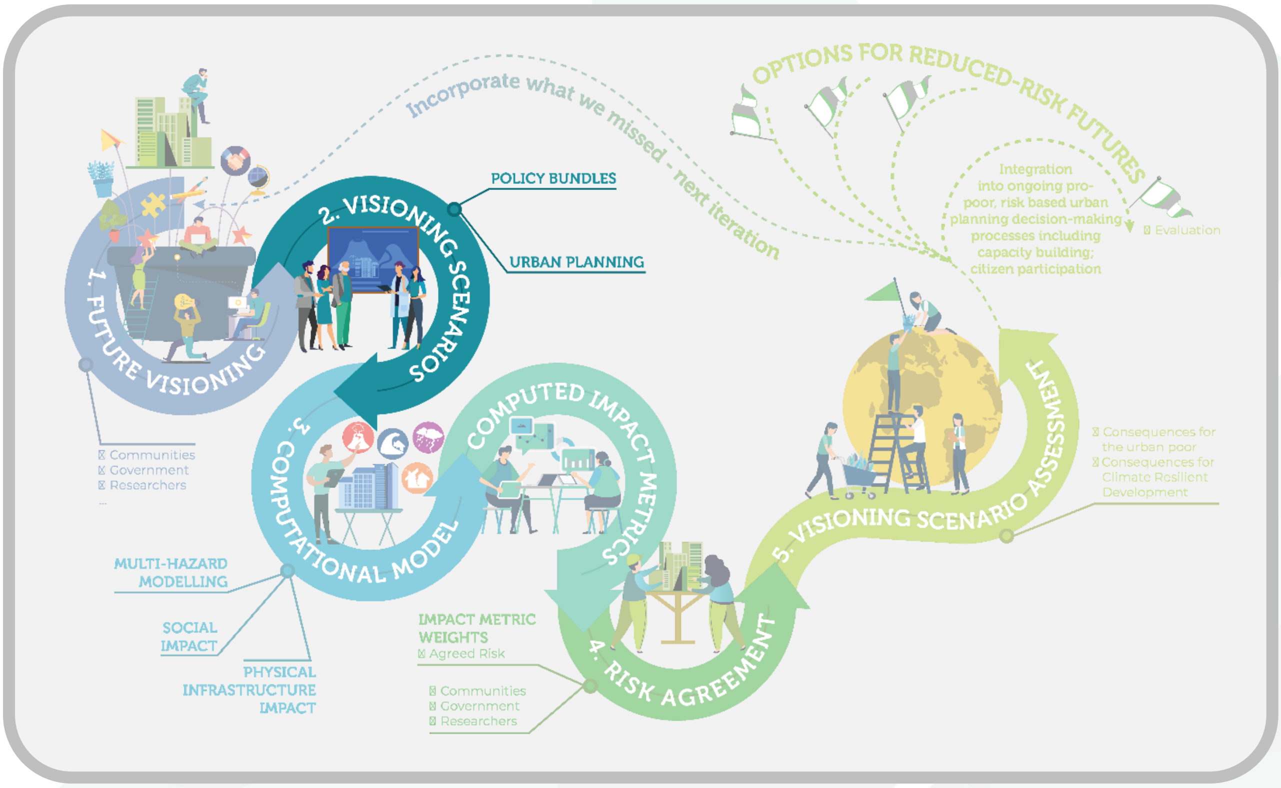
Tomorrow's CITIES
Urban Risk in Transition

Tomorrow's Cities Decision Support Environment (TCDSE) Course

Module 2: Visioning Scenario Development

Workbook



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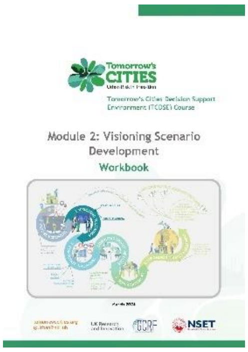

Workbook

Module 2: Visioning Scenario Development

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PREFACE

This workbook on Module M2: “Visioning Scenario Development” has been developed under the Capacity Strengthening program on Tomorrow’s Cities Decision Support Environment (TCDSE) Course of the Tomorrow’s Cities (TC) project. This course aims to enhance the capacity of professionals from the Tomorrow’s Cities and urban areas in utilizing the TCDSE and expand its reach so that the cities or urban areas can then adapt the framework based on scenarios specific to them and ultimately self-sustain.

This module M2: "Visioning Scenario Development” is the second module of the TCDSE course and is based on the Work Package WP2 on "Visioning Scenario Development” of TCDSE. This workbook presents the details of module 2: "Visioning Scenario Development”. This module is aimed to enable the participants to implement the TCDSE’s approach and methods to deploy visioning scenario development in their city.

Visioning Scenario Development is the second stage of TCDSE and is a more 'expert-centered' component of the framework. Target Audience of this module are urban planner, architect, GIS Expert, DRR officials from Wards and Municipalities, Ministries from local, provincial, and Federal government, academician, researchers, representatives of Private sector, and Civil Society organizations.

This module “Visioning Scenario Development (VSD)” has five major sessions: Introduction Session, Policy Development and its exercise session, Land Use Planning and its exercise session, Data Generation and its exercise session, Validating Visioning Scenarios session. Each session of Module 2 course describes the process of VSD providing both theoretical knowledge and practical skill through real time in-depth exercises. The course includes the key components of the TCDSE, VSD objectives, methodologies, and outputs describing how the VSD feeds to next step of TCDSE – Multi Hazard Physical and Social Impact Assessment, with three major components Land Use Plans, Policy Bundles and Data package. It also explains how VSD outputs contribute to the TCDSE and its various stages.

The module will be using various examples from TCDSE cities, including different methods used for VSD in different cities. The second, third and fourth sessions are followed by in-depth exercises which enable the participants to understand and practice the process/methods of VSD. This module is believed to be able to transfer the skill and knowledge which will empower participants to deploy VSD in their cities.

The goal is to empower participants with the tools and expertise needed to excel in VSD whether the participants are professionals seeking to deepen their understanding or a newcomer eager to explore new horizons, this module offers something valuable for everyone.

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ABBREVIATIONS

CCM	Cohort-Component Method
CO	Combinatorial Optimization
DBMS	Database Management System
DRR	Disaster Risk Reduction
ESA	European Space Agency
GIS	Geographical Information System
HM	Hierarchical Models
IPF	Iterative Proportional Fitting
IPU	Iterative Proportional Updating
INGO	International Non-Governmental Organization
LAPA	Local Adaptation Plan of Action
LiDAR	Light Detection and Ranging
LPCC	Lumbini Provincial Capital City
LRS	Load Resisting System
LUP	Land use planning
MCS	Monte Carlo Simulation Methods
MoUD	Ministry of Urban Development
NAPA	National Adaptation Program of Action
NASA	National Aeronautics and Space Administration
NGO	Non-Governmental Organization
NSET	National Society for Earthquake Technology-Nepal
TCDSE	Tomorrow's Cities Decision Support Environment
UN	United Nations
USGS	United States Geological Survey
VSD	Visioning Scenario Development
WP	Work Package
WP0	Work Package 0, City Scoping
WP1	Work Package 1, Future Visioning
WP2	Work Package 2, Visioning Scenario Development
WP3	Work Package 3, Multi Hazard Physical and Social Impact Assessment
WP4	Work Package 4, Risk Agreement

SESSION 1: INTRODUCTION TO VISIONING SCENARIO DEVELOPMENT

Author of the Chapter: Dr. Emin Yahya Mentese

1.1 Objectives

The major objective of this session is to introduce the M2: Visioning Scenario Development.

By the end of the session, the participants will be able to:

- Discuss the Tomorrow's Cities Decision Support Environment (TCDSE) and its key components
- List the Purpose, Objective and content of Module 2: Visioning Scenario Development (VSD)
- Describe VSD in TCDSE Context
- Briefly outline the Policy development process, the Land Use Planning process, the Future Exposure Data Generation process and the Visioning Scenario development process and the Validation Workshop process

1.2 Structure of Session 1

Structure
1. Purpose, Objective, target audience, course content and evaluation methods of Module 2: Visioning Scenario Development (VSD)
2. VSD in TCDSE Context
3. Policy Development
4. Land Use Planning
5. Future Exposure Data Generation
6. Validation Workshop
7. Visioning Scenario
8. Implementation of the next sessions

1.3 Purpose, Objective and content of Module 2: Visioning Scenario Development (VSD)

1.3.1 Introduction to Tomorrow's Cities Decision Support Environment (TCDSE)

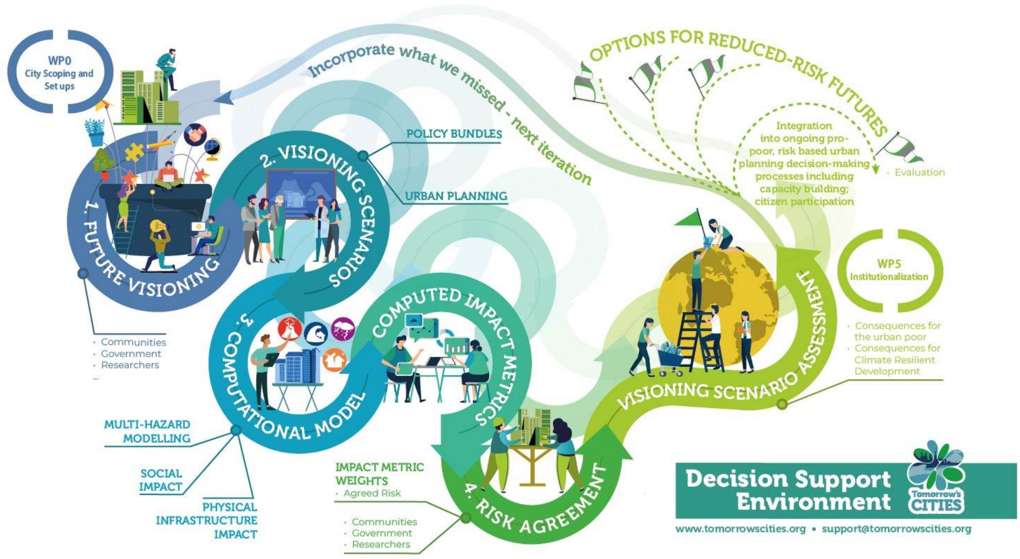


Figure 1: Summary of Tomorrow's Cities Decision Support Environment

Source: Tomorrow's Cities Communication Team.

The Capacity Strengthening program of Tomorrow's Cities is based on Tomorrow's Cities Decision Support Environment (TCDSE). The TCDSE is a flexible framework to support inclusive and evidence-based decision making, leading to a low-disaster-risk and more equitable urban development. As the name suggests, this is a process that supports informed decision making rather than making or enforcing decisions. Drawing on Tomorrow's Cities primary mission to reduce disaster risk for the urban poor, the TCDSE creates equitable and interactive spaces which allow multiple stakeholders and urban groups (whether institutional actors or urban residents) to think differently about risk. This is a space for learning; about the objective impacts of hazards on people, nature and the built environment, about different perceptions and experiences of hazardous events, and about how risk could be a negotiated concept. In a nutshell, the TCDSE articulates technical and political spaces of decision making by engaging in a systematic methodology composed of five stages: (1) Future Visioning, (2) Visioning Scenarios Development, (3) Multi-Hazard Physical and Social Impact Assessment, (4) Risk Agreement and (5) Institutionalization. It is important to note that, before the kick-off of the TCDSE, there is a preparatory stage (covered by Module 0 in this course) which deals with the assessment of existing data, a critical mapping and selection of stakeholder groups (on the basis of power imbalances in planning), besides other technical and logistical arrangements that allow the TCDSE to function.

- **Future Visioning** (Stage 1) encompasses a series of participatory engagements that explore desired urban futures with different city stakeholders, incorporating expectations for land uses and critical urban assets, as well as expected policies to tackle the negative impacts of future natural hazards.

- **Visioning Scenarios Development** (Stage 2) render these desired futures into detailed virtual representations that make Future Visions more realistic and connected to data-driven trends. Expected land uses are adjusted to meet planning standards, and a modelling of future exposure is incorporated. The latter means forecasting who the future urban residents will be, and where they will live and work. Further, Visioning Scenarios include a detailed refinement of policies discussed during Future Visioning workshops.
- **Multi-Hazard Physical and Social Impact Assessment** (Stage 3) subjects Visioning Scenarios to earthquake, flood and landslide events. This leads to an understanding of the consequences of the decisions made during future visioning and scenario building before a brick is laid. Maps of damage states combined with different impact metrics (number of casualties, of displaced households, etc) enable a clear visualisation of the spatial distribution of impact and help diagnose risk drivers back through complex causal chains in urban decision-making.
- **Risk Agreement** (Stage 4) opens up a collective definition of risk that accounts for the objective impact of hazards and the subjective priorities of key community and institutional groups that engaged with the TCDSE. Using digital tools, stakeholders unpack the consequences of spatial and policy decisions and how they increase or decrease disaster risk. They also assess the equity of the distribution of risk across space and the impacts of planning decisions on poor and disadvantaged communities in the event of natural hazard events, earthquakes, landslides or floods. Critical learning about risk, which results from our decisions, leads to an opportunity to modify our plans based on clear understanding of the risk they imply.
- **Iteration** (Stages 1 to 4 repeated) is one of the key innovations of the TCDSE. Having developed a vision, translated this into a detailed visioning scenario and exposed its risk consequences, stakeholders now revisit problematic aspects of their vision that have led to the risk uncovered by this analysis. The city team then repeat Stage 1, modifying some aspects of the future vision. These modifications then lead to changes in the visioning scenarios. The new visioning scenarios are now exposed to the same hazard events and the impacts metrics are recalculated. This leads to both a refined understanding of critical decisions leading to risk, and to discussions about how to transfer that learning into the actual decision environment of cities. This helps to promote policy uptake by institutions. The process can be repeated as often as required so that these new insights into decisions and their consequences lead to safer development planning and better decision making.
- **Institutionalisation** (Stage 5) happens once stakeholders have learned enough from the process of iteration. Cities could take concrete lessons and outputs from the TCDSE (e.g., actual plans and policy ideas) and the very tools and processes of Tomorrow's Cities into their institutional environments for a process of pro-poor risk reduction that is meaningful and long-lasting.

It is important to always keep in mind that this is a Decision Support Environment – not a Decision *Making* Environment - which means that the outputs of iterations are only informing planning discussions within cities. That is, the TCDSE offers a way to think differently about planning, in which risk is central. Although concrete solutions could be used, it is less of a prescription and more of a process of stimulating critical urban thinking.

1.3.2 Purpose of M2

Module 2: Visioning Scenario Development (VSD) is based on the WP2: Visioning Scenario Development (VSD) of Tomorrow's Cities Decision Support Environment TCDSE process. Module 2 is aimed to enable the participants to implement the TCDSE's approach and methods to deploy visioning scenario development in their city.

1.3.3 Objectives of M2

By the end of the module, the participants will be able to:

- Comprehend how policies may impact future urban contexts and how they function as a part of a visioning scenario that aims to reduce disaster risk.
- Produce land use plans based on the input from Future Visioning activities.
- Describe data collection, production, and management so that future exposure datasets are generated in a standardized way to be analyzed in WP3.
- Facilitate a bottom-up spatial planning approach that addresses the needs of the urban poor.

1.3.4 Target Audience of M2

Target Audience of this module are urban planner, architect, GIS Expert, DRR officials from Wards and Municipalities, Ministries from local, provincial, and Federal government, academician, researchers, representatives of Private sector, and Civil Society organizations.

1.3.5 Contents of M2

The M2 course is a 2-day course (9 hrs.) with 10 sessions including opening and closing sessions of the training. It covers theoretical sessions followed by their respective exercise sessions.

Table 1: Structure of M2

S.No.	Structure	Duration
1.	Opening Session: General Introduction, Pre-test, remarks	60 min
2.	Session 1: Introduction to Visioning Scenario Development	45 min
3.	Session 2: Policy Development	45 min
4.	Session 3: Exercise on Policy Development	60 min
5.	Session 4: Land Use Planning	45 min
6.	Session 5: Exercise on Land Use Planning	60 min
7.	Session 6: Exposure Data Generation	45 min
8.	Session 7: Exercise on Exposure Data Generation	60 min
9.	Session 8: Validating Visioning Scenarios	45 min
10.	Closing Session	60 min

1.3.6 Course Evaluation

The course is evaluated at different stages to collect feedback and, in turn, update the course to foster its effectiveness for future training. The following course evaluations will be conducted in this module:

i. Pre-/ Post-Test:

The pre/post- test is an evaluation of participant's knowledge before and after the training in order to evaluate knowledge improvement.

ii. Session Evaluation:

The evaluation of each session by the participants in terms of its relevance, content, delivery and duration.

iii. Daily Feedback:

Feedback on course content and management aspects collected from participants at the end of each training day.

iv. Overall Training Evaluation

The evaluation of the training done by the participants in terms of the overall training course. This entails an evaluation of the following: facilitators, in terms of subject matter knowledge, ability to facilitate, etc.; handouts and references; relevance and usefulness of the content; pedagogical methods; and comments on future improvements.

1.4 VSD in TCDSE Context

Tomorrow's Cities methodology is mostly concerned with the future; a timeframe of 30 years is the one usually used by cities to develop policies and plans. There are however different rationales for engaging in future-thinking, which could evolve into different methods. Probabilistic methods are usually asking how the future will look like if trends continue – this is a **predictive** rationale and is commonly called 'forecasting'. Qualitative methods are usually looking for desired future end states, asking how a good future (city) could look like – this is a **normative** rationale and is commonly called 'back casting'. In between forecasting and back casting, there are **exploratory** ways of thinking about the future, which could be more quantitatively or qualitatively inclined. These methods are usually relying on assumptions ('what if' questions) to produce alternative scenarios that relate to possible or feasible end-states. That is, exploratory approaches are usually asking what the future could look like if certain factors are maintained or introduced. These questions usually generate alternative scenarios.

TCDSE starts with Future Visioning, which entails both developing desired end-states (urban visions) and the policy alternatives to realise such visions. Future Visioning is a people-centred bottom-up approach, and it sets out to collectively assemble futures that reflect the aspirations, priorities, and experiences of different stakeholder groups.

Notwithstanding, because of Tomorrow's Cities task to reduce disaster risk for the urban poor, its approach to future visioning is informed by probabilistic information while also containing some degree of exploration. In practice, Future Visioning in the TCDSE is about thinking of futures (and trajectories) which are both desirable and possible. The image below suggests that process.

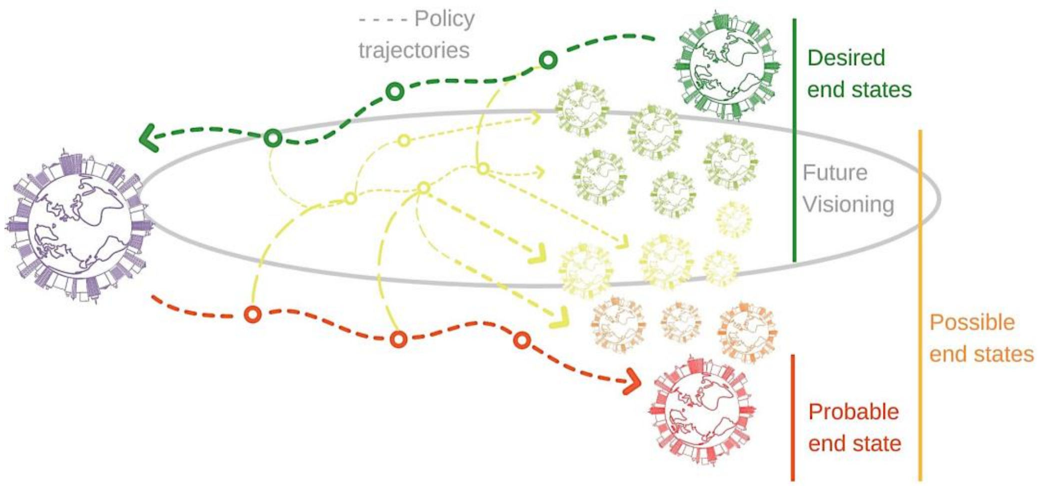


Figure 2: How Tomorrow's Cities approach to Future Visioning combined different rationales for future-thinking.

The image is inspired by IPCC Reports. Source: Future Visioning Toolbox, 2022.

Methodologically, VSD relies on an exploratory rationale and strategies for scenario development. A combination of future visioning and scenario development (representing and visualising future visions) is a novel and emerging technique used in the last decade for an effective communication of co-produced futures[2].

The literature on scenario development resonates with the above notes. In an extensive and recent review, different methods and approaches of scenario development are highlighted and referred to where three scenario development categories are defined based on the study by Borjeson et al. [3] : "predictive (forecasting), normative (visioning and back casting) and exploratory scenario planning". Predictive scenarios try to estimate the most possible, normative scenarios aim for the most desired and exploratory scenarios look for the multiple options that may arise in the future in order to have a more holistic perspective that also includes uncertainties [4].

Each approach has its own pros and cons but there are also hybrid modes of scenario development where planners rely on different scenario methods to incorporate local singularities and try to tackle complexity by generating flexible scenario processes in high-complexity/data-scarce contexts [5]. Interdisciplinarity lies at the core of scenario development, as it requires interaction and collaboration and know-how transfer among different disciplines [6]. Interdisciplinarity is integral also for identifying the complexity within urban systems for enhancing decision-making in urban extent [7] as interdisciplinary approaches include both qualitative (e.g. insights, narratives and social norms) and quantitative (e.g. environmental trends, biophysical characteristics) aspects regarding an urban extent[8], which provides a holistic perspective for future urbanisation scenarios.

The stage of Visioning Scenario Development draws on the outputs of Future Visioning and information on political context, hazards, urban planning norms and socio-economic trends. With this respect, there are three main tiers in VSD: i) policy development ii) land-use planning and iii) data generation. Policy development is the process of generating tangible policy options based on the solutions and aspirations gathered in future visioning. The land use planning is the process that translates the spatial expectations into land use plans compatible with the planning discipline and local planning criteria. Data generation is the process where these land use plans are detailed out to higher resolution by creating spatial and attribute information of buildings, households and individuals associated with the plan. A diagram representing this process is given in the Figure below.

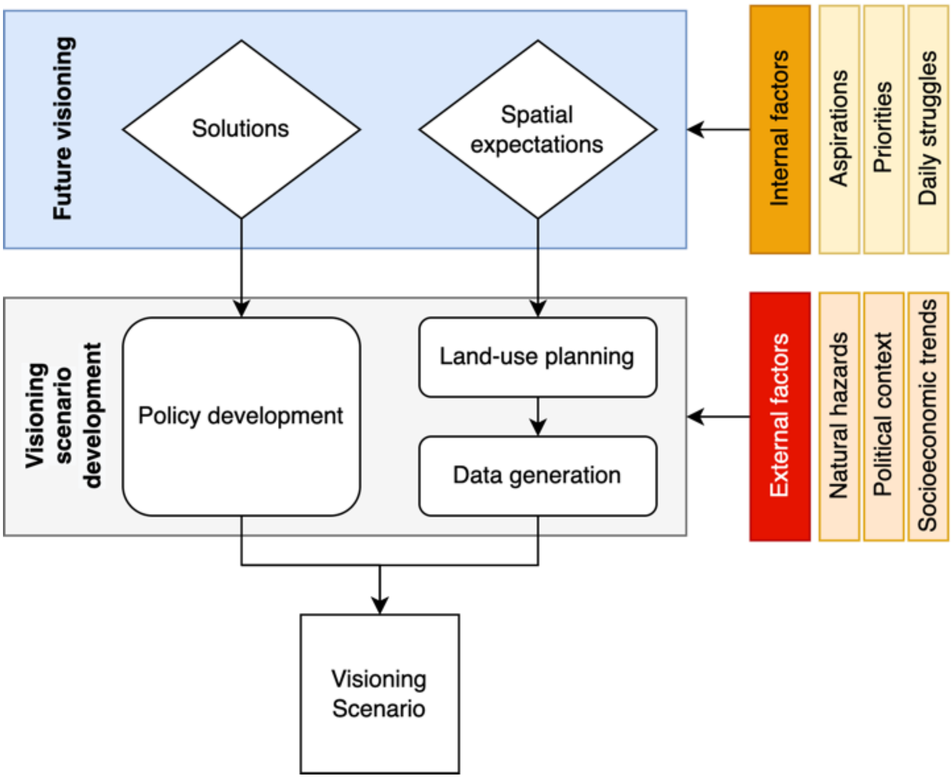


Figure 3: **VSD Process**

1.5 Policy Development

The **policy development** process consists of assessing policy expectations from Future Visioning workshops and providing expert notes and recommendations that make such options better connected to the context in question and oriented towards the potential negative impacts of future hazards. Whilst policy themes and alternatives – whether broad or specific – are usually connected to aspirations, policy experts try to inject realism into the process, by adding 'external factors' such as socioeconomic trends, political context, and natural hazards into the thinking process of stakeholders. The ultimate objective is to translate aspirations into tangible policy options that could be later speaking to already existing alternatives (but not yet implemented), adding new ideas into existing options, or prosing something novel. It must be noted that policy development is a cross-cutting activity that expands over the entire TCDSE process. In VSD process, policy development happens through a workshop - 'Validation Workshop' - in which potential policies are identified by the community groups with the **facilitation of the experts**.

For example, if a community group expects a specific policy option in the future (for the area of interest), this demand is questioned by the experts under three aspects:

- Is the demand sensible with respect to the socioeconomic trends in place?
- Is the demand already in the current political context and/or is it compatible with it?
- Is the natural hazard scape suitable for the demand?

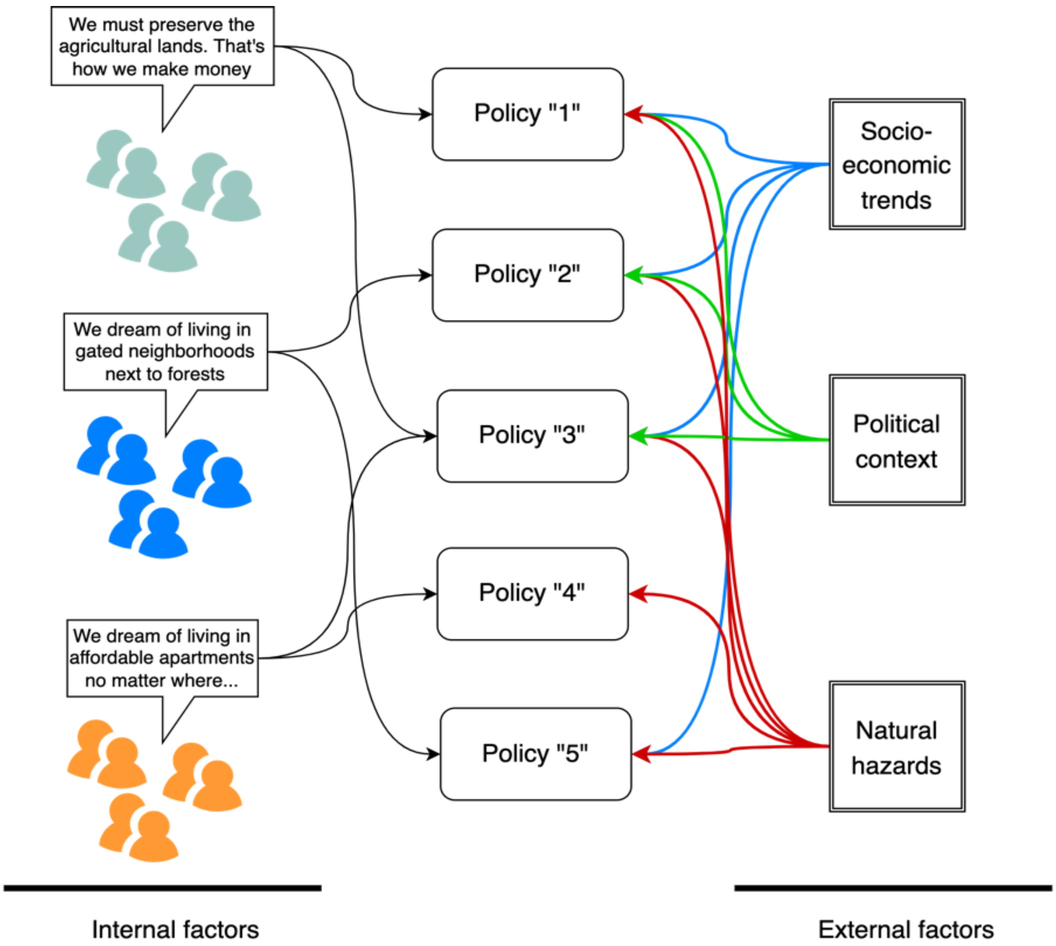


Figure 4: **A representative diagram for the transitions from aspirations to policy options**

Another critical component of the facilitation is the scope that is outlined by three main aspects:

1.5.1 Being future-oriented

This means although the daily problems of the communities are an important part of the discussion among stakeholders (in Future Visioning) the solutions they come up with must focus on future context. Thus, the policies framed in the VSD process must also aim for the future context rather than today's issues.

1.5.2 Focusing on disaster risk reduction

Disaster risk reduction can be addressed in different ways while developing policies. Within the scope of "prospective disaster risk management" the policy focus would be to avoid or mitigate the generation of new risks in the future. Within "compensatory disaster risk management" the focus would be on the residual risk that is difficult to mitigate where the socioeconomic resilience of the individuals and communities is aimed [9], [10]. The policies can be addressing either a single hazard or a multi-hazard based on the spatial context and impacts that are prioritised by the stakeholders.

