed a participatory orientation, aiming to ensure that results were locally owned and that institutional actors were fully engaged in capacity-building. Collaboration was encouraged across local authorities, government agencies, and civil society stakeholders, not only to assess the impact of the measures but also to identify barriers and specific needs in the Ulaanbaatar context. One of the most significant achievements was the definition of an integrated partnership model, established between CNR IRISS, the Municipality of Ulaanbaatar, the Fresh Water Resources and Nature Conservation Centre (FWRNCC), and the Italian technical partner Metellia Servizi. This platform allowed resources, skills, and responsibilities to be shared, reinforcing the institutional framework for sustainable waste governance.

The spatial tools developed – particularly the maps, the photographic reportage, and the StoryMap – represent an initial step toward the construction of a decision-support system for circu-

lar economy planning. By visually integrating quantitative and qualitative evidence, they create a shared knowledge base that can inform strategies and guide policy-making processes in line with collaborative planning principles. The results presented in this chapter demonstrate how the methodological approach, once spatialised and narratively restituted, is able to produce both analytical and operational knowledge. The atlas of thematic maps, enriched by GIS analysis, visual storytelling, and participatory engagement, shows the potential of spatial tools not only to describe urban complexity but also to underpin more inclusive and territorially grounded governance. These reflections provide the basis for the concluding discussion, where the outcomes are framed within wider perspectives of spatial justice, urban resilience, and the future applications of the approach in Ulaanbaatar and beyond.

The set of results presented in this chapter converges toward a single research output: the development of an integrated GIS for sustainable waste planning and management in Ulaanbaatar. By combining thematic maps, photographic reportage, and interactive StoryMap narratives, the UBSIWM approach demonstrates how spatial analysis can be transformed into a dynamic platform for governance. The system makes it possible to visualise ecological settlement mechanisms, assess infrastructural imbalances, and identify opportunities for new eco-hubs and collaborative networks. At the same time, it strengthens awareness and participation, ensuring that knowledge is not only produced for institutions but also shared with communities. In this way, the research delivers both a technical and a cultural infrastructure, capable of supporting future strategies for circular economy planning, urban resilience, and participatory decision-making in the Mongolian capital.

4. Discussion and conclusions

The methodological pathway developed within the 3R4UB project has demonstrated the dual value of spatial analysis as both a technical instrument and a social catalyst. The three-phase UBSIWM approach – comprising the definition of objectives and location criteria, operational mapping and pilot area selection, and the restitution and narrative construction of results – enabled a progressive convergence between quantitative evidence, qualitative interpretation, and participatory engagement.

From a technical standpoint, GIS proved indispensable for consolidating heterogeneous data sources into a coherent geodatabase, enabling multi-scalar analysis of Ulaanbaatar's urban metabolism. The superimposition of demographic, infrastructural, and environmental layers produced an integrated reading of the city that would have been difficult to obtain through sectoral analyses alone. This spatial intelligence allowed the research team to locate infrastructural deficits, identify optimal sites for eco-hubs, and visualise accessibility gaps across the three urban forms – planned, spontaneous, and transitional. In this respect, GIS functioned as a decision-support environment capable of translating the abstract goals of circular economy planning into spatially explicit scenarios.

Equally significant was the interpretative and communicative dimension of mapping. Rather than being treated as a purely descriptive output, the cartographic work was designed as a narrative device capable of engaging diverse audiences. The construction of an interactive StoryMap on the ArcGIS platform exemplified this orientation: by combining maps, textual explanations, and photographic documentation, the StoryMap facilitated a multivocal reading of the territory. This process confirmed that the value of GIS does not lie solely in its capacity to generate accurate representations but also in its ability to mediate between expert knowledge and public understanding, thereby acting as a bridge between technical evidence and participatory governance.

The pilot activities further revealed the potential of GIS to catalyse behavioural and institutional change. By mapping not only infrastructures but also stakeholders and practices, the research underscored that waste management is as much a social and cultural process as a technical one. This integrated perspective resonates with recent scholarship on collaborative GIS and the co-production of knowledge (Chambers, 2006; Turnhout et al., 2020), which emphasises the importance of embedding spatial analysis within a relational framework that acknowledges power dynamics, local practices, and community capacities.

Critically, the research highlighted spatial discontinuities and inequalities central to understanding Ulaanbaatar's challenges. The juxtaposition of Soviet-era planned districts with peripheral ger settlements revealed a fragmented urban landscape, in which access to waste services is uneven and environmental

exposure is spatially differentiated. By visualising these disparities, the maps acted as diagnostic tools, contributing to debates on spatial justice, urban equity, and the right to a healthy urban environment.

Overall, the methodological and empirical outcomes suggest that the UBSIWM approach constitutes an operational prototype for spatially informed waste governance. Its contribution lies in its ability to translate complex data into actionable knowledge, to mobilise multiple stakeholders around a shared understanding of problems and solutions, and to embed waste management within a broader agenda of sustainable urban transformation.

While the results presented here are anchored in Ulaanbaatar's specific socio-spatial context, the methodological approach holds considerable potential for application beyond the pilot areas and Mongolia. At the national level, the geodatabase and thematic atlas developed through the 3R4UB project could be expanded to include additional provinces and secondary cities, creating a comprehensive spatial framework for waste planning across the country. This would allow for the identification of regional-scale infrastructure needs, the optimisation of waste flows between urban and rural areas, and the design of decentralised treatment solutions that reduce the burden on Ulaanbaatar's overextended facilities.

The scalability of the approach will depend on institutional uptake and capacity-building. Ensuring that municipal and provincial authorities are equipped to maintain, update, and interpret the geodatabase is a key precondition for the long-term sustainability of the system. In this respect, partnerships with local universities, technical agencies, and civil society organisations could play a decisive role in consolidating skills and fostering a culture of evidence-based planning.

Beyond Mongolia, the UBSIWM framework may offer a replicable model for other transitional cities grappling with rapid urbanisation, informal settlement growth, and inadequate waste management systems. Post-socialist urban contexts in Central Asia and Eastern Europe, as well as fast-growing cities in the Global South, share similar challenges of fragmented governance, infrastructural deficit, and rising environmental pressures. The combination of GIS-based analysis, participatory en-

gagement, and narrative restitution developed here could serve as a transferable methodology, adaptable to different cultural and institutional settings while retaining its core principle of linking spatial intelligence with collaborative decision-making.

Future research should build upon these foundations in several directions. First, integrating real-time data streams - such as GPS tracking of collection vehicles, sensor-based monitoring of waste bins, or remote sensing for land-use change - could enhance the temporal resolution of the geodatabase, enabling dynamic planning and adaptive management. Second, the participatory dimension could be deepened through co-design workshops and community mapping initiatives, exploring whether citizen-generated data can complement official statistics and enrich the spatial analysis. Third, longitudinal studies could be conducted to assess the long-term impacts of the implemented interventions, measuring whether eco-hubs, educational campaigns, and mapping exercises lead to sustained behavioural change and improved service efficiency. Finally, comparative studies across different urban contexts could test the robustness of the UBSIWM framework, refining its criteria and validating its transferability as a model for circular economy planning in transitional settings.

The research has demonstrated that spatial mapping, when critically and inclusively employed, can act as both a diagnostic and a transformative tool. By integrating technical accuracy with participatory processes and narrative communication, the approach generated a shared knowledge base that is analytically rigorous, socially meaningful, and operationally relevant. The thematic atlas and interactive StoryMap developed in this work constitute not only research outputs but also relational infrastructures that can support the ongoing evolution of Ulaanbaatar's waste governance.

In conclusion, the contribution reaffirms the centrality of spatial intelligence in tackling complex urban challenges and highlights the importance of embedding GIS within a broader collaborative framework. In doing so, it contributes to advancing the theory and practice of spatially informed governance, offering a replicable and adaptable model that can inspire similar initiatives in other cities undergoing profound socio-spatial transitions.

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References

- Adami L., Schiavon M. (2021). From circular economy to circular ecology: a review on the solution of environmental problems through circular waste management approaches, *Sustainability*, 13, 2/2021, MDPI, Basel, Switzerland, https://doi.org/10.3390/su13020925
- Asian Development Bank. (2020). *Environmental monitoring reports for Ulaanbaatar infrastructure projects*. Retrieved April 14, 2025, from https://www.adb.org/sites/default/files/project-documents/45007/45007-004-emr-en_2.pdf
- Balram, S., & Dragićević, S. (Eds.). (2006). *Collaborative geographic information systems*. Idea Group Publishing. https://doi.org/10.4018/9781591408451
- Bolormaa B., Fürst C., Buyandelger M. (2019). Estimating the impact of urban planning concepts on reducing urban sprawl using some spatial indicators, *Geographical Issues*, 19, 2/2019, pp 42-61, https://doi.org/10.3390/land9120495
- Breathe Mongolia. (n.d.). *Citizen-driven air quality monitoring platform*. Retrieved April 14, 2025, from https://www.breathemongolia.org
- Byamba, B., & Ishikawa, M. (2017). Municipal solid waste management in Ulaanbaatar, Mongolia: Systems analysis. *Sustainability*, 9(6), 896. https://doi.org/10.3390/su9060896
- Chambers, R. (2006). Participatory mapping and geographic information systems: Whose map? Who is empowered and who disempowered? Who gains and who loses? *The Electronic Journal of Information Systems in Developing Countries*, 25(1), 1–11. https://doi.org/10.1002/j.1681-4835.2006.tb00163.x
- Duurenbayar B. (2016). *Informal Settlement and It's Upgrading Ulaanbaatar's Ger District*, (Master thesis) Politecnico di Milano,

School of Architecture Urban Planning and Construction Engineering Master of Science in Urban Planning and Policy Design, Avilable at: https://www.politesi.polimi.it/retrieve/a81cb05c- 4727-616b-e053-1605fe0a889a/2017_04_Duurenbayar.pdf

- Esposito De Vita G., Visconti C., Ganbat G., Rigillo M. (2023). A collaborative approach for triggering environmental awareness: the 3Rs for sustainable use of natural resources in Ulaanbaatar (3R4UB), *Sustainability*, 15, 18/2023, MDPI, Basel, Switzerland, https://doi.org/10.3390/su151813846
- Fraser, E. D. G., Dougill, A. J., Mabee, W. E., Reed, M., & McAlpine, P. (2006). Bottom-up and top-down: Analysis of participatory processes in urban planning. *Landscape and Urban Planning*, 75(1–2), 57–77. https://doi.org/10.1016/j.landurbplan.2004.09.001
- Healey, P. (2003). Collaborative planning in perspective. *Planning Theory*, 2(2), 101–123. https://doi.org/10.1177/14730952030022002
- Graham, M., & Zook, M. (2015). Visualizing urban inequalities: GIS and narrative mapping in social planning. *Urban Studies*, 52(10), 1883–1899. https://doi.org/10.1177/0042098013505158
- Gurjar, S. K., & Gaur, A. (2022). Application of remote sensing and GIS in integrated solid waste management: A short review. In *Advanced Organic Waste Management* (pp. 351–362). Elsevier. https://doi.org/10.1016/B978-0-323-85534-8.00014-7
- Japan International Cooperation Agency. (2009). *The Study on City Master Plan and Urban Development Program of Ulaanbaatar City (UBMPS)* (Final Report). Retrieved April 14, 2025, from https://openjicareport.jica.go.jp/pdf/11937166_01.pdf
- Jankowski, P. (2006). Defining collaborative GIS and group spatial decision processes. In S. Balram & S. Dragićević (Eds.), *Collaborative geographic information systems* (pp. 1–11). Idea Group Publishing. https://doi.org/10.4018/9781591408451.ch001
- Kahila-Tani, M., Broberg, A., Kyttä, M., & Tyger, T. (2019). Does mapping improve public participation? Exploring the pros and cons of PPGIS in urban planning. *Landscape and Urban Planning*, 186, 45–55. https://doi.org/10.1016/j.landurbplan.2019.02.019
- Karthe D., Lee H., Ganbat G. (2022). Fragmented Infrastructure Systems in Ulaanbaatar, Mongolia: Assessment from an Environmental Resource Nexus and Public Health Perspective, in *Urban infrastructuring: reconfigurations, transformations and sustainability in the Global South*, Deljana Iossifova, Gasparatos Alexandros, Zavos Stylianos, Gamal Yahya, Long Yin (eds), Urban Infrastructuring, Sustainable Development Goals Series, Springer, Singapore.
- Memon M. A. (2010). Integrated solid waste management based on the 3R approach, J*ournal of Material Cycles and Waste Management*, 12, Springer, pp 30-40, DOI 10.1007/s10163-009-0274-0.

- Miller E.J. (2013), "Nomadic and domestic: dwelling on the edge of Ulaanbaatar, Mongolia" (Phd thesis), University of California, Available at: http://gradworks.umi.com/35/55/3555240.html
- Moreno, C., Allam, Z., Chabaud, D., Gall, C., & Pratlong, F. (2021). Introducing the "15-minute city": Sustainability, resilience and place identity in future post-pandemic cities. *Smart Cities*, 4(1), 93–111. https://doi.org/10.3390/smartcities4010006
- Neofotistos, M., Hanioti, N., Kefalonitou, E., Perouli, A. Z., & Vorgias, K. E. (2023). A real-world scenario of citizens' motivation and engagement in urban waste management through a mobile application and smart city technology. *Circular Economy and Sustainability*, 3(1), 221–239. https://doi.org/10.1007/s43615-021-00087-6
- National Statistics Office of Mongolia. (2025). *Statistical data and reports*. Retrieved April 14, 2025, from https://www.nso.mn
- National Statistics Office of Mongolia. (2025). *Open data portal*. Retrieved April 14, 2025, from https://www.1212.mn
- Oppido, S., Ragozino, S., & Esposito De Vita, G. (2023). Peripheral, marginal, or non-core areas? Setting the context to deal with territorial inequalities through a systematic literature review. *Sustainability*, 15(13), 10432. https://doi.org/10.3390/su151310432
- Perrone, C., Marchigiani, E., Esposito De Vita, G., & Rossi, M. (2021). 'Terrestrial'. La sfida del gioco a tre. *Contesti*, 1, 5-20. DOI: 10.13128/contest-13191
- Park H., Fan P., John R., Ouyang Z., Chen J. (2019). Spatiotemporal changes of informal settlements: Ger districts in Ulaanbaatar, Mongolia, *Landscape and urban planning*, 191, Elsevier, Amsterdam, Netherlands, https://doi.org/10.1016/j.landurbplan.2019.103630
- Perkins, C. (2008). Cultures of map use. *The Cartographic Journal*, 45(2), 150–158. https://doi.org/10.1179/174327708X305118
- Sakshi, N., Neeti, K., & Singh, R. (2023). Diverse applications of remote sensing and geographic information systems in implementing integrated solid waste management: A short review. *Engineering Proceedings*, 56(109), 1–6. https://doi.org/10.3390/ecws-7-10900
- Sammarco, F.S., Daldanise, G., Esposito, F.M., Ganbat G., Esposito De Vita G., Rigillo M. (2025). Collaborative GIS for sustainable waste management: the case of Ulaanbaatar in 3R4UB. *TRIA 34*, 18(1), 173-194, DOI 10.6093/2281-4574/12569, ISSN 2281-4574, Classe A Anvur area 08 indicizzata WoS. https://serena.sharepress.it/index.php/tria
- Sieber, R. E. (2006). Public participation geographic information systems: A literature review and framework. *Annals of the Association of American Geographers*, 96(3), 491–507. https://doi.org/10.1111/j.1467-8306.2006.00702.x

- Sharma H. B., Vanapalli K. R., Samal B., Cheela V. S., Dubey B. K., Bhattacharya J. (2021). Circular economy approach in solid waste management system to achieve UN-SDGs: Solutions for post-COVID recovery, *Science of the Total Environment, 800*, Elsevier, Amsterdam, Netherlands, https://doi.org/10.1016/j.scitotenv.2021.149605
- Singh A. (2019). Remote Sensing and GIS Applications for Municipal Waste Management, *Journal of Environmental Management, 243*, Elsevier, Amsterdam, Netherlands, pp 22-29, https://doi.org/10.1016/j.jenvman.2019.05.017
- Sun, Y., Lv, Z., & Cabrera, J. (2016). Real-time collaborative GIS: A technological review. *ISPRS Journal of Photogrammetry and Remote Sensing, 115*, 143–152. https://doi.org/10.1016/j.isprsjprs.2015.10.011
- Turnhout, E., Metze, T., Wyborn, C., Klenk, N., & Louder, E. (2020). The politics of co-production: Participation, power, and transformation. *Current Opinion in Environmental Sustainability, 42*, 15–21. https://doi.org/10.1016/j.cosust.2019.11.009
- United Nations Environment Programme – UNEP WESR. (n.d.). *Climate change country profile: Mongolia*. Retrieved April 14, 2025, from https://wesr-cca.unepgrid.ch/cca/mongolia/climate-change
- Vohland, K., Land-Zandstra, A., Ceccaroni, L., Lemmens, R., Perelló, J., Ponti, M., Samson, R., & Wagenknecht, K. (Eds.). (2021). *The science of citizen science*. Springer. https://doi.org/10.1007/978-3-030-58278-4
- World Bank. (n.d.). *Environmental indicators for Mongolia (HDX dataset)*. Retrieved April 14, 2025, from https://data.humdata.org/dataset/world-bank-environment-indicators-for-mongolia
- Yaqin, S., Du, Z., Chen, Y., Liu, R., & Gong, J. (2022). Development of a multi-view and geo-event-driven real-time collaborative GIS. *International Journal of Digital Earth, 15* (4), 1034–1053. https://doi.org/10.1080/17538947.2021.2017034

CHAPTER 02

Shaping Ulaanbaatar's Waste Future: understanding system needs and co-designing practical solutions

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Abstract

This chapter introduces the 3R4UB Masterplan for sustainable waste management, developed as part of the European Union-funded SWITCH-Asia program, aiming at providing the Mongolia Capital City with a solid, future-oriented strategic environmental framework. Ulaanbaatar is a city in rapid growth in terms of population and built environment, suddenly changing consumption patterns, under an extreme climatic condition: this scenario poses complex challenges for urban waste management. The Masterplan, developed under the umbrella of the 3R4UB project, addresses these challenges through a sizing logic that goes beyond a static description of the existing system and links demographic and economic indicators to material flows and infrastructure needs in a structured way, with a view to 2035. This approach allows data and forecast scenarios to be translated into concrete operational choices, defining collection, treatment and recovery capacities consistent with the city's evolution. The project baseline was the awareness that transition to a circular model requires the socio-technical solutions designed and tested with the territorial actors involved, in a collaborative way, with appropriate co-design tools.