1.5.3 Considering the needs of the urban poor

Decisions on urban context have various implications over social environment. In TCDSE, DRR oriented interventions are also desired to be fostering the state of the urban poor. This means, such disadvantageous groups do not get harmed by the policies that are considered. For example, a DRR intervention can increase land values to an extent which leads to relocation of the urban poor in that specific area. In such a case, particular policy options must be there to protect the rights of the urban poor so that their access to livelihoods, services and resources are enhanced (or at least protected).

Some policy examples are given below:

- Provide access to green spaces within 15 minutes walking distance to each residential building
- Enhance the construction codes
- Provide low-cost credit loans for the low-income groups for reconstruction
- Create space in the plans for social housing
- Avoid settlements in the flood plains

1.6 Land Use Planning

The future urban representations rely on the aspirations that arise within the Future Visioning process along with natural, socioeconomic, and political trends that are inevitable and scientifically proven to occur in the future. As in policy development, the aspirations of the stakeholders establish the social foundation of the land use plan by providing insights on what kind of future urban context they desire (via the workshop mentioned in Section 4.1). Natural and socioeconomic trends on the other hand act as external barriers that rectify the aspirations and create a realistic urban context as much as possible. As a result, in land use planning, once the spatial expectations are identified, they are rectified to fit the external factors (Figure 6) through expert intervention.

For example, a community group may have selected a land use type for a given extent, but this may not be compatible with the natural hazards in place. Therefore, such land use type must be altered to fit the hazard scape in the area. Similarly, a land use demand may not be suitable with the socioeconomic trends (e.g.: demanding a low-density neighbourhood while the population increase is evident and low-density residential use is not realistic).

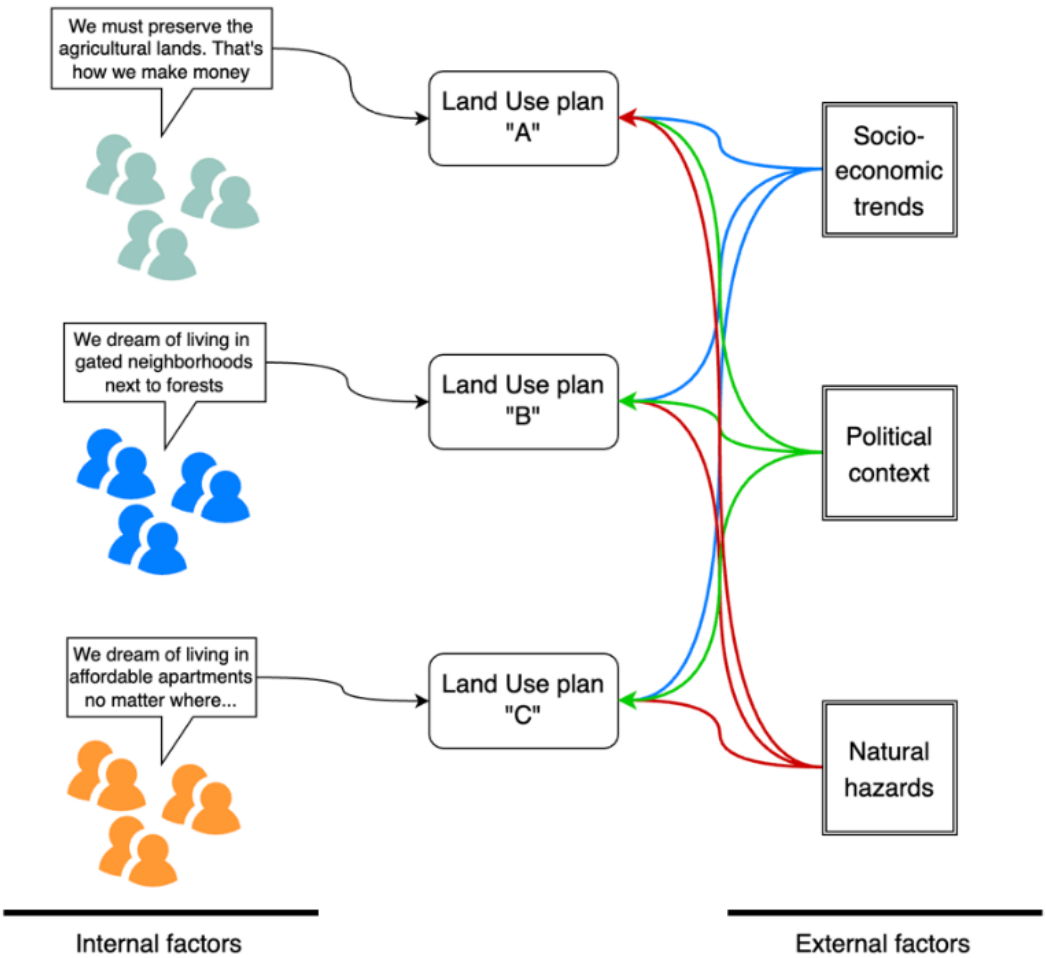


Figure 5: Generation of land use plans in line with stakeholder aspirations and external factors

In the figure below, it can be seen how a community-based sketch(a) is interpreted into a proper land use plan(b).

a)
b)

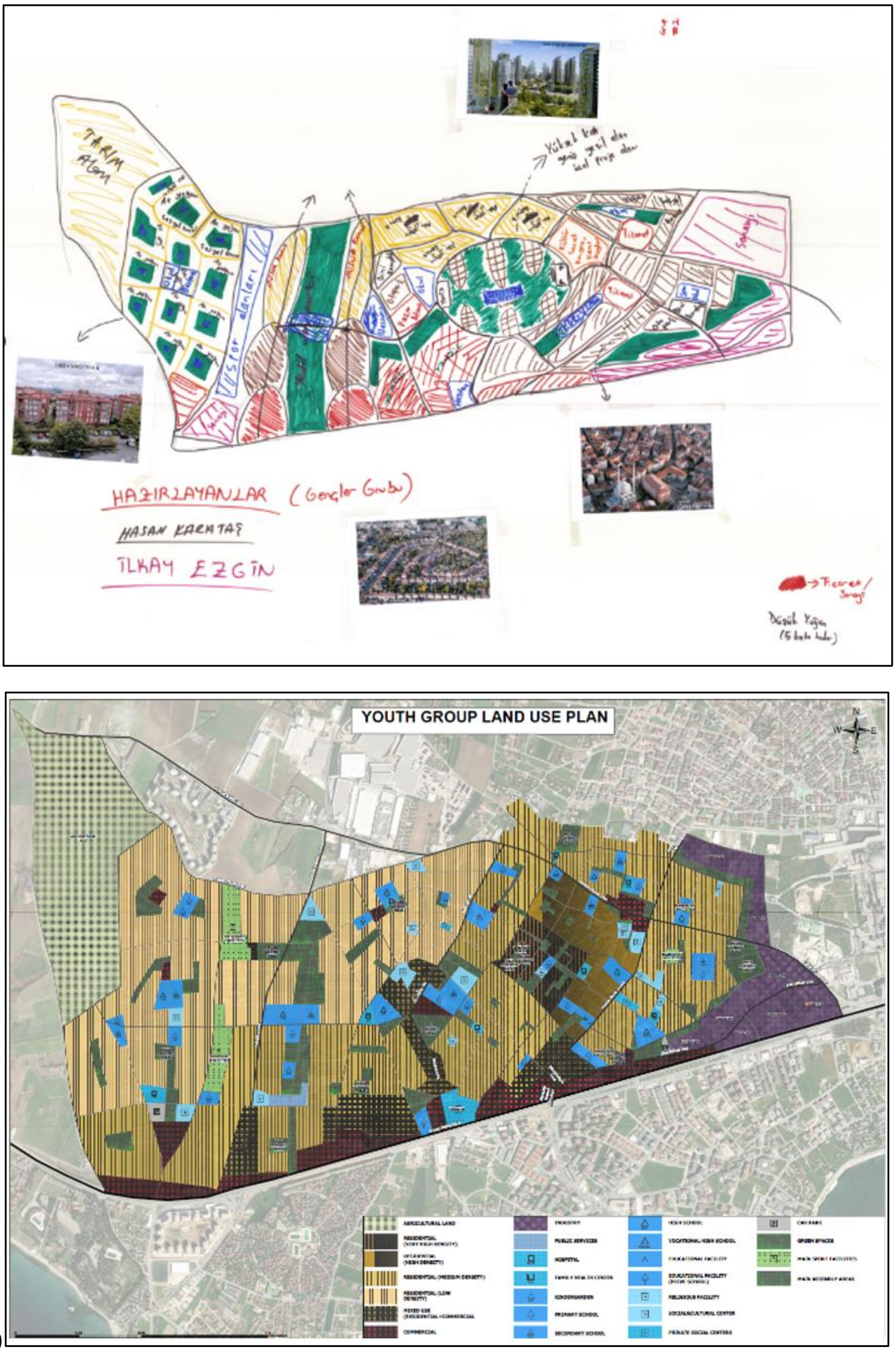


Figure 6: **a) Community driven land use sketch, b) Expert driven land use plan**

1.7 Future Exposure Data Generation

After the land use plans are designed, detailed future expansion data is generated based on future projections and assumptions on the urban context. The future exposure dataset includes building layouts, households and individuals that are produced via a GIS-based computation process including synthetic data generation where necessary. The details on data generation are given in Session 4.

Development of the future exposure data relies on a detailed data structure that includes the attributes required for constructing the datasets. The table structure of the dataset and their interrelation is given in the figure below. The tables in this figure represent a data that is a part of the urban context. Starting from the land use information, more detailed datasets are produced based on the interaction of the datasets. The arrows between the tables show how data is connected via specific key attributes. The definition of the data structure and details are given in more detail in Data Generation Session 4.

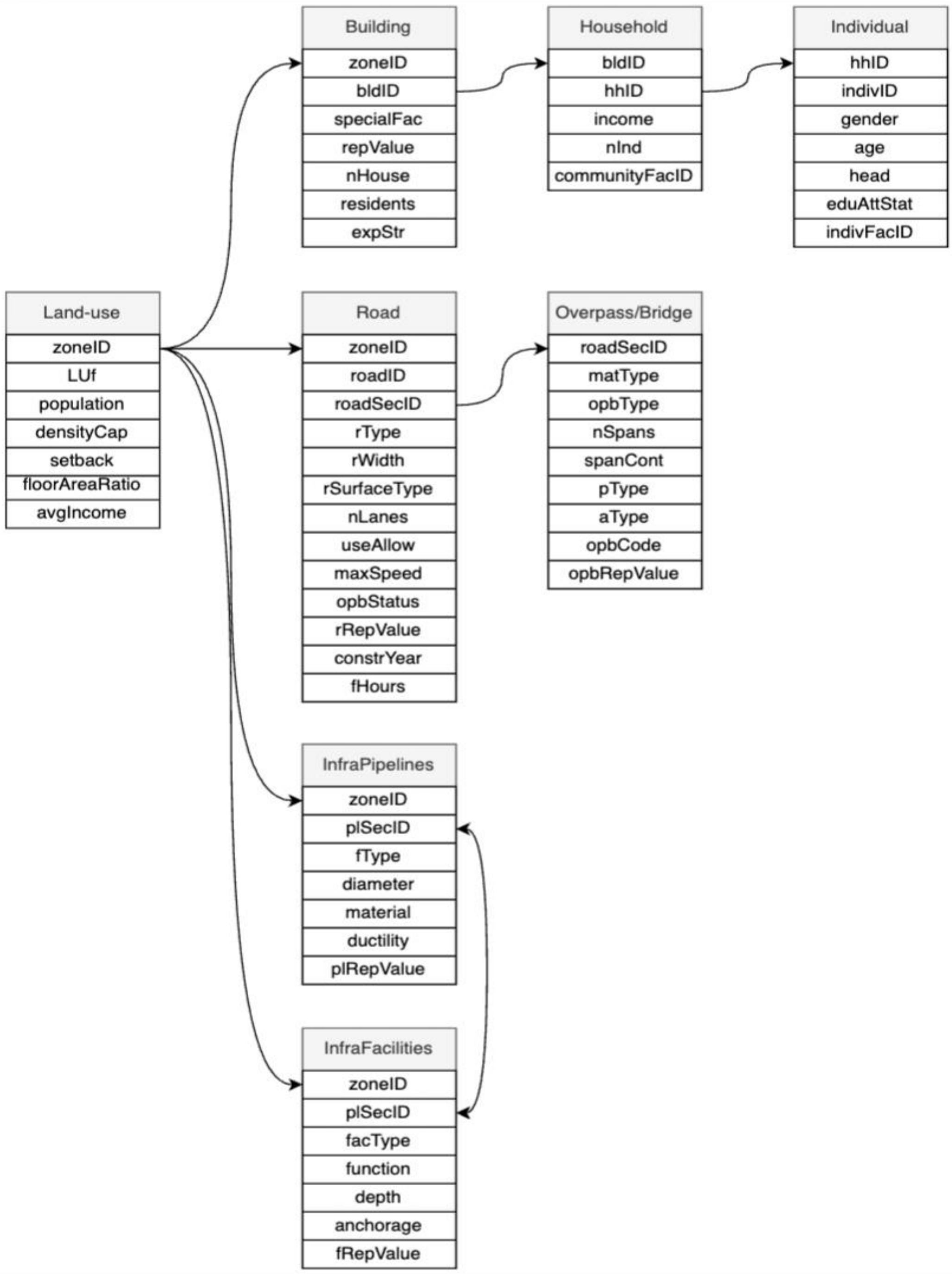


Figure 7: Future exposure dataset and data attributes

1.8 Validation Workshops

Once Visioning Scenarios are ready – including spatial urban plans and policies – the TCDSE team works to develop another participatory engagement; usually called 'Validation Workshop'. This is when the same stakeholders from Future Visioning gather to check the expert-driven interpretation of their plans, to discuss their policy alternatives (now better informed by contextual enablers and barriers), to navigate trade-offs, and to make proposals even more equitable (pro-poor oriented). Similar to Future Visioning, Validation Workshops still preserve the diversity of visions – displaying Visioning Scenarios in a disaggregated rather than hybrid way. This allows participants to understand similarities and contrasts in aspirations and concrete proposals. Yet, different from Future Visioning, the workshops are more injected by potential 'external factors' that requires Visioning Scenarios to be as feasible as they are desirable. This happens both through data and aids brought to workshops – e.g., 3D simulations of Visioning Scenarios – or through the presence of policy makers which observe and eventually provide constructive comments to participants visions. The TCDSE only moves to the computational modelling stage once participants agree that their Visioning Scenario is a fair representation of their visions, even despite necessary modifications.

1.9 Visioning Scenarios

As stated earlier, VSD has its roots in the community input from Future Visioning process. In implementation, each disaggregated community group develops their own visions and visioning scenarios. The policies, land use plans and future exposure datasets that are explained above constitute the visioning scenario. The diagram in Figure 9 represents the outputs that are generated by a community group through the VSD.

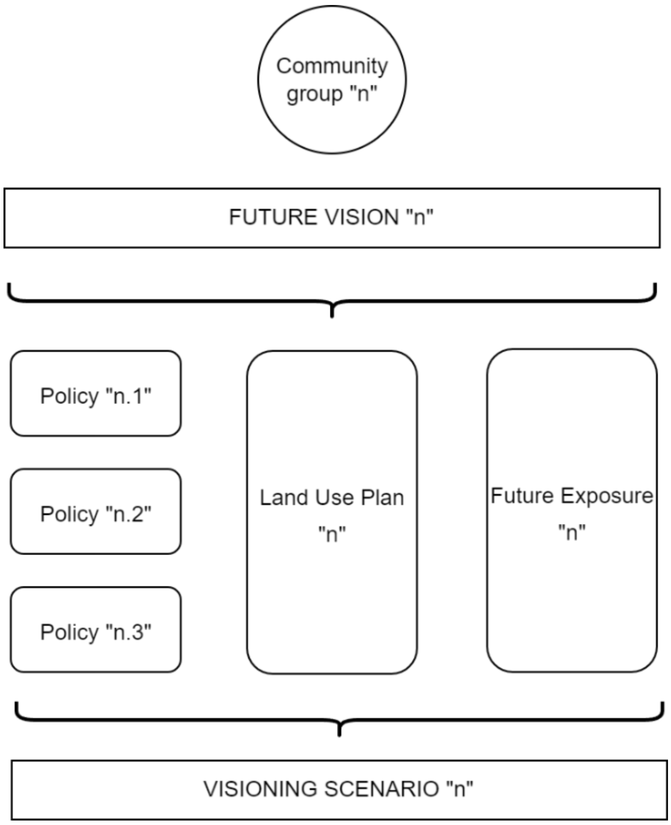


Figure 8: Outputs within the VSD process

Once the policies and future urban context are created; they are combined with each other to generate the visioning scenarios. A representative diagram for this process is given in Figure 9. A visioning scenario feeds into computational modelling process within TCDSE to evaluate the potential impacts that occur due to related hazards.

As a result, for each focus group taking place in the future visioning process, a visioning scenario is developed that includes urban plans and policies that are preferred by them. Then these scenarios are subjected to hazards and vulnerability assessments in the computational modelling stage. Please note, some of the policies may not be quantified and can be qualitative which cannot be analysed in the computational engine. In such cases, these policies can be a part of the discussion Risk Agreement, where the same focus groups will be discussing the feasibility of the visioning scenarios that are developed and analysed with respect to their multi-hazard risk level.

1.10 Implementation of the next sessions

The next sessions will focus on the details summarised in this workbook. For each session, there will be small exercises to showcase how the implementation can be done based on the background of the session. Then in the final session (Visioning Scenario Development), where a wrap-up for all sessions will be given, an extensive exercise will explicitly let participants understand how a visioning scenario can be developed. All these exercises will rely on a virtual urban testbed called Tomorrowville, which is developed as an interdisciplinary effort by the early career researchers in Tomorrow's Cities project. Producing Tomorrowville relied on a seven-month-long interdisciplinary scenario development process involving 19 researchers and experts from different disciplines, such as engineering, physical science, risk modelling, social sciences, and urban planning. This process ultimately defined assumptions on future urbanisation patterns[11] which were used to populate the urban characteristics of Tomorrowville visioning scenarios based on the proposed exposure data structure.

Tomorrowville is a virtual area of around 500 ha that reflects the physical and social characteristics of a global south context that is prone to several types of hazards such as earthquakes, landslides, and floods. The urban context of Tomorrowville is inspired by Kathmandu and Nairobi cities that house around 40.000 inhabitants.

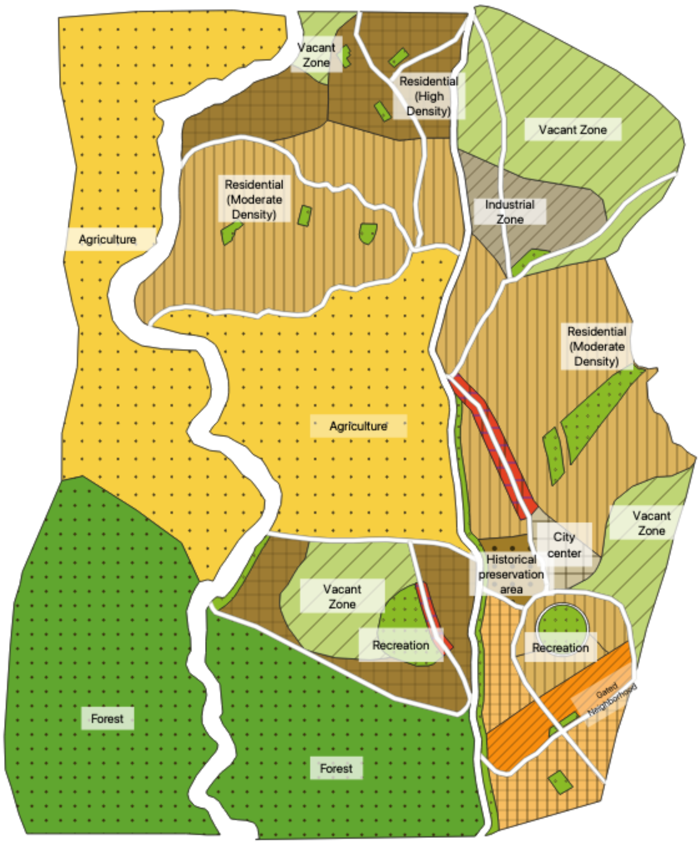


Figure 9: **Tomorrowville land use map**

SESSION 2: POLICY DEVELOPMENT

Author of the Chapter: Ms. Aditi Dhakal

2.1 Objectives

The main aim of this session is to enable participants to understand the expert-driven process that supports the refinement of policy expectations emerging from Future Visioning. In this regard, by the end of this session the participants will be able to:

- Describe the concept of Policy Development in the context of TCDSE framework.
- Identify the methods of Policy Development at different stages of TCDSE.
- Analyze the challenges in the Policy Development process.
- List the examples on Policy Development.

2.2 Structure of Session 2

The structure of session 2 is as follows:

Structure
1. Introduction to Policy Development
2. Policy development at different stages of TCDSE
3. Challenges in Policy Development
4. Annexes: Examples of Policy Development

2.3 Introduction to Policy Development

In the context of Tomorrow's Cities, a policy could be broadly defined as a set of actions adopted by a governance body or concerned stakeholders to achieve desired outcomes that tackles negative effect of hazard. Within Tomorrow's Cities Decision Support Environment (TCDSE), policies aim at reducing future risk in targeted planning areas and are usually framed under a 30-year period. Working alongside spatial urban planning interventions, policies are one of the critical aspects of Visioning Scenarios (VS) and should be modelled as a 'bundle' of options. That is, policies are a package of actions that help spatial urban plans to perform better in the event of future hazards.

Because co-production is one of the foundations of the TCDSE, policy bundles should emerge from stakeholders' aspirations rather than from pre-defined agendas. Yet, policy expectations elicited during Future Visioning workshops could be vague or not well tied to the local context. During the stage of Visioning Scenario Development (Work Package 2), an expert assessment is produced to inform discussions that happen during 'Validation Workshops' - to be further explained (refer to Fifth Session: Validating Visioning Scenarios). This means in practice helping stakeholders to understand if their expectations speak to pre-existing policies, if any adjustments or additions are required (e.g., updating elements of a policy) or if there is novelty involved in those expectations. Further, expert assessments should help participants to better orient policies towards reducing the potential negative impacts of hazards, to understand enabling factors and constraints (e.g., funding or implementation issues), and to analyse potential policy outcomes against the principle of equity – the pro-poor ethos of Tomorrow's Cities.

Meaningful participatory processes usually take longer than ‘in-house’ (technocratic) proposals and are prone to trigger more social conflicts. Yet, they are more likely to generate solutions that come from a bottom-up problem assessment, and therefore matter more to stakeholders. As one of the primary objectives of Tomorrow’s Cities is to democratise the concept of risk, it is crucial that policies emerge from in-depth deliberation and a critical assessment of impacts and options. Uncertainty is also reduced by an exploratory approach in which diverse options are presented and tested. In short, the TCDSE must balance a policy development process that is both meaningful, participatory, and rapid, and that values social differences whilst focusing on the need to solve problems that are shared.

This session provides guidance for the development of expert-driven assessments that will inform the final choice of policy bundles of each Visioning Scenarios. It is worth reminding that each disaggregated social group will produce one Visioning Scenario and will therefore develop with the support of experts a set of action- and DRR-oriented policies. The assessment helps to shape the final design and outcomes of Validation Workshops. The crosscutting nature of policies in the TCDSE

2.4 Policy Development in different stages of TCDSE

To understand the expert-driven assessment that takes place in Work Package 2, it is important to recognise that policy development is a crosscutting activity that starts during the preparatory stages of the TCDSE (Work Package 0), when existing policies (somehow relevant for DRR in a given context) are scoped. In Future Visioning (Work Package 1), disaggregated groups of stakeholders gather to discuss their aspirations for the future, which leads to the identification of main spatial and non-spatial policy expectations – later divided into themes through the ‘wheel of urban assets’. During the stage of Visioning Scenario development (Work Package 2), such expectations are assessed, refined, and articulated with existing policies for the composure of bundles.

It is important to highlight however that, during Future Visioning, policies are still only reflecting expectations; they might not necessarily tie well to context. It is only during Validation Workshops (part of Work Package 2) that stakeholders refine their policy options now better informed by the context. That informed decision making is supported by experts, who collate the policies scoped in Work Package 0 and tie them with the expectations outlined in Future Visioning.

This process is suggested in the diagram below. 'Pink dots’ represent the policy context, which are pre-structured according to certain questions and criteria. ‘Green dots’ represent policy expectations, which may or may not relate to context. ‘Blue dots’ represent lessons from elsewhere that could inform participants choices when their aspirations entail significant novelty (to be assessed by experts). Work Package 2 has therefore the mandate to produce a framing that supports the finalisation of bundles; connecting context to aspirations and expectations and suggesting ways to detail and polish options. The process however does not end with the initial formation of bundles per group. The diagram below also suggests how policy bundles are discussed in further Work Packages. It is important to highlight that after Work Package 4 – and with the reiteration of the TCDSE – bundles could change depending on how policies lead to impact for each group.

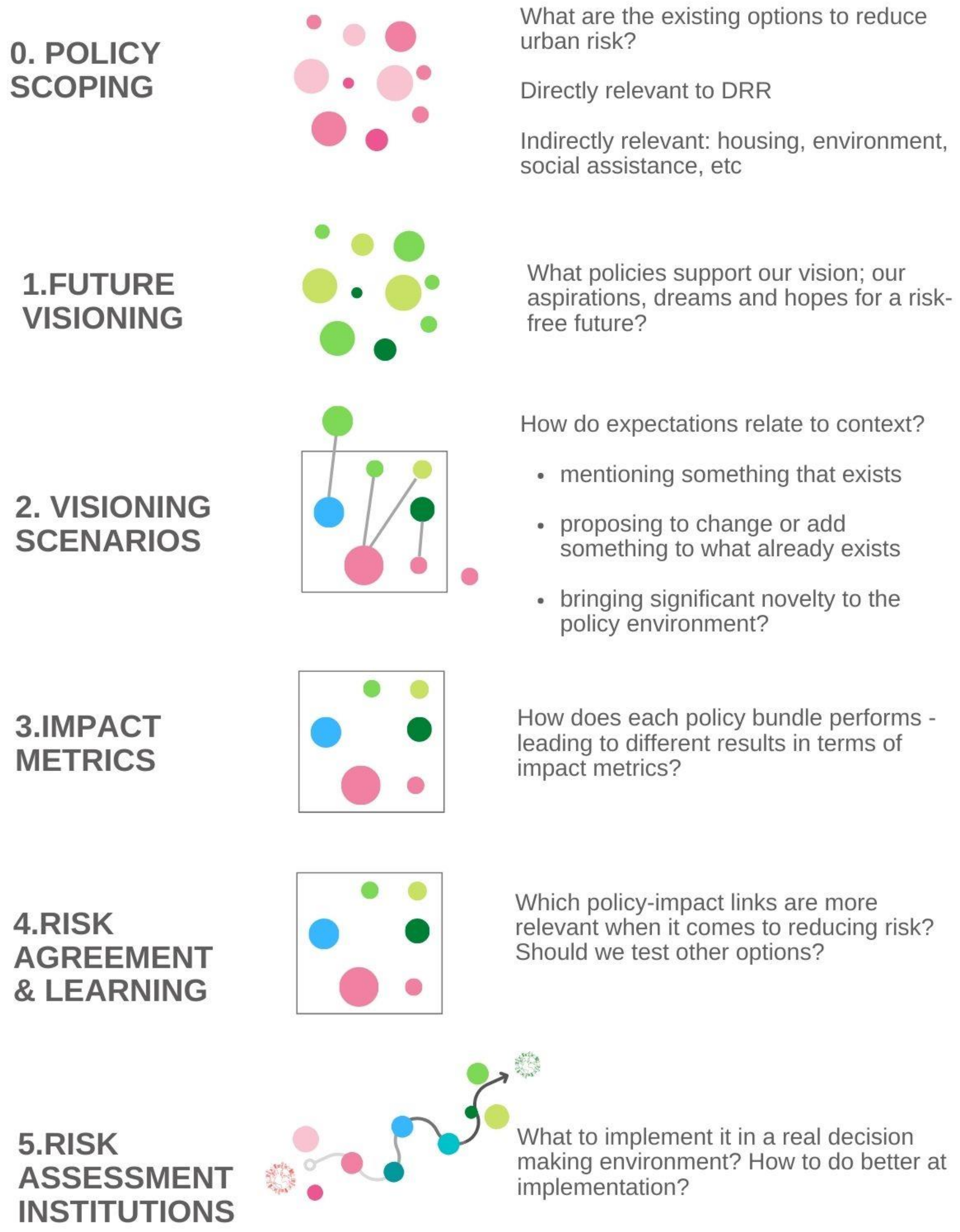


Figure 10: **Policy alternatives cutting across TCDSE Work Packages**

Source: TCDSE, Tomorrow's Cities

2.4.1 Policy Scoping (WP0)

During the stage of city scoping cities receive a template and are requested to list all options that might be relevant in the context of the TCDSE. This includes policies at different levels or scales, as well as different sectors. That is, cities could list options that are directly related to DRR (for instance, building codes and disaster management strategies) or indirectly related (for instance, social security policies or environment protection acts). All options are recorded and the list could be increased or collated depending on the discussions carried during Future Visioning workshops.

Table 2: Example of Policy Scoping (partial excerpt) in the context of Nepal

SN.	Name of Policy	Scale/Degree of Consolidation	Relevance to Risk	Ambition for positive impact	Dimension of the wheel of urban assets	Formulating Agency	Enforcing Agency	Implementing level/agency
Policy Scoping (WP0)								
Urban Planning								
1	National Land Policy, 2019	National/ National	Indirectly related to risk	Policy aims to provide security of land rights and ownership, safe and managed settlement, assurance of right to food, environmental conservation, reduction of climate change effects, poverty alleviation, gender equality and provide long-term and sustainable solution to land related issues	Social Assets	Ministry of Land Reform and Management	Ministry of Land Reform and Management	National/ Provincial/local level Urban Planning Agencies
2	Land Use Act 2019	National/ National	Indirectly related to risk	Assign rights, responsibilities, and duties to the federal, provincial, and local governments regarding land use, Provide land use categories	Institutions and Rule of Law	Ministry of Urban Development	Ministry of Urban Development	National/ Provincial/local level Urban Planning Agencies
Infrastructure Planning								
3	Public Road Act,1974	National	Indirectly related to risk	Provisions for public roads and acquire lands for public roads and to collect development tax from landholders near the roads.	Macro infrastructure	Ministry of Physical Infrastructure and Transport	Ministry of Physical Infrastructure and Transport	National/ Provincial/local level Urban Planning Agencies, Architects and Civil Engineers
Disaster Risk Reduction								
4	Disaster Risk Reduction and Management Act 2017	National	Directly Related to rick	Provide provision to set-up National Council for Disaster Risk Reduction and Management	Institutions and Rule of Law	Ministry of Home Affairs	Ministry of Home Affairs	All Agencies working in DRR

Source: TCDSE, Tomorrow's Cities

2.4.2 Future Visioning (WP1)

Future Visioning harnesses aspirations through diverse activities that promote stakeholder interactions. Such interactions are partially guided by 'the wheel of assets', which allows participants to understand aspirations in relation to different urban dimensions as shown below. This helps to shape collective goals and understand potential future problems which are further tackled by policies. Such policies are nonetheless more vague and conceptual expectations to be refined – and later confronted with realities on the ground.

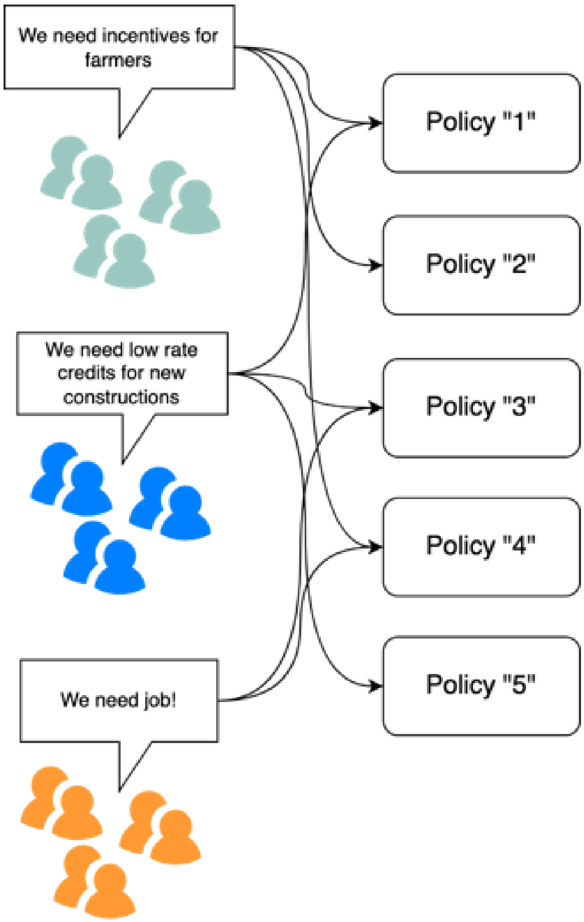


Figure 11: **Development of Policy from Aspiration**

i. The wheel of urban assets

The wheel of urban assets is an analytical device and planning tool consisting of seven dimensions: Micro-infrastructure and Housing (i.e., small scale infrastructure connected or embedded in homes), Macro Infrastructure and Facilities (e.g., transport, electricity and water networks, hospitals, schools, roads and bridges), Institutions and rule of law (i.e., aspects of governance and policy implementation or enforcement), Environmental Assets (e.g., rivers, forests, etc), Social Assets (e.g., affective relations and kinship, social protection networks and structures for mutual supports, etc), Jobs and Livelihoods (I.e., economic aspects related to the sustenance of life in the city) and knowledge and cultural assets (e.g., conservation of cultural heritages, intangible assets related to information and education, etc).

During Future Visioning workshops this wheel is shown to diverse stakeholders to support the development of aspirations and the outlining of policy expectations. This helps to organise and provide more detail to otherwise conceptual visions. The image below illustrates how that happens.

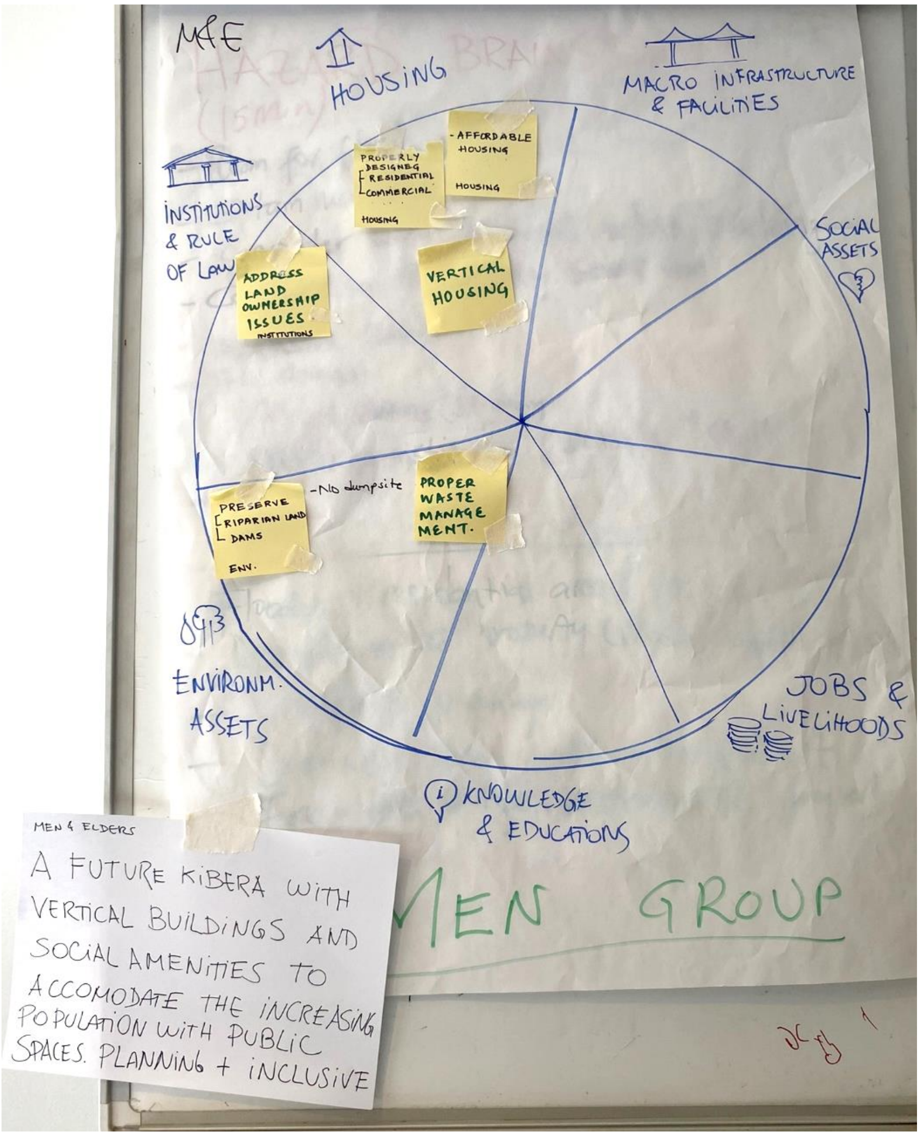


Figure 12: Wheel of Urban Assets showing the policy expectations from a group of Men & Elders in Kibera, Nairobi.

Source: TCDSE, Tomorrow's Cities

Table 3: Example of Database for the recording of policy expectations produced during Future Visioning (WP1).

What is the name of the policy?	What is the primary aim of the policy?	To which scale/area this policy applies?	What is the timeline for implementing that policy?
Name	ambition for positive impact	Neighbourhood/municipal level/ national level	Short term/medium term/ long term

Which sector does this policy primarily relate to?	What are the dimensions of the wheel of urban assets that this policy would relate to?	How could this policy reduce the potential negative impact of hazards?	Were there other relevant notes?
Housing/ Infrastructure/ Agriculture	Macro infrastructure/Micro infrastructure/Knowledge and cultural assets	Directly/Indirectly	Anything relevant that was not covered yet

The scoped policies are analyzed for the following:

Name

- How policy documents define that – if a law, an act, a program, etc

Scale

- If primarily implemented or enforced at the national, provincial, or municipal level (varies from context to context)
- Relevance to risk
  - If defined as a DRR measure or otherwise (but still relevant – the case of public road acts, for example)
- Ambition for positive impact
  - What the policy sets out to do (in discourse).
- Dimension of wheel of urban assets
  - could be more than one
- Formulating, enforcing, and implementing agencies

The expectations of each disaggregated group are recorded separately.

2.4.3 Visioning Scenario Development (WP2)

Based on the policy expectations generated during Future Visioning workshops, Tomorrow's Cities and other local policy experts review the Policy Scoping so to produce an assessment of the priority policy expectations produced by stakeholders. Depending on the number of policies, not all get to be analysed. The objective is to support participants to later detail and refine their policy options so that they are aware of the context - and therefore of the constraints and possibilities. Such work also entails injecting more focus on disaster risk reduction – exploring pathways for each policy to tackle the potential negative impact of hazards – and on equity – exploring the potential consequences of policies when it comes to redistributing risk across social groups (particularly the urban poor).

i. First phase of Analysis of Policy

In the first phase of WP2, the same policy from WP1 is analyzed based on their potential to impact exposure, and vulnerability. Then the policies are related to the existing policies that are scoped during WP0. This is done to understand if some standards already support the implementation of these policies.

As these policies are expected to be implemented, they are also analyzed based on the probable constraints for their implementation. These constraints may play important role in hindering the implementation of the policies. These constraints can be political or governance factors, physical, infrastructural, or natural constraints, and socio-economic factors. Political factors are the constraints such as lack of political will or implementation issues that can hinder the implementation of the proposed policy. Natural obstacles are the barriers such as land uses for instance landfills site which cannot be located near residential areas, airports which cannot be located near landfill sites and so on. Socio economic factors could range from budget issues to issues of knowledge, awareness, or social conflict e.g. lack of annual budget , lack of funds to consider DRR measures etc.

Natural hazards are one of the most critical components while supporting the development and polishing of policy options. Whilst a risk assessment does not exist yet (in WP2) simplified existing hazard information (if available) could be integrated into the process of policy development. During Future Visioning processes, participants are asked how their policy expectations could prevent, mitigate, or compensate for the potential negative impacts of future hazards. This is a form of thinking not supported by quantitative data, but by lived experience with hazards, which could nonetheless be useful. During the expert-driven assessment, such speculations could be either confirmed or challenged using preliminary data. For example, participants may prioritize policies for containing rivers – e.g., building canals or dams – due to the belief that this is a useful way to reduce flooding risk in the future. However, through evidence and lessons from elsewhere, policy experts could recommend other solutions – e.g., nature-based solutions or complementary soft management strategies that are more effective and progressive, while still meeting participants aspirations (for instance, to have clean rivers and a flooding-safe city).

Later, once Visioning Scenarios are modelled and the process is reiterated, the ways in which hazards – as external factors – shape policies should become more explicit and analyzed in further depth.

Additionally, these policies are also analyzed to check how they contribute to the equity concerns. Policy expectations that are elaborated from good intentions may lead to unexpected negative outcomes. One of the main roles of experts in this sense is to guide a policy development process that – not only meets aspirations and reduces disaster risk – but that also does not push risk and other negative consequences towards poor and marginalized populations. For example, policies to protect natural resources or reduce density are often based on an aspiration for a more healthy, pleasant, green, and sustainable urban environment. Yet such policies – if not mindful of trends such as informality and the needs of certain groups – could be increasing the value of land or excluding certain groups from valued urban areas.

Other examples:

- If we change the use of land from residential to commercial concerning the high commercialization of that area, gentrification may occur due to a dramatic increase in land value.
- Transfer of a squatter settlement or residential area may lead to loss of livelihood.
- The chosen policy may not be a wholistic policy and may exclude some of the prominent issues.

So, we must check if the land proposed for low-income groups will be affordable by the low-income class? If the proposed low-income residential area is accessible to the nearby hospitals or schools or green areas and so on.

Finally, some comments that emerged during interviews or desktop research are also added to support the policy analysis and based on all these, experts provide their recommendations to make policy effective for tackling the constraints. The sample of table used for the first phase of policy Analysis in Visioning Scenario Development is as follows:

Table 4: Sample of table used for first phase of WP2 Policy Analysis

What is the name of the policy?	Potentials: will it likely impact exposure? Why? How?	Potentials: will it likely impact vulnerability? Why? How?	How does this policy relate to the scoping conducted in WP0?	What are the main political or governance factors that could prevent that policy from being effective?
As WP1	If yes: briefly justify If no, write no	If yes: briefly justify If no, write no	Is the policy (a) an exact match, (b) similar with adaptations (c) new alternative?	political will/corruption/data scarcity or unavailability

Are there any physical, infrastructural or natural constraints for implementation/activation?	What are the main socioeconomic factors that could prevent that policy from being effective?	Do you have any equity concerns for that policy?	Any additional notes?	What is your overall constructive assessment?
Hazard(flood,landslide), land uses (agriculture, landfills), topography(slope)	budget concerns, issues of knowledge, awareness or social conflict	housing/land affordability, access to critical infrastructure, services & green or recreational areas?)	comments that emerged during interviews or desktop research	recommendation to make policy effective for tackling the constraints

ii. Second phase of Analysis of Policy

After checking the constraints and supports for the implementation of the policies, they are analysed again to check how exactly they can be implemented. In this phase, the policies are analyzed to find the implementable solutions. For instance, how these policies could reduce the risk to exposure or vulnerability, and in which phase this implementation should be done. For instance, if the policy is "Policy related to access to housing", then this policy is expected to increase the exposure by changing the location and number of houses. This policy is also expected to increase physical vulnerability if the increased number of buildings do not comply with the building code. Then we must analyze the policy based on the action point. Which means if this policy increases physical vulnerability, then the remedy or the action point can be considered as an increase in code compliance. Finally, we need to recommend the phase in which we make this action point and for the above-mentioned example the changes can be made in the exposure generation phase.

Table 5: Sample of table used for second phase of WP2 Policy Analysis

Group Name	What is the name of the policy?	Exposure	Physical Vulnerability	Action	Phase
As WP2	As modified in validation workshop	Problem and Solution to any changes in exposure brought about by the	Problem and Solution to any changes in vulnerability brought about by the mentioned policy	What are the action points	In which phase is the action proposed

		mentioned policy			

2.4.4 Multi Hazard Physical and Social Impact Assessment (WP3)

This stage does not entail significant participatory engagements. However, it will be essential for participants to later understand how their policy choices led to risk. During the computational modelling stage, policies get 'calculated' against hazards. That is, based on scientific evidence modellers simulate how different spatial urban plans – one per group – perform differently when supported by different policy options. This means that the policy design of the bundle must necessarily embed a narrative on the ambition of each action when it comes to hazards – I.e., through which means is that policy (as an action) actively contributing to reduce, mitigate or compensate the effects of future hazards on that area and on its inhabitants. This means that, the more detailed policy options are – when it comes to spell out actions -, the better.

Example of how a policy is expected to bring significant change in the impact factor. For instance:

Low-Cost Housing Development Policy

- May decrease x% of displaced people.
- May decrease x% of low-quality construction.
- May encourage peoples' participation by x%

2.4.5 Risk Agreement & Learning (WP4)

In this step, participants analyse the results of their products – the performance of their Visioning Scenarios – with the support of experts from the team. The critical policies – those that led to more significant outcomes when it comes to impact metrics – are discussed. The reiteration of the TCDSE further allows participants to deepen their learning by testing other policy options – from the project's database – and therefore further reducing risk.

2.4.6 Risk Assessment and institutionalization (WP5)

Participants – and critical urban decision makers – discuss ways forward and how to take such learning to the actual decision-making environment of the city. This ideally leads to a pathway where stakeholders decide what are the critical steps to achieve a risk-reduced desired future.

2.5 Concluding notes: Challenges of Policy Development

Development of a policy is not as easy as it sounds. Its validity is usually concerned as it is normally developed for 20-30 years period. It requires series of community discussions, and stakeholders' involvement which makes it time consuming. It consumes certain amount of fund for its development. Policy does not stand alone; it needs to be supported by the existing legal framework. The policy may not become a wholistic standard if it does not include hazard risk reduction parameters. The developed policy might not address the prominent issues apparently not fulfilling its purpose.

The challenges of policy development are:

Uncertain: Normally, urban planning works are targeted for 20-30 years. Working with such a large timescale entails the recognition of uncertainty. Policies that seem realistic, progressive, innovative, and impactful today might not be so in the future.

Contextual: The success of policy development depends on articulating complex legal, economic, environmental, technological, ecological, and social factors. DRR policies are usually cross-cutting diverse governance sectors, besides requiring contextualised problem framing and strategic forms of planning.

Participatory: Policy options in democratic urban contexts should reflect social diversity, and therefore encompass meaningful participatory processes. The latter aspect imposes logistical as well as political challenges. Participatory processes usually take longer than 'in-house' (technocratic) proposals and are prone to trigger more social conflicts. Yet, they are more likely to generate solutions that come from a bottom-up problem assessment, and therefore matter more to stakeholders.

Expensive and time consuming: Participatory policy making consumes both time and money.

2.6 ANNEXES

2.6.1 Annex1: Few examples of Policies of Nepal (Urban Planning)

i. Land Use Act 2019

The Land Use Act, 2019 is particular in emphasizing federal and provincial control over local government in land use planning activities. A state of reliance on federal and provincial government actors' looms over local governments. Overall, the Land Use Act, 2019 has assigned rights, responsibilities, and duties to the federal, provincial, and local governments. Similarly, the Land Use Act 2019 specifies/categorizes the land in the country in ten different categories. These ten categories are – agricultural land, residential land, commercial land, industrial area, mines and minerals area, forest area, river, brook, lake and wetland area, area of public use, area of cultural and archaeological significance.

ii. Land Use Policy 2015

Land Use Policy of 2015 is an interdisciplinary document containing policies regarding the use of land and its resources. This policy aims in utilizing maximum land resources and long-term benefits of land and land resources through land classification, proper use, and effective management.

iii. Local Government Operation Act, 2017

The Local Government Operation Act 2017 empower municipalities to formulate Settlement Development, Urban Planning and Building Construction byelaws suitable for their local condition. The Act specifies the rights, roles, and duties of the local government. It outlines requirements such as population, infrastructure, school, and health facilities among others, for different geographic areas to be considered as municipality and rural municipality thus defining constituencies for local government based on it. Under the federal system, local governments are responsible for much larger territories and are mandated to manage the local services, local level development plans and projects, including disaster management. Section 3, function, duties and rights of rural municipality and municipality (n) provides the authority to the local governments to conduct land survey and measurement and keep the land record and to facilitate and coordinate in the land acquisition for the public use.

In the same section of the Act, it provides the right to the local government to formulate law, policy, and regulation related to disaster management and its implementation and monitoring. It directs the local government to make the preparedness plan and decide for the search, rescue, and relief distribution as part of disaster preparedness. Based on the right of the local municipality to formulate land use laws and policy and plan, it allows the local level to identify the disaster-prone settlement and plan for relocation. The Act also allows the local government to coordinate and cooperate and seek support from central and federal governments, local community organizations, and private sectors in disaster management.

iv. National Urban Development Policy 2007

The National Urban Development Policy (2007) published by Ministry of Urban Development (MOUD) gave the criteria for the designation of urban areas in Nepal, where density, contiguity and occupational structure were key aspects. The policy also seeks to promote a balanced national urban structure, with integrating land use and a clean, safe, and well-developed urban environment, poverty reduction, and effective urban management by capable local institutions. Further, the policy has also prioritized ensuring access by the urban poor to low-cost housing, housing finance, and income-generating activities and development in excluded regions.

v. National Urban Development Strategy 2017

The National Urban Development Strategy 2017 has weaved the strategy in the four basic elements of resiliency:

- Physical status: its deals with physical planning such as building codes, land use zoning, etc. based on hazard maps and geological feature of the area to minimize the effects of natural disasters.
- Social Status: It considers social capital of the community, which has direct implication on their preparedness to response during disasters, which is a critical factor of vulnerability.
- Economic status: The economic condition of people is also critical in determining their vulnerability as it is directly proportional to levels of poverty.
- Institutional status: The strength of local and national governments, and institutions both in the government and non-government sectors to plan, prepare, respond, and recover from the disaster is vital in reducing vulnerability of the people.

The National Urban Development Strategy has suggested multi-hazard approach in dealing with disasters including climate change through preparation of risk sensitive resource mapping identifying high risk areas in all urban areas based on available information, preparation of multi-hazard map of all urban areas, incorporation of disaster risk management component in urban development plans, formulation of National Adaptation Plan (NAP) on urban settlements and infrastructure.

vi. Building Act 1998

The Preamble of this Act provides for disaster resistant building design and construction standards to make buildings safe from natural disasters like earthquake, fire, floods, among others. Section 4 (b) calls for the formulation and adoption of a building code and implementation of the same with the end in view of improving the quality and safety of each building. Section 8 mandates the categorization of buildings into different classes and the issuance of a building permit prior to construction in the municipal areas.

However, the Building Regulations under the Building Act do not establish a mechanism for approval of smaller buildings at local level, although these are covered in the Act itself.

vii. Basic Guideline(bylaws) related to Settlement Development, urban planning and building construction 2015/016.

This settlement Development, Urban Planning and Building Construction basic bylaws cover the rules and regulations on settlement development, Urban Planning and building construction in all urban and rural municipalities in Nepal. The guidelines mainly guide local governments to manage and implement building codes while developing safe and resilient private and public building construction and encourages managed settlement development based on National Building Code 2004.

viii. National Building Code 1994/2015/2020

The National Building Code first drafted in 1994 and subsequent amendment in 2015 and 2020, establishes the building permit system, the certification of construction practices and implementation of land use planning measures. It provides criteria and necessary procedural guidance for various engineering designs and various construction material for constructing small houses to towering building structures earthquake resilient. Moreover, this offers guidance on designing techniques and analysing earthquake-resilient buildings as per the established engineering norms and principles. Based on this code, any structures can be made earthquake-resilient using any technology and construction material.

2.6.2 Annex2: Policies of Nepal (Disaster Risk Reduction and Management)

i. National Policy for Disaster Risk reduction 2018

The National Policy for DRR 2018 has been prepared and endorsed to build a safer, adaptive, and resilient nation by reducing the existing risks and prevention of new and potential risks. The policy considers the national needs as well as international agreements and obligations, which is more focused on achieving the targets and commitments made in the Sendai Framework for Disaster Risk Reduction, the Sustainable Development Goals, and the Paris Convention on Climate Change. It has identified 59 activities to cover all sectors and designated roles and responsibilities to sector ministries to carry out sectoral activities.

ii. Disaster Risk Reduction and Management Act 2017

Disaster Risk Reduction and Management Act, 2017 has made provision to set-up National Council for Disaster Risk Reduction and Management under the chairmanship of the Prime Minister. To implement policies and plans formulated by the Council, there will be an Executive Committee under the Home Ministry. Different experts involving thematic areas such as, geology, environment, infrastructure, and others will be as a team for the executive committee. National Disaster Reduction and Management Authority (NDRMA) will be set-up under the Home Ministry. At Province level, there will be Province Disaster Management Committee (PDMC) under the chairmanship of Chief Minister.

iii. Disaster Risk Reduction and Management (DRRM) Rules 2019

The DRRM Rules, 2019, specified the effective and timely implementation of policies and plans laid down by the National Council for Disaster Risk Reduction and Management. According to the rule, there shall be established an executive committee. The committee will coordinate with agencies and stakeholders at the federal, provincial, and local levels to implement the integrated and sectoral policies, plans, strategic plans, and program pertaining to various aspects of DRRM.

iv. Nepal Disaster Risk Reduction National Strategic Plan of Action (2018-2030)

The National Strategic Plan of Actions for Disaster Risk Reduction is technically built on Sendai Framework for action for Disaster Risk Reduction. While the Sendai Framework for action for Disaster Risk Reduction covered a fifteen-year period to achieve its objectives, the National Strategic Plan of Actions has an extended twelve-year period (2018-2030) to achieve its own, aligning in that respect its timeframe to the Sustainable Development Goals. This strategic plan of action has fixed following four priority areas and eighteen priority actions.

v. Water Induced Disaster Management Policy 2015

Water Induced Disaster Management Policy (2015) developed by the Department of Soil Conservation and Watershed Management, aims to conserve, and develop watersheds in Nepal through inclusive and participatory principles. The policy has an objective to minimize the physical and economic damage caused by water-borne disasters by adopting participatory methods through embankments, spurs, check dams, bioengineering, and other suitable technologies.

vi. National Adaptation Program of Action (NAPA 2010)

The National Adaptation Program of Action (NAPA) 2010 considers the existing coping strategies at the community level and to build upon these to identify priority activities, rather than focusing on scenario-based modelling to assess future vulnerability and long-term policy at the national level. The goal of a NAPA is to enable countries to respond strategically to the challenges and opportunities posed by climate change. A key strategy of the NAPA is to ensure comprehensive stakeholder input in all stages of the implementation process, involving national and local level government institutions, non-governmental organization, civil societies groups, academia, international organization, and donor agencies.

vii.Framework for Local Adaptation Plan of Action 2011 (LAPA)

This framework is prepared to provide the effective delivery of adaptation services to the most climate vulnerable areas and people of Nepal. It supports the design of new and implementation of existing LAPA that have already been designed and piloted. It is expected to help integrate climate adaptation and resilience aspects in local and national plans. The main entry points to the LAPA are as follows: (1) Agriculture, 2) Forestry, 3) Health, 4) Water and Sanitation, 5) Watersheds, 6) Microfinance, 7) Education, 8) Infrastructure, 9) Disasters. The guiding principles of the framework are that the process of integrating climate adaptation and resilience into local and national planning is both bottom-up, including, responsive and flexible.

viii. National Disaster Response Framework 2013

The government of Nepal made the first amendment to the National Disaster Response Framework 2013, in line with the federal governance system and other prevailing laws related to disaster risk reduction for mobilization of national level resources. The framework helps to carry out and guide comprehensive disaster response and maintain coordination among all three level of government for preparedness during large scale disasters. The framework will facilitate and expedite activities, such as search and rescue operation and arrangement of emergency shelters, besides ensuring protection of lives and property.

ix. National Strategy for Disaster Risk Management 2009

The National Strategy for Disaster Risk Management in Nepal adopted by the Government of Nepal in 2010, is a complex and large document containing a great deal more than a disaster management strategy. It includes substantial data on the risk profile of Nepal and a detailed analysis of the existing and proposed institutional and legal system for disaster risk management.

x. Disaster Preparedness and Response Plans Guideline 2011

The Disaster Preparedness and Response Plan guideline developed in 2011, is aimed at assisting Government officials, the Red Cross Movement, I/NGOs, and UN agencies who will be engaged in the disaster preparedness and response planning process at the district level. This guideline is an important resource material for all DDRC members to manage disaster planning initiatives in the districts annually. The product of the planning process is the Disaster Preparedness and Response Plan (DPR Plan)

xi. Environmental Protection Act 2017

The Environment Protection Act 2017, concern both broad environmental management (EM) and environmental impact assessment (EIA) of proposals to carry out development work or physical activity that may bring about change in the existing environmental conditions or any plan, project or program which changes the land use.

2.6.3 Annex3: Policies of Nepal (Other Supporting legal provisions)

i. Constitution of Nepal

The Constitution of Nepal stipulates that disaster risk reduction and management as a sole authority of local government, and as a shared responsibility amongst federal, provincial and local governments.

ii. Lands Acts of 1964

The main objective of the Land Reform Act 1964 was to redistribute land to tenants and improve agricultural production through new technology and promoting high yielding crop varieties. The Land Reform Act mainly focused on land use, distribution, and regulation. It also establishes the procedures for determining and controlling the use of land, and the fragmentation of plots (including minimum unit size).

iii. Land Acquisition Act 1977

The Land Acquisition Act, 1977 is the core legal document to guide tasks related to land acquisition and resettlement activities in Nepal.

iv. Forest Policy 2017

The Forest Policy of 2017 has envisioned of invigorating prosperity with the use of forest usage. One of the major objectives of this forest policy is the conservation of forest area and promote its multifaceted use. The policy mentions about the government's policy to promote green industry and businesses based on expansion of forest areas and the promotion of herbs.

v. Forest Act 2017

The Forest Act mentions that the land ownership of the national forest shall be vested in the Government of Nepal (GoN) and the Act prohibits one from changing possessory right of the national forest. The Act prohibits anyone to register land within the territory of a national forest.

vi. National Industrial Policy 2010

The industrial policy bought out in 2010, has defined its objectives towards making contribution to the goal of poverty reduction through a broad-based industrial growth facilitating the interplay of public, private, and cooperative sectors.

vii. Right to Housing Act 2018

While securing the right to every citizen to an appropriate housing by allowing citizens to use his or her house peacefully, the Act makes provision for providing safe and appropriate housing facilities to homeless citizens.

viii. Ancient Monument Preservation Act 1956

The Ancient Monuments Preservation Act formulated in 1956, was amended for the last time in 1995. Under this Act, Nepal's constitution has vested authority of maintaining archaeological sites, heritage monuments and museums to all three echelons of the government: Federal, Provincial and Local.