Keywords

Sustainable waste management, Masterplan, Socio-technical solutions, Co-design

1. Introduction

Building an effective and sustainable waste management system requires, first and foremost, the ability to measure, model and predict. Without a quantitative understanding of the volumes of waste produced, its composition and its geographical distribution, it is not possible to define coherent policies, plan adequate infrastructure or guide long-term investments. In rapidly changing urban contexts, this need becomes even more crucial. The 3R4UB Masterplan for sustainable waste management, developed as part of the European Union-funded SWITCH-Asia program, was created with the aim of providing Ulaanbaatar with a solid, future-oriented strategic framework.

The Mongolian capital is a prime example of a city where population growth, changing consumption patterns and extreme climatic conditions intersect, posing complex challenges for urban waste management. The Masterplan addresses these challenges through a sizing logic that goes beyond a static description of the existing system and links demographic and economic indicators to material flows and infrastructure needs in a structured way, with a view to 2035. This approach allows data and forecast scenarios to be translated into concrete operational choices, defining collection, treatment and recovery capacities consistent with the city's evolution. However, planning alone is not enough: the transition to a circular model requires that the solutions designed be tested, adapted and shared with local actors.

"The capacity of the system must not be defined by what exists, but by what will be needed to ensure environmental resilience."

(*3R4UB Masterplan, 2025*)

This is the context for the co-designing process promoted by the 3R4UB project, which has found its first significant application in the ECO-UB Urban Recycling Centre. Conceived not only as a sorting plant, but also as a demonstration and training space, ECO-UB represents the meeting point between strategic planning and operational experimentation. Its joint design involved Italian and Mongolian engineers, local administrations and private operators in an iterative process aimed at adapting advanced technical solutions to the specific climatic, social and infrastructural conditions of Ulaanbaatar.

Through this participatory approach, the ECO-UB center is not an 'imported' technology, but an infrastructure rooted in the local context, capable of responding to the city's needs and serving as a replicable model. The combination of data-based sizing, shared design and field testing is at the heart of the 3R4UB experience and is the common thread running through the volume, offering an integrated vision of how data, technologies and social processes can converge in the construction of a truly sustainable urban waste management system.

2. Conceptual Approach

The sizing of waste management systems is not just a technical exercise, but a fundamental interdisciplinary process in the transition towards sustainable and circular urban models, integrating demography, urban sociology, circular economy and material flow engineering. It answers a fundamental question: how much infrastructure is needed, where and for whom, not only today but in the medium and long term. Measuring the quantities and the flows is therefore essential to ensure that collection, treatment and disposal capacities are in line with actual and projected needs, avoiding both underinvestment and oversizing. Sizing is not a purely numerical exercise, but rather the translation of complex social, economic and territorial processes into technical requirements that can guide policy decisions and infrastructure planning. Waste production is the visible result of broader dynamics - population growth, household composition, consumption patterns, spatial organization of the city and seasonal behavior - and cannot be effectively addressed without an integrated analytical framework.

According to the mapping, it is possible to recognize different urban patterns (cfr. Chapter 1), typologies of settlements as well as the informal Ger districts (ger khoroolol), sprawling residential areas surrounding Ulaanbaatar featuring traditional yurts (gers) or small detached houses inside fenced parcels, mostly lacking central water, sewage, or heating (Harrison et al., 2024). The built environment has been studied in order to collect the spatial demands. The overlapping of spatial and social data was integrated by the qualitative analysis caried out with the civic engagement program. We can say that the traditional approach to waste of the yurts settlements was also considered: the nomadic communities adopt a self-sufficient approach by reusing

waste, anticipating the symbiotic model that underpins the circular economy.

The analysis of Ulaanbaatar waste management demand highlights the complexity of urban dynamics and the multiplicity of issues related to the accelerated transformations of the capital city. Rapid population growth, largely driven by migration from rural areas to cities, is accompanied by the fragmentation of households and a gradual shift towards more packaged and disposable consumer goods. These trends directly influence per capita waste generation and alter the composition of municipal solid waste, increasing pressure on existing collection systems and disposal facilities. At the same time, the city's unique territorial structure, which includes densely populated urban neighborhoods, vast ger areas and scattered commercial zones, introduces significant spatial variability in waste generation and accessibility.

The 3R4UB Masterplan addresses this complexity through a dimensional approach that integrates three complementary analytical areas:

1. Material Flow Analysis (MFA) – quantification of waste inputs, transformation and outputs.
2. Geospatial Assessment (GIS) – mapping of generation patterns and accessibility.
3. Scenario modelling – projection of future demand based on different socio-economic trends.

The material flow analysis (MFA) is used to quantify the inputs, transformations and outputs of waste streams, enabling planners to understand how materials move through the urban system and where leaks or recovery opportunities occur. This quantitative framework supports the identification of priority fractions for recycling, composting or energy recovery.

The Geospatial Assessment (GIS) is used to map waste generation patterns, collection routes and access constraints across the metropolitan area. This spatial perspective is crucial in a city like Ulaanbaatar, where weather conditions, road infrastructure and settlement typologies significantly influence service efficiency. GIS analysis makes it possible to identify underserved areas, optimize facility locations and ensure equitable access to waste services.

The **scenario modelling** enables the projection of future waste management demands under different socio-economic trajectories. By combining demographic forecasts, economic indicators and policy assumptions, the Masterplan evaluates alternative development paths and their implications for infrastructure capacity. This forward-looking dimension is essential to ensure that investments remain resilient in the face of uncertainty and evolving urban dynamics.

Beyond these technical tools, the dimensioning process adopted within 3R4UB is inherently interdisciplinary. It brings together demography, urban sociology, circular economy principles and engineering design to capture the full spectrum of factors influencing waste generation and management. In Ulaanbaatar, for instance, seasonal phenomena such as the winter production of ash in ger areas, the spatial concentration of commercial activities, and the role of informal markets in the recovery of metals and plastics all contribute to shaping material flows. Ignoring these elements would result in infrastructure that is technically sound but operationally misaligned with local realities.

By integrating quantitative analysis with territorial and social understanding, the 3R4UB dimensioning approach ensures that infrastructure investments are **proportionate, scalable and territorially balanced**. It provides decision-makers with a robust evidence base for planning systems that can adapt over time, support higher levels of material recovery and contribute to the broader objectives of environmental sustainability and urban resilience.

3. Demographic Trends, Waste Projections and Scenario Modelling

A robust definition of waste management system dimensions must be grounded in a clear understanding of demographic dynamics and their long-term implications for material flows. In rapidly urbanizing contexts such as Ulaanbaatar, population growth acts not only as a quantitative driver but also as a catalyst for profound structural changes in waste generation patterns. Demographic projections developed within the 3R4UB Masterplan indicate a steady increase in the urban population up to 2035, accompanied by significant trans-

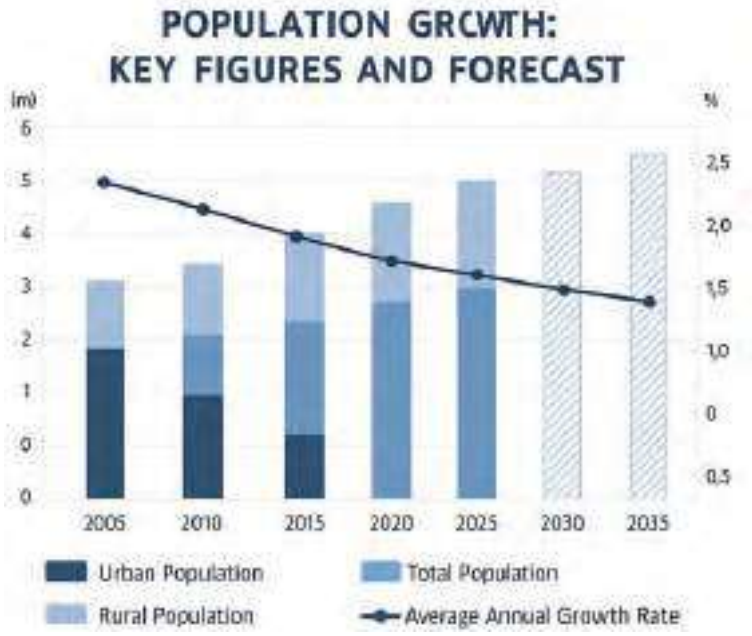

Fig. 1 – Analytical Framework for Waste System Dimensioning

Year	Population (millions)	Waste (kg/cap/day)	Total (t/day)	Growth vs. 2025
2025	1.54	0.66	1 020	–
2030	1.70	0.74	1 258	+23 %
2035	1.82	0.80	1 332	+31 %

Fig. 2 – Waste Generation Forecast Curve (2025–2035)

formations in household composition, consumption behavior and spatial distribution across the metropolitan area. These demographic trends translate into a marked increase in total waste generation over the planning horizon. Between 2025 and 2035, the population of Ulaanbaatar is expected to grow from 1.54 to 1.82 million inhabitants, while per-capita waste generation is projected to rise from 0.66 to 0.80 kg per person per day. As a result, daily municipal waste volumes are forecast to increase from approximately 1,020 tons to over 1,330 tons, corresponding to an annual production of around 480,000 tons by 2035. Beyond absolute growth, these projections highlight a gradual change in waste composition, reflecting evolving lifestyles, income levels and access to consumer goods.

Spatial variability further complicates this picture. Central districts tend to generate higher proportions of food waste and packaging materials, while peripheral and ger areas produce larger quantities of ash, bulky waste and construction debris. Seasonal effects, particularly those linked to winter heating practices, can alter waste composition by an estimated 8–10 percent over the year. Capturing this heterogeneity is essential to avoid uniform solutions that fail to respond to local conditions. To address these challenges, waste-flow modelling within the 3R4UB Masterplan relies on a combination of input–output

Fraction	**Share %**	**Potential Treatment**
Organic	22	Composting / Anaerobic digestion
Plastics	15	Sorting and recycling
Paper & Cardboard	10	Reuse / pulping
Glass	5	Remanufacturing
Metals	4	Refining
Others (inerts, textiles, mixed)	44	Landfill / WtE

Fig.3 – Waste Composition in Ulaanbaatar (2025)

matrices, household-based growth curves and specific generation coefficients for individual waste fractions. This framework allows planners to simulate how waste streams evolve under different socio-economic conditions and to disaggregate flows by material type, urban area and service catchment. Additional analyses explore correlations between income levels and the generation of dry, recyclable fractions, as well as the influence of policy instruments – such as tariff systems and cost-recovery mechanisms – on household behavior and source separation performance[1].

Scenario modelling also plays a crucial role in addressing uncertainty. Climate-related events, economic fluctuations and sudden demographic shifts can significantly affect waste generation patterns. For this reason, alternative scenarios are used to test the elasticity of material flows under stress conditions, providing insights into the resilience of proposed system configurations. Taken together, demographic forecasting, material characterization and scenario modelling provide a systemic understanding of variability and uncertainty, forming the analytical basis for informed infrastructure planning.

1 The data collection included the documents provided by the Municipality of Ulaanbaatar: Urban Waste Strategy (2024); Urban Waste Infrastructure Plan (2024).

4. Infrastructure Dimensioning and the Transition from Planning to Practice

Building on the analysis of future waste flows, the 3R4UB Masterplan translates projected demands into concrete infrastructural requirements through a structured dimensioning logic. Infrastructure is conceived as a hierarchical system composed by interconnected layers, ranging from primary collection points and district-level transfer and sorting stations to central treatment facilities, transport fleets and final disposal sites. This hierarchy ensures that each component performs a specific function within an integrated system, avoiding both bottlenecks and redundancies.

The dimensioning process is guided by three key proportional relationships: population growth, per-capita waste generation and the targeted diversion rate from landfill through recycling and composting. These relationships are synthesized in the expression [Q_{target} = P \times W {cap} \times (1 - D)], where (Q_{target}) is the quantity of residual waste requiring disposal, (P) represents the projected population; (W_{cap}) is the waste generation per capita; and (D) act as diversion rate, which defines the quantity of residual waste requiring final disposal. Applying this logic to the 2035 horizon demonstrates that, with a diversion target of 60%, daily landfill inputs could be reduced from approximately 1,020 tons to around 532 tons. This reduction underscores the strategic role of recovery and treatment infrastructure in achieving long-term sustainability objectives.

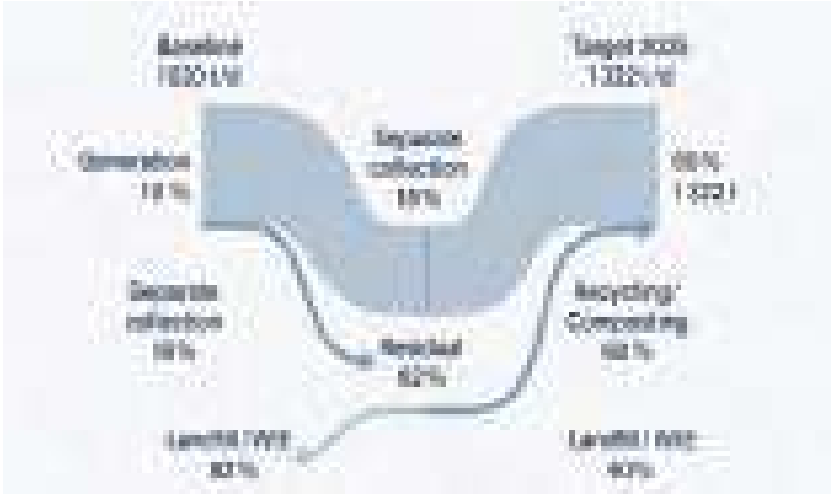

Fig. 4 - Material Flow Diagram (Baseline vs. Target 2035)

Fig. 5 – Infrastructure Hierarchy Diagram

On this basis, the Masterplan proposes the development of two new sorting hubs in western and eastern Ulaanbaatar, the construction of a central composting facility and the modernization of existing transfer stations to accommodate increasing flows.

The full implementation of the system between 2025 and 2035 requires an estimated capital investment of €36.5 million, complemented by annual operational costs of €4.5–5.0 million. These investments are justified by substantial environmental and socio-economic benefits, including increased recycling rates, reduced greenhouse gas emissions, compost production and job creation. The investments include Sorting plants (35%), Fleets and collection processes (25%), Composting (20%) as well as Landfills rehabilitation and ICT and monitoring activities (10% each).

The anticipated environmental and socio-economic benefits of this transition are substantial. By 2035, the Masterplan forecasts an increase in the recycling rate from 18 to 60 percent, a

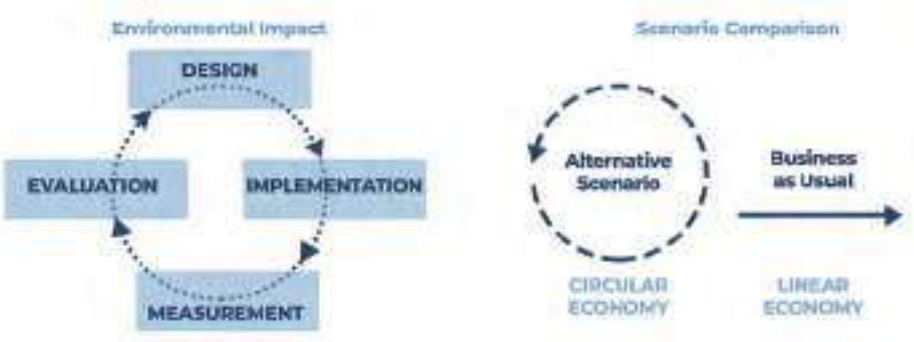

Fig. 6 – Environmental Impact Dashboard and Scenario Comparison Chart

landfill diversion rate of 40 percent, the avoidance of approximately 12,000 tons of CO_2 equivalent emissions per year, the production of around 20,000 tons of compost annually, and the creation of up to 200 new jobs.

However, infrastructural capacity alone is insufficient without corresponding institutional capacity. For this reason, the Masterplan proposes a three-tier governance model involving strategic coordination at municipal level, operational responsibility at district level, and regulatory oversight by national agencies. The establishment of a dedicated Waste Management Coordination Unit within the Municipality of Ulaanbaatar is recommended to oversee data collection, budget planning and public–private partnership negotiations.

Crucially, infrastructure planning within 3R4UB is not conceived as a purely technical exercise. The transition from planning to implementation is supported by a strong collaborative dimension, involving Italian and Mongolian engineers, municipal officers and private operators. Joint validation sessions, training exchanges and simulations of plant operation under full load have been used to test design assumptions and operational procedures. This learning-by-doing approach has demonstrated that imported technologies must be carefully adapted to local constraints, particularly in terms of maintenance requirements, availability of spare parts and operational continuity under extreme climatic conditions.

Through this process, infrastructure dimensioning becomes not only a matter of sizing facilities, but also of building shared knowledge and institutional ownership. The experience gained

through collaborative design and pilot-scale experimentation provides a critical bridge between strategic planning and long-term system operation, ensuring that the waste management infrastructure of Ulaanbaatar is both technically robust and contextually appropriate.

5. Social and territorial implications

Strategic planning and system dimensioning represent essential foundations for sustainable waste management, but their effectiveness ultimately depends on the ability to translate analytical frameworks into operational reality. Designing a waste management system therefore implies not only forecasting future needs and sizing infrastructure accordingly, but also **testing solutions in real-world conditions**, verifying assumptions, and adapting technologies and organizational models to local constraints. This transition from theory to practice is a critical step in ensuring that planning tools evolve into functioning systems.

Within the 3R4UB framework, this transition is embodied in the conception and implementation of the **ECO-UB Urban Recycling Centre**, which serves as a pilot facility designed to operationalize the principles outlined in the Masterplan. The pilot approach reflects a deliberate choice to move beyond abstract planning and to create a tangible testing ground where technical, organizational and social dimensions of waste management can be observed, evaluated and refined.

Fig. 7 - ECO-UB Co-Design Process

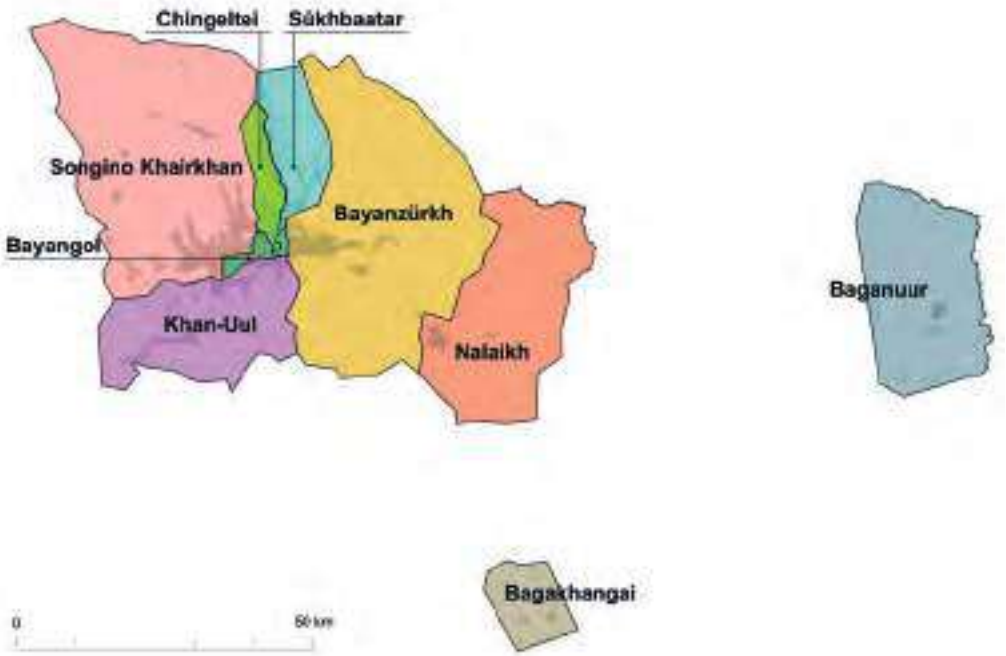

Fig. 8 - Map of Ulaanbaatar

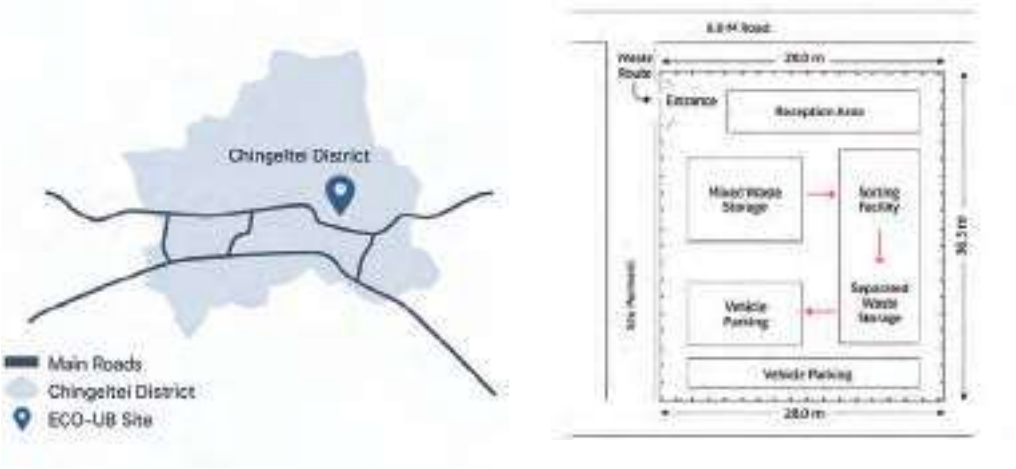

Fig. 9 - Site Location Map and Functional Layout of ECO-UB

The realization of sorting and recycling facilities has implications that extend well beyond technical performance. Such infrastructures influence the social fabric of the city, contributing to the creation of new professional profiles and employment opportunities, particularly for women and young people.

In the context of Ulaanbaatar, they also provide opportunities to recognize and strengthen the role of informal actors and cooperatives involved in material recovery, facilitating their gradual integration into more structured value chains. At the same time, these facilities interact with citizens' everyday practices, shaping how waste is separated, handled and perceived at household and community level.

The ECO-UB center has been conceived not only as a treatment facility, but also as a space for social learning and cultural transition. Visitors are not merely exposed to information about waste separation and recycling; they are actively involved in observing and understanding concrete processes, from manual sorting to storage of recyclable materials. This experiential dimension supports behavioral change by linking abstract environmental concepts to visible and tangible actions, reinforcing the role of participation as a lever for systemic change.

At the core of the ECO-UB experience lies a co-design process that brought together Italian and Mongolian engineers, municipal officers, private operators and technical experts. Rather than transferring a predefined technological solution, the project adopted a participatory approach based on continuous dialogue, joint validation sessions and iterative design reviews. This exchange enabled the adaptation of European expertise to the specific climatic, logistical and institutional conditions of Ulaanbaatar.

Climate adaptation emerged as a particularly critical design challenge. Extreme winter temperatures, reaching well below −30 °C, required specific engineering solutions, including insulated structures, enclosed conveyors, heated working areas and layouts designed to ensure operational continuity throughout the year. The selection line, plant layout and technologies were therefore shaped not only by capacity requirements, but also by the need for resilience, ease of maintenance and compatibility with locally available skills and resources.

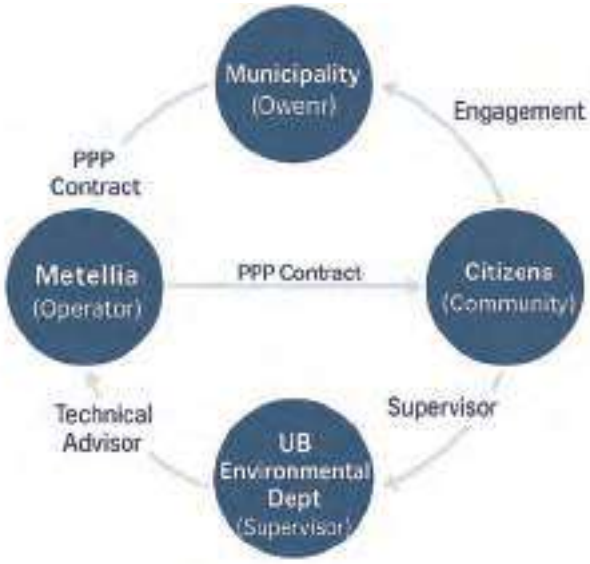

Fig. 10 - Governance Structure Diagram

Equally important was the transfer of technical competences accompanying the physical realization of the plant. Training activities, hands-on workshops and joint simulations of plant operation under full-load conditions enabled local technicians and operators to build familiarity with equipment, safety procedures and maintenance routines. This learning-by-doing approach proved essential in highlighting the need to adapt imported technologies to local realities, particularly regarding spare-parts availability, maintenance schedules and long-term operational sustainability.

Through this process, the ECO-UB pilot facility functions as a bridge between strategic planning and long-term system implementation. It demonstrates how the principles of dimensioning, circularity and participation outlined in the Masterplan can be translated into a working infrastructure that is technically sound, socially inclusive and institutionally embedded. In doing so, it sets the stage for the more detailed discussion of co-design, operation and replication potential.

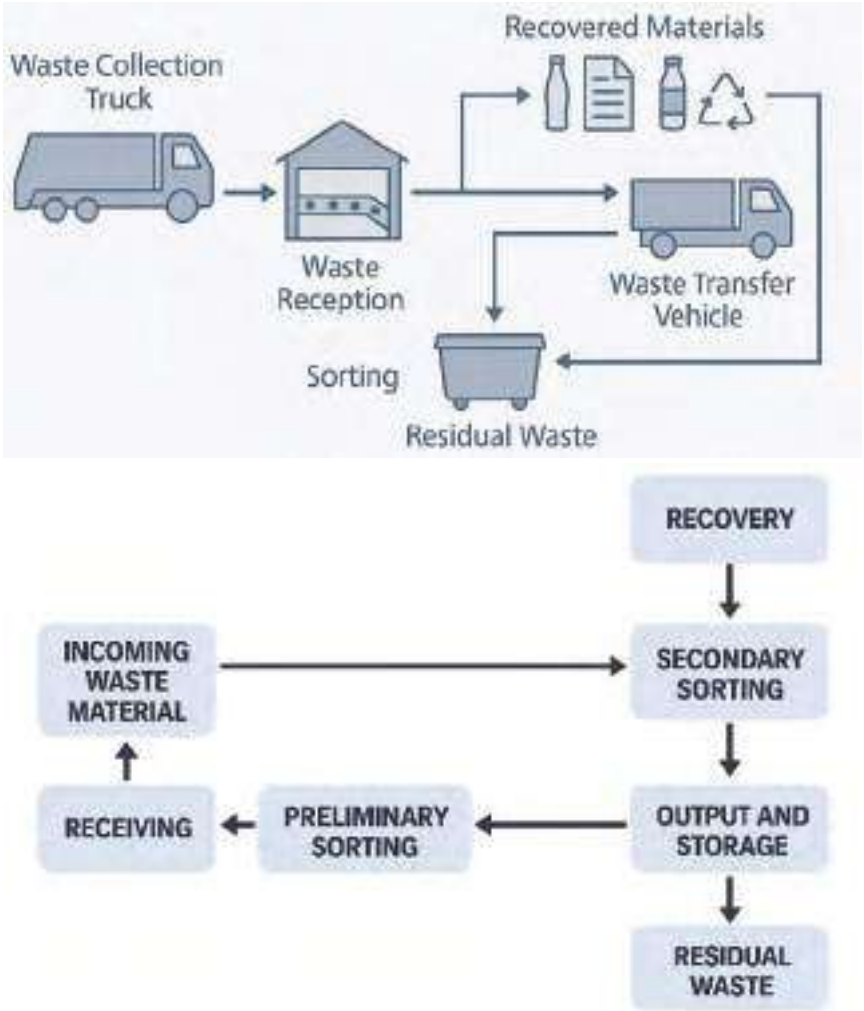

Fig. 11 - Educational Interface and Visitor Flow and ECO-UB Performance Dashboard

6. Conclusions

The analytical and operational foundations of the 3R4UB approach to sustainable waste management in Ulaanbaatar demonstrate how strategic planning, quantitative modelling and participatory design can be integrated into a coherent and forward-looking framework. The Masterplan demonstrates that effective waste management cannot be built on static descriptions or short-term responses but requires a structured logic capable of linking demographic trends, economic dynamics,

material flows and infrastructural needs over time.

Through the dimensioning process, waste generation is interpreted as the outcome of complex social and territorial processes, translated into technical requirements that guide investment choices and system configuration. Demographic projections, waste-flow modelling, material characterization and spatial analysis collectively provide a systemic understanding of variability and uncertainty, enabling the design of infrastructures that are proportionate, scalable and resilient. In this sense, data and scenarios do not remain abstract tools but become instruments of governance and decision support.

At the same time, the chapter highlights that infrastructure planning alone is insufficient without verification through practice. The transition from theory to implementation represents a decisive moment in which assumptions are tested, technologies are adapted and organizational models are refined. The ECO-UB Urban Recycling Centre embodies this transition, functioning as a pilot facility where the principles of the Masterplan are translated into operational solutions and observed under real conditions.

The experience of ECO-UB also underscores the social dimension of waste management systems. Beyond technical performance, sorting and recycling facilities shape employment opportunities, foster inclusion, support the professionalization of local actors and influence everyday practices of citizens. Through co-design, training and learning-by-doing, the project demonstrates how technological solutions can be embedded within local contexts, ensuring ownership, adaptability and long-term sustainability.

The 3R4UB Masterplan bridges planning and implementation, combining quantitative rigor with participatory processes and experimental practice. It establishes the methodological foundations necessary to consolidate and replicate a circular waste management system in Ulaanbaatar and beyond.

References

- CNR-IRISS et al. (2025) *3R4UB Masterplan for Sustainable Waste Management in Ulaanbaatar*. https://www.switch-asia.eu/resource/master-plan-for-separate-waste-collection-in-ulaanbaatar/
- Harrison, Dao H; Nielsen, Olivia; Fremont, Emile; Sengupta, Pallavi. (2024) *Reimagining Mongolia's Ger Districts : A Blueprint for Green, Resilient and Affordable Housing in Mongolia*, Washington, D.C. : World Bank Group. Http://documents.worldbank.org/curated/en/099120524125074017
- CNR-IRISS et al. (2025) Impact Sheet: 3R4UB - Advancing Circular Economy and Waste Reduction in Ulaanbaatar. Https://www.switch-asia.eu/resource/impact-sheet-3r4ub-advancing-circular-economy-and-waste-reduction-in-ulaanbaatar/
- European Commission. (2023) SWITCH-Asia Programme Guidelines. https://www.switch-asia.eu/switch-asia/branding-guide/
- OECD. (2021). *Circular Economy in Cities and Regions*. https://www.oecd.org/en/topics/circular-economy-in-cities-and-regions.html
- UN-Habitat. (2022). *Solid Waste Management in Rapidly Urbanizing Cities*. https://unhabitat.org/topic/solid-waste-management

CHAPTER 03

Strengthening Local Capacity for a Circular Future: Training, Governance, and Community Engagement

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Abstract

This chapter presents the training and capacity building activities accompanying the 3R4UB Masterplan for sustainable waste management, developed as part of the European Union-funded SWITCH-Asia 3R4UB Project. Capacity building is a core pillar of the 3R4UB project, ensuring that the infrastructure investments and technical improvements introduced through the Masterplan can be effectively operated, maintained and replicated by local administrations over time. The Project training activities, knowledge-transfer tools and institutional strengthening measures were implemented between 2024 and 2025 under the joint coordination of Metellia Servizi, CNR-IRISS, TML Group and the Municipality of Ulaanbaatar. These actions were designed to support the development of a competent and motivated technical workforce within Mongolian local authorities, capable of managing the entire waste management cycle—from data collection and strategic planning to facility operation and citizen engagement.

Keywords

Sustainable waste management, Capacity building, Scalability, Co-design

1. Introduction

Capacity building is a core pillar of the 3R4UB project, ensuring that the infrastructure investments and technical improvements introduced through the Masterplan can be effectively operated, maintained and replicated by local administrations over time. Without adequate human and institutional capacity, even well-designed systems risk underperforming or failing altogether.

This chapter presents the training activities, knowledge-transfer tools and institutional strengthening measures implemented between 2024 and 2025 under the joint coordination of Metellia Servizi, CNR-IRISS, TML Group and the Municipality of Ulaanbaatar. These actions were designed to support the development of a competent and motivated technical workforce within Mongolian local authorities, capable of managing the entire waste management cycle – from data collection and strategic planning to facility operation and citizen engagement.

The chapter explores in depth the enabling strategies that underpin the implementation of the 3R4UB Masterplan, describing the methodologies adopted, the tools developed, the results achieved and the future perspectives for institutional growth. By expanding the analysis, it highlights how technical and operational learning is closely linked to the broader process of institutional innovation and resilience within the Municipality of Ulaanbaatar. The main challenges of the project were enhance competences and self-sufficiency in managing the day-by-day challenges, thus developing long term strategies.

"Infrastructure without human capacity is a monument to inefficiency." (*3R4UB Sustainable Waste Masterplan, 2025*)

2. Capacity Building as a Strategic Enabler

The long-term effectiveness of waste management systems depends not only on infrastructure and technology, but also on the capacity of institutions and professionals responsible for their operation. Within the 3R4UB project, capacity building was identified as a fundamental pillar to ensure that the investments promoted through the Masterplan could be sustainably managed, maintained and replicated by local authorities over time.

Fig. 1 – Structure of 3R4UB Capacity Building Programme

The 3R4UB training programme was designed to:

1. Strengthen the institutional capacity of UB Municipality and Districts.
2. Enhance technical knowledge on 3R (Reduce, Reuse, Recycle) principles.
3. Foster interdepartmental collaboration.
4. Build familiarity with EU environmental and procurement standards.
5. Encourage exchange between Mongolian and European experts.

Training and institutional strengthening were therefore conceived as enabling strategies, essential to transforming technical solutions into operational routines and resilient governance structures.

Between 2024 and 2025, a comprehensive capacity-building programme was implemented under the joint coordination of Metellia Servizi, CNR-IRISS, TML Group and the Municipality of Ulaanbaatar. The programme was designed to develop a skilled and motivated technical workforce within Mongolian local authorities, capable of managing the entire waste management cycle—from data collection and strategic planning to facility operation and citizen engagement. Rather than relying on isolated training events, the initiative adopted an integrated approach aimed at embedding learning processes within everyday institutional practices and strengthening institutional continuity.