2.6.4 Annex4: Policies in Turkey

i. Urbanization Policies

Keleş (2014) lists the following institutions which influence the urbanization in Turkey:

- Former State Planning Organization/Ministry of Development and presently the Presidential Office for Strategy and Budgeting which is on the top level by developing a National Development Plan for five-year period and regional plans for some areas.
- Ministry of Environment, Urbanization and Climate Change that covers TOKİ (Mass Housing Administration) which approves provincial physical plans with its authority to regulate macro spatial planning in the country.
- Ministry of Interior with authority over local governments.
- General Directorate of Highways affecting processes of urbanization with its investments in main roads passing through the cities
- Metropolitan and District (if available) Municipalities by preparing Spatial Implementation Plans (micro level zoning plans) and city-level infrastructure investment.

Main responsible body for coordinating urban spatial planning in Turkey is the Ministry of Environment, Urbanization and Climate Change with Decree 644. Duties of the Ministry is as follows according to the Decree 644:

- To prepare and approve spatial strategy plans and territorial plans.
- To approve plans regarding the areas authorized by the Cabinet, all public investments, and facilities regarding national security, prohibited military zones, energy, and telecommunication.
- To approve plans regarding the practices done by the Mass Housing Administration according to Illegal Housing Law 775 and, Mass Housing Law 2985 and investments to be made on all real estates by public or private sector and on special project areas.
- To prepare or have it prepared and approve geological surveys, maps, territorial plans, master plans, implementation plans and parcellation plans of any type or scale and relevant changes in case of not being approved by the responsible authority in 3 months;
- Conducting duties related with coastal edge line, land development planning and approval procedures regarding coasts and coastal investments.
- To conduct geological surveys, mapping and land development plan implementation works,
- To provide financial and technical support to local authorities.

Municipalities are primarily responsible for the preparation of city plans and the infrastructure and other services in the cities. “Metropolitan Municipality Law No. 5216” defines the duties and responsibilities of metropolitan and district municipalities in metropolitan areas. According to the 2012 amendment to the Law, settlements with a population of over 750,000 can become a Metropolitan Municipality. The main responsibilities of Metropolitan Municipalities under the Law can be listed as follows:

- Preparing the budget according to the annual plans,
- Approving 1/5000-1/25000 scale land use (zoning) plans according to the Provincial Physical Plan,
- Licensing and supervising businesses,
- Planning urban transportation and providing public transportation services,
- Making the road infrastructure and numbering the buildings,
- Environmental protection and waste management,

- Establishing geographic information systems,
- To provide water and sewerage services,
- Preserving historical buildings,
- Managing wholesalers and cemetery services,
- Installing central heating systems,
- To provide social and cultural services for different groups.

According to the Law, District Municipalities; perform infrastructure / transportation, waste collection and licensing services in coordination with Metropolitan Municipalities. They are also responsible for exercising their powers within the scope of the "Illegal Housing (*Gecekondu*) Law No. 775" and evacuating disaster-risk buildings. Their other duties consist of social and cultural services and the construction of parks, car parks and mosques.

ii. Urban Planning Legislation in Turkey

The spatial planning hierarchy in Turkey according to the "Zoning Law No. 3194" and the "Regulation for the Preparation of Spatial Plans" is as follows:

- National Development Plan (an economic plan also covering some spatial / geographical issues).
- Regional Plan (if available, those plans are prepared when needed for the development of some regions having special importance or being underdeveloped);
- National Spatial Strategy Plan (that is still in preparation process by the Ministry of Environment, Urbanization and Climate Change)
- Provincial Physical Plan ("*Çevre Düzeni Planı*") (plan having scales 1/50000 or 1/100000 covering some environmental protection issues together with macro level urban development for different sectors and transportation arrangements in provinces which has to in line with the National Spatial Strategy Plan);
- Land use Plans (physical plans of 1/5000 ("*Nazım İmar Planı*") and 1/1000 ("*Uygulama İmar Planı*"- Implementation Plan) scales for cities developed by local governments in line with the Provincial Physical Plan).

In addition, the Ministry of Environment, Urbanization and Climate Change presently develops some plans with not so much physical decisions but containing some zoning rules (i.e. Integrated Coastal Zone Plans). Further, upon a recent legislative amendment presently there is work on "National Spatial Strategy Plan" at national scale standing above all spatial plans.

Physical land use plans covering urban development / zoning / spatial implementations are called "*imar planı*" in Turkish legislation ("Zoning Law dated 1985 and numbered 3194") which are the most important instruments in urban planning in Turkey that parcel urban land; identify the location of buildings, roads, green spaces, etc., setting limits to the height of buildings and so on. The most well-known article of the law, Article 18, determined the rate to be cut for the road, parking lot, green spaces, mosque, and police station area from the property owners in the areas to be planned. The zoning (or can be named land use) plans are compulsory in settlements with population over 10,000 and developed by Municipalities. Nevertheless, the Ministry of Environment, Urbanization and Climate Change has its authority to develop such plans in some areas with special environmental status, transformation zones, major transportation investments, etc. There are also some other institutions with authority to develop such plans in special areas such as tourism & cultural protection (i.e., Ministry of Culture and Tourism).

The new Regulation for the Preparation of Spatial Plans come into effect in 2014 and the previous regulations were repealed. This regulation is the implementation regulation of the Zoning Law dated 1985 and numbered 3194. In the “Regulation for the Preparation of Spatial Plans”:

- Hierarchy of spatial plans was clarified and relations with other special plans were defined.
- The definitions of spatial strategy plan, integrated coastal zones plan, action plan, urban design project, and long-term development plan were defined for the first time.
- Principles regarding every plan were brought in addition to the general planning procedures.
- Principles and procedures regarding the plans and the data analyses to be made were specified separately.
- Applications speeding up and shortening the planning process were allowed.
- Tools that will ensure the publicity of and participation in plans were developed.
- Legend (representations in the appendices) and standards (sizes of schools, health, worship areas and green areas determined according to the population in the appendix) were regulated.

Another important legislation according to the Zoning Law is the “Planned Areas Zoning Regulation”. The regulation covers the areas where the implementation zoning plan is made and defines the properties (such as areas) of parcels, buildings, and other structures in different land uses within the plan and standards have been set for height and road-garden-building distances. Moreover, the “Istanbul Zoning Regulation”, which was prepared according to the Zoning Law and the Decree No. 644, is a legislation that covers the issues like the Planned Areas Zoning Regulation in more detail for Istanbul.

For the coastal cities in Turkey such as İstanbul, The Coastal Law must be mentioned together with the Zoning Law for the development in coastal areas. The Law defines the special conditions of zoning plans for coastal areas and gives the plan approval right to the Ministry instead of the Municipality. The Law envisaged that the first 100 meters of the coastal edge line, which must be determined according to the geological & geomorphological structure of the coast, should be reserved only for green areas, roads and structures that can only be built on the coast such as harbours and piers. Since it came out after the 1990s, this Law provided a great benefit in terms of using the coasts as open green spaces.

iii. Urban Transformation Policy

Istanbul is the largest metropolitan city in Turkey. It is situated in a hazard prone zone, namely the Marmara Region, with approximately 16 million people and accounting for about 19% of the entire population in the country. In terms of fast population growth and urbanization, after the 1950s İstanbul city itself and the Marmara Region developed very fast and Istanbul became the heart of Turkey’s economy similar to its historical position where the new capital Ankara was in front after proclamation of the Republic in 1923 until 1950s (Keleş, 2014). İstanbul’s population which was about 1.268.771 in 1955 increased to about 16 million in 65 years. Although there was massive construction and housing development in the peripheries of İstanbul after 1970s, these houses were not affordable for the newcomers or for poor sections of society. As a result, newcomers either moved into the emptied old historical urban houses with low quality which were located in the centre of the city or tried to build their own homes in the illegal status mostly situated in the hazard risk zones like flooding, earthquake or landslides both in the centre or in the periphery of the city. Therefore, illegal construction processes producing the gecekondu (in Turkish, houses built-up in one night) become common in almost every part of the city (Tekeli, 2011). From a political economy perspective, the underlying cause of this is the delayed process of capitalist development in the country where in spite of the pace of rural-to-urban migration new urban dwellers could not be provided with employment opportunities in productive sectors and there was an absence of adequate funds to social housing where they built their illicit houses (“gecekondu”) instead (Tekeli, 2011; Keleş, 2014; Şengül, 2009).

In the neo-liberal period together with the effects globalization, after 1980s the number of buildings grew in the city in a higher rate. Almost 30% of all buildings in Istanbul were constructed between 1980 and 1989. This trend continued in the next ten-year period between 1990 and 2000 with 32.5% (Atun and Menoni, 2014). After 1980s, urbanization trends in the city caused severe imbalances in housing stock in different areas. The construction sector focusses increasingly on various urbanization projects which were mostly covering dense apartment building construction after 1980s and gated communities and residences as a new demand of rising middle class since 2000s (Atun and Menoni, 2014). The position of the low-income residents of İstanbul become much worse in terms of housing with the neoliberal era, where the urban land speculation become more dominant in the economy increasing the housing rents and more control over the land by authorities to keep the land from illegal dwellings. On the other hand, this period also speeded up the urban renewal schemes in the city which gave opportunity for some low-income population in the city to renew their dwellings with apartment blocks in a better condition as if they are “eligible owners of land”. The others become losers within gentrification processes or because they are not eligible owners (they are tenants or out of the coverage of housing amnesties). Therefore, land tenure security come up as an important factor in DRR based urban transformation projects in İstanbul which has a direct effect on social vulnerability of residents in an area.

In that respect, urban renewal projects flourished mainly in transforming of *gecekondu* areas as illegal settlement areas where the ones done until 1980s were legalized partially with Squatter Amnesty Laws in relation with the political-economic context of the country (Keleş, 2014). However, 1999 was the turning point for the housing construction and urban development. Uncontrolled and unplanned development continued in Istanbul until 1999 when two major earthquakes hit the region causing at least 18,000 deaths and $16 billion economic loss. These events changed the authorities’ perspective to earthquake risk and its mitigation. As a result, the “Earthquake resistant design code” (published one year before the 1999 earthquakes) was widely implemented. Several initiatives such as programmes for strengthening of schools, hospitals and transportation systems had also started subsequently. In the recent period, after the 1999 Marmara Earthquake, there is a new understanding of urban renewal in Turkey where the main target is transforming the housing stock that is not resistant to earthquakes together with illegal settlements.

The National Law No. 6306 dated 2012 regarding the “Redevelopment of Areas Prone to Disaster Risks” is according to the new understanding that is the disaster risk related renewal of buildings that are not only in the squatter areas.

This Law can be translated as Turkey’s Urban Transformation act, which provides the basis for most of the current urban redevelopment activities based on the definition of two types of redevelopment schemes that are[12]:

- Buildings that are deemed at-risk (building based reconstruction-BBR),
- The redevelopment of large urban areas at risk (area-based reconstruction-ABR) which also covers a third definition as the development of reserve areas.

According to the Asian Development Bank (ADB) Report; in most cases, the process of urban redevelopment under the relevant legislation is carried out using the BBR approach, in which owners rebuild their houses based on current building standards covering both the earthquake resilient construction and energy efficiency regulations[12]. In contrast, urban planners propose the ABR method to have healthy neighbourhoods with social amenities and better infrastructure in the settlement scale. This also gave the legitimacy to a number of increasing urban regeneration projects in the city.

iv. Policies for Disaster Risk Reduction in Turkey

Disaster risk reduction policies in Turkey are mainly concentrated on the recovery period after a disaster. Hence, they are mainly focused on "disaster risk management" and improving recovery capacities rather than mitigation and preparedness.

In that capacity, the responsible institutions are the Ministry of Environment, Urbanization and Climate Change (Ministry of EUC), the Disaster and Emergency Management General Directory (AFAD), İstanbul Metropolitan Municipality and the Ministry of Family and Social Services (MFSS). Responsibilities and services of each of these institutions have been defined by different laws.

The Ministry of EUC is responsible mainly for the identification of hazard-prone zones and buildings according to Law 6306 (law on transformation of areas at disaster risk) (1; 2; 3 from online references). According to this Law, the Ministry is responsible for determining the risk level of buildings based on the assessment of authorized companies. There is a loan facility for the money to be paid to these firms if the house owner cannot pay. If the building is found risky, there is a low-interest loan from banks to have it demolished, and one year rental assistance for the landlord during the demolition process. In addition, there is a one-time money for the tenants to move to another building. Rebuilding is usually through the contractors in return for some new flats.

The Mass Housing Administration (TOKİ) is also a major institution providing new houses to disaster victims. To claim a new house from TOKİ, get low interest credits or get any loan, houseowners need to be included into the housing insurance system called DASK (Compulsory Earthquake Insurance) (Azimli Çilingir, 2018). DASK insurance system was designed after the 1999 Marmara Earthquake. TOKİ builds new houses for the victims either in empty areas or on already disaster effected areas after the demolition by coordination with other institutions for site selection. This rebuilding process usually starts after an area is announced by the Disaster and Emergency Management Directorate (AFAD) as a disaster region and the buildings that are in high level of damage are identified by the Ministry of EUC.

AFAD has mainly a coordinating role during and after disasters. The Law no. 7269 (1959 Law on Supports to be made and measures to be taken in case of disasters which threaten the public life) defines the responsibilities of AFAD (4). Besides being a coordinating institution and crisis management centre in times of disasters, AFAD also has to give support to victims whose houses are damaged and need to move their household goods. To those who cannot enter their houses because of risk, some money can be given to compensate for their basic furniture needs. AFAD and TOKİ also have to work together for helping with the rebuilding of small businesses and shops.

Local governments have major responsibilities in times of disasters. İstanbul Metropolitan Municipality (IMM) has developed a specific initiative to fasten the urban transformation process of risky zones. The experts visit risky neighbourhoods and inform the residents about disaster risk to raise awareness and give guidance about what to do. This kind of policy has double significance: while raising awareness, it also gives technical and financial support to the poor to improve and strengthen their houses (5). Furthermore, in İstanbul, almost 95% of all schools, major hospitals and other public buildings have been renovated and strengthened for earthquake risk after 1999 under the initiative of the Governor's Office (6) which is the provincial organization of the central government.

SESSION 3: EXERCISE ON POLICY DEVELOPMENT

Author of the Chapter: Ms. Aditi Dhakal

3.1 Objectives

At the end of the session, participant will be able to:

- Assess policy expectations/actions from Future Visioning/WP1 and analyse them

3.2 Structure of Session 3

The structure of session 3 is as follows:

Structure
1. Background
2. Relation to previous Work Package (Future Visioning)
3. Exercise

3.3 Background

Theoretical background is not sufficient to understand the overall policy development thoroughly. Hence, this exercise session is designed to impart idea on how policy is analysed in real scenario.

3.4 Relation to previous Work Package (Future Visioning)

In this exercise we will be continuing with what was done during M1 “policy development exercise”. We all know, Module 1 collects aspiration and translates that to policy. In module 2, in an expert driven process, we analyze policies based on their relation to vulnerability and exposure, based on their relation to existing policies, based on the constraints, based on equity concerns, and provide ways of implementing policies.

This exercise continues with a scenario from Tomorrow Ville. This scenario highlighted that this is an imaginary city inspired by data from Nairobi & Kathmandu. It is highly urbanizing with a population doubling in 30 years. It has an Informal settlement by the side of River. It is Peri-urban with 60% involved in Agriculture. 10% of its residents work in Industry and live nearby.

It consists of 60% Low income, 20% high income and 20% medium income population. It has middle income households in gated communities. 30% of head of household are women and 20% are migrants. This area has a mild slope from N to S. It is exposed to Earthquake, Flood and Landslide with records of casualties related to these incidents.

In this exercise role play takes place in three different groups of urban planners. In this exercise, we make the participants access few policy expectations or actions as examples from future visioning exercise. These policy expectations or actions are detailed out to analyze them.

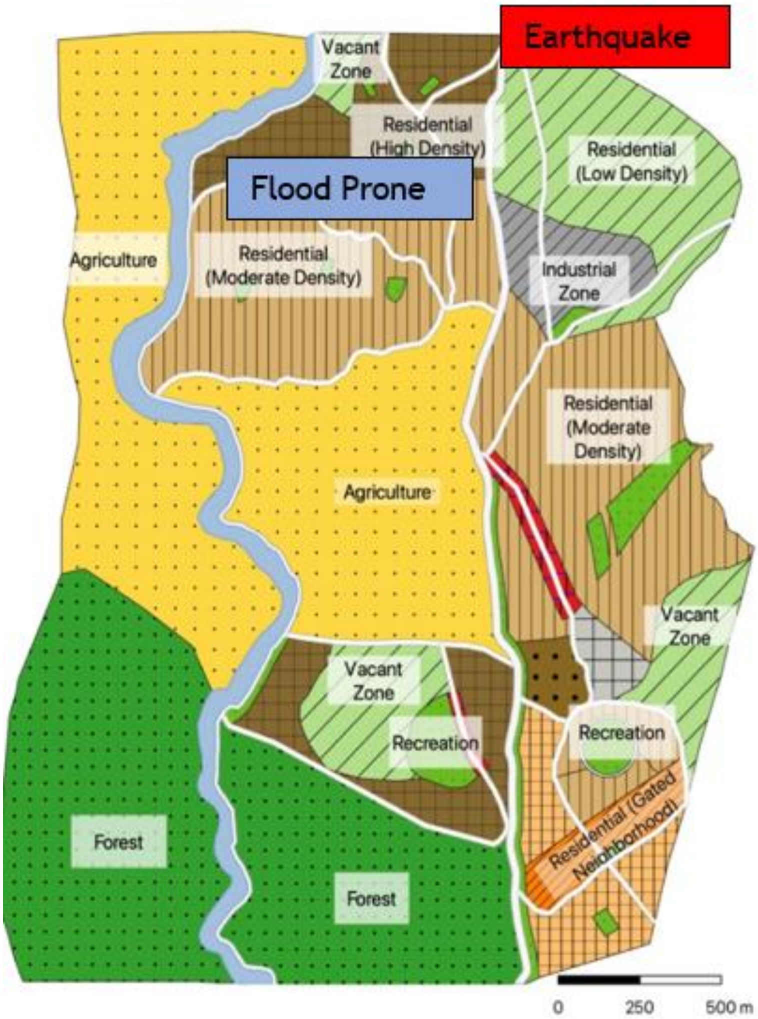


Figure 13: **Tomorrow ville**

3.5 Exercise

Exercise consists of three different tasks which are explained below:

3.5.1 Task 1

Read the case study for no more than 2 minutes just to understand why we need these policies. For instance, in the given scenario, there is an occurrence of earthquake and flood. There are informal settlements. These give hints of why we need the policies that are given as examples in the exercise.

3.5.2 Task 2

Assessment of Policy Expectations:

- Enforcement of Building and Infrastructure Development Bylaws (G1)
- Policy for construction of earthquake-resilient buildings (G2)
- Policy to provide Land ownership (G3)

There are three policies as examples. Each group is responsible for analyzing different policies. The group is asked to read all these policies for 2 minutes.

3.5.3 Task3

The third task consists of analyzing policies based on the following:

- The impact of the given policy to exposure and vulnerability,
- The relation of the policy to the existing policy,
- The relationship of the policy to the constraints: political, physical, natural, or socio-economic
- The relationship of the policy to equity concerns

A table is provided in jam board for the participants to fill in the answers for the above-mentioned questions.

The table below shows the example of task 3:

Table 6: Example of Task 3

Name	will it likely impact exposure? How?	will it likely impact vulnerability? How?	Is it a part of existing policy?	Constraints((political, physical, natural or socio-economic)	Equity Concern
Enforcement of Building and Infrastructure Development Bylaws (G1)	No, it is primarily a concern of vulnerability than exposure.	Yes, this policy brings significant change in physical vulnerability.	Planning Bylaws	Political interference (allowing to construct beyond bylaws) No Physical constraint. Lack of awareness,lack of local technical capacity.	Will allow people from all class to have a safe building and settlement.

3.5.4 Exercise module

Total Timeline for exercise is: 45 minutes consisting of 5 mins of briefing from the instructor, 2 mins for task one, 2 mins for task 2 and 20 minutes for task 3. The exercise takes place in a discussion mode. Each group should present their work (5 min by each group) at the end of this exercise. The presentation should be done by a leader selected by the group. There will be 2 minutes for feedback from instructor at the end. Feedback will include concluding remarks about the group works.

SESSION 4: LAND USE PLANNING

Author of the chapter: Dr. Nuket Ipek Cetin

4.1 Objectives

This session explores how land use planning contributes to the development of Tomorrow's Cities Decision Support Environment (TCDSE). It includes the practical framework for the participants about the preparation of land-use plans for urban development implementations in cities. Therefore, it aims to demonstrate how to produce disaster risk-sensitive land-use plans which speak to diverse urban assets.

In this regard, by the end of this session the participants will be able to:

- Discuss about the practical linkages between land-use planning, Disaster Risk Reduction (DRR), and the TCDSE.
- Identify the urban development trends and drivers based on land-use change and urban growth.
- Describe the land-use planning models and tools.
- Discuss the methodology for developing disaster risk-sensitive land use plans in the TCDSE.

4.2 Structure of Session 4

The structure of session 4 is as follows:

Structure
1. Introduction to Land Use Planning
2. Basics of land use planning
3. Role of land use planning in TCDSE
4. Development of land use plans
5. City Case Implementations

4.3 Introduction to Land Use Planning

Land use planning (LUP) is a repetitive procedure that relies on communication and collaboration among various parties with the goal of reaching a consensus and making informed choices regarding the sustainable utilization of land in rural regions. Additionally, it involves the initiation and oversight of the actual implementation of these decisions.

While the term "land use planning" may not be commonly used in everyday conversations, its principles and practices are evident in various aspects of our lives. For instance, whenever people inhabit land and utilize its resources, whether consciously or not, they are essentially engaging in the process of planning how to best use the land.

When considering the importance of land-use planning in the context of disaster risk reduction, it becomes apparent that the absence of effective planning can lead to detrimental consequences. Issues such as unregulated urban development, unplanned urban growth, inadequate governance, and social deprivation, among others, pose significant challenges. When these factors intersect with natural hazards, they result in heightened vulnerability and exposure for populations, infrastructure, housing, and production capacities.

Land use planning serves as an effective mechanism for integrating disaster risk reduction into the process of urban development. That helps to Promote sustainable urban growth with no new risks; Address environmental issues in detail; Identify and mitigate risks embedded in existing land use; Regulate land use patterns at individual parcel level, Modify and reduce vulnerabilities of people and places; Reduce human losses and increase the ability to recover; Reduce the economic, social, and environmental costs of disasters, Enforce safe construction practices at project level, Coordinate community-based early warning systems and provide support. Basics of land use planning

4.4 Basics of Land Use Planning

This session describes the three major issues need to be organized in advance for a smooth land-use planning process within the TCDSE framework:

a. Meeting data requirements
b. Assessing urban growth and land use changes
c. Defining land use planning models and tools

4.4.1 Meeting data requirements

Land use planning must draw on various spatial as well as statistical datasets. Spatial data showing the current land use/land cover as aggregated zones (e.g., residential, industrial, commercial, agricultural, natural), natural aspects of the area such as topography, soil characteristics (e.g., infiltration rates), slopes are utilised while identifying the land use types.

Statistical data for spatial units such as provinces, districts, or neighbourhoods are also needed for aggregating relevant demographic and socio-economic factors, such as the number of inhabitants, age structure, gender, education level and income to understand the socio-demographic outlook in the planning area.

All relevant data used in land-use planning are compiled firstly in WP0 where city scoping is carried out and secondly in WP1 where future aspirations are gathered, which guide the identification of land use types. After the compilation of existing datasets and future aspirations; statistical information with respect to population growth, demographic and socioeconomic distributions among the area are valuable to model future social context. The details on how such a modelling is done is explained in detail in Session-2 and the detailed instructions can be found in Spatial Data Guideline.

Among those detailed information, essential data that are required for land use planning are given in table below.

Table 7: Examples of datasets, their scales, and potential sources necessary for land use planning.

Data sets	Appropriate scale	Potential source
Land use/land cover	Parcel level, 1:10,000	Aerial photos, satellite imagery, NASA, ESA data resources
Topography, Slope map, Digital elevation model	1:10,000 - 1:25,000	USGS, NASA, ESA
Socio-demographic and economic factors,	Per district, constituency, neighbourhood	Municipalities, Local authorities, census datasets

(population, age, gender, education, livelihood, etc.)		
Soil map	Soil types	Environmental agencies, USGS
Hazard maps (floods, erosion, landslides)	Depends on the context and hazard type Must be at a resolution to evaluate the asset level impacts	
Buildings and infrastructure (lifelines and transportation)	Asset level	Municipalities Open Street Map
Service facilities (social welfare, education, medical, etc.)	Asset level	Municipalities
Meteorological data: precipitation, wind, etc.	National and/or regional level	Meteorological agencies

4.4.2 Assessing Urban Growth and Land-use Changes

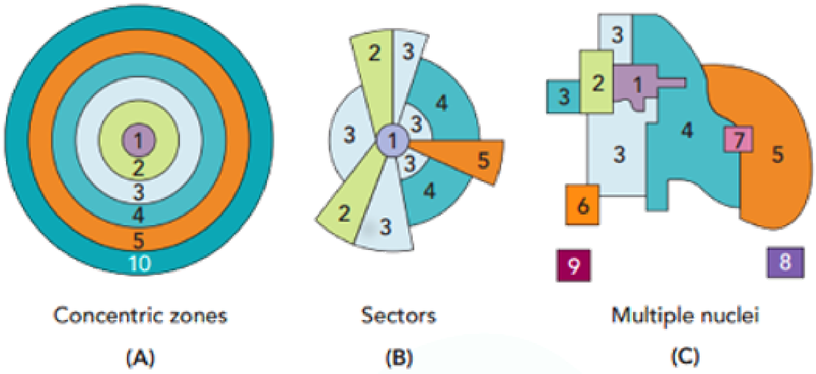
An increasing population commonly leads to land-use changes both in the natural and built environment. Especially in rural areas, large natural lands such as forests, grasslands, wetlands, or arable lands are converted into ‘developed land’ (built-up areas with concentrated housing, industry, and infrastructure), which increase the exposure to natural hazards, particularly to floods and landslides[13].

Assessing or predicting such land-use changes, which can be typically interpreted as urban growth modelling, is critical for natural-hazard risk assessment especially in TCDSE context as the focus is on future urban development. Exposure to future hazards is particularly vital for the global South, as these newly expanded urban areas are expected to occur in low- and middle-income contexts. Therefore, the exposure to multi hazards is disproportionally affecting the urban poor in such countries. Such communities have also less financial, institutional, or social support and means to prepare, cope, and respond to hazards[14] [15] which increase the potential impacts on them.

An assessment of urban growth considers both infrastructural and social components which lead to exposure and vulnerability in areas which are prone to change[15]. A more granular revealing of sensitive locations in the future is crucial to engage in informed discussions that decide which policies and spatial changes should be prioritised.

Urban ecologists examine how people adapt to their environments. They focus on the social context (environment) and the spatialization of modern behaviour. For them, the form of the city is the result of “natural” growth—expansion, immigration, succession, etc. The figure below are the three models of urban growth developed by urban sociologists in the US. In general, a city grows from the centre, then outwards. Different sectors/zones in city are the result of the convergence of these social forces. In Model A, Zone 1 is the central business district. Zone 2 is a transitional area containing rooming houses and deteriorating housing which breed poverty, disease, and vice. Zone 3 is the area thrifty workers have moved to escape the transitional Zone 2 yet maintain convenient access to their work. Zone 4 contains more expensive apartments, hotels, single-family home, etc. Commuters live in Zone 5 which consists of suburbs or satellite cities that have popped up around transportation routes.

In Model B, concentric zones can contain different sectors, one of working-class homes, another of expensive housing, and one of businesses, etc., all competing for the land. With immigrants settling in lower-rent areas, the population spills over to adjacent areas. In Model C, a city may have several centres of “nuclei”. Each nucleus contains a specialized activity—such as clusters of fast-food restaurants or retail districts. Areas with similar activities cluster together to draw consumers, or because land-use is similar in adjacent areas.



Legend				
1. Central business district	3. Low-class residential	5. High-class residential	7. Outlying business district	9. Industrial suburb
2. Wholesale and light manufacturing	4. Medium-class residential	6. Heavy manufacturing	8. Residential suburb	10. Commuter zone

Figure 14: Urban Models

These sociologists acknowledged that no city perfectly fits these ideal models, with geography, development of transportation, innovated business models, cities are becoming increasingly diverse. For example, in the 1970s, the “growth machine” theorists emerged, arguing that instead of “natural processes”, urban growth is driven by a coalition of interest groups who all benefit from continuous growth and expansion. For them, the growth of cities is a social phenomenon.

The literature on the topic shows that urban growth has been modelled in various ways, based on simulation techniques that test diverse spatial theories on locations and fundamental interactions among urban land use classes[16], [17] [18]. Most of these models have common objectives, but they differ in implementation or theoretical assumptions (Musa, et al. 2016). Among these, geospatial-based urban growth models are the more utilized ones due to their powerful capabilities to combine remote sensing and GIS, therefore providing innovative solutions to produce accurate, timely, reliable, and periodic data (by remote sensing) and representing different scenarios for land-use planning and management (by GIS) such as revealing the land use change trend for evaluating the urban growth.

As stated in by Triantakonstantis & Mountrakis[19], urban growth models can be classified in five groups based on their underlying modelling algorithm. There are:

- Cellular Automata modelling
- Artificial neural networks modelling (ANN)
- Fractal modelling
- Linear/ logistic regression modelling
- Agent-based modelling (ABM)
- Decision-trees modelling

(For the detailed information on the urban growth models in theory and implementation, check[19] [20], [21] [22] and [23].

These algorithms can also be used in hybrid forms by considering empirical, statistical, and dynamic approaches. For instance, ABM a has been combined with weighted geographical regression [24], logistic regression[25], and Bayesian networks[26], whereas CA has been coupled with Markov chain methods[27] [28] in diverse case studies. [29] Cremen et al. mention and give several examples that urban growth may also be simulated using empirical [30] or semiempirical [31] methods, landscape metrics [32], machine learning approaches (such as artificial neural networks[33], coupled Markov chain genetic algorithm models [34], the weight of evidence[35], socioeconomic storylines[36]. There are also several examples in the literature with the combination of ANN and MC[37], CA and linear regression [38] MC and linear regression[39] [40]. Herein, it is also important to mention that several CA packages have been already developed to simulate land-use change such as UrbanSim, Dinamica EGO, SLEUTH, CLUE-S, CA-Markov in IDRISI, FLUS, and UrbanCA [41] [42] [43] [44] [45] and they are widely used in research.

Cremen et al. [46] also mentioned several case studies, including assessing the leveraged population and economic growth projections. For instance, urban growth modelling with per capita land approximations (that were determined based on forecasted population and economic growth values), estimating the built-up area derived from future population projections or estimating annual increases in housing number depending on population increases [47] [48] are other outlooks that can be used to estimate future urban pattern.

The question of how to select an appropriate model for urban growth assessment, at that point, is basically related to whatever data are used besides the physical and urban expansion characteristics of the planning area. The comparison of data requirements, model applicability, and strengths and limitations between models can be found in [22] [21] [23].

4.4.3 Land use planning models and tools

Land-use planning is the activity of arrangement of land use in a certain range of time and space, according to land resources, land suitability and demands of economic and social trends. Therefore, land use models are effective tools to describe the activities of related actors and their competition for land in an urban setting by determining the spatial distribution of activities at present and projecting future land uses. These actors are households, firms and/or retail establishments, each with requirements for space and access to jobs, schools, and markets.

The conventional land use planning approach, which is today's main implementation perspective, especially in the Global South is usually based on a top-down approach and focused mainly on technical and/or political aspects related to the planning area. Social factors such as people's perceptions of urban-related problems, their immediate needs, their aspirations, and the creation of a negotiation platform to ensure an informed decision-making process are rarely taken into consideration in land use planning. Therefore, many land use plans are less successful than expected. Additionally, conventional land use planning is presented to the land users by government officials, technical agencies or international experts anticipating hereby the automatic adoption and widespread application by communities. Therefore, communities who inhabit on the land do not see their interest and need to be reflected in the land use decisions due to giving low value for the integration of local and indigenous knowledge in land resource management.

As a solution for those constraints, participatory approaches have been integrated into land use planning practices since the 1990s. Agenda 21 calls for the importance of reorganizing and strengthening decision-making structures including policies, planning and management procedures which need the participation of all stakeholders in land use decision-making as well as bridging the gap between the production and income objectives of land users. That is also emphasizing long-term objectives of preserving natural resources and reducing the impacts of natural hazards on communities.

Participatory land use planning follows a holistic, integrated, and interactive approach to developing sustainable land use patterns. Because it assesses the biophysical, socioeconomic, institutional, and legal variables that determine the land-use system. Thus, all stakeholders have a natural right to have a role in decision-making with the negotiation process between decision makers at the different levels to create consensus on important land-use decisions. Key components of participatory land use planning are:

- It follows a multidisciplinary approach based on a set of methods from different thematic areas and it integrates various methodological elements such as people's participation, natural barriers and potentials, legal and institutional framework evaluations, and negotiation on land-use options.
- It respects the complex ecological and socio-economic variables which determined the land-use system to ensure the implementation of the plan.
- It is problem-oriented and focuses on the demands of land users.

In this context, land use models are an essential component of a comprehensive & participatory planning approach to project and evaluate the consequences of policy decisions and various actions on land use patterns in the planning area. Models are basically mathematical representations of the real world and typically implemented through computational simulation tools that describe, explain, forecast, and evaluate the complex interactions between different elements of the land use system, mostly supported by GIS in contemporary practices. Therefore, land use models allow better understanding of future impacts of different planning policies, supported by knowledge about economic theories and social behaviours and they serve significant purposes as:

- An explanatory role by helping to achieve a better understanding of the urban dynamic system.
- A predictive role by enabling virtual experimentation of possible impacts for new infrastructure, technologies, or policies to be determined.
- Policy and design roles by facilitating participatory processes for collaborative decision making.

Additionally, land use models could support to stimulate thinking and facilitating discussions, rather than to make definite statements about the future. This also promotes in narrowing down the number of possible policy interventions, without making a predictive statement about the only or optimal solution.

Land use models can be divided into different classes depending on their theoretical foundation and functional mechanism and most common types in the literature can be listed as:

- **Spatial input-output models**

Spatial input-output models are used to analyse the economic interactions and interdependencies between different regions or areas within a city or metropolitan area. These models typically incorporate data on the flow of goods and services, money, and people between different locations, and are used to understand how changes in the economy or land use patterns in one area can impact the economy and society in other areas.

Spatial input-output models are often used to analyze the economic impacts of proposed developments or infrastructure projects, such as a new shopping center or transportation link, and can be used to estimate changes in employment, income, and other economic indicators that may result from these projects. They can also be used to analyze the potential impacts of changes in land use regulations or zoning policies on the economy and development patterns within a city or metropolitan area.

- **Agent-based models**

Agent-based modelling (ABM) is a computational approach used to simulate the behavior and interactions of individual agents, such as households, businesses, and government entities, within a city or metropolitan area. The goal of ABM is to understand how the collective behaviour of these agents, interacting within a simulated urban environment, shapes the city's overall structure and dynamics.

Agent-based models are built from the bottom-up, starting with a set of simple rules that govern the behaviour of individual agents. These rules are based on observed or hypothesized behaviours and decision-making processes of real-world agents, such as households seeking housing or businesses searching for locations. The agents in the model interact with each other and with their environment, such as land prices and zoning regulations, and make decisions based on their individual rules and the information available to them. The interactions between the agents and the environment will affect the state of the system, including land-use patterns, population densities, and other characteristics of the simulated urban area.

- **Multi-agent simulation models**

Multi-agent simulation models are a type of agent-based modelling (ABM) that involve the multi-agent simulation models are a type of agent-based modelling (ABM) that involve the simultaneous simulation of multiple types of agents and their interactions within an urban environment. These models are used to simulate and analyse the behaviour and decision-making of different types of agents, such as households, businesses, and government entities, within a city or metropolitan area.

Multi-agent simulation models are typically built by creating separate modules or "agents" for different types of agents in the urban system, such as households, businesses, or government entities. Each agent is assigned a set of rules or behaviours that govern their decision-making processes and interactions with other agents. The agents interact with each other and with their environment, such as land prices, zoning regulations, and transportation infrastructure, and make decisions based on their individual rules and the information available to them.

- **Rule-based spatial allocation models**

Rule-based spatial allocation models are a type of spatial modelling technique that are used to simulate and analyse the allocation of land uses, such as residential, commercial, and industrial development, within a city or metropolitan area. These models typically involve the use of a set of predefined "rules" or decision-making processes that govern the location and development of land uses within a simulated urban environment.

A rule-based spatial allocation model starts with a set of assumptions about the decision-making processes of different types of agents, such as households, businesses, or government entities, and how they interact with the urban environment, such as land prices, zoning regulations, and transportation infrastructure. The model then simulates the decisions of these agents, and the resulting allocation of land uses over time, based on the rules that have been defined.

- **Cellular automata models**

Cellular automata models are a type of spatial modelling technique that are used to simulate and analyse the dynamics of land use patterns and urban growth within a city or metropolitan area. These models are based on the concept of cellular automata, a computational approach that involves the use of a grid of cells to represent an area and a set of simple rules to govern the changes in the state of the cells over time.

A CA model for urban planning is typically implemented as a two-dimensional grid of cells, where each cell represents a small area of the urban environment, such as a parcel of land or a neighbourhood. The state of each cell is defined by a set of variables, such as land use type, population density, or economic activity. The model then simulates the evolution of the urban area over time by applying a set of simple transition rules that govern the changes in the state of the cells based on the states of their neighbouring cells and other external factors such as infrastructure or zoning.

4.5 Role of land use planning in TCDSE

Rapid urbanization, socioeconomic and spatial inequalities, and climate change are turning an increasing number of human settlements into potential hotspots for disaster risk. Uneven access to safe and planned urban areas leads to the growth of informal settlements, exacerbating existing vulnerabilities and contributing significantly to disaster risk in cities, which is often experienced more acutely by poor and marginalized communities. In 2015, annual losses from disasters totalled US$260 billion and this is expected to rise to US$414 billion by 2030[49]. Trillions of dollars of future investment will be poured into today's hazard-prone urban areas, mainly because the drivers of urban risk are neither properly understood, nor addressed [50]. Urban planning tools such as land-use planning can be effective to reduce or eliminate probable disaster risks, which is also defined as a priority action for disaster risk reduction (DRR) in The Sendai Framework for Disaster Risk Reduction [49].

Land-use planning is the process of identifying suitable land-use options for allocating resources in the future by considering environmental, economic, and social factors. It concerns legislation and policy, adopting planning instruments like governmental statutes, regulations, rules, codes, and policies to influence and enforce land use. Thus, land use plans are to some extent a spatial representation of the future layout of physical and social environments, which contain the type, location, size, and amount of land needed to carry out different functions of the urban environment, such as residential, commercial, industrial, infrastructure, or public facilities. The spatial organization of land-use types in a planning area (how the land will be used in the future), and how to define the location selection criteria of certain economic sectors or building construction conditions, also determines the level of vulnerability and exposure to disaster risks in urban areas.

For the purposes of TCDSE, land-use planning should be a systematic and iterative process, often carried out at the local scale and led or supported by local governments to enhance the sustainable use and development of land resources considering people's needs and demands. A central point, in that sense, is the initialization of communication processes in which diverse stakeholders express their interests, aspirations, and expectations, negotiating future land uses in an equitable way. Beyond needs and expectations, land use plans should account for future hazards and be conscious of components such as exposure and vulnerability[29], [46]. This is why such a planning process should somehow express both a translation of social needs and aspirations and responses to the possible negative impacts of future hazards. Moreover, land use plans should account for trends and constraints that somehow lead to capacity to respond to risk. For instance, it should consider issues such as population growth and informalization, existing policies and regulations, and agendas for the future such as the implementation of green infrastructure and intentions for environmental protection. Therefore, it is possible to develop people-centred and disaster-risk-oriented urban environments which respond to the interests, aspirations, and expectations of urban citizens, particularly those that are poor and/or marginalised.

In this context, **land-use planning is the core implementation tool for transforming or translating the conceptual visions of stakeholders into quantitative spatial components in**

the TCDSE framework. Because the organization of land-use functions and urban patterns mainly determined by land-use plans can influence the trajectory of hazards in the built environment such as the increasing impact of impermeable surfaces on flood hazards or construction of high-density residential areas in earthquake-prone zones. Therefore, co-produced future visions-oriented land-use plans act as an input to hazard calculations to demonstrate physical infrastructure impacts and social impacts in Visioning Scenarios. For this reason, land use planning is highly interconnected with several modules in TCDSE framework (Future Visioning, Visioning Scenario, and Computational Model) by being the input or output of the implementation process.

In the initial stage of the TCDSE (City Scoping phase-WP0), current urban development dynamics and potential future urban expansion based on these dynamics are assessed. This is a comprehensive process, in which current natural, socio-economical, and infrastructural information and historical land use/ land cover data are collected towards the preparation of future-oriented land-use plans. Such assessment presents current strengths, weaknesses, opportunities and threats, besides existing urban development trends and dynamics in the planning area.

Critical to this endeavour is that historical land use/land cover maps are used as basis to estimate and model urbanisation trends and forecast future urban growth along with assumptions on socio-economic trends and existing policies. The output is a representation of organic urban growth or a model which considers existing plans for that area (this will depend on the content). Accompanied by the policies the future urban model would be the baseline scenario (usually called 'S0') in the TCDSE framework which is then also used in the Computational Model and Risk Agreement as a "business as usual" scenario.

The outputs of Future Visioning workshops, including spatial and non-spatial policy expectations produced by stakeholder groups, provide input to produce alternative future (i.e., different from business as usual) land-use plans in which it is possible to grasp planning goals and objectives. At this point, the land-use plans for each disaggregated group are developed based on their ambitions in response to **what the land-use pattern will be formed in the planning area if the aspired future of stakeholders (including Policy Bundles for DRR) is implemented**. These aspirational land-use plans are used as input to develop detailed future exposure datasets that constitute a Visioning Scenario when coupled with relevant policies.

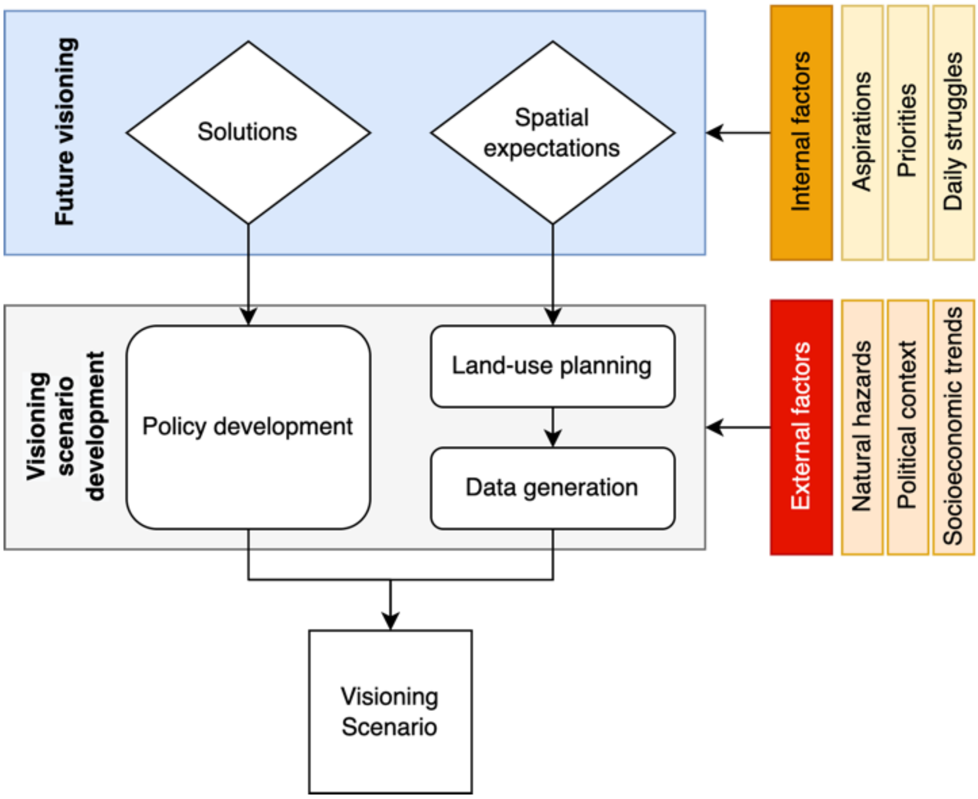


Figure 15: **The land use planning within the visioning scenario development process**

4.6 Development of land use plans

The development of the land use plans in TCDSE follows a sequence of steps as shown in the figure below. The process starts with synchronic studies for comprehensive assessment of the planning area and future visioning activities. The outputs of these steps are integrated in Step 3 to define land-use planning goals and objectives for translating future visions into quantitative spatial components for visioning scenarios. After that, detailing land-use options supported by participatory planning activities should be translated into GIS for visualising aspired future of stakeholders.

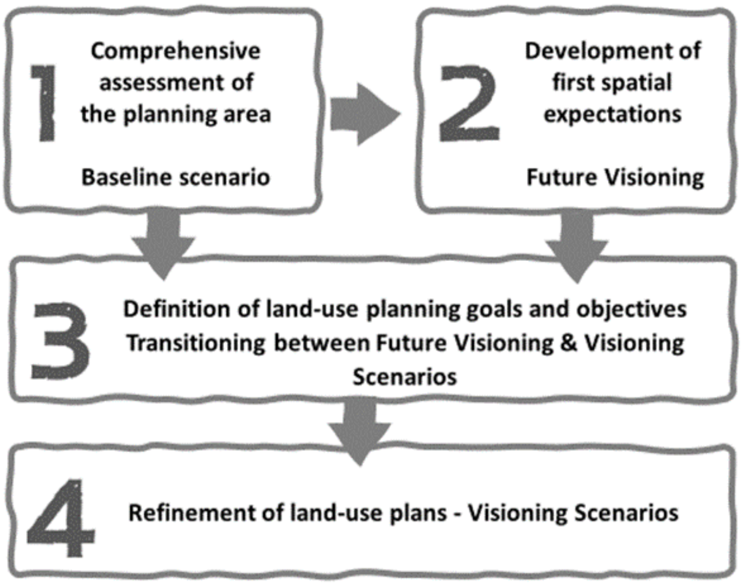


Figure 16: **The process of generating land use plans in TCDSE**

The content and the outcomes of each step are detailed below:

4.6.1 Comprehensive assessment of the planning area - current situation (baseline scenario)

Before carrying out land use planning it is crucial to conduct a comprehensive assessment of the planning area for a range of reasons. Firstly, it provides decision-makers with valuable insights into the current state and dynamics of the area. Secondly, it enables the identification of strengths, weaknesses, opportunities, and constraints. Thirdly, it facilitates the evaluation of the environmental implications of proposed land uses. Additionally, it allows for the assessment of existing infrastructure, services as well as social and economic factors. Furthermore, such an assessment promotes stakeholder engagement and provides a foundation for monitoring progress by establishing benchmarks.

Following are the Critical categories for a proper assessment of the current situation of the planning area:

i. Natural environment (location, topography, climate, biodiversity, geology, bathymetry, hydrology etc.)

- What are the geographical and morphological features?
- What are the natural assets and climatic conditions?
- What are the geological and hydrogeological characteristics?

ii. Cultural & historical environment (cultural and historical assets such as religious, sacred, or commonly used sites)

  - What are the features of cultural and historical environments?

iii. Urban environment

  - What is the socio-economic structure in demographic and economic context?
  - What is the status of physical and built environment in terms of land use/land cover, building stock and technical infrastructure?

  - What is the status of community and critical services (education, health, social facilities, green spaces etc.)?

iv. Natural hazards and single/ multi-hazard risk assessment for the current land-use pattern to define the spatial constraints or limitations- Land suitability mapping
  - What are the natural hazards in the area?
  - What is their likelihood and potential intensities?

v. Assessing the urban growth to estimate the probable future of urban environment
  - What is the probable future of the urban environment under current urban development dynamics (such as population growth, policy developments etc.)?

4.6.2 Development of first spatial expectations - Future Visioning

Future visioning establishes clear goals and objectives that reflect community aspirations. It also plays a vital role in defining spatial organization of the planning area by anticipating future trends and challenges from the eye of the communities. As a result, the future visioning activities act as the basis for land use planning process in TCDSE.

i. During Future Visioning workshops participants will provide the first basis for land-use plans that somewhat translate aspirations for the future and corresponding spatial expectations. This entails:
ii. Exploring how future visions (aspirations, expectations) need to be refined or adapted in the face of future hazards
iii. Discussing the possible negative impacts of hazards on the future city (developed case study area) and how to protect valuable assets from such events
iv. Co-developing sketched land-use plans and maps which represent future urban assets or current assets which should be protected (this requires using the wheel of urban assets and considering hazard information and urban trends)
v. Identifying which expectations are not spatial and/or require additional actions such as soft policies to reduce the impact of future hazards on that land and its assets (For more information, check Module 1).

4.6.3 Definition of land-use planning goals and objectives and transitioning between future visioning and visioning scenarios

This process ensures land use plans are purposeful, actionable, and responsive to the needs and aspirations of the community. At this stage, the external conditions are also considered and requirements on the land use functions are assessed based on planning norms that are valid in the local context. Such information helps translating the visions into spatial plans by:

i. Defining land-use planning objectives which meet stakeholders’ future aspirations.
ii. Combining population projections, potential future hazards and political context with aspired futures
iii. Determining the spatial land-use needs in a particular aspired future (at least one per group)
iv. Calculations on how much land is needed to supply the future land-uses executed by experts using local land-use planning standards/ norms with population projections for determining the quantity of:
  - Residential areas (assignment the distribution of population density)
  - Urban green spaces (required size of urban green space to meet the needs of future population)

- Education facilities (primary, secondary and high schools etc.)
- Health facilities
- Social facilities (religious services, community centres, social centres etc.)
- Commercial units
- Industrial units
- Technical infrastructure (road, electricity, natural gas, water, sanitation network etc.)

v. Define the characteristics of settlement patterns (low, medium, or high density building& population density)
vi. Define the building construction conditions for land-use classes considering the land suitability and disaster risk assessments.

4.6.4 Refinement of land-use plans

This last step produces a refined land use plan that reflects diverse perspectives of the communities and external constraints that come from planning norms and standards. As a result of this process, the land-use options address both community aspects and technical requirements mandated by regulations.

This refinement process considers:

i. The outputs of co-mapping activities in Future Visioning to develop technical illustration of aspired future of stakeholders
ii. Provide sufficient size and quantity for required land-uses
iii. Provide easily accessible infrastructure for public facilities to all social groups
iv. Spatial constraints and limitations in location choice of land-uses (based on the natural hazards, socioeconomic trends, and existing spatial policies)

4.7 City case implementations

In this section, implementations on how to develop disaster risk-sensitive land use plans in TC Hub cities are presented in accordance with the land-use plan generating process in TSDSE framework.

4.7.1 Understanding city context

The first task in Istanbul has been to develop an extensive "City Scoping Report and Database" with a district scale assessment that includes the study site. With this report, it is aimed to understand the dynamics behind the urban development of the area of interest and the underlying drivers that formed the urban context. The report includes detail as given in section 5.1. The report also includes supplementary datasets that are used as basis in the planning process right after. The report can be accessed here[51].

In addition to scoping the current context, urban growth modelling of the area is also carried out to estimate the potential future urban expansion trends in the district. This is done through analysing the past datasets of aerial imagery and land use / land cover datasets and estimating the direction and extent of the future urbanisation. The past datasets were basically used to understand how the urban extent was changed in different periods. Then based on these trends, potential urban expansion zone is identified.

Figure 17: **Satellite imagery examples that are used for assessing past urbanisation**

4.7.2 Understanding future aspirations and expectations

In this step, as part of the future visioning activities; insights of disaggregated community groups are gathered. Through focus group discussions and a future visioning workshop:

- Future visions of each group are defined.
- Policy themes are proposed by the groups.
- Spatial demands collected in terms of land-use types & attributes.
- Spatial organization of future land uses generated considering earthquake hazard.

By the end of these exercises, potential policy themes and co-mapped land use sketch have been gathered as outputs for each disaggregated community group.

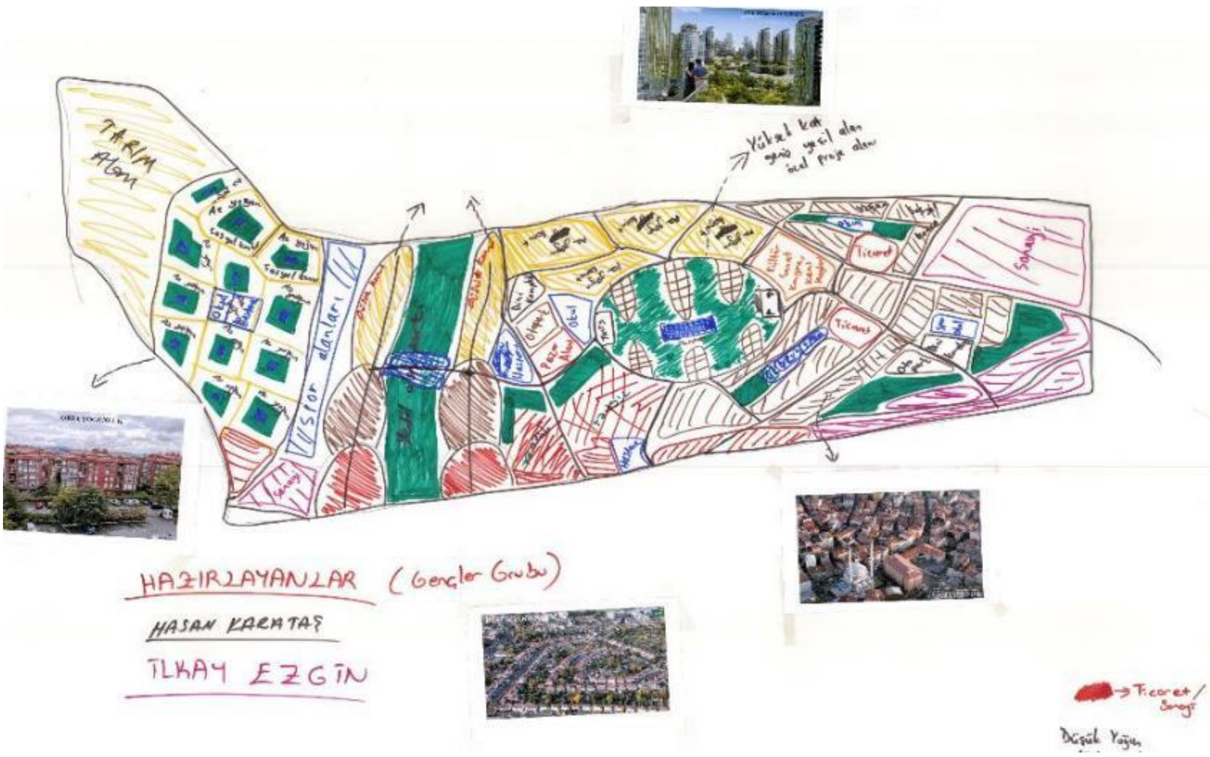


Figure 18: **Community driven land use sketch for the youth group in Istanbul**

4.7.3 Transition from aspirations into land use objectives

At this stage, the expectations of the community groups are translated into land use planning objectives. These objectives can be considered as spatial policies that shape the plan. In the table below, the interpretation of the aspirations and their translation into land use planning objectives is given.

Table 8: Reflections of aspirations as land use plan objectives

Spatial expectations & aspirations:	Objectives
Development of Wide-Open Green Areas System including social centers for young people and other disaggregated groups, with open sports areas such as skating/ skateboarding. Cultural activities can be held regularly and they can be used as assembly sites after disasters.	Development of recreational spaces
Low density horizontal settlements (not more than 5 floor) can ben developed	Promoting low density residential settlements
Renewal of illegal buildings and old buildings that include sea sand as material must be promoted	Promoting urban renewal practices for vulnerable residential areas
More schools on the neighbourhood scale but not only primary education but also secondary and high schools to be available	Increasing the quantity and accessibility of educational facilities in all levels

The second component of the transition is the identification of the quantities of the critical services based on the population projections. In line with the future population quantity, sufficient number of green spaces, commercial areas, religious facilities, education centres and healthcare facilities must be assigned. During this assignment, current local and global planning norms can be taken into account. In this regard, community's expectations on the building heights and density of the residential areas are embedded into plan's attributes as population density information in the unit of person/hectares. The density information and classification can change from city to city, meaning that "low-density" residential area can have different values in different cities.

Another component at this stage is the assignment of potential income groups who may reside in a given location within the plan's boundaries. This assignment is sourced from the discussions in the future visioning workshop particularly the conversations on the equity aspect of the plans. It must be noted that income assignment is not a precise and exact one but instead it reflects a general judgment of the community and experts.

4.7.4 Refinement of land use plans

As a result of these calculation and estimation procedures, the way in which the community driven plans will change is understood. In GIS environment, the rectifications and revisions are made. In the figure below, the finalised plan that is produced because of this procedure is given.

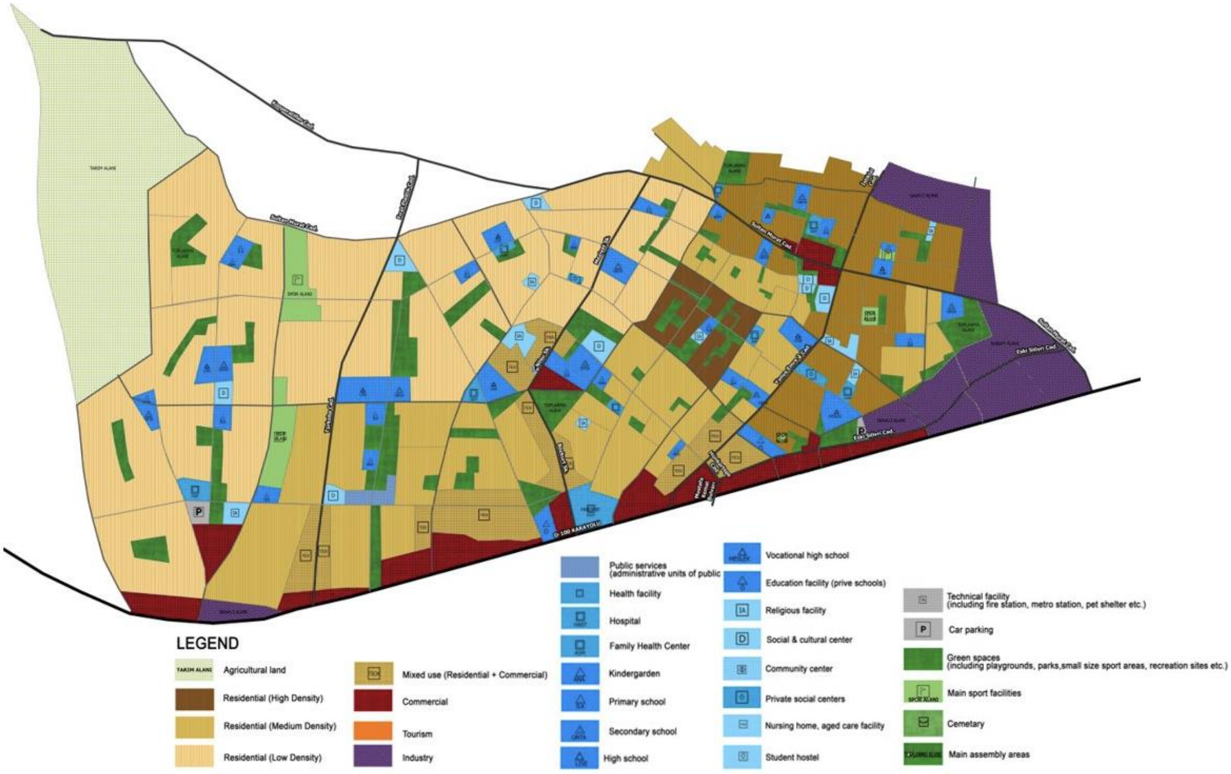


Figure 19: Refined land use plan of the youth group in Istanbul

SESSION 5: EXERCISE ON LAND USE PLANNING

5.1 Objectives

At the end of this session, participants will be able to:

- Draw a basic land use plan with roads

5.2 Group Work

There will be 4 groups. Each will have a facilitator to facilitate on GIS online platform. The exercise will take 30 mins. At the end of the exercise each group will present their outcome in 5 mins per group.