This approach was operationalised through a diversified and complementary set of training activities, tailored to different learning needs and institutional levels, and combining theoretical foundations with applied experience and continuous professional development. Training activities included classroom

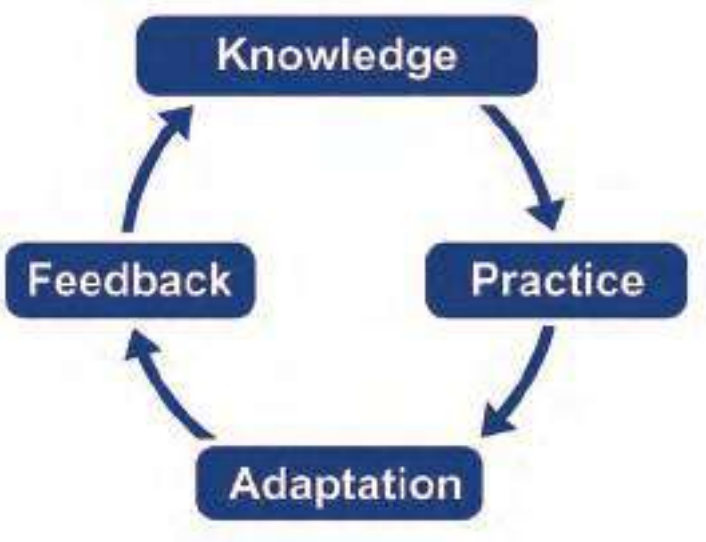

Fig. 2 - Training Methods and Learning Cycle

seminars focused on conceptual and regulatory frameworks, on-site workshops at the ECO-UB Urban Recycling Centre, technical study visits to advanced waste management facilities in Italy – such as the Metellia Servizi plants in Viterbo and the Acerra waste-to-energy facility – as well as digital training modules designed to ensure continuous learning beyond the duration of the project.

The training programme was structured around four thematic modules, each addressing a critical dimension of waste management governance and operations. The first module focused on waste system governance, clarifying the roles and responsibilities of national and local authorities under Mongolian legislation, exploring the alignment of local practices with European Union waste directives, and strengthening capacities related to budgeting, monitoring and performance evaluation. This module aimed to reinforce strategic decision-making and regulatory awareness within municipal and district administrations.

The second module addressed technical operation and occupational safety, with a strong emphasis on the practical management of sorting plant operations at the ECO-UB facility. Participants were trained on occupational health and safety procedures, including personal protective equipment stan-

dards, as well as on equipment maintenance routines and systematic data recording. Hands-on activities and operational simulations played a central role in translating technical knowledge into day-to-day operational competence.

The third module introduced circular economy principles and business development opportunities linked to waste management. Training activities explored pathways for waste valorisation, mechanisms for start-up incubation, the implementation of extended producer responsibility schemes and the role of public–private partnerships in supporting sustainable investment and service delivery. This module contributed to broadening the perspective of participants, linking operational waste management to economic development and innovation.

The fourth module focused on communication strategies and community engagement, recognizing the central role of citizens in the effectiveness of waste management systems. Participants were trained in the design of awareness-raising campaigns, the development of eco-education initiatives in schools and the establishment of feedback mechanisms to support two-way communication with residents. This component aimed to strengthen social acceptance, behavioral change and trust between institutions and communities.

Across all modules, particular emphasis was placed on experiential and applied learning. Operational simulations, on-site audits, field mentoring and the joint development of safety and operational protocols were integrated into the training process. This learning-by-doing approach proved essential in consolidating technical knowledge, strengthening problem-solving capacities and fostering reflective practice among both operators and managers. Continuous mentoring emerged as a key element in bridging the gap between formal training environments and the complexity of real-world operational challenges.

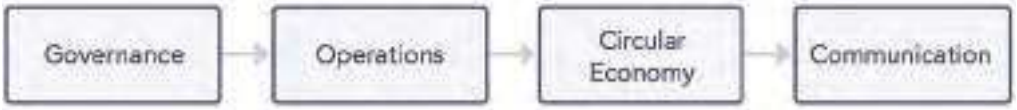

Fig. 3 - Modular Training Framework

3. Institutional Partnership and Training Architecture

A key component of the 3R4UB training programme was the international study visit to Italy, which enabled Mongolian officers to observe the full operational chain of European waste management systems and to gain first-hand exposure to advanced technical and governance practices. Between March and May 2025, three delegations — representing the Municipality of Ulaanbaatar, Chingeltei District and TML Group — participated in these study visits.

Fig. 4a - Field visit at the waste management facilities in Campania

The programme included visits to municipal sorting and composting facilities operated by Metellia Servizi, to the Acerra waste-to-energy plant (Fig. 4a, 4b), where energy recovery from non-recyclable waste is implemented at scale, and to CNR-IRISS in Naples (Fig. 5), where participants engaged with experts on policy development, strategic planning and circular economy frameworks. These visits provided a comprehensive overview of the European waste management value chain, from material recovery and treatment to policy design and institutional coordination.

Fig. 4b - Field visit at the waste management facilities in Campania

The overall architecture of the training programme was structured around a multi-level institutional partnership reflecting the governance model proposed in the 3R4UB Masterplan. Three main target groups were identified: senior managers and decision-makers responsible for policy formulation and governance; technical staff directly involved in plant operation, logistics and occupational safety; and community facilitators engaged in education, awareness-raising and citizen participation. This differentiation ensured that training content and methodologies were aligned with the specific roles and responsibilities of each group.

Training methods were deliberately diversified to address these differentiated needs. They included classroom lectures to establish common conceptual and regulatory frameworks, hands-on workshops at the ECO-UB Urban Recycling Centre, digital learning modules supporting continuous capacity devel-

Fig. 5 - Meeting and seminar at the CNR IRISS Headquarter, Naples

opment, and international study visits to Italy. The latter played a particularly important role in exposing participants to European operational standards while simultaneously encouraging critical reflection on their transferability and adaptation to the Mongolian context.

Institutional strengthening was further supported through mechanisms aimed at enhancing cooperation between municipal departments, district administrations and private operators. Data sharing procedures, process standardisation and the systematic documentation of best practices were promoted as key tools to improve administrative resilience and continuity. By reducing reliance on individual expertise and fostering organisational learning, these measures contributed to the consolidation of institutional capacity and long-term system sustainability.

Fig. 6 - Training Journey Diagram (Campania Focus)

3. Socio-Economic Impacts of Training and Knowledge Transfer

The thematic content of the training programme was structured around four core areas: governance and regulatory frameworks, plant operation and occupational safety, circular economy principles, and public communication and citizen engagement. These thematic modules were supported by a comprehensive set of training tools and materials developed in both English and Mongolian, with the aim of ensuring accessibility, consistency and long-term usability within local institutions. Training resources included ten interactive e-learning modules, printed manuals – such as the Waste Management Toolkit for UB Officers – safety and operational guidelines for plant management, and video tutorials focused on sorting-line operation and maintenance. All materials were integrated into the Municipality of Ulaanbaatar's training infrastructure, enabling contin-

Fig. 7 - Training Toolkit Overview

uous access beyond the project's implementation period.

The outcomes of the training programme were significant both in quantitative and institutional terms. Overall, 74 municipal officers were trained, exceeding the initial target by 23 per cent, with women representing 47 per cent of participants. Beyond numerical indicators, the programme contributed to a series of structural improvements, including the establishment of a dedicated Waste Management Unit within the Municipality of Ulaanbaatar in 2025, the designation of district-level focal points in Chingeltei, Songinokhairkhan and Bayanzürkh, and the adoption of standardised reporting templates for waste data. These measures enhanced coordination between munic-

Fig. 8 - Institutional Capacity Flow (Source: 3R4UB Project – Training Local Officers, 2025)

ipal and district administrations and improved interaction with private contractors involved in service delivery.

In parallel, the programme generated important qualitative outcomes. Participants demonstrated stronger motivation, a greater sense of ownership over operational processes and improved efficiency in reporting, supervision and day-to-day management activities. Environmental awareness was increasingly integrated into district-level planning, reinforcing the link between technical operations and broader sustainability objectives.

Importantly, the impact of the training extended beyond technical capacity, contributing to wider socio-economic and institutional benefits. By supporting the professional development of

public-sector staff, the programme strengthened career pathways within the waste management sector and contributed to the creation of qualified employment opportunities.

The high level of female participation highlighted the potential of capacity-building initiatives to promote inclusiveness and gender balance in technical and managerial roles traditionally dominated by men. The latter is an important achievement of the project in terms of capacity building and an opportunity to fill the inclusion gap that is one of the pillars of the research and knowledge transfer actions at the CNR IRISS.

Motivation and staff retention emerged as critical factors for long-term sustainability. By explicitly linking training activities to defined operational responsibilities and institutional recognition, the programme helped reinforce professional identity and commitment among participants. In this way, capacity

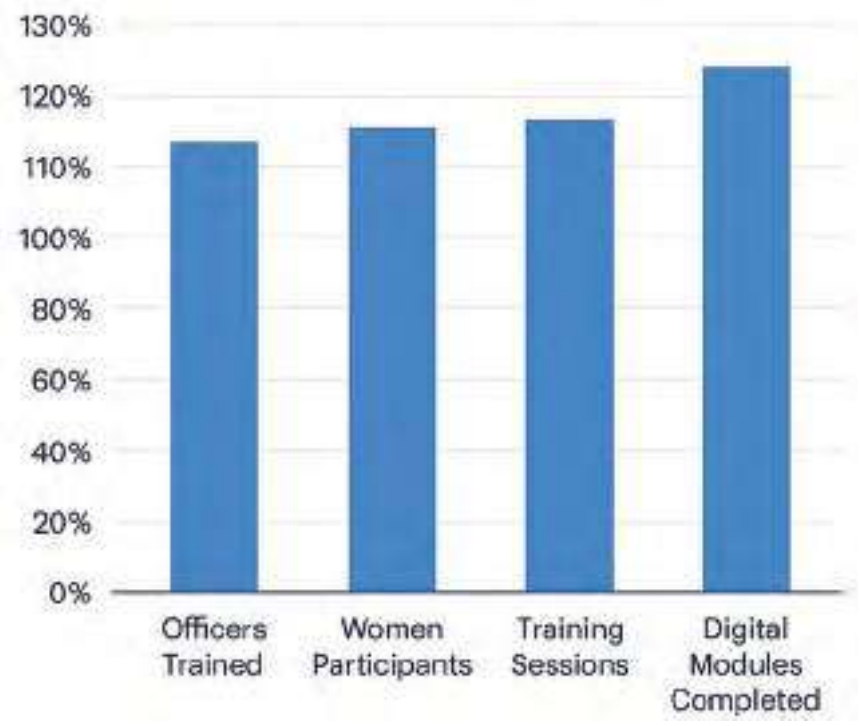

Fig. 9 - Training Results Dashboard (Source: 3R4UB Project – Training Local Officers, 2025)

building functioned not as a one-off intervention, but as a strategic lever for organisational stability, continuity and long-term system resilience.

4. A Strategic Vision for the Future

The capacity-building strategy implemented under the 3R4UB project has proven to be a decisive factor in supporting a sustainable and long-term transition towards a circular waste management system in Ulaanbaatar. By investing not only in infrastructure and technology, but also in human capital and institutional structures, the project has contributed to the creation of the "human infrastructure" necessary to operate, maintain and further develop the systems introduced through the Masterplan.

The experience demonstrated that continuous mentorship and learning embedded in everyday practice are significantly more effective than short-term or stand-alone training initiatives. Hands-on activities, such as site visits to the facilities and operational demonstrations, played a crucial role in ensuring knowledge retention and in strengthening the practical problem-solving skills of both technical staff and decision-makers. At the same time, peer learning and exchange among districts emerged as powerful mechanisms for accelerating institutional growth, fostering cooperation and promoting the dissemination of good practices across administrative boundaries. A snowball effect was triggered by the onsite visits in Italian facilities and in person meeting with experts, reinforcing the knowledge transfer initiated through online sessions and training materials.

The adaptation of training materials to local languages and contexts proved essential in enhancing accessibility and inclusiveness, while the strong participation of women highlighted the positive impact of gender-sensitive capacity-building approaches on community engagement and institutional performance. These elements reinforced the social dimension of waste management, underscoring the importance of combining technical competence with communication, participation and organisational learning.

As a result of participatory training, international exposure and institutional coaching, local authorities in Ulaanbaatar are now better equipped to manage waste infrastructure systems au-

tonomously and to plan their future expansion. Looking ahead, the consolidation of these achievements will depend on the institutionalisation of continuous training programmes, the further strengthening of municipal and district-level structures, and the replication of capacity-building activities across additional neighbourhoods and facilities.

Future developments are expected to build on enhanced digitalisation of data management, the establishment of permanent district-level training hubs, closer collaboration with universities and technical institutes, and more structured forms of international cooperation. By embedding capacity building within institutional strategies and long-term planning processes, the 3R4UB project lays the foundation for a waste management system that is not only technically efficient, but also socially inclusive, institutionally robust and capable of continuous learning and adaptation.

References

- CNR-IRISS & Metellia Servizi (2025). Training Manual for Waste Management Officers. https://3r4ub.org/mn/
- UB Municipality (2025). Waste Management Unit – Internal Reports.
- SWITCH-Asia Programme (2024). Capacity Building for Sustainable Consumption and Production. https://www.switch-asia.eu/resources/resource-library/
- SWITCH-Asia (2024). Proceedings of the ASEAN Circular Economy Stakeholder Platform Webinar Series. https://www.switch-asia.eu/resource/the-circular-economy-asean-perspectives-and-insights-on-policy-practice-and-way-forward-in-the-region/
- Metellia (2025). Operational Safety Guidelines for ECO-UB. https://www.switch-asia.eu/project/3r4ub/

CHAPTER 04

Prototyping Urban Circularity. Urban Hubs for Circular Economies

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Abstract

The depletion of the natural resources of the Earth is prompting governments and institutions to adopt strategies and policies inspired by the principles of Circular Economy (COM/2019/640 final; COM/2020/98 final). This latter aims at reducing the withdrawal of natural resources and greenhouse gas emissions thanks to a life cycle-oriented design, so that both biocycle and techno-cycles can feed more extended and interconnected supply chains. On this line, the European Commission placed resource conservation as prime objective for the Union, also focusing on the social engagement as crucial for a successful strategy.

According to these remarks, this study implements a method for prototyping a decision process to design a new type of infrastructure for spreading circular economy. The study proposes a network of Circular Hubs to spread circular activities within the city of Naples, mostly located in peri-urban areas, notably in the abandoned spaces (namely wastescapes). The proposal applies to a GIS-based method to identify abandoned sites suitable for hosting the net of urban Circular Hubs. These latter are conceived as multi-functional spaces to place micro and small enterprises apt to carry on circular activities based on redistributing, reselling, repairing and reusing discarded objects. Circular Hubs were designed to be attractive and vibrant spaces where people can meet, interact, and spend time. Most of all, Circular Hubs could be the way by which people can directly experience circularity as a new type of local economies. Circular Hubs are featured for being well designed and attractive to overcome the typical social rejection with respect to the waste management activities and places. According to these remarks, this proposal aims at generating the comprehensive

conditions for assuming Circular Hubs as catalysts for contemporary, sustainable, and lively public spaces. The sum of a number of Circular Hubs in the city depicts an integrated network of spaces and activities dedicated to circular economy, providing a sort of social infrastructure for spreading circular practices in the urban life.

This study focuses especially on textile products and wood furniture due to the specific potential and constraints related to supply-chains. The proposal works both on urban design and social innovation. It envisions social practice and business opportunity by which discarded objects could be insert into new life cycles or transformed into higher-value products. The case study area is the Western District of Naples, Italy and it acts as pilot for testing the method and to adjust it to be repeated in the city of Ulaanbaatar Mongolia.

Keywords

Circular Economy, Short Supply Chain, Systemic Design, Urban public Space, Upcycling

1. Introduction

Globalization intensifies the interdependence between economies and resource availability, generating both opportunities and challenges for sustainable development. In recent years, the rapid increase in material extraction and energy consumption has driven toward unsustainable environmental impacts (EMF, 2020) as well as severe geopolitical consequences. Scientific metrics indicate that the global economy has used more resources than was used throughout the entire 20th century in the last six years. This rise in depletion also jeopardizes the planet's ecological limits, showing that the natural environment has already perceived as a great reservoir of resources at the service of consumerist needs and desires, in the context of Western modernity.

In this scenario, cities play a crucial role. Cities are the main hotspots of resource consumption, energy uses, and waste production, accounting for up to 80% of global energy consumption, 70% of greenhouse gas emissions, and more than 75% of the world's natural resource consumption (IUCN, 2023) and 50% - 70% of global waste (OCSE, 2025). At the same time, cities are also a key part by moving from a linear-city model to a closed-loop one, and by supporting more inclusive, sustainable, and intelligent living models (OCSE, 2020). In line with these goals, specific policies have been launched by the European Union since 2015, notably those dedicated to facilitating digital and ecological transition with a strong focus dedicated to circular economy, advocating for action at national, regional, and local levels (COM(2020) 98 final; Zero Waste Europe (ZWE) Strategy (2025-20230). Despite these efforts, circular economy is still a minor realm in many EU countries (Fig.01), by accounting for only about 2% of total EU GDP while the circular material use rate of 12% in 2023 (OCSE, 2025). Studies demonstrate that the primary obstacles to the circular economy transition are not technological, but related to the policy environment, notably governance, regulation and financing (OCSE, 2025).

Such a scenario leads to a change of course in the EU's institutional framework of action, which is becoming more attentive to the territorial and social dimensions of circular objectives. To fully integrate circular economy into both social and economic perception, the 2025 OCSE Report recommends adopting a

territorial approach based on the "3P Framework" (Fig.02). This latter could be a key option to integrate a circular economy into local challenges, focusing on the specific culture and needs of cities and regions, including the involvement of different stakeholders to support collaborative and long-term decision-making processes.

The "3Ps Framework People, policies, and "places" provide a clear understanding about the deep interaction among people's behaviours, territorial contexts, and policies' effectiveness (OCSE, 2020). This framework especially focuses on social behaviours, which are at the centre of a more effective approach to circular economy. Social habits, needs, and desires influence both production and the business sector so that they can be the engine for new governance models. Further, social interaction is a key ingredient to implement circular economy, both in supply chains and social perception as for the continuous interchange between the functions of promoters, facilitators, and enablers. Indeed, people can determine the failure or the success of the circular policies, according to their different roles as inhabitants, consumers, users.

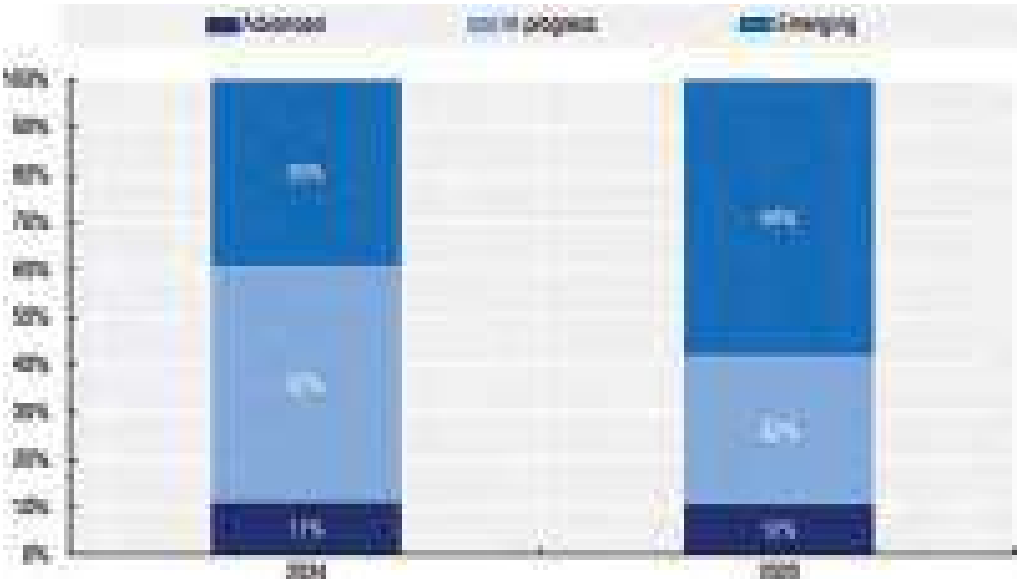

Fig. 1 - Results of the 2024 OECD Survey (Source: OECD (2025), The Circular Economy in Cities and Regions of the European Union, OECD Urban Studies, OECD Publishing, Paris, https://doi.org/10.1787/e09c21e2-en)

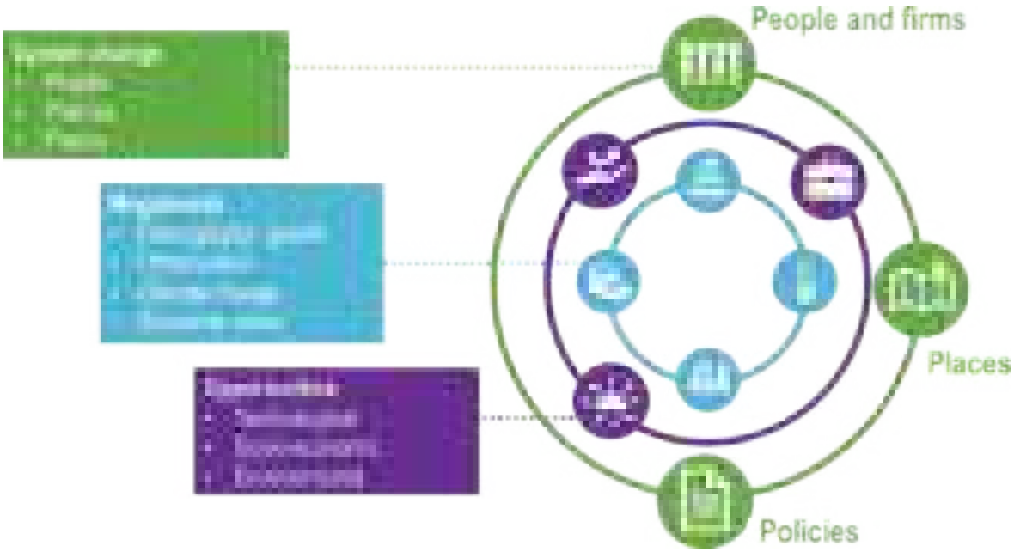

Fig. 2 - OECD 2020 3P Framework (Source: OECD (2020[2]), The Circular Economy in Cities and Regions: Synthesis Report, https://doi.org/10.1787/10ac6ae4-en.)

Social engagement is also crucial to spreading the culture of circular economy, and to test the success of policies and economic efforts in creating new supply chains and job opportunities.

These paths fall within the scope of capacity building and civic engagement approaches, both of which concern citizen science, i.e. the active involvement of the public in the production of research outputs. Citizen science has undergone significant development in Europe thanks to the support of European research networks and funding, which have promoted a wide spectrum of initiatives ranging from nature observation to participation in social research projects. However, challenges remain, such as expanding participation. The strengthening support infrastructure (Vohland et al., 2021) work done by associations and programs - such as the European Citizen Science Association (ECSA) and Doing It Together Science (DITOs) - have strongly contributed to the definition and dissemination of this field, promoting the '10 principles for good practice' (Robinson et al., 2018; Haklay et al., 2020).

To address these challenges, the study adopts a systemic design approach (Bistagnino, Campagnaro, 2014) aimed at managing material flows within innovative supply chains designed to interconnect typical social processes and technical operations. These extended supply chain includes practices such as

reuse, redesign and upcycling, together with social education and advanced training. Based on the co-design principles, these processes involve citizens and stakeholders, bringing circular waste management into the new demands of public spaces in the urban environment.

In the light of these considerations, this research aims to explore alternative paths for ecologically sustainable globalization, by working on both social innovation and urban design. The research theoretical framework assumes the EMF approach, stating that the circular economy is a transformative model operating through "design and intentions". In fact, circular design approach minimizes waste and can decouple growth and resource consumption by preserving the value of products, materials, and resources for as long as possible. On other hand, social intention is the key for changing the ways in which waste is produced, marketed, consumed, and managed.

From this perspective, circularity becomes a pillar for responsible and forward-looking at territorial and urban planning (Kaza et al., 2018). Especially in urban areas, this design approach implies rethinking the concept of urban metabolism by extending the concept of life cycle to the city itself. So abandoned urban areas (namely, wastescapes) can be considered as in-pause spaces waiting for being re-integrate in the city's uses, interacting with both the issues of waste management and civic infrastructures (Wan et al., 2019; Adami & Schiavon, 2021).

This study aims at prototyping a decision planning process for creating a network of new circular equipment in the urban areas. The study provides an effective design hypothesis for a network of 'Circular Hubs', conceived as eco-sociotechnical equipment within the urban spaces, and aimed at spreading the CE practices in cities. These hubs work at neighborhood level and have been designed for hosting a mix of commercial and educational activities by which it is possible to practice circularity directly.

Hubs work on waste prevention, and on promoting, reuse, and repairing discarded products, by extending the life cycle of discarded products. Hubs also implement social practices such as re-distribution and re-selling, rather than specific training programs on repair and re-design. The study deepens specific types of waste flows, namely wood furniture and textile products, and it works on extending their supply chains.

This chapter presents research by which design experimentations, teaching, and transfer programs joint together. This research has been carried out by the CNR IRISS with the Department of Architecture of Naples and other local stakeholders involved in the waste management sector (notably ASIA, in Naples).

This approach is consistent with the EU waste directive (Directive 2008/98/EC) and with the repair directive (Directive 2024/1799/EC). Notably, the research stresses the topic of waste prevention by implementing a new circular strategy at urban and neighborhood levels aimed at providing effective social occasions for developing micro and small enterprises, locally. This point is in line with the OCSE 3P Framework (OCSE, 2020) because a special focus is given to the relationship between people, policies, and places due to the systemic approach to hub's design and placing. Further, the study aims at fostering complementarities across different stakeholders and social subjects, adapting social needs to the urban features. The research also aims to enhance responsibility among stakeholders and create special alliances with not-for-profit organizations and public bodies, putting people at the centre of a cultural shift towards social innovation and business. Academics and research centres play a key role in spreading knowledge and design methods, contributing to boosting innovation and social opportunities, as well as raising awareness and building capacities.

This chapter is organized into five parts, including introduction. The first sub-chapter deals with the theoretical framework of the research, by deepening the concepts of urban mining and urban metabolism in the framework of the CE principles. A further focus is given to co-design practices as the main operative means adopted by research. Then, the chapter describes the Circular Hub project, enhancing the design program and its functional requirements. Within this description, the construction features are described as well.

The third sub-chapter is about the relationship between the circular hubs and the urban wastescapes. In this part, Authors describe the GIS-based method adopted to place the circular hubs in the city, according to the specific characteristics of both circular hubs' program and dismissed sites. The fourth sub-chapter reports the application of the designed methodol-

ogy to the pilot area of Western Naples, Italy. The pilot aims to tests demonstrating how creative local recycling can improve resource efficiency, local empowerment and urban resilience through multi-stakeholder cooperation between academic actors, research institutes, enterprises and local communities. Finally, in the fifth part the results discussion gives evidence to the repeatability of the design experience to the Mongolian city of Ulaanbaatar leading toward the chapter conclusions.

This work is part of the initial results of the European project SWITCH-ASIA 3R for resource efficiency in Ulaanbaatar (3R4UB), aimed at reducing and reusing waste in accordance with EU Directive 2008/98/EC. The project involves collaboration between research centers, institutions, businesses, ministries and Mongolian agencies for the protection of natural resources. The 3R4UB overall objective is to implement a Smart Consumption Plan (SCP) based on knowledge sharing and co-design processes, involving communities and stakeholders in defining innovative and competitive solutions to the environmental and social challenges facing the Mongolian capital. Within the 3R4UB framework the research deepened the issue related to citizen science and the civic engagement.

2. Theoretical Framework

This study focuses on urban metabolism and urban mining as key concepts for addressing circularity within the cities connecting the life cycle of urban spaces with the ones of discarded products. The research declines the concept of Urban Mining within the principles of the circular economy. This thesis looks at the entire city's building stock as a potential depository of resources that are already available for further uses. Urban Mining envisions the city as a material capital that can regenerate itself through reuse and recycling processes (Cossu et al., 2012). Similarly, the study takes up and develops the concept of Urban Metabolism (Wolman, 1965), as far Michelangelo Russo (2018) definition: "a complex system of transformation and exchange between the anthropic, natural, and economic environments" (Russo, 2018 pp.39). Both the concepts of Urban Mining and Urban Metabolism are rooted into an innovative approach to the city's project, looking at the urban transformative processes of the city though a life-cycle centered point of view. These concepts interact with the CE principles to better consider and

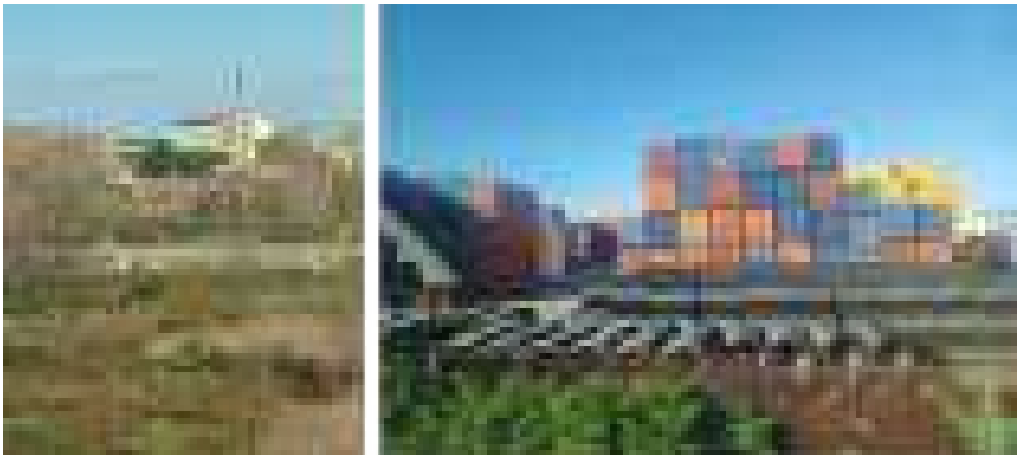

Fig. 3 - Wastescape in the peri-urban area of Naples, Itay (Photo credits: Marina Rigillo)

translate these latter into urban design and planning, by working among different levels of actions and implementations. Furthermore, both concepts are considered as driving forces for territorial CE policies according to the OCSE 3P Framework and in coherence with Objective 11 of the SDGs 2030, Sustainable Cities and Communities.

According to this metabolic logic, the study focuses on abandoned urban areas, which are once again in the spotlight as places 'waiting" for innovative and more efficient uses (Fig.03). The abandoned sites in the urban system are reinterpreted as spaces for inflows and outflows of materials, resources and social interactions, in connection with the surrounding areas of the city and beyond. The study looks at these areas as the potential catalysts for urban development, looking at them as a sort of embedded driving force of urban hypercycles. The research adopts the term 'hypercycle' from a resilient perspective, that is the one adopted in chemistry and biology where hypercycle is the principle for the circular connection of positive and autocatalytic feedback (Rigillo, 2016).

These assumptions become the basis for configuring new design approach for shifting from a siloed mode to a holistic urban design thinking. This means to think the city as a complex and adaptive system where physical and social interconnections randomly reach a new 'critical' state that enables new structure to emerge. Such a self-regeneration process could be oriented and accelerated by design and policies, in a way that enable

local stakeholders and inhabitants to cooperate to regenerate former abandoned area through new uses and purposes.

Looking this way, the research intends the city as a "superorganism": [...] «In more scientific terms, one could say that a city is a complex system, made of overlapping components (people, social systems, buildings, infrastructure, services and so on) interacting amongst them in multiple and non-linear relations, while determining circular cause and effects mechanisms, which is why cities display a potentially circular nature. However, they are generally planned and managed in a linear way: the single components are dealt with as single compartments, with no consideration for their interactions. Oftentimes, a key element is neglected, first and foremost cities are made of people. With the urban metabolism approach, components are instead reintroduced within a sort of "urban super organism" which can be fully analyzed and redesigned in terms of innovation and sustainability» (Pluchino, 2021).

In this scenario, social innovation plays a key role: users are no longer mere consumers, but co-creators of value within new circular models that affect lifestyles. This transformation requires a deep understanding of community needs, so that circular models are socially accepted and consistent with local experiences and expectations (UNDP Philippines, 2021). Participation has been a key principle of sustainable development policies since the 1992 Rio Declaration, according to which environmental actions are only effective when they involve the entire citizenry. A more advanced awareness of circularity is influencing communities to act towards objectives of self-management and subsidiarity at a local scale. Social experiences in co-designing intercept both the envisioning of new material/ physic conditions (production of energy, food and essential services, adaptation and climate mitigation) and that of social relations. The latter works on a "multi-scaling" design approach which intercepts both the neighborhood and global dimensions, thanks to digital networks and enabling technologies.

According to the above-mentioned remarks, the project adopts Systemic Design intended as an interdisciplinary and participatory approach that integrates systemic thinking and human-centered design (Fig.04). This method operates on multiple scales – from the global to the local and down to the individual

Fig. 4 - Co-design process and users profiling in the establishment of the circular hub design program (Courtesy of Sara Garmanjani and Hanieh Khorami)

– connecting processes, actors and systems and assessing their overall impacts. This method responds to an emergent request coming from a 'bottom-up' demand that calls for the prompt adaptation of urban areas to the ongoing changes. Systemic design is consistent with the idea of urban renewal, where the design of the physical space is deeply linked to the demand for more inclusive, sustainable, and intelligent uses of the space itself.

Hence is the importance of configuring the circular economy not only as a regulatory obligation for the waste management sector; further, it is a strategic opportunity to design new urban infrastructure, tailored to apply CE principles to the specificities of the territories and communities.

As far as the definition of the Ellen McArtur Foundation (EMF, 2014), the alliance between design and intentions needs to be applied to the built environment, working on the continuous valorization of the extracted resources, as well as on the existing urban spaces and on the social processes.

The need for more sustainable urban spaces works together with social innovation processes, due to the relationship between people and spaces has long been based on reciprocity, often by developing a kind of mutual altruism and care.

Fig. 5 - EMF Butterfly Diagram (source: Circular economy systems diagram (February 2019) www.elenmacarthurfoundation.org Drawing based on Braungart & McDonough (cradle to cradle (C2C).

This observation pushes the research design approach towards complex cooperation strategies, so that the design of circular habitats is intended as a socially shared and economically achievable goal (Corsini & Moultrie, 2021).

According to these remarks, the research's theoretical framework emphasizes the idea of techno-cycles as depicted in the Ellen McArthur Foundation's (EMF) Butterfly Diagram (Fig.05), in contrast to a common (mis)conception that mainly identifies circular economy with recycling, almost exclusively. Although recycling allows us to produce new Secondary Raw Materials that can be used in industrial processes, it does not address resource consumption in a structural way, neither does it encourage responsible social behaviors, and it doesn't cover every potentiality of the circular economy.

The Ellen MacArthur Foundation's report clearly highlights the

need to design both material and social processes. Circular Economy is a multiscaling approach, ranging from micro enterprises to the industrial sector, from informal social practices to established ones. In line with this approach, the Butterfly Diagram depicts the very different opportunities to work on designing extended supply chain where products could to be re-distributed, reused, repaired and re-designed without returning in the industrial cycle. Such ambitious goal explains the fact that Circular Economy is "restorative by design and intention" covering both products, peoples and places. On the one hand, the design phase accounts for approximately 80% of the overall environmental impact of the products. On the other hand, the emergence of more responsible habits within urban communities makes it possible to create local enterprises and business opportunities and to activate new supply chain (the most relevant social "intention" of the present days). By making reuse and repair practices more accessible and widespread, new employment opportunities can also be generated.

As part of the theoretical framework, the study assumes as its regulatory framework of reference the European waste hierarchy, introduced by Directive 2008/98/EC, as well as the New Circular Economy Action Plan (COM(2020) 98 final), and the Zero Waste Europe (ZWE) strategy (2025-2030).