In the exercise a community drawn map in online GIS application will be provided to the participants. These land use plans will be provided with Land use zones and Transportation network.

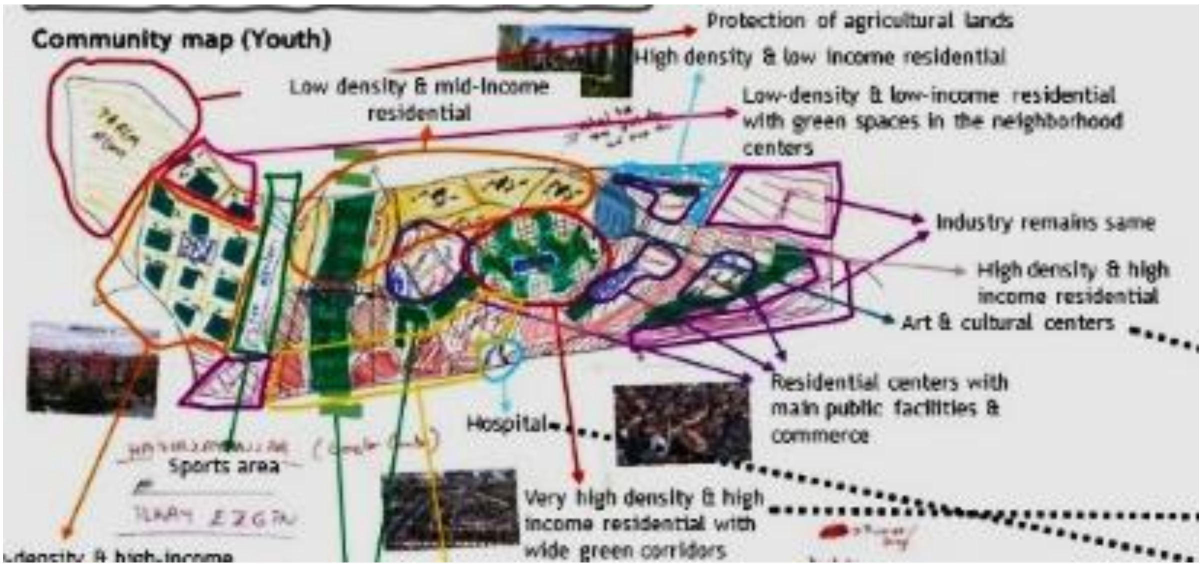
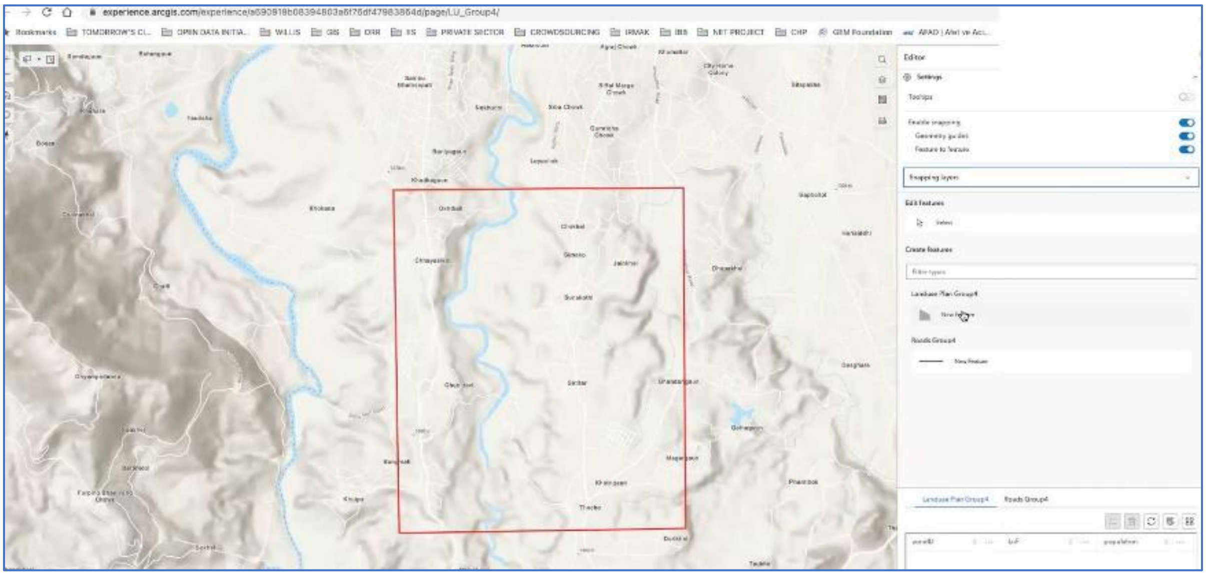


Figure 20: **Example of community driven land use for the youth group in Istanbul**

5.2.1 Drawing Land Use Polygon

First, we set the snap options and check all the boxes in snapping layers.



To draw Land use polygons, we should double click on the polygon option. The attributes are on the right-hand side. In the attribute, identify a zone ID and then identify the land use function. The population here means today's nighttime population. Density cap is the density of this zone. If this is a residential area, population and population density need to be specified. Similarly, floor area ratio and set back i.e. the distance from the road or distance from the plot also need to be specified. The screen on online platform looks like the one below:

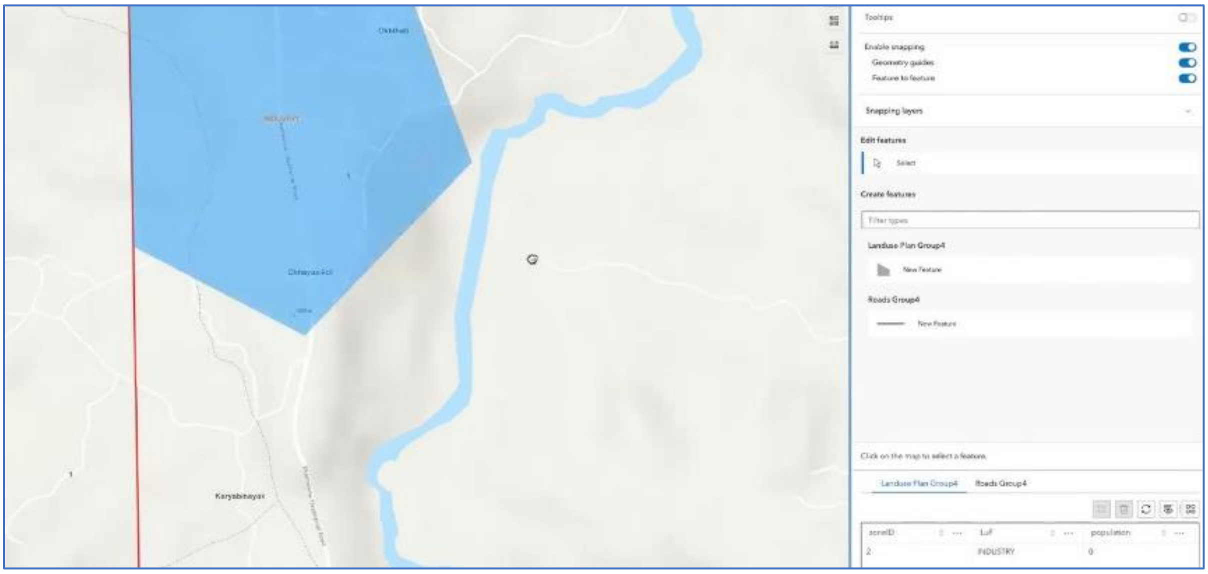
5.2.2 Assumptions and Unit

Some assumption should be provided to the participants. For instance, the floor area ratio as 3.5 and setback as 1 meter, and all the units in meter.

Average income should be identified. When everything is done, a create button should be clicked to create a land use zone. Now we have a residential Polygon. Similarly, all land use polygons can be created.

5.2.3 Drawing Road

To draw a road, an ID will be assigned to a road. Then the number of lanes needs to be assigned.



SESSION 6: DATA GENERATION

Authors of the chapter: Dr. Erdem Ozer, Dr. Prashant Rawal

6.1 Objectives

As a result of this session, we aim for the participant to be able to:

- Check data availability in compliance with TCDSE Data Guideline
- List out the currently available datasets
- Deal with data scarcity
- Access to open-data sources and make use of them
- List out the requirements for developing database for storing and accessing the data
- Produce a probabilistic distribution table to feed the data generation process
- Identify the general framework for programming languages that are relevant to TCDSE

6.2 Structure of Session 6

The structure of session 6 is as follows:

Structure
1. Data Generation in TCDSE
2. Types of data
3. Data types and collection methods
4. Data generation methods
5. Data generation methods in TCDSE
6. Tomorrowville case study

6.3 Data Generation in TCDSE

In this session, the data generation process in TCDSE is provided comprehensively. With this respect, Section 2 reviews data types and data collection methodologies. Section 3 thoroughly explains data generation methods and introduces handling scarce/missing data issues by focusing on synthetic data generation. Section 4 elaborates on the details of exposure data generation within TCDSE, and Section 5 details the case study of Tomorrowville. Finally, Section 6 gives a practical exercise regarding exposure data generation using TCDSE data generation tools.

It should be noted that the data generation and adoption must comply with the TCDSE Data Guideline [52] as a minimum requirement. The subject guideline gives details on what kind of data must be used and their associated attributes. The guideline depends on an integrated data structure adopted from the future exposure modelling study [11]. In addition to the four main datasets; Land-use, Building, Household and Individual given in [11], Transportation Network and Utilities themes are also detailed in the guideline as given in the figure.

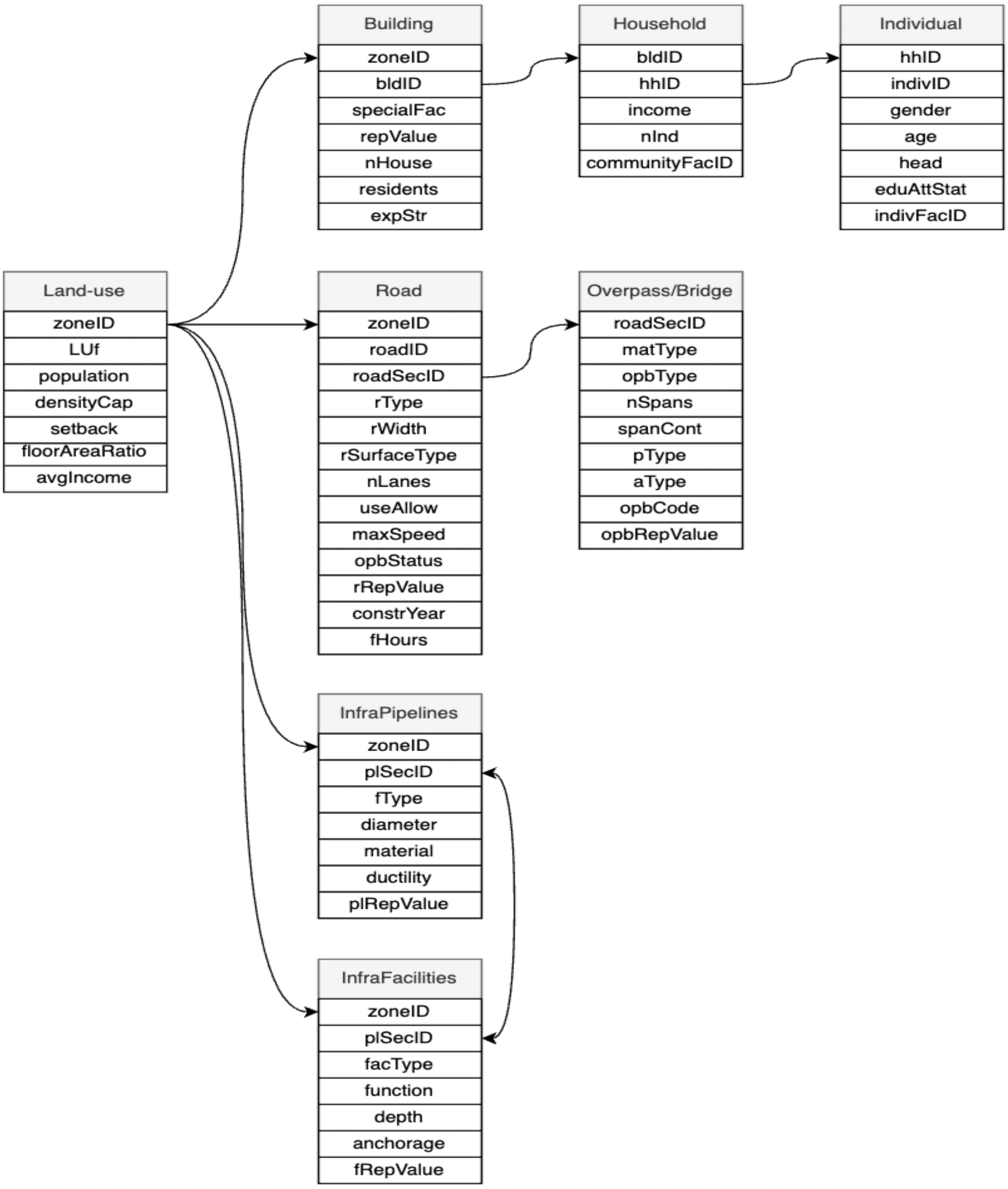


Figure 21: **Proposed exposure data structure and interrelation of components**

Please refer to the TCDSE Data Guideline for more thorough and explanatory information.

6.4 Types of Data:

There are various types of data that are used in TCDSE implementation. In this section, we highlight the ones that are mainly used in data generation and modelling. The types of data can be classified into three main categories:

a. Raster data
b. Vector data
c. Non-spatial data

6.4.1 Raster Data

Raster data is any pixelated (or gridded) data where each pixel is associated with a specific geographical location. The value of a pixel can be continuous (e.g. elevation) or categorical (e.g. land use). If this sounds familiar, it is because this data structure is very common: it's how we represent any digital image. A geospatial raster is only different from a digital photo in that it is accompanied by spatial information that connects the data to a particular location. This includes the raster's extent and cell size, the number of rows and columns, and its coordinate reference system.

i. Remote Sensing

A number of different, and equally correct, definitions of remote sensing are given below [53]:

- Remote sensing is the science of acquiring, processing and interpreting images that record the interaction between electromagnetic energy and matter.
- Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation.
- Remote sensing is the instrumentation, techniques and methods to observe the Earth's surface at a distance and to interpret the images or numerical values obtained in order to acquire meaningful information of particular objects on Earth.

Common to the three definitions is that data on characteristics of the Earth's surface are acquired by a device (sensor) that is not in contact with the objects being measured. The result is usually, though not necessarily, stored as image data (in this book, aerial photographs are also considered as 'image data'). The characteristics measured by a sensor are the electromagnetic energy reflected or emitted by the Earth's surface. This energy relates to some specific parts of the electromagnetic spectrum: usually visible light, but it may also be infrared light or radio waves.

- **Optical Remote Sensing**

Optical remote sensing makes use of visible, near infrared and short-wave infrared sensors to form images of the earth's surface by detecting the solar radiation reflected from targets on the ground. Different materials reflect and absorb differently at different wavelengths.

- **Microwave Remote Sensing**

Active microwave sensors provide their own source of microwave radiation to illuminate the target. Active microwave sensors are generally divided into two distinct categories: imaging and non-imaging. The most common form of imaging active microwave sensors is RADAR. RADAR is an acronym for Radio Detection and Ranging, which essentially characterises the function and operation of a radar sensor. The sensor transmits a microwave (radio) signal towards the target and detects the backscattered portion of the signal. The strength of the backscattered signal is measured to discriminate between different targets, and the time delay between the transmitted and reflected signals determines the distance (or range) to the target.

ii. Photogrammetry

The American Society has defined photogrammetry for Photogrammetry and Remote Sensing as the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena. As implied by its name, the science originally consisted of analysing photographs; however, the use of film cameras has dramatically diminished in favour of digital sensors. Photogrammetry has expanded to include analysis of other records, such as digital imagery, radiated acoustical energy patterns, laser ranging measurements, and magnetic phenomena.

- **Aerial Photogrammetry**

Aerial photography (or airborne imagery) is the taking of photographs from an aircraft or other airborne platforms [3]. When taking motion pictures, it is also known as aerial videography. Platforms for aerial photography mainly include fixed-wing aircraft, helicopters, and unmanned aerial vehicles (UAVs or drones). Secondary alternatives are balloons, blimps and dirigibles, rockets, pigeons, kites, or using action cameras while skydiving or wingsuiting. Handheld cameras may be manually operated by the photographer, while mounted cameras are usually remotely operated or triggered automatically.

- **Terrestrial Photogrammetry**

It deals with photographs taken with cameras located on the surface of the earth. The cameras may be handheld, mounted on tripods, or suspended from towers or other specially designed mounts.

6.4.2 Vector Data

Vector data structures represent specific features on the Earth's surface, and assign attributes to those features. Vectors are composed of discrete geometric locations (x, y values) known as vertices that define the shape of the spatial object. The organisation of the vertices determines the type of vector that we are working with: point, line or polygon.

i. Traditional Surveying

Performed using total station, theodolite, level, rod, measuring tape.

ii. Global Navigation Satellite System(GNSS)

Global Navigation Satellite System refers to a constellation of satellites providing signals from space that transmit positioning and timing data to GNSS receivers. The receivers then use this data to determine location [4]. By definition, GNSS provides global coverage. Examples of GNSS include Europe's Galileo, the USA's NAVSTAR Global Positioning System (GPS), Russia's Global'naya Navigatsionnaya Sputnikovaya Sistema and China's BeiDou Navigation Satellite System.

The performance of GNSS is assessed using four criteria:

Accuracy: the difference between a receiver's measured and real position, speed or time;

Integrity: a system's capacity to provide a threshold of confidence and, in the event of an anomaly in the positioning data, an alarm;

Continuity: a system's ability to function without interruption;

Availability: the percentage of time a signal fulfils the above accuracy, integrity and continuity criteria.

iii. Light Detection and Ranging (LiDAR)

LiDAR is a method for determining ranges (variable distance) by targeting an object or a surface with a laser and measuring the time for the reflected light to return to the receiver. It can also be used to make digital 3-D representations of areas on the Earth's surface and ocean bottom of the intertidal and near coastal zone by varying the wavelength of light. It has terrestrial, airborne, and mobile applications. LiDAR is an acronym of "Light Detection and Ranging" or "laser imaging, detection, and ranging". It is sometimes called 3-D laser scanning, a special combination of 3-D scanning and laser scanning. It is commonly used to make high-resolution maps, with applications in surveying, geodesy, geomatics, archaeology, geography, geology, geomorphology, seismology, forestry, atmospheric physics, laser guidance, airborne laser swath mapping, and laser altimetry. It is also used in control and navigation for some autonomous cars and for the helicopter Ingenuity on its record-setting flights over the terrain of Mars.

6.4.3 Non-spatial data

The main proportion of the non-spatial data in TCDSE is related with demographical information. The methods of demographic data collection are divided into four general categories: censuses, registration systems, surveys, and synthetically-produced data [5]. Censuses, registries, and surveys are the more traditional sources of demographic data, although synthetically produced statistics such as population estimates and projections have become standard tools for most planning, marketing and business development activities.

i. Census

A census involves a complete count of individuals (or entities) residing in a specific place at a specific time [5]–[7]. In order to assure a complete count of residents at the time of the census, the street address is used as the key locator.

ii. Registration Systems

A second method of data collection that generates information for demographers is represented by registration systems. A registration system involves the systematic compilation, recording, and reporting of a set of events, institutions, or individuals. The implied characteristics of a registry include the regular and timely recording of the phenomenon in question. Most registration systems relevant to this discussion are maintained by some branch of government, although other sponsors of registration systems exist as well. For demographers the best-known registration activities are those related to "vital events", such as births, deaths, marriages, and divorces.

iii. Surveys

A sample survey involves the administration of an interview form to a portion of a target population that has been systematically selected. The sample is designed so that the respondents are representative of the population being examined. This allows conclusions to be drawn for the total population based on the data collected from a sample. The use of sample surveys has several advantages relative to the census and registry methods. Two of the major advantages are more frequent data collection and the ability to probe more deeply into the subject under study. The relatively small sample sizes for such surveys have the additional advantages of quicker turnaround time and easier manipulation than large-scale operations such as the census.

iv. Synthetic Data

Synthetic data refers to statistics that are produced in the absence of actual data using models that simulate reality. Synthetic data are generated by merging existing demographic data with assumptions about population change to produce estimates, projections, and forecasts. These data are particularly valuable given that census and survey activities are constricted because of budgeting and time considerations. Further, there are situations in which no actual data are available for a particular population, geographic unit or time period. Consequently, there is a large and growing demand for information between years when data are actually collected. This demand is being met by government agencies and commercial data vendors, with private data vendors generally providing more detail and data for smaller geographic units than government agencies. Demographers have long used population estimates and projections in the absence of actual data, and a variety of techniques are utilised to generate estimates and projections.

6.5 Data generation methods

6.5.1 Overview

Data generation refers to the process of accumulating existing geospatial and demographic data, as well as making future projections for urban planning based on the existing data. Thus, we have two datasets, one containing present information, and the other containing different scenarios of projected futures.

The process of data generation for any future planning will always happen under data scarcity because it involves the task of projecting future trends based on present circumstances and trends. At best, we may have a comprehensive set of census data for the present. Even this may not be available in some places, and we may need to fill in a lot of gaps using suitable assumptions. In case we have all the desired present data, future trends are still impossible to accurately project, and this situation is what is referred to as 'data scarcity' in this context. Therefore, any method of future projection will involve making reasonable assumptions based on a thorough understanding of current socio-cultural and economic factors. If the assumptions turn out to be invalid, all the planning effort based on it will be wasted. This is the reason why data production remains one of the most challenging and important aspects of urban planning.

We must also be clear regarding the nature of any future projection. They may either be an extrapolation of existing trends, or an envisioning of a different future altogether. Various future events, which are impossible to predict, may nullify the current trends and the extrapolation could turn out to be unrealistic.

6.5.2 Generating non-existent data

Non-existent data is used as a term to address the data scarcity of "today" and the unknown context of the "future". In most cases, collecting non-existent data for urban planning requires a significant amount of time due to data scarcity and/or lack of future projections. Removing the data gap is critical as such information is a fundamental component in deciding the future urban context. Data scarcity is particularly evident in social sciences as the social domain is related to individuals, households, communities, and their implicit interaction in between. Therefore, understanding the socio-demographic context comprises significant uncertainties. Forecasting future socio-demographic context is even more complicated.

There are several approaches and methods that address the non-existent data problem. These techniques are useful to generate synthetic information that is utilised to comprehend today's situation and explore potential future urban conditions.

Data scarcity can be addressed by the following means:

a. Social surveys and extrapolating their results for understanding today's conditions

A commonly used approach to creating synthetic data for these models combines aggregate summaries—for example, from the census, with sample individual-level data that is collected from surveys [8]. Census data would normally provide information like household composition, income, and number of children. The aggregate data would normally cover the whole population of interest but may not have all the needed variables and not to the level of granularity that is desired. The survey data will cover a sample of the population but have very detailed and extensive variables.

b. Demographic Projection Methods

The general methodologies for producing population projections fall into four general categories [54]:

- Ratio Allocation Methods;
- Mathematical Extrapolation Methods;
- Econometric Methods; and
- Cohort-Component Methods.

Ratio Allocation Methods are used to allocate an existing population projection for a state or region among the subareas that comprise the larger area. Mathematical Extrapolation Methods involve the application of a selected growth rate into the future. Econometric Methods project population as part of an overall forecast of the economy in an area and usually generate a population projection by linking future population levels to expected future employment. Cohort Component Methods project population by examining separately for each cohort (or age group) the three major components of population change: births, deaths, and net migration. Cohort component methods generally result in projections with the highest level of detail by age, race, and sex of any projection method.

As mentioned above, population change involves three separate components: births, deaths, and migration. Component models consider the separate effects of each of these factors and require more comprehensive and detailed data than usually are available to local planners. Models that use the net effects of the three components are called non-component models. Most models that project population below the state scale are usually of the non-component variety because of data limitations (and demographic skills). Non-component models may be based on past patterns of net population growth, or they may relate net growth to some indicator information, such as changes in housing or the economic base of the community. Symptomatic data often are useful in these models because there is a correlation between population size and various other events, such as tax returns, voter registration, school enrolments, telephone installations, utility meter connections, occupancy permits issued, and motor vehicle licenses. Non-component models lack detailed age-sex breakdowns which are useful in planning for schools, community services, and different housing types. Overall, it is desirable, although not always possible, to consider the three components of population change separately and combine, not average, their effects. This is particularly true for mid- and long-range projection periods because the forces driving births, deaths, and migration may not be correlated. The comparison of non-component and component population estimation & projection methods is given in Table below.

Table 9: Comparison of population estimation & projection methods [54]

Type of Model	Estimation or Projection	Historic Counts	Vital Statistics	Other Indices	Period	Scale	Complexity
NON-COMPONENT							
Trend Extrapolation	Both	X		X	Short	Local	Moderate
Comparative Forecast	Projection	X			Short	Local	Simple
Ratio Trend	Both	X			Short-Middle Long	Local-State	Simple
Density Ceiling	Projection	X			Middle-Long	Local	Complex

Ratio Correlation	Estimation	X		X	Short	Local	Complex
Housing Unit	Both	X		X	Short-Middle	Local	Complex
Market Force	Projection	X	X	X	Short-Middle Long	Local-State National	Complex
Greenberg-Kruckeberg-Mautner (GKM)	Projection	X	X	X	Short-Middle Long	Local-State	Complex
COMPONENT							
Residual	Estimation		X		Short	Local-State National	Simple
Vital Rates	Both		X		Short	Local-State	Moderate
Cohort-Survival	Both		X		Short-Middle Long	Local-State National	Complex
Cohort-Component	Both		X		Short-Middle Long	Local-State National	Complex
Composite	Both	X	X	X	Short-Middle Long	Local-State	Complex

c. Non-component models

Trend Extrapolation: Nearly all projection methods, to some extent, extrapolate past or present trends into the future. A trend extrapolation model refers specifically to a simplistic model that uses the historical growth pattern to project the future growth pattern. Such a model deals with the net effects of births, deaths, and migration rather than with the individual components. After graphing past population growth (either the actual numbers or the rates of growth), one fits a curve to that growth and extends it into the future. Past growth may show a linear, exponential, or logistic curve over the historic period. Linear and nonlinear regression formulas also can be used. The prime disadvantage of trend extrapolation methods is the lack of component detail. The future growth rates also become dependent upon the depth of the historical period analysed. If the past twenty-five years are examined, for example, the projections may be influenced by a rapid period of growth in the 1950's, but if only the past ten years are used in the analysis, projections may be considerably different.

Comparative Forecasting: A locality's past growth pattern can be examined in conjunction with growth patterns of older, larger, civil divisions. The assumption behind this method is that the locality's growth pattern will match that of communities more advanced in their stage of growth. Comparative forecasting is useful for short-term projections but is not used as an estimating method. There may be no reason to assume that factors currently affecting the components of population will produce patterns of net growth exhibited by the older minor civil divisions.

Ratio Trend or Step-Down Techniques assume that the relationship of a locality to some larger geographic entity--county or state--will prevail in the future. For example, if the city accounted for 25 percent of the county's population in 1980, it is assumed that it will account for 25 percent of the county's projected population in 1990 and 2000. Or, if the city's share of the county's population has been growing over the years, its share will continue to increase according to the same pattern in the future. This method assumes that population projections at the larger scale represent degrees of reliability and component detail that are not possible to achieve at the small scale of analysis. As with the two previous techniques, this method is flawed in that historic trends may not hold in the future, and the length of the historical period used for determining the ratios will influence future growth rates. Sometimes there is no simple historic relationship between, for example, a city and its surrounding county or region.

Density Ceiling models employ capacity constraints. Such a model assumes that when a given density is reached, population will either stabilize or decline. The density model may utilize linear, exponential, or logistic curves to express population density growth rates. Maximum population levels are typically determined via zoning and land use development patterns that affect population density. The advantages of density ceiling models are that they provide practical means of con- straining the levels of population projection, and they provide empirical detail regarding probable distribution and concentrations of population. They also provide a basis for experimentation with zoning changes. The obvious disadvantage of the density model is the accurate selection of maximum densities. These methods are subject to the same flaws as methods that extrapolate net population growth.