Further reference is the EU research program "New European Bauhaus (NEB)" aimed at promoting aesthetics, sustainability, and inclusiveness in the built environment, in accordance with the pioneering ideas of the original Bauhaus (https://new-european-bauhaus.europa.eu/index_en). NBH aims at engaging people at the local level, with a special buit on neighborhoods. Such a new approach is critical to building effective circular policies based on the real experience of co-decision processes.

To do this, the NEB program funds research designed to implement urban projects tailored to different communities, in order to ensure a more concrete and lasting impact. In this scenario, both design and implementation processes must incorporate the views of various stakeholders, fostering transparency and cooperation. People and places remain at the center, not forgetting the social inclusion, economic competitiveness, and strategic autonomy of the EU.

The general compliance of the study with the Eu framework of

actions is enforced by the 2020 EU Grean Deal. In this framework, the New Action Plan for the Circular Economy underlines the EU's role in a transition to a circular economy that is systemic, deep, and transformative, both within and outside the EU borders. Furthermore, as part of the Next Generatin EU program, the Italian Recovery and Resilience Plan (PNRR 2021-206) promotes social processes for the circular economy in urban areas and incorporates the EU Green Deal objectives for the ecological and digital transition (COM/2019/640 final); COM(2020) 98 final). Within the Italian PNRR 2021-2026, the MISSION 2 aims to promote culture and social awareness on circular economy issues through more effective support to local authorities in the Central and Southern Regions. To do this, the implementation of the Faro projects allocates 60% of the overall financial resources.

Such a scenario defines a completely new political and financial context, which offers scope for research and new approaches to public space design. The focus is on innovation, which is understood as the convergence of knowledge, ability to do things, and awareness of institutional roles and responsibilities.

3. Urban Circular Hubs

Circular Urban Hubs are conceived as an emerging eco-sociotechnical equipment which is designed to involve the urban population in the practice of circularity. Hubs aim to standardize typical circular activities (reuse, repair, and re-design) within urban neighborhoods thanks to the direct involvement of local subjects and population.

Each Circular Hub is designed as a part of a wider, urban infrastructure apt to accommodate new forms of economies to facilitate the reintroduction of discarded products into trade cycles. To do this, Circular Hub deepens the concept of techno-cycles described by the Ellen McArthur Butterfly Diagram with a view to extending this concept to emergent social practices such as re-distribution and re-selling.

In technological terms, each Hub is consistent with the principles of Life Cycle Design by reducing its construction impacts from the very early stage of pre-production until the dismission phase. In the process of decisions, Life Cycle Design has been mostly used to orient the Hub's project towards reducing re-

source consumption and adopting dry assemblage to facilitate maintenance and dismission. A further commitment is the one related to energy sufficiency using PV panels which have been sized to ensure hub operations and other potential uses for the neighborhood community and other users.

According to these premises, the Hub's project is based on the upcycling of dismissed shipping containers, reconfigured and adapted in both shape and functions.

Shipping containers play a key role in this proposal. The container's anatomy highlights the correspondence between shape and materials that is finalized to increase mechanical resistance to vertical loads and distribute weight on surfaces. The roof and the side wall panels are made by Corten Steel Sheets with corrugated profiles for strength and rigidity, while the top and floor rails have the function of bracing the structure and improving its mechanical resistance. The 28 mm Laminated Marine Plywood floor inside the container adds to its rigidity and resistance performance (Fig. 06)

Learning from the Lot-Ek experience (https://lot-ek.com/), the research team worked on the fact that containers are parallelepiped volumes, easy to combine in many different layouts. Looking at this way, such a design approach recalls the typical 'Lego-blokes' philosophy, in which a very few construction joints may allow a huge set of combinations.

Therefore, the Hub's project is conceived with respect to a ba-

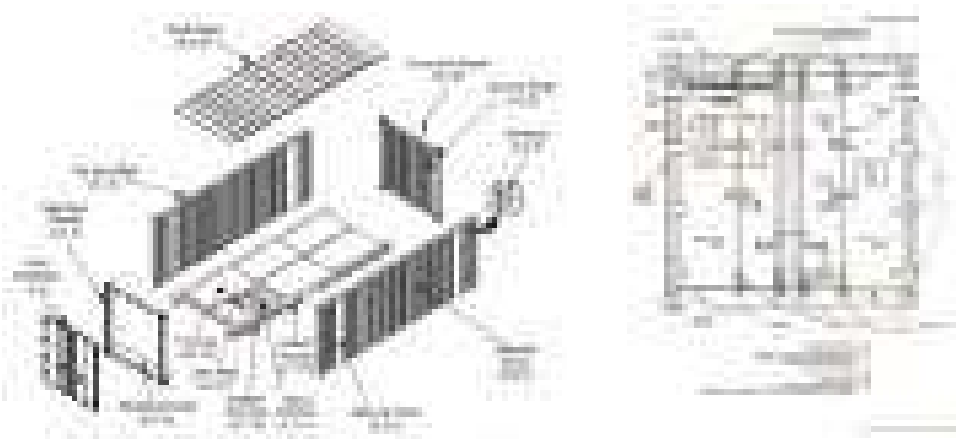

Fig. 6 - Container Anatomy (Source: https://www.shippingandfreightresource.com/anatomy-of-a-shipping-container/)

sic module, repeatable and adaptable to the diversity of urban contexts. Modularity the Hub fits to adapt to a wide range of urban settings according to the inner differences of the urban places both in terms of size and geometry. It is designed with

low-cost and low-tech technologies and must be easily assembled and then, if necessary, dismantled and reassembled elsewhere according to different functional layouts.

The Hub can travel easily thanks to the shipping container's dimensions, and it doesn't need heavy operations for foundation and for the functional nets (water, sewage, electricity).

Focuses on defining an advanced prototype of an urban hub: a mobile and modular structure, organized as a network of devices capable of responding to the specific eco-socio-technical needs of each local context. These hubs are configured as discrete urban entities, characterized by open and flexible functional layouts and equipped with elements dedicated to the various techno-cycles of reuse, repair, redesign and upcycling. Each Circular Hub hosts a complex functional program in which circular activities are integrated with complementary uses such as leisure spaces, sports facilities, and educational services (Fig. 07). Named "CIRO," the hub is conceived as a non-specialized infrastructure aimed at extending the value and life cycle of waste products. It is realized through the combination of decommissioned shipping containers, adapted and refunctionalized through combinatory processes that exemplify emerging requirements of contemporary living (Fig. 08).

The hub is designed as an atopic space, adaptable to different urban contexts in terms of both spatial extension and geometric configuration. Based on low-cost and low-tech solutions, it is intended to be easily assembled, disassembled, and relocated according to different functional layouts. The system is conceived to be energy self-sufficient and capable of integrating additional modules for leisure or exhibition purposes.

A key aspect of the project is its focus on a specific user cluster, identified through user-centered design methodologies. For this target group, a dedicated digital application has been developed to support and enhance communication and engagement with the hub's activities.

The educational experience was further supported by two co-design workshops conducted in collaboration with Metellia,

the in-house company of the Municipality of Cava de' Tirreni responsible for urban waste management. The company is interested in activating new processes of exchange, training, and social education within the framework of the circular economy, in line with the program agreement signed with the Department of Architecture. In this context, the hub was conceived as a "demonstrator" of the techno-economic feasibility of emerging productive and social supply chains, acting as a driver of virtuous behaviors aimed at environmental, economic, and social benefits. At the same time, it represents a new technical product for urban space, capable of expressing innovative technological and use-related requirements associated with evolving sustainability values.

This research focuses on the transferability of innovation and on the possibility of prefiguring conditions of co-evolution among existing technological domains, with the aim of enhancing their alignment with the principles of the green economy, smart environments, and climate mitigation. Among the project's priority actions is the definition of technological devices supporting design solutions structured around a new set of habitability requirements. These "emerging" requirements respond to an increasingly sophisticated demand for adaptability, characterized by the continuous interaction between physical, digital, and social dimensions in the organization of indoor, outdoor, and in-between spaces.

From a regulatory point of view, the Hub falls within the framework defined by Campania Regional Law 14/2016, which promotes the creation of centers for the recovery of durable goods, such as furniture and materials from the textile sector, as part of the planning of territorial area plans. The first two phases of the research provided an overall picture that guided further analysis of the supply chain.

Looking ahead, the ultimate goal is to facilitate the transition to contemporary circular societies capable of structuring regenerative economies based on local resources and territorial culture. This transition aims to address the consequences of the Anthropocene and the problem of environmental externalities by promoting models capable of integrating waste management, social innovation and technocycles into a common strategy for sustainable transformation.

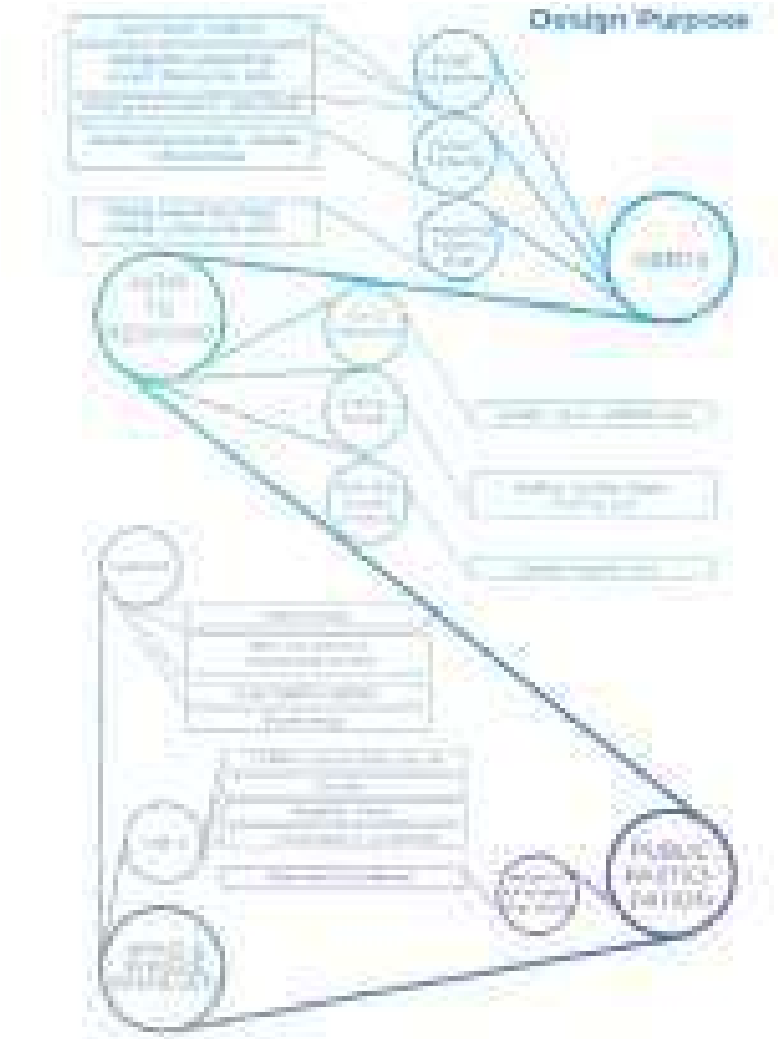

Fig. 7 - Design program (Courtesy of Francesca D'Auria and Maria Staiano)

Fig. 8 - Design modules and functions (Courtesy of Sara Garmanjani and Hanieh Khorami)

4. Planning the Net. A Gis-based method to place the urban circular infrastructure

This study analyses the processes of reuse, redesign and upcycling of existing resources as part of strategies aimed at maximizing the value of products and materials throughout their life cycle. The proposed methodology is aimed at prototyping a collaborative decision process to manage circular supply chain at neighborhood level, considering the specific of the eco-socio-technical context, its cultural traditions and the habits of local communities. The aim is to reduce waste production for extending the life cycle of products and integrating citizen science practices with circular economic processes.

Such a new infrastructure works on a system of new public spaces (urban circular hubs) and it is original in both the purpose and methods. In fact, the study overcomes the typical sectorial approach on waste management and planning and it implements the concept of circular infrastructure as a traditional sectorial planning on waste by introducing a site-specific design approach able at spatializing waste flows within the city, in so depicting a network of urban hubs conceived as eco-socio-technical infrastructures that enable cycles of reuse, repair, redesign and up-cycling of discarded products.

Therefore, the project of new urban infrastructure for the circular economy is not merely a technical or marketing operation aimed at attracting new development. It rather appears as an opportunity to harmonize the emerging demands for urban quality, including the ones of the extended accessibility to public spaces and of the "reuse" of the city.

5. Pilot project in Western Naples, Italy

Urban hubs are designed as nodes within an integrated network capable of interacting with the physical and logical structure of the city, with the primary objective of promoting sustainability (Chang, et al., 2008). They function as devices capable of mitigating climate risks and activating new circular economy dynamics, assuming a central role not only in the production of physical spaces, but also in the provision of essential services for everyday life. In this context, adaptability, flexibility and versatility emerge as key principles for ensuring effective and last-

ing implementation. Based on these assumptions, the research work develops from three central questions. Firstly, it examines how to manage waste flows according to a logic of proximity, identifying the supply chains that are best suited to being reconfigured in a circular manner. Secondly, it analyses how to select, within the study area, the most suitable locations for a new urban infrastructure dedicated to these practices. Finally, it explores which products and activities can actually be managed within the hub, thus defining its functional and operational role. In the case of the western area of Naples, the objective was to develop a quantitative approach to planning waste flows from the textile, wood-furniture supply chains in order to identify new production chains and urban infrastructures specific to the area. The analysis is based on a multi-scale methodology implemented through a GIS platform capable of spatializing and quantifying data.

The research method involved an initial phase in which the two mapping criteria were defined in order to identify the most suitable areas. The two categories of criteria are 'hard' for the technical and physical aspects of surface area, land cover, road accessibility and proximity; the 'software' criteria are economic and social and concern the identification of direct and indirect users and the actors present in the area. Once the strategic sites had been identified, the wastescapes in the area were mapped and, for each supply chain, an area was selected in which to estimate the incoming flows and the activities to be carried out within the hub (Figure 09 - 10). This approach integrates social and technical systems within the design thinking by promoting the idea that "Circular Economy is regenerative by design and intentions" (EMF 2014).

As regards the wooden furniture supply chain, an area was identified near Circumflegrea station in Pianura district, characterized by the presence of waterproof surfaces and proximity to car parks, schools and small craft businesses (Figure 11). In this case, the logistical requirements associated with the bulkiness of the materials made the availability of space for parking and handling the products particularly important. Another location was identified in the Soccavo district, near the Circumflegrea stations, the church, the local market and a Rom camp, with which collaborative work inclusion programs are planned.

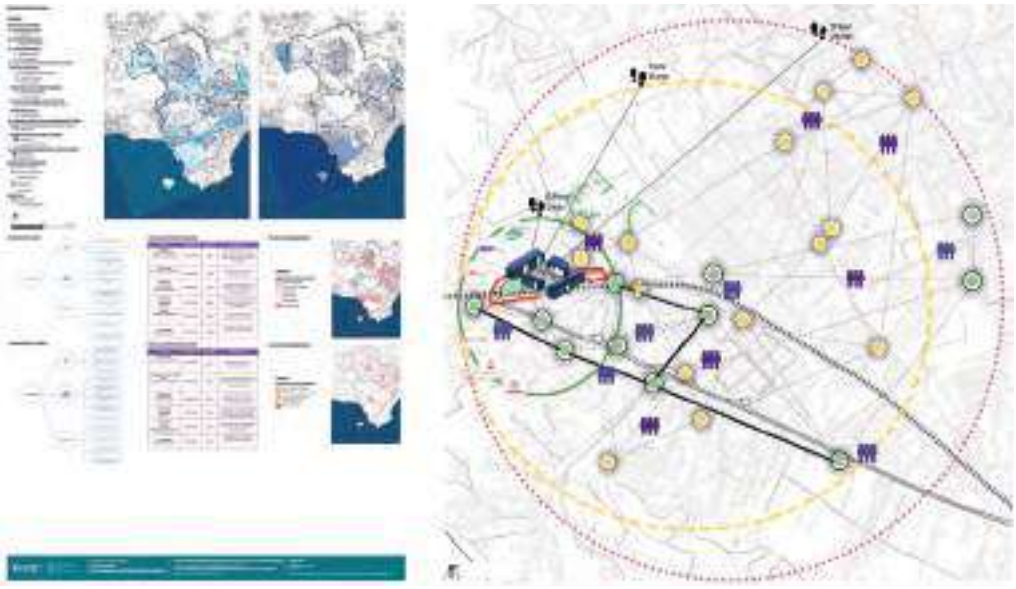

Fig. 9 - Perimeter definition process, selection of areas and activities for the design of a circular urban hub for wooden furniture (Courtesy of Francesca D'Auria and Maria Staiano)