The Ratio Correlation Method is an estimating technique rather than a projection technique. It is similar to the ratio trend method except that population is treated as a function of some other variables - employment, housing units, motor vehicles registered, or other symptomatic data. Multiple regression may be used to determine the population's historic relationship to the independent variables. Current shares or logarithms of past shares may also express the relationship among the variables. The advantage of this method is that it uses indicators of actual population to determine growth rates. It also can provide good detail on spatial or occupational distribution of the population.

Housing Unit Method can be used for both projection and estimation purposes. It establishes a relationship between the number of dwelling units and population via a family-size multiplier. Dwelling units can be estimated by utility or telephone connections, building permit data, land use surveys, vacancy rates, construction data, home interviews, and other local records. Net changes in dwelling units are presumed to indicate net changes in population.

Market Force Methods include the following techniques: holding capacity, deterministic regression models, multiplier studies, and mathematical programming. Market force methods are generally more complex causal models. Linear regression may be used to formulate equations that will relate population distribution to such factors as vacant land, the presence of minority group populations, accessibility to work, land values, and other important variables. Employment forecasts made by shift and share, economic base, and input-output techniques may be converted by the use of multipliers to population forecasts. Finally, the future distribution of population may be treated by a procedure to improve conditions in which an objective such as minimizing travel time to work is sought, subject to equations representing constraints on supply and demand for developable land, availability of services, and other factors. These models are more applicable at the state and regional scales than at the scale of local government because more information about causal relationships is available.

The Greenberg-Kruckeberg-Mautner model seeks information at different scales of analysis; it combines historical extrapolation, ratio trend, and density ceiling alternatives at the local scale and constrains these with federal-state-county population projections developed by component and market force techniques. The model gives the user the option of five separate sub-models to project local population. It is quite useful when state projections are to be distributed to various minor civil divisions within its boundaries.

d. Component models

The Residual Method is used for estimation. It starts with a known population, usually based on the last census. Records of births and deaths are examined, and the population adjusted accordingly to produce an estimate of current population. The difference between this anticipated population and the actual population is assumed to be the result of net migration. This method is relatively simple and does not call for age-sex breakdowns of the population.

The Vital Rates method is a ratio technique that relates total population to births and deaths. Ratios are developed between state and local births and deaths from the historical record. Birth and death rates for the local unit are obtained for the estimated period by substituting the known state rates into the ratio and solving for the local rates. The rates are used to develop estimated populations based on births and deaths, Then the estimates based on the ratio are averaged to reduce errors involved in each of the projections. This is both an estimating and a projection technique. It assumes that a change in the rate of vital statistics signals a change in population size. The assumption that the relationship between the vital statistics and population remains constant and the difficulty of developing accurate ratios between population and births and deaths are drawbacks of this method. Another drawback is that rapid migration, which affects the age structure, will impact the vital statistics, and produce inaccurate estimates.

Cohort-Survival Models are the most basic method for providing age-sex detail. While it is a component model, it does not account for the migration component. The cohort-survival model projects future population based on growth due to natural increase. Population is disaggregated into male and female age cohorts. Each cohort spans five years. Age-specific death rates (or survival rates) are developed and applied to each cohort. Age-specific fertility rates are applied to female cohorts between the ages of 15 and 44. Each cohort group is then "aged forward" towards the final projection year, with mortality and fertility rates applied to the survivors at five-year intervals. Births are added to the bottom of the pyramid and aged forward accordingly. The advantage of this technique is the excellent detail provided in projecting future demand for age-specific needs, such as schools, jobs, or services for the elderly. It is a fairly accurate forecasting technique when migration is either known or negligible. Various methods of estimating and projecting migration can be added to the basic model; the result is known as a cohort-component method.

Various Cohort-Component Methods have been developed by the Bureau of the Census. Method uses school enrolment data to estimate the migration component - net migration is assumed to be the difference between the growth rate of school-age cohorts at the national level and the growth rate of school-age population at the scale of analysis method. It assumes that the migration component is the difference between the anticipated school-age population, based on natural increase, and the actual population of school age. A variation of Method II is the grade progression method that breaks down school enrolment by grades. Cohort component models are effective in creating alternative projection sets because of the simplicity of varying assumptions. For example, one may use high fertility with low migration, or vice versa. The shortcoming of these census methods is the tendency to underestimate young married couples, elderly, and single migrants. Other migration estimates can be made by extrapolating migration trends from past decades (e.g., by using a residual method), or by a ratio-correlation method that relates migration to symptomatic data, such as dwelling units.

The Composite Model applies different techniques to different segments of the total population. Like the component method, it uses age-specific information on births and deaths. Instead of analysing the three components of change, however, the composite method projects population for different age groups using different methods and then sums them for a total population figure. It takes advantage of the fact that different methods are better focused for estimating population of different groups.

The choice of a projection methodology is best made by considering its relative accuracy, the type of data available, the quality of available data, the scale of the analysis, the geographic level of the projection, the length of the projection period, the purpose of the projections, and the budget and time frame implications of the projection study. The simpler methods have a wider range of application and may be used to produce population projections at almost any geographic level. Econometric and Cohort-Component models have more extensive data demands and may be less appropriate for smaller geographic areas.

Some examples of mentioned methods are given below:

Example 1: Male population projection between 2009 to 2014 using Cohort-Component Method (CCM).

As already mentioned, the CCM makes use of all three population component processes (fertility, mortality, and migration) and applies them across varying population cohorts to arrive at a future population. Equation 1 outlines the basic structure of the CCM [55]:

$$P_{t+n} = P_t + B_t - D_t + I_t - E_t \tag{1}$$

where P_t is the population at time t, B_t and D_t are the numbers of births and deaths occurring between t and $t+n$, I_t and E_t are the numbers of immigrants to and emigrants from the country during the period t to $t+n$.

Table 10: Population projection using CCM

Age in 2009	Male Population	Annual mortality rates	Annual net migration rates	Deaths 2009-2014	Surviving population to 2014	Net migration 2009-2014	Projected male population	Age in 2014
	Mx 2009	ammx	anmmx	Dmx 2009-14	Sm2014 x+z	NMM2014 x+z	M2014 x+z	
0–4	27137	0.0001	0.044	18	27119	5970	33089	5–9
5–9	31877	0.0001	0.013	15	31862	2072	33934	10–14
10–14	33250	0.0001	0.001	15	33235	166	33401	15–19
15–19	27651	0.0004	0.015	52	27599	2074	29672	20–24
20–24	20596	0.0003	0.03	35	20561	3089	23650	25–29
25–29	28587	0.0006	0.026	83	28504	3716	32220	30–34
30–34	34474	0.0007	0.042	114	34360	7240	41600	35–39
35–39	48248	0.0006	0.024	150	48098	5790	53888	40–44
40–44	43705	0.0015	0.002	318	43387	437	43825	45–49
45–49	35218	0.0022	0.004	381	34837	704	35542	50–54
50–54	24822	0.004	0.016	492	24330	1986	26316	55–59
55–59	16581	0.0046	0.021	382	16199	1741	17940	60–64
60–64	14754	0.0096	0.02	710	14044	1475	15519	65–69
65–69	13221	0.0144	0.013	950	12271	859	13130	70–74
70–74	9318	0.0259	0.008	1206	8112	373	8485	75–79
75–79	4778	0.0424	0.009	1013	3765	215	3980	80–84
Above 80	3331	0.0885	0.013	1475	1856	217	2073	Above 85
Total	417548	—	—	7409	410139	38124	448264	—

Example 2: Regression analysis between population and built-up area for Yongin using Logistic Regression Method among Mathematical Extrapolation Methods [56].

B_Y = Built-up area = $0.0263PN^{0.5997}$

PN = Projected population

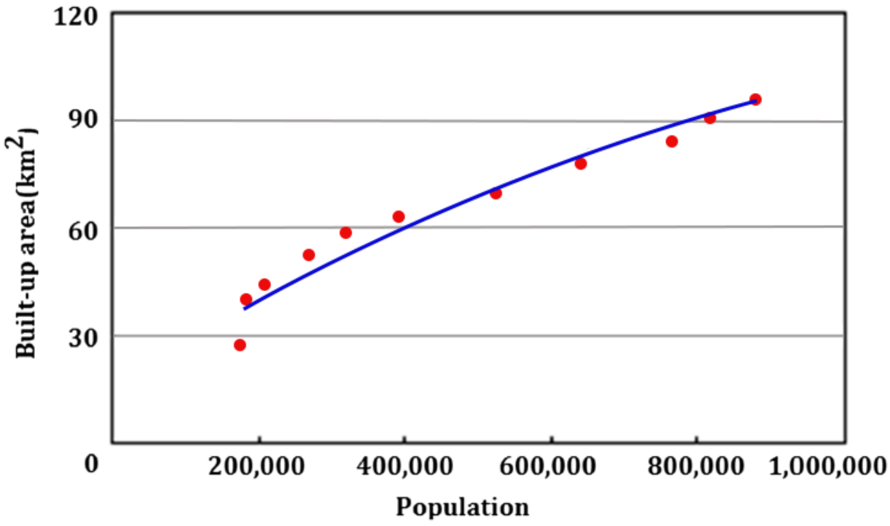


Figure 22: **Built-up area projection using CCM**

Example 3: Built-up area change estimation for Yongin by projecting the population using CCM, quantifying the demand for urban land use based on a regression model between population and urban land use and optimising the weighting values for six land-use types using the weighted scenario method (WSM), cellular automata model, and GIS in order to make a grid-based optimal potential suitability map for urban growth [56].

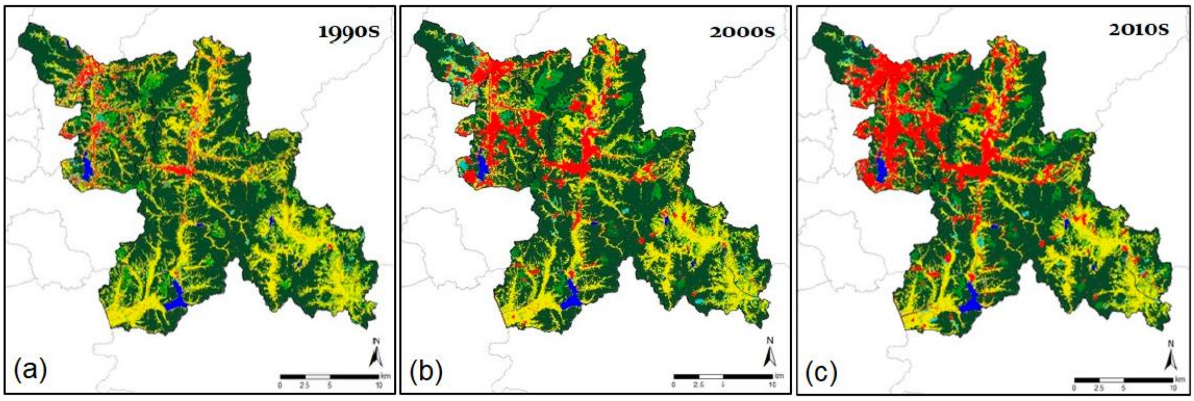


Figure 23: **Built-up areas**

in red color of Yongin for (a) 1990s (b) 2000s (c) 2010s modified from [57]

e. Social Data Disaggregation

- **Iterative Proportional Fitting (IPF)**

IPF is used to construct a sample that is consistent with known statistics of a target population. The method requires information about marginal distributions of individual attributes as well as a frequency cross-table of all attributes involved that defines their correlations. An iterative reweighting procedure is employed to fit the multi-dimensional cross-table conditional on the marginal distributions. The generated sample exactly matches the target marginal distributions of attributes and preserves the provided correlation structure.

- **Iterative Proportional Updating (IPU)**

IPU is a hierarchical version of IPF, in which the multi-dimensional tables are fit using single joint weights that simultaneously account for individuals and households.

- **Monte Carlo Simulation Methods (MCS)**

MCS covers a variety of simulation-based techniques, including Markov Chain Monte Carlo simulation. These approaches draw synthetic samples of individuals from conditional distributions of individual attributes, which form a partial view of the true population structure. The empirical distribution of the simulated population is as close as possible to the unique joint distributions in the actual population.

- **Combinatorial Optimisation (CO)**

CO covers a variety of approaches, including simulated annealing. The procedure starts with a random subset of households/individuals from the provided micro sample. The selected households/individuals are iteratively replaced to improve their fit to the target marginal distributions; if a change improves the fit, then the swap is accepted. The performance of the fit is continuously assessed, and the algorithm terminates when the most accurate synthetic population is obtained.

- **Hierarchical Models (HM)**

These methods can cover any of those mentioned in previous tables (i.e., IPF, CO, and MCS) and their adaptation to account for both individual and household attributes, associating these interdependent attributes in the most optimal way possible. HM also covers Bayesian Updating approaches, which use directed acyclical graphs to describe the conditional distribution of random variables and respect the hierarchical structure of households and individuals. Furthermore, HM covers Hierarchical Mixture Modeling. Little attention has been paid to reproduce cross-level and within-household associations.

f. Statistical Imputation

- **Mean Imputation**

It is one such method in which the mean of the observed values for each variable is computed and the missing values for that variable are imputed by this mean. This method can lead into severely biased estimates even if data are missing completely at random[58].

- **Imputation from Another Variable**

Suppose some of the recorded variables are closely related, so that their values for a subject tend to be similar. If one value is missing, the value of another variable may be used instead. A transformed variable, or a variable constructed from several variables, may be used instead of an originally recorded variable. A familiar example of this scheme is Last Observation Carried Forward in longitudinal surveys [59].

- **Nearest Neighbour Imputation**

In nearest-neighbour imputation, the incomplete record of a subject (called recipient) is completed by the values of the same variables of another subject (donor) whose record is complete. A drawback of this scheme is that the quality of the imputation is uneven. Some recipients have many close neighbours, while others are in relative isolation. Conversely, some donors may be very popular — their values are used for many recipients, whereas other subjects, even some with complete records, would not be donors for any recipients [59].

- **Hot Deck**

Hot-deck imputation is closely related to nearest-neighbour schemes. In hot deck, a pool of donors is defined for each recipient, and a donor is drawn from the pool at random. The pool is defined so that it contains the subjects who are similar to the recipient and have recorded values for the variables. The imputation can be organised so that the recipients are also grouped, into sets that share the same pool of donors [59].

- **Weight Adjustment**

Records in a survey dataset are usually associated with sampling weights. The sampling weight for a member of the population is defined as the reciprocal of the probability that the member would have been included in the survey, as per plan, that is, in the complete dataset. The weights for the subjects (selected members) are factors in many common estimators of population quantities. Weight adjustment is a device for reflecting the survey nonresponse in such estimators. It is motivated by the desire to maintain the good properties of the complete-data estimators without having to alter them substantially. The only change that takes place is in the sampling weights. The changes made can be related to estimation of the probabilities of selection in the realised design. For example, if a greater fraction of men than women fail to respond the weights associated with men are increased so that the fewer men in the subsample of respondents would represent well the men that were intended to be in the sample [59].

- **Regression Imputation**

Suppose variable Y is recorded with some values missing and variable Z is recorded completely. If Y and Z are associated, their similarity may be exploited by estimating (predicting) the missing values of Y.

- **Expert Judgement**

In surveys that collect a lot of information, in a variety of formats, formal rules for imputation are difficult to set. However, an expert knowledgeable about the population and the subject matter of the survey could propose a set of realistic values for the missing items after carefully studying the available part of the subject's record. Experts' guesses may be much more credible for imputation than using a simple or model-based imputation scheme. On the other hand, using experts is much costlier and time consuming, especially when only a few suitably trained and instructed experts are available. In brief, experts will make the database look more normal than it should be. This deficiency is shared with regression imputation [59].

g. Artificial Intelligence (AI) based Methods

In the present context, AI based methods can be used for tasks involving computer vision (e.g., land use classification, building type and height identification) and statistical imputation.

While being very useful tools, AI based methods (machine learning, artificial neural networks) are not immune to errors, because limited availability of data for any given location will make it difficult to train the algorithm and using data from other regions might result in unrealistic outcomes. Therefore, human judgement based on a thorough understanding of the particular location is more likely to yield realistic projection in comparison to a black box approach.

If machine learning techniques are being used, the data situations can be grouped into five categories and possible solutions for data scarcity for machine learning are summarised as follows [60]:

- No Data
  - Open Source Datasets
  - Online/Incremental/Stream Learning
  - Federated Learning
  - Secure & Private Learning
  - Strategic Methods
- Small Data
  - Data Augmentation
  - Transfer Learning
  - Problem Reduction
  - Modelling Techniques
  - Synthetic Data
- Rare Data
  - Few-shot Learning
- Costly Data
  - Self-Supervised Learning
  - Semi-Supervised Learning
  - Active Learning
  - Weak Supervision/Bootstrapping
- Imbalanced Data
  - Sampling & Weighting

6.6 Procedural Modelling for Transportation Road and Utilities

Procedural modelling is widely used in generating street and infrastructure datasets. An interactive tool that allows untrained users to design roads with complex, realistic details and styles is proposed in [16]. Roads are generated by growing a geometric graph. During the sketching phase, the user specifies the target area and examples. During the growing phase, two types of growth are effectively applied to generate roads in the target area; example-based growth uses patches extracted from the source example to generate roads that preserve some interesting structures in the example road networks; procedural-based growth uses the statistical information of the source example while effectively adapting the roads to the underlying terrain and the already generated roads. User-specified warping, blending, and interpolation operations are used at will to produce new road network designs inspired by the examples. Finally, the proposed method computes city blocks, individual parcels, and plausible building and tree geometries. The approach is tested to create road networks covering up to 200 km2 and containing over 3,500 km of roads.

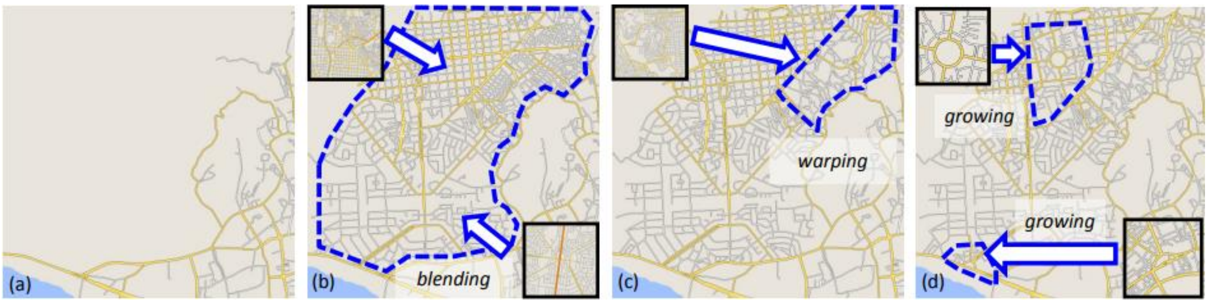


Figure 24: **Modelling**

a) Starting with a virtual city b) Selecting target space c) Replacing roads by a selected example of curved roads d) Inserting other road network configurations [61].

6.7 Data generation processes in TCDSE

Data generation in TCDSE starts with translating the visions produced in "Future Visioning" to land-use plans. These plans (as explained in Session-3) and specifically tailored future projection tables are used to populate future exposure data.

As already mentioned, the adopted exposure data structure depends on the framework proposed [11]. In order to develop exposure data based on this structure, a set of equations and assumptions has to be considered. The related steps are given in figure below.

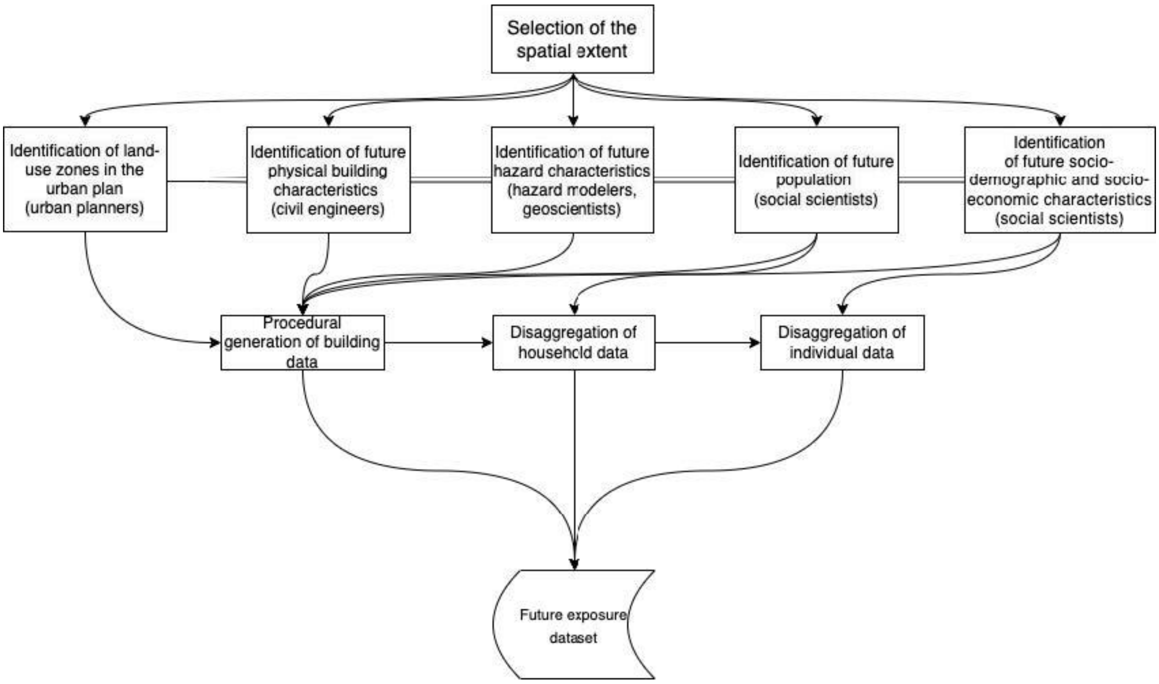


Figure 25: **Development of exposure data based on the proposed data structure [11]**

Please refer to the subject paper for the details of mentioned equations and assumptions.

Considering the above information, the exposure data generation process within TCDSE can be summarised as follows:

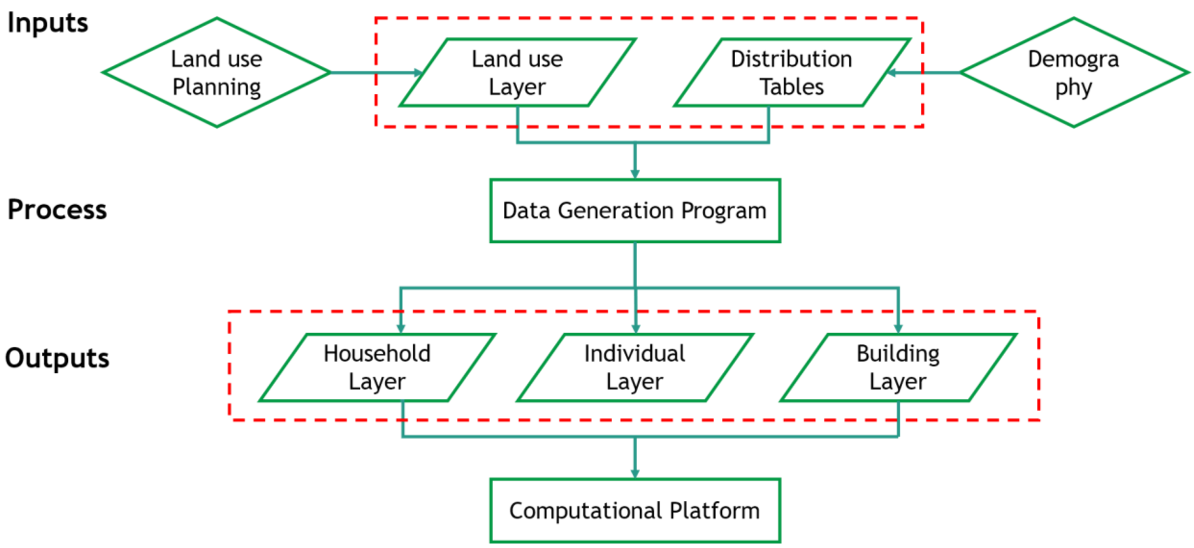


Figure 26: **TCDSE exposure data generation overview**

In summary, exposure data generation is needed to simulate future data and refers to the process of generating detailed attributes for individuals, households and buildings based on land use data and probability distributions within the context of TCDSE.

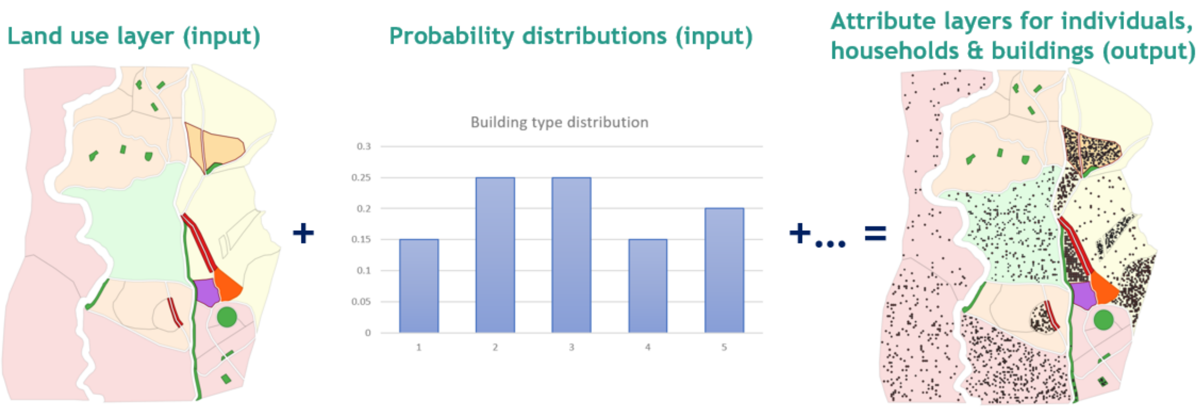


Figure 27: **TCDSE exposure data generation I/O schema**

6.7.1 Land-use Layer

Land-use zoning can be regarded as the main task of urban planning, in which stakeholders (e.g., governments, municipalities, communities, re-searchers, private sector) decide the future functionality of a given space for a certain period. A land-use layer typically includes attributes on the type of use and the associated maximum population densities, floor area ratio and/or setback distances of the given space.

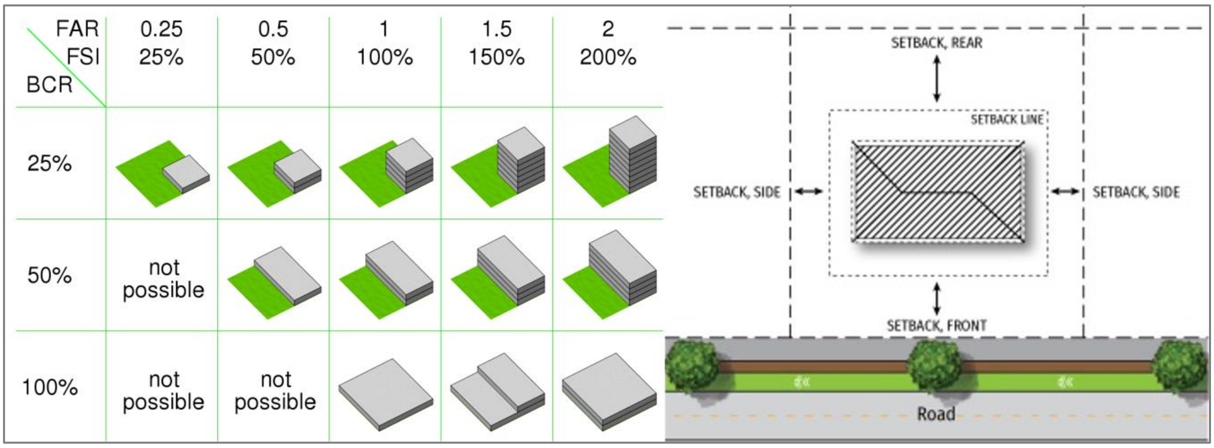


Figure 28: Visualisations for optional features: floorAreaR (left) & setback (right)

These attributes determine how and by how many people urban space can be in-habited in the future. The land-use plan layer of our proposed data structure broadly follows this convention, incorporating some supplementary attributes related to socio-economic status (SES) and demographic characteristics. SES-related attributes can be defined based on the acknowledged SES literature that suggests income, education, and occupation as the main components defining SES. Among these three attributes, there are income level as a proxy to represent SES within the boundaries of a land-use type, because income-based segregation within residential areas is quite common. The proposed land-use attributes and their definitions are given in Table below.

Table 11: The attribute table of the land-use layer.