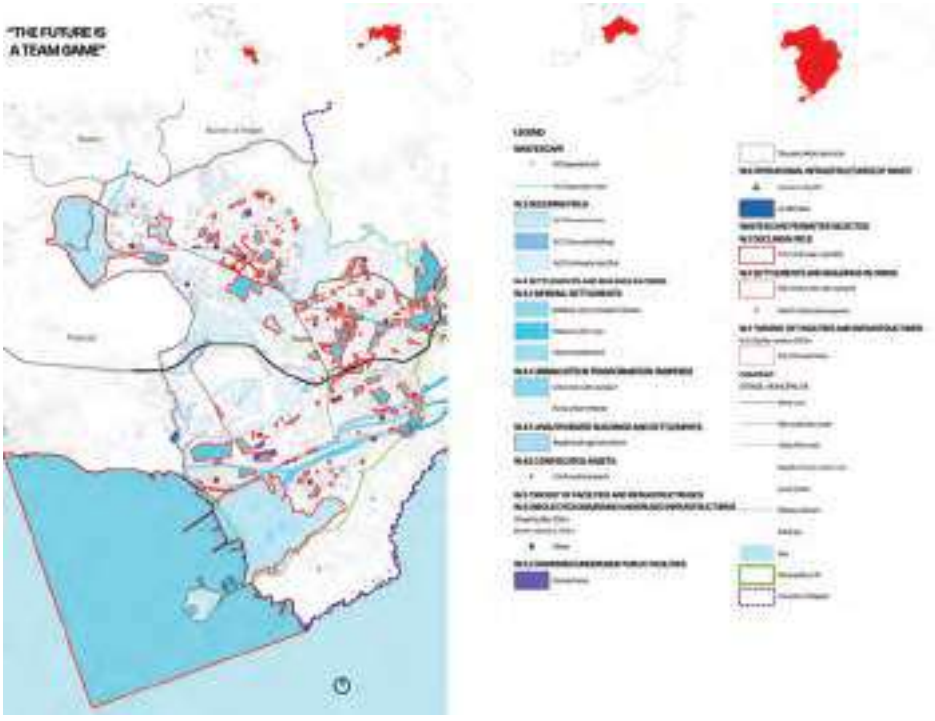

Fig. 10 - Selection of a suitable area to host a Circular Hub for wooden furniture (Courtesy of Francesca D'Auria, Maria Staiano, Giovanni Estatico, Antonia Tartaro, Pietro Stefanelli, Ciro Amato, Fabiana Varriale, Maddalena Raimondi, Alessandra Ascione, Christian Orfano, Catarina Ferolla)

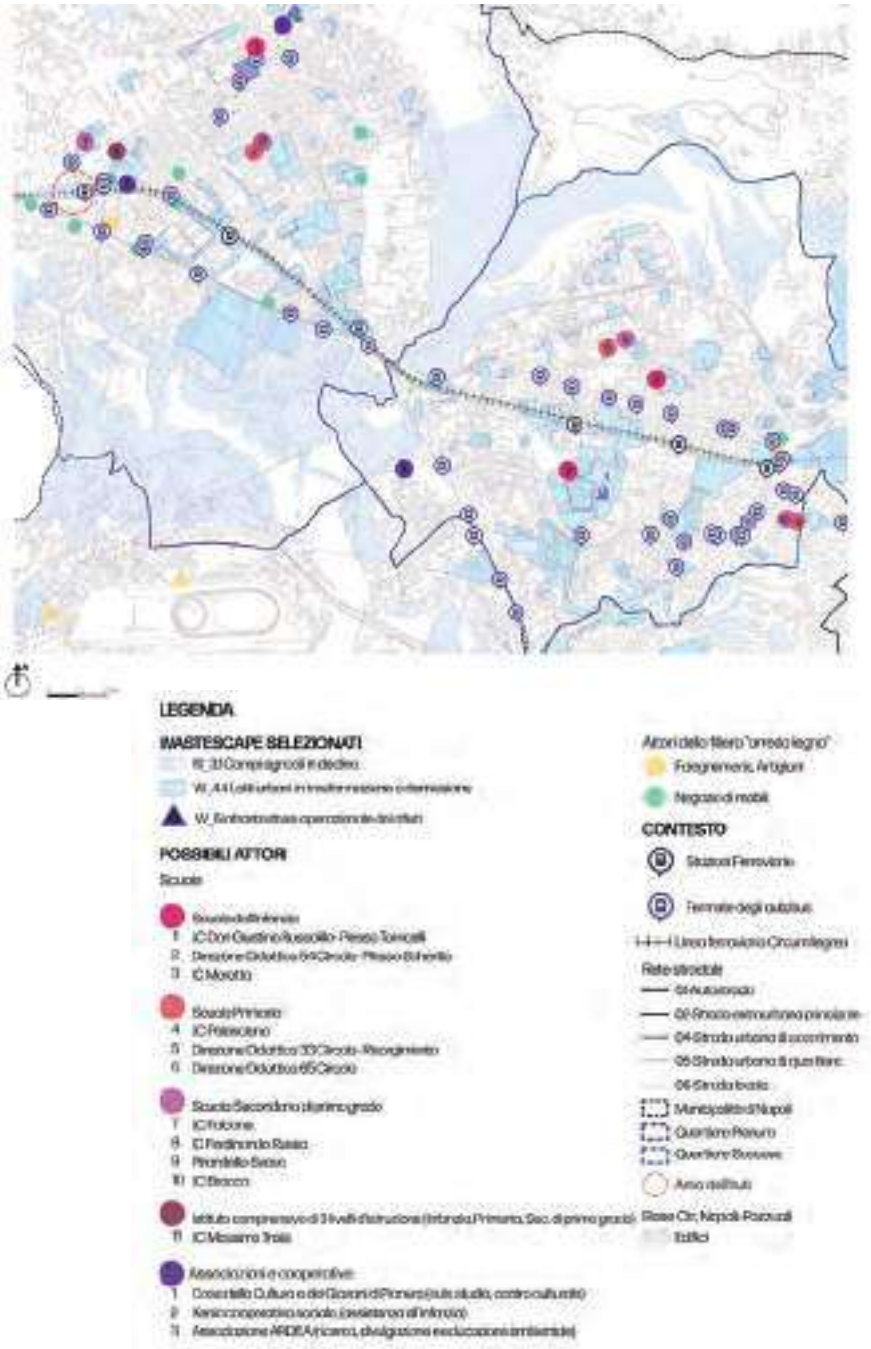

Fig. 11 - Selection of a suitable area to host a Circular Hub for wooden furniture. Image created by students of the SRT degree programme (Courtesy of Francesca D'Auria and Maria Staiano)

For the waste electrical and electronic equipment (WEEE) supply chain, an area was selected that is close to disposal and recycling facilities and has good connections to the urban transport network, which is necessary to facilitate the flow of materials and management operations.

Finally, regarding the textile supply chain, an area has been identified that is easily accessible by public transport and located close to commercial areas and markets, in particular local circuits specializing in the sale of clothing. This location simplifies logistics operations and at the same time facilitates distribution and reuse close to schools and everyday locations.

6. Research repeatability and transfer in Ulanbaatar Mongolia

The 3R4UB project investigates the repeatability and transferability of a collaborative research methodology aimed at supporting circular waste-management processes in Ulaanbaatar, Mongolia. The project explores how knowledge, methods and design tools derived from experiences in spatial planning, environmental and community-based design can be critically adapted to a different territorial and socio-institutional setting. In this sense, transferability is understood as the capacity to reconfigure a methodological framework in response to local environmental, cultural, social and institutional conditions.

This interpretation is particularly relevant in Ulaanbaatar, where rapid urbanisation, informal settlements, climate vulnerability and fragmented waste-management systems generate complex environmental and social challenges. These conditions require solutions that are not only technically efficient, but also spatially grounded, socially embedded and institutionally feasible. The project therefore operates as a methodological bridge between the Italian and Mongolian contexts, combining spatial analysis, systemic design, participatory planning and technological innovation to support context-sensitive circular transition processes.

Within this framework, the hub is conceived as an adaptive infrastructure able to translate circular economy principles into a spatial, social and technological device.

Its role is not limited to waste collection or resource manage-

Fig. 12 - Target and Beneficiaries diagram. Beneficiaries: MSMSs operating in the waste recycling sector, so that the Mongolian economy will grow thanks to better management of economic resources and the reduction of waste; the inhabitants of Ulaanbaatar will live in a healthier and cleaner environment © 3r4ub.

ment, but extends to the activation of local circular flows involving waste, energy production, food, essential goods and services, as well as climate adaptation and mitigation strategies. At the same time, the hub is designed to foster social exchange, community participation and local capacity building, becoming a flexible space for collective use and community empowerment.

For the Ulaanbaatar case study, the hub is planned as a temporary and seasonal structure, mainly active during the hottest months of the year. This choice reinforces its adaptability to climatic conditions and seasonal community needs, while allowing the prototype to be tested as a flexible infrastructure rather than as a permanent and rigid intervention. From a technological perspective, the hub is designed to optimise resource use, improve energy efficiency and thermal performance, reduce consumption and increase levels of self-sufficiency. Its spatial and operational configuration can therefore vary according to

available resources, user needs, climatic conditions and local economic capacities.

The adoption of a Systemic Design approach supports the definition of a model that is standardised in its methodological structure but adaptable in its physical, technological and organisational configurations. This approach enables the development of hubs that can be replicated in different contexts while remaining responsive to specific economic conditions and capable of generating positive impacts on local resources and economies (Attaianese et al., 2023).

Community involvement represents a fundamental condition for the effectiveness of this transfer process. Participatory planning practices, capacity-building actions and the creation of training and employment opportunities are therefore integrated into the project as operational components of the methodology. For Ulaanbaatar, user profiles were defined through the User-Personas method, following the perspective of A User Management Perspective for a Circular Economy, which enabled the identification of target groups, specific needs and possible patterns of use for different configurations of the prototype. This step supports a more accurate correspondence between spatial design, technological solutions and the expectations of local communities.

The Ulaanbaatar case demonstrates that the international transfer of circular economy strategies requires a balance between methodological standardisation and contextual adaptation. The research confirms that transferability depends on the capacity to adapt tools, governance models and participatory processes to different territorial, socio-economic and climatic conditions (Esposito De Vita et. Al., 2023).

7. Conclusions

The project is part of a scientific and technological context aimed at promoting environmental sustainability, social inclusion and the ability to adapt to ongoing socio-economic changes. The experiments conducted and the results achieved have led to the development of an innovative device capable of integrating advanced technological solutions with a particular focus on the socio-environmental dynamics of the territories involved. Its main value lies in its ability to extend the life cycle

of waste materials and, at the same time, encourage virtuous behavior aimed at reducing environmental impact.

The topic is part of a broad scientific debate, characterized by multiple contributions related to upcycling practices in urban areas. However, much of the literature tends to focus on the technical and operational aspects of the process, leaving in the background the potential role of small local businesses and creative actors in promoting local upcycling models capable of impacting the neighborhood scale through new forms of management, production and socio-economic organization.

The future development of the project could focus on defining collaborative decision-making processes, involving these actors in the construction and activation of local circular supply chains. This implies the adoption of co-design and co-evaluation processes with citizens, stakeholders and institutions, enhancing community traditions, practices and habits in the redevelopment of urban spaces. These processes are part of capacity building and community engagement approaches, aimed at promoting the active participation of different social components in the production of shared results, useful both to the community and to scientific progress.

The results of the study confirm that upcycling processes can be effective tools for rethinking urban metabolism and the circulation of materials, contributing to the creation of new economic opportunities and social inclusion. The integration of systemic design, spatial analysis conducted using GIS tools and participatory approaches demonstrates the potential of models capable of regenerating local economies and fostering new collaborative ecosystems. The cooperation between CNR IRISS, the Department of Architecture of the University of Naples Federico II and the SWITCH-Asia program testify to the effectiveness of interdisciplinary partnerships in concretely promoting the circular economy agenda.

The next stages of the research will focus on monitoring the environmental and social performance of the experimental hubs, developing digital platforms for data sharing and transparency, and adapting the model to other urban contexts in the Mediterranean and Asian areas. Ultimately, the Urban Waste Hub is a replicable and adaptable model capable of promoting circularity, creativity and community empowerment in contemporary cities.

References

- Adami, L., & Schiavon, M. (2021). *From circular economy to circular ecology: A review on the solution of environmental problems through circular waste management approaches.* Sustainability, 13(2), 925.
- Attaianese, E., & Rigillo, M. (2021). Ecological-thinking and collaborative design as agents of our evolving future. *TECHNE – Journal of Technology for Architecture and Environment*, (2), 97–101. https://doi.org/10.13128/techne-10690
- Attaianese, E., Castellano, C., Clemente, M. F., Paragliola, F., & Rigillo, M. (2023). Attrezzature emergenti per lo spazio urbano: Processi di upcycling per filiere circolari. *ECO Web Town*, 27, 126–135.
- Bhatt, D., Silverman, J., & Dickson, M. A. (2019). Consumer interest in upcycling techniques and purchasing upcycled clothing as an approach to reducing textile waste. *International Journal of Fashion Design, Technology and Education*, 12(1), 118–128.
- Bistagnino, L., & Campagnaro, C. (2014). Systemic Design. In A. C. Michalos (Ed.), *Encyclopedia of Quality of Life and Well-Being Research*. Springer. https://doi.org/10.1007/978-94-007-0753-5_4033
- Bridgens, B., Powell, M., Farmer, G., Walsh, C., Reed, E., Royapoor, M., Gosling, P., Hall, J., & Heidrich, O. (2018). Creative upcycling: Reconnecting people, materials and place through making. *Journal of Cleaner Production*, 189, 145–154.
- Cassidy, T. D., & Han, S. L. C. (2017). Upcycling fashion for mass production. In M. A. Gardetti & A. L. Torres (Eds.), *Fashion and Textiles: Values, Design, Production and Consumption* (pp. 148–163). Routledge.
- Chang, Y., Lee, Y., & Stolterman, E. (2008). Personas: From theory to practices. *Proceedings of NordiCHI*, 20–22 October 2008.
- Circularity Gap Report. (2022). https://www.circularity-gap.world/2022
- Circularity Gap Report. (2023). https://www.circularity-gap.world/2023
- Conduit, J., Karpen, I., & Willmott, T. (2023). User circularity practices: Adopting a user stewardship perspective for a circular economy. *AMS Review*, 13, 211–231.
- Corsini, L., & Moultrie, J. (2021). What is design for social sustainability? A systematic literature review for designers of product-service systems. *Sustainability*, 13(11). https://doi.org/10.3390/su13115963
- Cossu, R., Salier, V., Bisinella, V. (2012), "Introduction: The Urban Mining Concept", in Cossu, R., Salier, V., Bisinella, V. (eds), *Urban Mining: A global cycle approach to resource recovery from solid waste*, CISA, Padova, pp.13-20

- V. (eds), *Urban Mining: A global cycle approach to resource recovery from solid waste*, CISA, Padova, pp.13-20
- Dissanayake, G., & Sinha, P. (2015). An examination of the product development process for fashion remanufacturing. Resources, *Conservation and Recycling*, 104, 94–102.
- Earley, R. (2011). Upcycling textiles: Adding value through design.
- Ellen MacArthur Foundation. (2013). *Towards the circular economy*. Journal of Industrial Ecology, 2(1), 23–44.
- Ellen MacArthur Foundation. (2020). *The circular economy: A transformative Covid-19 recovery strategy*.
- Esposito De Vita, G., Visconti, C., Ganbat, G., & Rigillo, M. (2023). A collaborative approach for triggering environmental awareness: The 3Rs for sustainable use of natural resources in Ulaanbaatar (3R4UB). *Sustainability*, 15(18), 13846. https://doi.org/10.3390/su151813846
- European Commission. (2019). *The European Green Deal* (COM/2019/640 final).
- European Commission. (2020). *A new Circular Economy Action Plan* (COM/2020/98 final).
- Fletcher, K., & Grose, L. (2012). *Fashion & sustainability: Design for change*. Hachette UK.
- Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The circular economy: A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757–768.
- Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The governance of global value chains. *Review of International Political Economy*, 12(1), 78–104. https://doi.org/10.1080/09692290500049805
- Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy. *Journal of Cleaner Production*, 114, 11–32.
- Gunderson, L. H. (2000). Ecological resilience: In theory and application. *Annual Review of Ecology and Systematics*, 31, 425–439.
- Haklay, M., et al. (2020). ECSA's characteristics of citizen science.
- IUCN (2023) Cities and Nature, Issues Brief at: https://iucn.org/resources/issues-brief/cities-and-nature
- Janigo, K. A., & Wu, J. (2015). Collaborative redesign of used clothes. *Fashion Practice*, 7(1), 75–97.
- Jones, P. (2021). Systemic design: Design for complex, social, and sociotechnical systems. In *Handbook of Systems Sciences* (pp. 787–811). Springer.
- Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerden, F. (2018). *What a waste 2.0*. World Bank.

- Kamleitner, B., Thürridl, C., & Martin, B. (2017). The lure of a product's origin: How upcycling attracts consumers. *ACR North American Advances*.
- Lacy, P., Rutqvist, J., & Lamonica, B. (2016). *Circular economy: Dallo spreco al valore*. EGEA.
- Memon, M. A. (2010). Integrated solid waste management based on the 3R approach. *Journal of Material Cycles and Waste Management*, 12, 30–40.
- Moggridge, B. (2006). *Designing interactions*. MIT Press.
- Morseletto, P. (2020). Targets for a circular economy. *Resources, Conservation and Recycling*, 153, 104553.
- OECD (2020), *The Circular Economy in Cities and Regions: Synthesis Report*, OECD Urban Studies, OECD Publishing, Paris, https://doi.org/10.1787/10ac6ae4-en.
- OECD (2025), *The Circular Economy in Cities and Regions of the European Union, OECD Urban Studies*, OECD Publishing, Paris, https://doi.org/10.1787/e09c21e2-en.
- Paras, M. K., & Curteza, A. (2018). Revisiting upcycling phenomena. *Research Journal of Textile and Apparel*, 22(1), 46–58.
- Paola Pluchino, Urban metabolism: the city as a living organism is circular by nature, [Online] RENEWABLE MATTER#36 - 2021
- Rigillo, M. (2016), Note per un approccio cognitivo alla mappa dei drosscape, in Gasparrini, C., Terracciano, A. (eds) *Drosscity. Metabolismo urbano, resilienza e progetto di riciclo dei drosscape*, LISt Lab Rovereto (TN), pp. 78-91
- Robinson, L. D., et al. (2018). Ten principles of citizen science. In *Citizen Science*, UCL Press.
- Russo, M. (2018). "Rethinking resilience, design the city through its metabolism". *TECHNE - Journal of Technology for Architecture and Environment*, (15), 39–44. https://doi.org/10.13128/Techne-23200
- Sharma, H. B., et al. (2021). Circular economy approach in solid waste management for post-COVID recovery. *Science of the Total Environment*, 800, 149605.
- Singh, J., Sung, K., Cooper, T., West, K., & Mont, O. (2019). Challenges and opportunities for scaling up upcycling businesses. *Resources, Conservation and Recycling*, 150, 104439.
- Steger, M. B. (2023). *Globalization: A very short introduction*. Oxford University Press.
- United Nations. (2015). *Transforming our World: The 2030 Agenda for Sustainable Development*.
- Vohland, K., et al. (2021). *The science of citizen science*. Springer.

- Wan, C., Shen, G. Q., & Choi, S. (2019). Waste management strategies. In *Encyclopedia of sustainability in higher education* (pp. 2020–2028). Springer.
- Wolman, A. (1965), "The metabolism of cities", *Scientific American*, Vol. 213, No. 3, pp. 179-190

CHAPTER
05 Mongolia: Divergent Accounts

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Abstract

The wind of the steppe carries stories that intertwine in unexpected ways. In contemporary Mongolia, these narratives converge on Ulaanbaatar, where half of the national population – approximately 1.7 million people out of 3.4 million – is concentrated in a deeply dual urban ecosystem. On the one hand, there is the formal, infrastructured 'city of stone'; on the other, there are the ger districts, informal settlements characterised by radically different levels of service.

Mongolia: Divergent Narratives is a photographic project created to highlight the effects of this transformation through a precise narrative structure: the diptych. Each pair of images juxtaposes two seemingly distant but deeply interconnected realities, constructing a narrative of contrasts that reveals the tensions of a country in rapid transition.

Keywords

Visual narratives, Ulaanbaatar, picture diptych

1. The structure of the diptych

The choice of the diptych is not formal but methodological. Placing two images side by side – one of traditional rural life, the other of the urban suburbs of Ulaanbaatar – means constructing a visual device that forces the gaze to move between the two poles, to seek connections, to recognise divergences.

The project alternates between two modes of photography that correspond to two scales of territorial interpretation. The photographs taken from the ground convey the human dimension: they allow us to recognise the presence of people, to capture gestures and relationships, to maintain the complexity of individual lives behind urban processes. Aerial drone footage, on the other hand, introduces a perspective that reveals spatial patterns invisible from the ground: the distribution of gers in pastures in relation to urban densification, the extent of landfills, the irregular geometry of settlements, the logic of land occupation. This alternation between two distances constructs a layered narrative that connects everyday experiences to systemic dynamics.

2. Reuse versus waste

One of the most striking contrasts concerns the relationship with materials and waste management. In rural areas, necessity and distance from supply centres have developed a deeply rooted culture of reuse. Objects have long life cycles: tyres become fences, metal drums are transformed into stoves, wood is recovered and reassembled, plastic bins and cans are used to store objects, clothes or food. Nothing is wasted because nothing is easily replaceable. This practice does not stem from an ideological choice but from a pragmatic necessity rooted in widespread knowledge.

In ger districts, this logic clashes with different consumption patterns. Waste accumulates along unpaved roads, on the edges of properties, in improvised landfills that dot the landscape. Plastic, metal, construction waste, tyres and discarded appliances create layers that tell the story of a system incapable of metabolising its own waste production. Ger districts do not have adequate infrastructure for separate waste collection: regular services mainly cover the 'stone city', leaving informal neighbourhoods excluded, with concrete environmental and health consequences.

In this context, along the roads connecting the two main landfills in Ulaanbaatar, micro-craft activities have sprung up that operate an informal form of sorting. These activities recover what can be sold – car wrecks, plastics, tyres, metals – and leave the rest to go to the unsorted landfill. Inside the fences that delimit these activities, there are often two or three gers: one serves as a home for the family, the others are workspaces where materials are stored, dismantled and sorted. Domestic life and economic activity coexist in the same space, in a continuity reminiscent of rural logic but applied to a degraded urban context, where working with waste becomes a form of subsistence.

The diptychs make this gap visible. On the one hand, images of rural camps where objects are integrated into an ecosystem of reuse; on the other, aerial views of suburbs where waste defines the urban landscape, marking the boundaries between properties, filling the gaps between dwellings, and changing the topography of the territory.

3. Open space, denied space

The difference between the countryside and the city can also be measured in terms of the availability of space. In rural areas, gers are distributed according to a logic that favours distance, visibility and the relationship with natural elements – water sources, pastures, shelter from the wind. Families have significant portions of land at their disposal, where children can play, animals can graze and the view can extend as far as the mountains.

In ger districts, space becomes a scarce and contested resource. Gers are clustered on small plots, separated by fences made of reclaimed wood or sheet metal. The streets are narrow, often unpaved, and rutted with deep grooves that turn to mud during the rains or become covered with dust in the dry season. Urban greenery is almost entirely absent: there are no trees, gardens or equipped common areas between the dwellings. Children play in the spaces between the gers, in improvised courtyards, on ground that alternates between clay and piles of materials.

This densification responds to specific economic dynamics. Families migrating from rural areas try to settle as close as possible to the 'stone city', where job opportunities, health services

and schools are concentrated.

But the cost of land is rising steadily, forcing many to occupy increasingly smaller plots in increasingly peripheral areas. Unlike rural ger settlements, urban ger settlements are not chosen for mobility but out of necessity dictated by precariousness.

4. Architecture of vulnerability

Traditional gers – circular wooden structures covered with felt – are designed for mobility. They can be dismantled and reassembled in a few hours, adapting to the seasonal cycles of nomadic pastoralism. In ger districts, they lose this characteristic. They are fixed to the ground, surrounded by permanent fences, flanked by brick or sheet metal structures – warehouses, kitchens, outdoor bathrooms built in the ' '. This hybridises a mobile architectural form with sedentary settlement logic, creating housing solutions that combine traditional elements and contemporary improvisations.

This hybridisation reveals the vulnerability of the inhabitants. Ger districts are mainly inhabited by the poorest sections of the population: families who cannot afford flats in the 'city of stone', who do not have access to mortgages or loans, who live in informal conditions even with regard to property titles. Many occupy land without proper documentation, in a precarious situation that exposes them to possible eviction and prevents them from requesting connection to water or sewerage networks even where these would be technically available.

The photographic diptychs show this difference, which is not only architectural but also social. The families portrayed in front of rural gers possess capital – herds, horses, knowledge of the territory – that guarantees a form of autonomy. Families in ger districts depend on informal economies, precarious jobs, and mutual aid networks that replace absent public services.

5. The landscape as an archive

Looking at these diptychs also means observing how the landscape records social and economic processes. The steppe preserves minimal traces of human presence: paths marked by the passage of animals and vehicles, temporary wooden fences, small buildings for storing equipment. It is a landscape that can

return to its original state once families move elsewhere.

Ger districts, on the other hand, accumulate. Every intervention leaves permanent marks: excavations for foundations that were never completed, piles of extracted earth, traces of planned but unbuilt roads, rubbish that accumulates over time. It is a landscape that records attempts, abandonments, and temporary measures that become permanent.

Aerial views are particularly effective in making these processes legible. From above, the geometry of rural settlements appears organic, dispersed, integrated into the natural topography. The ger districts, on the other hand, show an irregular grid, where properties fit together according to a logic of incremental occupation, where the gaps between dwellings are filled with waste materials, where the absence of planning produces chaotic but functional urban forms.

6. Divergent narratives, converging destinies

Mongolia: divergent narratives is part of the research project 3Rs for a sustainable use of natural resources in Ulaanbaatar (3R4UB), funded by the European SWITCH-Asia programme, which promotes sustainable approaches to urban waste management. In this context, photography is not only a means of documentation but also a tool for knowledge that allows us to capture aspects that escape quantitative data, to make spatial and social relationships visible, and to construct narratives that can engage with different audiences.

The narratives that the project presents are divergent but not separate. Families living in ger districts often maintain ties with rural areas: they return periodically to their areas of origin, send money to relatives who have remained in the countryside, and preserve cultural practices and knowledge related to pastoral life. Migration is not a one-way process but a continuous movement between city and countryside, between modernity and tradition, between aspirations for social mobility and nostalgia for ways of life that are disappearing.

The diptychs capture this tension. They do not offer a romanticised view of rural life or a simplistic denunciation of urban decay. Instead, they show the complexity of an unfinished transition, where temporary solutions become permanent, where

the absence of planning produces forms of self-management, where poverty coexists with forms of resilience and adaptation.

The future of urban Mongolia is being played out in these peripheral spaces, in these border areas between the formal and the informal. Mongolia: Divergent Narratives offers no answers, but poses necessary questions through a visual language that invites us to look beyond the surface, to recognise connections, to imagine possibilities.

In the following pages the diptyches combine the pictures taken by the author during the fieldwork in Ulaanbaatar.

Fig. 1 - Family portraits

Fig. 2 - Power and Heritage

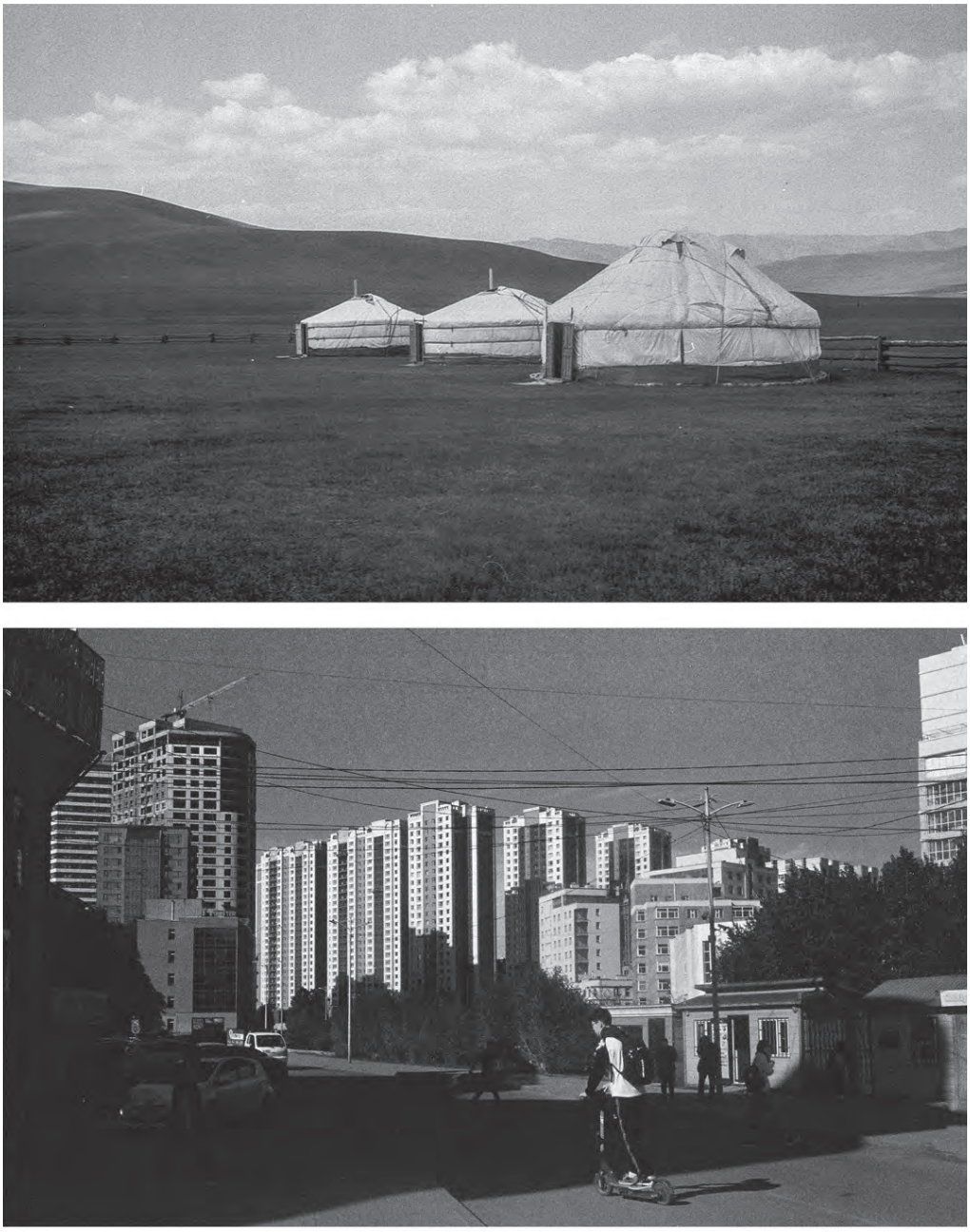

Fig. 3 - Where home is

Fig. 4 - Freedom! Freedom?

Fig. 5 - Over the border

Fig. 6 - Dreaming (?) about the city

Fig. 7 - Density Issues

Fig. 8 - Toolsthe city

Fig. 9 - Reuse

Fig. 10 - A question of care

Fig. 11 - Welcome back home

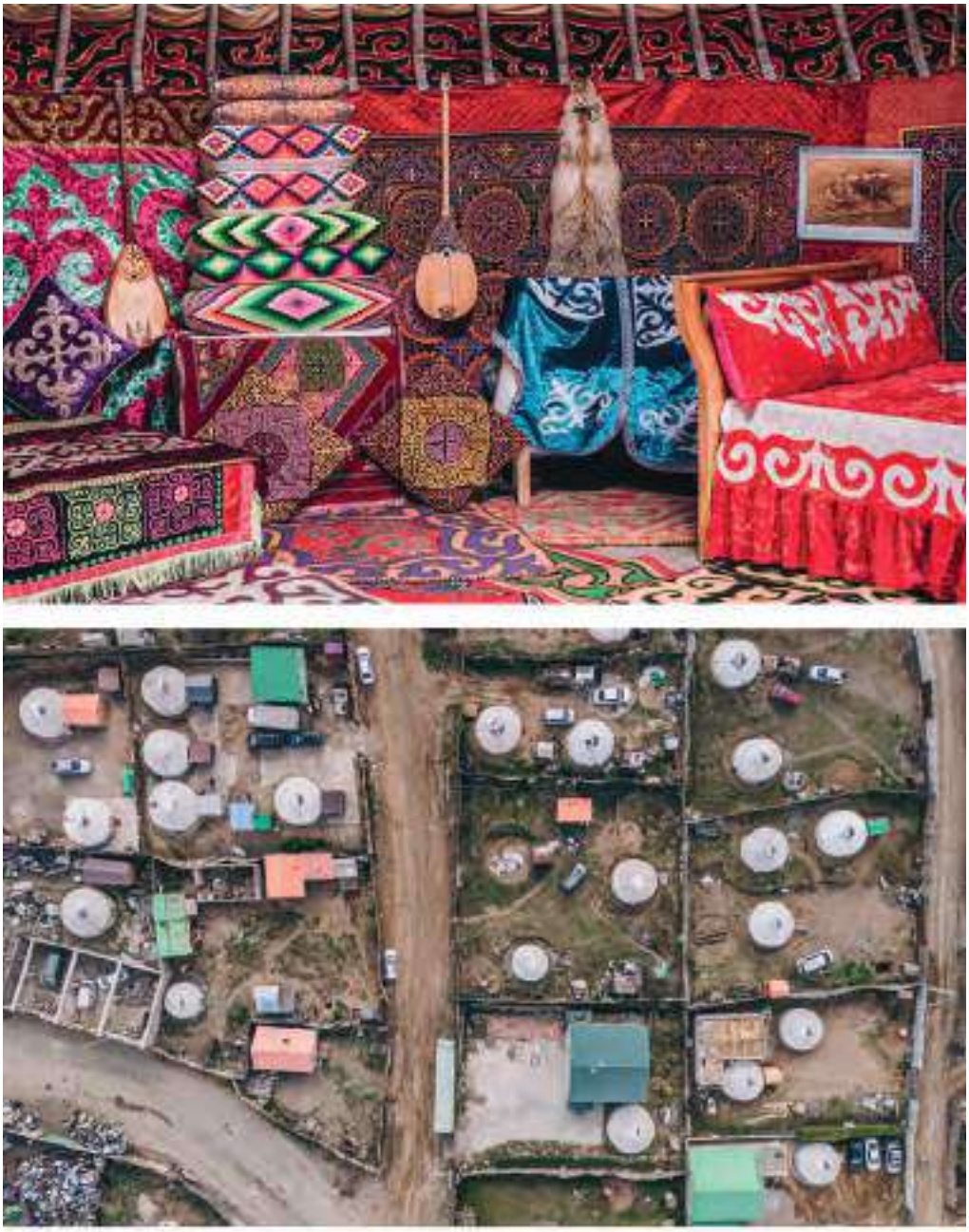

Fig. 12 - Indoor / Outdoor

Fig. 13 - As far as the eye can see

Fig. 14 - Spirits

Fig. 15 - Landscape / Wastescape

switchasia
Funded by the European Union

This volume is the second of the 3R4UB series developed to share the results of the project and enhance the awareness regarding the opportunities of a circular waste management. This volume focuses on the spatial dimensions of the project, integrating the different sectorial technical solutions within a system approach to the 3Rs. It starts by mapping the specificity of urban patterns, city's stratification and the settlement typologies of Ulaanbaatar, a critical perspective feeds the Spatially Informed Waste Management (UBSIWM) framework integrating multilayer datasets and qualitative data into a coherent GIS-based tool. The UBSIWM approach introduces the masterplan for waste management, co-designed with the Mongolian partners by applying a systemic planning approach to detect the specific needs of the Ulaanbaatar neighbourhoods: differences in building typologies, population densities, and accessibilities have been considered within the masterplan. This latter has also been paired with a capacity building program, including training to UBCity officials, community engagement and analysis of best practices. The dialogue with Mongolian universities and the involvement of scholars and students from the University of Naples Federico II gave to the research group the opportunity to explore innovative solutions to enhance the potentiality of a circular approach: circular hubs for the waste management cycles have been designed in order to involve local communities in a daily circular experience. A visual survey concludes the book. Photographs made by Francesco Sammarco during his fieldworks in Mongolia offers original perspectives of UBCity, its inhabitants, and its habits.

Profiles

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