Field	Alias	Definition	Type
zoneID	Zone ID	Unique land use-zone identifier number	Integer
LUf	Proposed land use type	Proposed land-use type in the case of defined densities are met	String
population	Population at t0	Number of people inhabited within the zone by the time (t0) of the generation of the land use plan	Integer
densityCap	Maximum density capacity	Maximum number of persons per hectare in the zone (density capacity of the zone)	Float
floorAreaRatio	Floor Area Ratio	The ratio of building plot over building's parcel area (land plot)	Float
setback	Setback distances	The minimum distance of the building footprint boundaries from the outer land parcel boundaries or a road.	Float
avgIncome	Average income level	Average income level within the land use zone in case residential occupation exists. This is an average value of average income levels of the households within the zone.	String
Example land-use plan table			

zoneID	LuF	population	densityCap	floorAreaR	avgIncome	setback
39	RESIDENTIAL (HIGH DENSITY)	2966	350	0	lowIncomeB	0
38	RESIDENTIAL (HIGH DENSITY)	1076	250	0	lowIncomeA	0
33	INDUSTRY	0	0	0		0
31	RESIDENTIAL (LOW DENSITY)	1391	100	0	highIncome	0
27	RESIDENTIAL (GATED NEIGHBORHOOD)	1297	100	0	highIncome	0
28	RESIDENTIAL (MODERATE DENSITY)	738	200	0	highIncome	0
29	RESIDENTIAL (MODERATE DENSITY)	1290	200	0	highIncome	0
44	NEW PLANNING	0	250	0	midIncome	0
43	RESIDENTIAL (MODERATE DENSITY)	1152	200	0	midIncome	0
41	RESIDENTIAL (MODERATE DENSITY)	9161	200	0	midIncome	0
42	RESIDENTIAL (MODERATE DENSITY)	1453	250	0	midIncome	0
30	RESIDENTIAL (LOW DENSITY)	1110	100	0	highIncome	0

6.7.2 Building Layer

The proposed building layer includes a list of the minimum attributes required for quantifying related future impact metrics. Each building is signed a unique building ID linked to the land-use layer through the zoneID field, which contains the ID of the land-use zone (polygon) hosting the building. The attribute "specialFac" identifies the special facility status of the building; it is an integer equal to zero for "standard" occupancy types (i.e. residential, commercial, industrial) and greater than zero for special occu- pancy types (e.g., 1 for schools, 2 for hospitals). The "repValue" attribute indicates the economic cost of replacing the building in case of complete re- construction. For buildings with residential occupations, the "nHouse" and "population" attributes respectively indicate the number of households and residents within the building. These two attributes are equal to zero for non-residential buildings. (The number of people occupying non-residential buildings at a given time of day can be estimated using the "indivFacID" attribute in the Individual layer, which indicates a building that a given individual regularly visits, such as a workplace or a school). Physical attributes of each building related to the physical impacts of natural hazards are condensed in the exposure taxonomy string attribute "expStr". An example for the exposure taxonomy string is given below:

Format: Structural_system_type + Code_compliance + Number_of_storeys + Building usage

Rci+MC+3s+Res

Structural_system_type: BrCfl (brick and cement with flexible floor), BrCri (brick and cement with rigid floor), RCi (Reinforced Concrete) etc.

Code_compliance: Low, medium and High compliance (LC, MC, HC).

Number_of_storeys: 1s, 2s, 3s etc.

Building usage: Residential (Res), Commercial (Com), Industrial (Ind), Mixed Residential+Commercial (ResCom).

The attribute table of the building layer is provided in below.

The attribute table of the building layer.

Field	Alias	Definition	Type
zoneID	Parent polygon ID	Unique ID number of the land use zone where the building is located	Integer
bldID	Building ID	Unique ID number for each building	Integer

specialFac	Special Facility Status	A unique number corresponding to the type of building whether it is a "special facility" or not.	Integer
repValue	Replacement value	Total replacement value of the building	Float
nHouse	Number of Households	Number of households in the building	Integer
residents	Residents	Number of residents in the building (only for buildings that include residential occupancy)	Integer
expStr	Exposure taxonomy string	Taxonomy string based on GED4ALL	String

6.7.3 Household Layer

This layer represents the social connections of individuals who are members of the same households and can be leveraged to capture their collective experience of a natural-hazard-related disaster. This layer is interconnected with the underlying residential building information through the bldID attribute. This field also makes it possible to determine which land-use zone the household is living in and what type of socio-economic status is dominant in the area. Indicating a household's income level (field: income) enables impact metrics to be disaggregated based on the socio-economic characteristics of affected people. This is essential for highlighting disproportionate impacts of natural-hazard events that are often experienced by the poorest households; low-income households are generally exposed to and affected by hazards more than wealthier ones, since they lose a more significant portion of their income and assets in case of a disaster and have fewer resources to recover after a disastrous event. The layer includes information on the closest critical facilities to the household (field: communityFacID) - which could include medical facilities, schools, or grocery stores, for instance - to help determine consequences that arise from a lack of accessibility to these services after a disaster. The attribute table of the household layer is provided in Table below .

The attribute table of the household layer.

Field	Alias	Definition	Type
bldID	Parent building ID	ID number of the residential building in which the household lives (i.e., the appropriate value associated with the "ID" attribute in the building layer)	Integer
hhID	Household ID	Unique household identification number	Integer
income	Household income	Indicates the level of income of the household (can be classified specific to context)	Integer
nIND	Number of individuals	Number of individuals living in the household	Integer
CommunityFac ID	Community facility ID	ID numbers of the closest building (such as a hospital, grocery store or a fire station) to the location of the household's residence (i.e., the value associated with the "ID" attribute in the building layer)	Vector

6.7.4 Individual Layer

Documenting the characteristics of future individual members of an urban system is critical for quantifying people-centred disaster-risk impacts, such as unemployment, displacement, and inaccessibility to education. The attribute table of the individual layer includes information on gender (field: gender), age (field: age), educational attainment (field: edu- AttStat), and head-of-household status (field:head), which are widely used indicators of social vulnerability that can be leveraged to distinguish a person's general reliance on the built environment. For instance, a child may depend on a school, a working adult of high educational attainment may work in an office, and a woman of low educational attainment who is not the head of the household may spend a significant amount of time at their residence. These dependencies – which are documented in terms of individual buildings within the attribute table (field: indivFacID) - can then be used to characterise the consequent disruption to daily lives that would result from disaster-induced damage to the built environment. Note that these individual facilities are different from the buildings provided for field: communityFacID in the household layer; meaning that these buildings are specifically relevant for a given individual and do not necessarily serve the same household members. The attribute table of the individual layer is provided in table below.

Table 12: The attribute table of the individual layer.

Field	Alias	Definition	Type
hhID	household ID	ID number of the household to which the individual belongs (i.e., the appropriate value associated with the "HH_ID" attribute in the household layer)	Integer
indivID	Person ID	Unique identification number for the individual (which should be the same number as the INDIV_ID entry in the corresponding household of the household layer)	Integer
Gender	Gender	Indicates the gender of each individual within the household	Integer
Age	Age	Aggregated age groups. Indicates the age range of the individual. Each number corresponds to a specified age range provided by the user, e.g., 1=0-10 years old, 2=10-20 years old, etc. Note that these numbers and the age range they represent can change depending on data availability.	Integer
parent	Parent	Indicates whether this individual has a parent role in the household. Binary values (0 and 1) are preferrable as values.	Integer
eduAttStat	Education Attainment status	Indicates the education attainment level of adults. Each number corresponds to a specified education attainment level provided by the user, e.g., 0=no primary education, 1=primary education only, 2=secondary education only. Note that these numbers and the educational attainment level they represent can change depending on data availability	Integer
healthStat	Health status	Indicates the health status of an individual to provide information on disability, need to specific medication or medical service such as dialysis	
indivFacID	Individual Facility ID	bld_ID of the of the building that individual regularly visits (can be workplace, school etc.)	Vector

6.7.5 Transportation Network Layer

The attribute tables of the transportation network layer are provided in the tables below:

Table 13: The attribute table of transportation network layer - road.

Field	Alias	Definition	Type
zoneID	Parent polygon ID	Unique ID number of the land use zone where the road section is located[1]	Integer
roadID	Road ID	Unique ID number of the entire road (consisting of many segments)	Integer
roadSecID	Road Section ID	Unique ID number for the section of the road	Integer
rType	Road type	Type of the road network (i.e. pedestrian, artery, streetway, highway, railway)	String
rWidth	Road Width	Width of the road (in meters)	Integer
rSurfaceType	Road surface type	Surface cladding of the road	String
nLanes	Number of lanes	Number of lanes that serve for traffic	Integer
useAllow	Use allowance	Allowance of the road to specific transportation modes (i.e. automobile, bus, truck, pedestrian, motorcycle, bicycle)	Vector
maxSpeed	Maximum speed	Maximum speed that is allowed	Integer
opbStatus	Overpass status	The status that identifies if the segment is an overpass or bridge (0=no, 1=overpass, 2=bridge)	Integer
rRepValue	Road replacement value	Approximate budget if the road is damaged and needs fix (a unit price per meter)	Integer
constrYear	Construction time	Year of establishment	Integer
fHours	Functioning hours	An integer value to represent the daily hour interval that the road section operates (0=24/7, 1=00.00-06.00, 2=06.00-12.00, 3= 12.00-18.00, 4= 18.00-24.00)	Vector

Table 14: The attribute table of transportation network layer – bridge/overpass.

Field	Alias	Definition	Type
roadSecID	Road Section ID	ID number of the road section	Integer
matType	Material type	Overpass/Bridge material type (ie. Concrete, steel, masonry)	String
opbType	Overpass/Bridge type	Overpass/Bridge type (i.e., Suspension, frame, tee beam)	String
nSpans	Number of spans	Number of spans	Integer

[1] to avoid a road segment to cover in more than one land use zone, sections will be divided so that they are related with only one land use zone.

spanCont	Span continuity	Attribute to identify the continuity of the spans: continuous, discontinuous (in-span hinges), and simply supported	String
pType	Pier type	Number of piers used	Integer
aType	Abutment type	Bearing types used	String
opbCode	Code Level	Hazard code level (i.e., Seismic design code) that the structure is designed and constructed.	String
opbRepValue	Overpass/Bridge Replacement value	Approximate budget if the overpass or bridge is damaged and needs fix (a unit price per meter)	Integer

6.7.6 Utilities

The attribute tables of the utilities layer are provided in tables below.

Table 15: The attribute table of utilities layer – pipelines.

Field	Alias	Definition	Type
zoneID	Parent polygon ID	Unique ID number of the land use zone where the road section is located	Integer
plSecID	Pipeline Section ID	ID number of the pipeline section	Integer
fType	Fluid type	Function of the pipeline (potable water, sewage water, natural gas etc.)	String
diameter	Diameter	Diameter of the pipeline	Float
material	Material	Material type of the pipeline	Integer
ductility	ductility	Ductility level of the pipeline (1=brittle, 2=ductile)	Integer
plRepValue	Pipeline Replacement value	Approximate budget if the pipeline is damaged and needs fix (a unit price per meter)	Integer

Table 16: The attribute table of utilities layer – facilities.

Field	Alias	Definition	Type
zoneID	Parent polygon ID	Unique ID number of the land use zone where the road section is located	Integer
SecID	Pipeline Section ID	ID number of the pipeline section related/connected with this facility (can be null)	Integer
facType	Facility type	Type of facility with respect to the fluid within	
function	Function	Function of the facility (ie.: pump, tank, well)	String
depth	Depth	Depth of the facility from ground	Float
anchorage	Anchorage	Anchorage status of the facility	Integer

fRepValue	Facility Replacement value	Approximate budget if the facility is damaged and needs fix (a unit price per meter)	Integer

6.7.7 Road Exposure data format for network analysis

The road network is defined by these 2 files in geojson format: 1) Node, 2) Edges

i. Node

nodes — rapti_road_nodes — Features Total: 1523,

	node_id	Remarks
1	1	Near Bhaluwang
2	2	Ransing bridge node
3	3	Ransing bridge node
4	4	Sishaniya-Mahadew...
5	5	Sishaniya-Mahadew...
6	296303961	NULL
7	296303967	NULL
8	3353006532	NULL

The fields for road network nodes are:

1. node_id: Unique identifier for each node
2. Remarks: Optional field to describe each node

ii. Edge

edges — rapti_road_edges — Features Total: 3659, Filtered: 3659, Selected: 0

	edge_id	from_node	to_node	length	bridge	bridge_type	Remarks
1	118	4	5	860	true	HWB2	Sishaniya-Mahadewa bridge, 860m
2	9991118	5	3762944938	NULL	false	HWB2	Sishaniya-Mahadewa bridge approach
3	9990118	3658104725	4	NULL	false	NULL	Sishaniya-Mahadeva bridge approach
4	53	2	3	1042.448	true	HWB2	Ransing bridge, 117 m
5	18	3385919037	3	1042.448	false	Bridge Linked	Ransing Bridge approach
6	999153	3414900424	2	1042.448	false	Bridge Linked	Ransing bridge approach
7	3	296303967	1	456.663	true	HWB2	Bhaluwang Bridge, RCC 300m
8	60	3414900569	1	456.663	false	Bridge Linked	Bhaluwang
9	1	296303961	3414900695	557.595	false	NULL	0
10	2	296303961	8396494952	230.111	false	NULL	0

The fields for road network edges are:

1- edge_id: Unique identifier for each edge
2- from_node: node_id where the edge originates
3- to_node: node_id where the edge terminates
4- length: Length of edge. This field is not essential and is automatically downloaded from osmnx. The length of bridge, however, is sometimes needed to select the appropriate fragility function.
5- bridge: true if the edge is a bridge, otherwise false.
6- bridge_type: Type of bridge in the fragility function database
7- remarks: Optional field to describe the edges

The 'from_node' and 'to_node' fields in the Edge file must correspond exactly to the 'node_id' in the node file. The order of from and to nodes does not matter. For example, if an edge lies between nodes 5 and 6, either 5 or 6 could be the 'from_node'.

The road network also includes bridge data. Separate data structure for bridge is not needed.

6.7.8 Power Exposure data format for network analysis

The power network is defined by these 2 files in geojson format: 1) Node, 2) Edges

The coordinate reference system must be EPSG 4326 – WGS 84.

i. Node

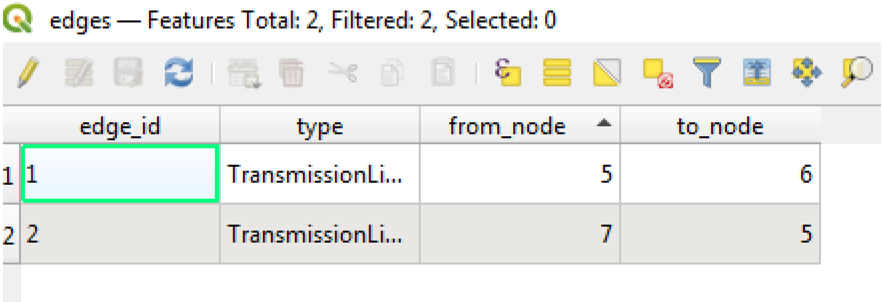
nodes — Features Total: 3, Filtered: 3, Selected: 0

	node_id	pwr_plant	n_bldgs	fl_vuln	SS_type	eq_frgl	ls_frgl	ls_susceptibility	fl_water_depth
1	5	0	1	HazusSS	HV	ESS1	LSS1	low	0.05
2	6	0	1	HazusSS	HV	ESS1	LSS1	low	0.05
3	7	1	0	HazusPP	NA	ESS1	LSS1	high	0.05

The fields for power network node are:

1. node_id: Unique identifier for each node. Nodes are currently either substations or powerplant.
2. pwr_plant: This value is 1 if the node is a power plant, otherwise 0.
3. n_bldgs: If this node directly serves the buildings, this value is 1.
4. fl_vuln: Name of the flood vulnerability function in the vulnerability database
5. SS_type: Type of the substation (HV = High Voltage, MV = Medium Voltage, LV = Low Voltage)
6. eq_frgl: Name o earthquake fragility function in the fragility databse
7. ls_frgl: Landslide susceptibility value in the landslide fragility database
8. ls_susceptibility: Landslide susceptibility (low, medium or high)
9. fl_water_depth: Flood water depth. This field is temporary and is used when flood hazard map is not available for the node location.

ii. Edges


edges — Features Total: 2, Filtered: 2, Selected: 0

	edge_id	type	from_node	to_node
1	1	TransmissionLi...	5	6
2	2	TransmissionLi...	7	5

The fields for power network edges are:

1. edge_id: Unique identifier for each edge.
2. Type: Optional field describing the type of edge. Example: transmission line
3. from_node: node_id where the edge originates.
4. to_node: node_id where the edge terminates.

The 'from_node' and 'to_node' fields in the Edge file must correspond exactly to the 'node_id' in the node file. The order of from and to nodes does not matter. For example, if an edge lies between nodes 5 and 6, either 5 or 6 could be the 'from_node'.

6.7.9 Data Generation Process

The data generation process starts with the initial input of land use plan. Using the density attributes and current population in the plan, total new population that can be catered is calculated. After this initial step, individual dataset and household datasets are generated based on the distribution table and assumptions list. After that, building attributes are generated and related with the household and individual datasets. The data generation flow adopted in TCDSE is given step by step in the table below. In addition, the related assumptions and distributions are specified in tables below.

Table 17: TCDSE data generation flow (from land use plan to exposure dataset)

SN.	Action	Inputs required	Method	Assumption	Distribution Table	Output	Layer	Attribute
1	Identify population	Number of population to be inhabited	Based on the land use plan table: max_population =(densityCap-population/$AREA)*$AREA	NA	NA	Number of new populations	Stored at the backend (passive)	nPeople
2	Identify the number of households	Number of new populations: nPeople	nHouse = nPeople / (sum(household_prob.*nInd))	Assumption1	Dist_Table1	Total number of households	Passive	nHouse
		Probabilistic distribution of household size (nInd per household)				Household IDs	Household	hhID
3	Identify the household size and assign "nInd" values to each household	Probabilistic distribution of household size (nInd per household)	Random assignment	Assumption1	Dist_Table1	Number of individuals per household (household size)	Household	nInd
4	Identify and assign income type of the households	Information on how households are distributed wrt avgIncome of land use types	Random assignment	NA	Dist_Table2	Household income	Household	income
5	Identify and assign a unique ID for each individual	Total number of population (sum of "nInd" in each household)	Random enumaration based on total number	NA	NA	Person ID	Individual	indivID
6	Identify and assign gender for each individual	Gender distribution probability	Random assignment	Assumption2	Dist_Table3	Gender	Individual	gender

SN.	Action	Inputs required	Method	Assumption	Distribution Table	Output	Layer	Attribute
7	Identify and assign age for each individual	"gender" attribute for each individual and Age distribution probability	Random assignment	Assumption3	Dist_Table4	Age	Individual	age
8	Identify and assign education attainment status for each individual	"gender" attribute for each individual and Education attainment distribution probability	Random assignment	Assumption4	Dist_Table5	Education attainment status for each individual	Individual	eduAttStat
9	Identify and assign the head of household	"gender" and "age" attribute for each individual and Head of household distribution wrt gender	Random assignment	Assumption5 & Assumption6	Dist_Table6	Head of household status for each individual (binary result: 0 or 1)	Individual	head
10	Identify and assign the household that each individual belongs to	hhID (in household layer) and indivID	1- Each household head is assigned to a hhID 2- Rest is assigned randomly	In relation with Assumption6, no individuals under 20 years of age can live alone in an household	NA	Primary key household ID	Individual	hhID
10a	Identify school enrolment for each individual	Household layer Individual layer	Random assignment	Assumption16	Dist_Table5a	School Enrolment status of each individual	Passive	schoolEnrollment
11	Identify total residential building area	Nr of households (hhID @ household layer) Income type of	Multiply average dwelling area with nr of households wrt income type	Assumption7a	NA	Total building area	Passive	totalBldArea

SN.	Action	Inputs required	Method	Assumption	Distribution Table	Output	Layer	Attribute
		households (income) Average dwelling area						
12	Identify number of residential buildings and generate building layer	Total building area Footprint area Land use type	1- Identify LRS for each building 2- Identify NrStoreys for each building 3- Identify footprint area for each building 4- Generate buildings until there are no dwellings to assign into a building	Assumption7	Dist_Table8 and Dist_Table7	Total number of buildings LRS attribute of each building FPT attribute of each building nStoreys attribute of each building Building IDs Land use zone IDs for each building Building IDs	Passive Passive Passive Passive Building Building Household	nBuilding LRSBld FPTBld nStoreyBld bldID zoneID bldID
13	Identify and assign occupation attribute and SpecialFac status for residential buildings	Building Layer as generated in Step 12	1- occ = "Res" 2- SpecialFac="0"	NA	NA	Occupancy type (for residential blds) Special Facility status (for residential blds)	Passive Building	OccBld SpeacialFac
14	Identify and assign code level for residential buildings	Building Layer as generated in Step 13	Random assignment	NA	Dist_Table11	Code level for each residential building	Passive	CLBld
15	Assign exposure string for each residential building	Building Layer as generated in Step 14	expStr= LRSBld+CLBld+nStoreyBld+Occ Bld	NA	NA	Exposure string for each residential building	Building	expStr
16	Identify and assign number of households and residents for each	Building Layer as generated in Step 15 Household Layer	nHouse=sum of households/dwellings that are assigned at Step 12 residents= sum of number of individuals (nInd) within each	NA	NA	Number of households in each residential building Number of	Building Building	nHouse Residents

SN.	Action	Inputs required	Method	Assumption	Distribution Table	Output	Layer	Attribute
	residential building		household in each residential building			individuals in each residential building		
17	Identify and generate commercial and industrial buildings	Building Layer Land Use type	1- Based on relevant assumptions, calculate number of industrial and commercial buildings 2- By using Dist_Table9 and number of residential buildings, identify commercial+residential, commercial and industrial buildings 2a- Warn user if number of "ind" and "com" number of buildings are bigger that the maximum number calculated in item 1. 2b- Revise the number of "ind" and "com" buildings or the distribution probabilities in relevant tables	Assumption10 Assumption11	Dist_Table9	Number of industrial buildings Number of commercial buildings Number of commercial and residential buildings	Passive Passive Passive	nBldInds nBldCom nBldComRes
18	Identify and assign the attributes for commercial and industrial buildings	Building Layer as generated in Step17	Random assignment	NA	Dist_Table10	For each non-residential building - Exposure string - FPT area	Building Passive	expStr FPTBld
19	Generate school and hospitals	Number of units	Deterministic assignment based on given ratios/statistics Assign schools and hospitals to zones starting from the highest population until the number of schools are reached	Assumption14 and Assumption15	NA	Number of schools Number of hospitals	Passive Passive	nSchool nHospital

SN.	Action	Inputs required	Method	Assumption	Distribution Table	Output	Layer	Attribute
20	Generate expStr for schools and hospitals	nSchool nHospital	Random assignment based on Dist_Table15	NA	Dist_Table14	Exposure string for each school and hospital Special facility status FPT attribute for each school and hospital zoneID for each school and hospital	Building Building Passive Building	expStr SpecialFac FPTBld zoneID
21	Employment status of the individuals	Age of the individuals Land use types Gender of the individuals EduAttStat of the individuals bldIDs	1- Calculate number of working individuals by using Dist_Table13 2- Identify EduAttStat of working individuals by using Dist_Table14	Assumption9	Dist_Table12 Dist_Table13	Number of employed individuals Work status	Passive Passive	nEmpInd work
22	Assign IndividualFacID	work status for individuals (Step21) age attribute of individuals (Step7) schoolEnrollment status (Step10a) Special Facility status = "school" for buildings	Random assignment of individuals to 1- commercial 2- industrial 3- commercial and residential occupation types of the buildings	Assumption13 Assumption17	NA	Unique building IDs for each individual on where they work and go to school	Individual	indivFacID
23	CommFacID	Building Layer	Random assignment (Identify closest facility for each individual in the next version)	NA	NA	Unique building IDs for each household on where they go to hospital	Household	CommFacID
24	Assign repValue	Building Layer Occupation type Unit price for replacement	Deterministic assignment based on unit price for replacement	Assumption12	NA	Replacement value for each building	Building	repValue

Table 18: Assumption list (example for Tomorrow Ville virtual urban testbed)

1	Household size distribution is same for different income types
2	Gender distribution is same for different income types
3	Age profile is same for different income types
4	Education Attainment status is same for different income types
5	Head of household is dependent to gender
6	Only (age>20) can be head of households
7	Range of footprint area (sqm) with respect to Income type
7a	Average dwelling area (sqm) with respect to income type
8	FPT uniform distribution wrt. average income type
8a	User Defined
9	Only 20-65 years old individuals can work
10	Nr of commercial buildings per 1000 individuals
11	Nr of industrial buildings per 1000 individuals
12	Unit price for replacement wrt occupation type and special facility status of the building
13	Each individual is working within the total study area extent.
14	1 school per 10.000 individuals
15	1 hospital per 25.000 individuals
16	Schooling age limits
17	Each individual (within schooling age limits) goes to school within the total study area extent.

Table 19: Probabilistic Distributions

Dist_Table1. Household Size Probability Distribution for Living Individuals									
	1	2	3	4	5	6	7	8	9
Assumption1									

Dist_Table2 Household Income Distribution for average income type					
	LIA	LIB	MI	HI	(Household)
LIA					
LIB					
MI					
HI					
(Zone type)					

Dist_Table3. Gender Distribution		
	Female	Male
Assumption2		

Dist_Table4. Age profile Distribution wrt. Gender									
	AP1	AP2	AP3	AP4	AP5	AP6	AP7	AP8	AP9
Male									
Female									
Assumption3									

Dist_Table5. Education Attainment wrt. Gender

	EA1	EA2	EA3	EA4	EA5	EA6
Male						
Female						

Assumption4

Dist_Table5a. School Enrolment wrt HH income+EduAttStat of HH Head

	HH Head EA1	HH Head EA2	HH Head EA3	HH Head EA4	HH Head EA5	HH Head EA6
LowIncome						
MidIncome						
HighIncome						

Dist_Table6. Head of Household	
	Head
Female	
Male	

Assumption5

Assumption6

Dist_Table7. Number of Storeys					
	LRS1	LRS2	LRS3	LRS4	LRS5
LUT1					
LUT2					
LUT3					
LUT4					
LUT5					
LUT6					
LUT7					
LUT8					

Dist_Table8. LRS wrt. Land use type					
	LRS1	LRS2	LRS3	LRS4	LRS5
LUT1					
LUT2					
LUT3					
LUT4					

LUT5					
LUT6					
LUT7					
LUT8					

Dist_Table9. Occupancy Type wrt. Land use Type				
	Res	Ind	Com	Res+Com
LUT1				
LUT2				
LUTn				

Dist_Table10. Commercial and Industrial buildings information				
	FPT-area	Ns	Code Level	LRS
Com	95-150	5-10 floor	[]3 discrete numbers	[] vector with 5 classes
Ind	85-105	5-10 floor	[]3 discrete numbers	[] vector with 5 classes

Dist_Table11. Code Level wrt LRS and Land use type (Res)					
	LRS1	LRS2	LRS3	LRS4	LRS5
LUT1					
LUT2					
LUTn					

Dist_Table12. Labor Force wrt. Gender

	Lab. Force
Female	
Male	

Assumption9

Dist_Table13. Employment Prob Dist. Wrt Education Attainment Status and Gender						
	EA1	EA2	EA3	EA4	EA5	EA6
Female						
Male						

Dist_Table14. Special Facility buildings information					
	FPT-area	Ns	Code Level	LRS	RepVal
School	95-150	5-10 floor	[]3 discrete numbers	[] vector with 5 classes	
Hospital	85-105	5-10 floor	[]3 discrete numbers	[] vector with 5 classes	

6.8 Tomorrowville case study

In this section, we elaborate on how these methods and data generation techniques are utilised as a part of Tomorrow's Cities Project within Tomorrowville case study area that is a virtual urban testbed. In Tomorrowville case, exposure data development is a hybrid process, combining the predictive and exploratory scenario development approaches. The exposure dataset is generated for a time 50 years in the future (i.e. $t_f = t_{50}$) when Tomorrowville is expected to accommodate approximately 80,000 people. Data generation process ultimately defines assumptions on future urbanisation patterns, which are used to populate the urban characteristics of Tomorrowville visioning scenarios based on the proposed exposure data structure. These assumptions are based on relevant studies of Kathmandu and Nairobi as well as expert judgement. In the sections below, we elaborate how exposure datasets are generated starting from land use plan[11].

6.8.1 Land-use plan

Future land-use types within Tomorrow Ville address pertinent demands for housing, workplaces, and public services (e.g. school, hospital), and facilitate agricultural areas as well as natural environment spaces (i.e. forests). There is also a historical preservation area with a unique socio-cultural significance, representing an "old-town" settlement.

Residential zones are classified on the basis of population density into four land-use types: i) "low-density residential"; ii) "moderate-density residential"; iii) "high-density residential"; and iv) "gated neighbourhood". The "avgIncome" field has four possible values: i) "highIncome"; ii) "moderateIncome"; iii) "lowIncomeA"; and iv) "lowIncomeB", where "lowIncomeA" rep-resents a relatively higher income level than "lowIncomeB". Assignment of attribute values for the land-use plan layer are summarised the table below (Note that the "floorAreaRatio" and "setback" fields are not used in the case study, since Tomorrow Ville does not have defined land plots in yet-to-be developed areas).

Table 20: Assigned attribute values in the land-use plan layer.

LuF	Population (number of people)	densityCap (person/hectares)	avgIncome
Agriculture	1308	40	lowIncomeA
City Center	1049	300	midIncome
Commercial and Residential	556	250	midIncome
Commercial and Residential	1107	250	midIncome
Commercial and Residential	443	250	lowIncomeA
Commercial and Residential	273	250	lowIncomeA
Historial Preservation	914	350	na
Industry	0	125	na
Recreation	0	0	na
Residential (Gated Neighbourhood)	1297	100	highIncome
Residential (High-Density)	5437	350	lowIncomeB
Residential (High-Density)	4069	350	lowIncomeA
Residential (Moderate-Density)	2028	200	highIncome
Residential (Moderate-Density)	11776	250	midIncome

Residential (Moderate-Density)	6309	250	lowIncomeB
Residential (Low-Density)	2501	100	highIncome

6.8.2 Building Layer

To create future building layouts, a data generation algorithm is developed to:

i. synthetically generate a set of buildings consistent with an assumed population demand; and
ii. assign building-by-building attributes based on coarser data (e.g. land-use data) and a set of assumed input parameters given below.
    1- All buildings within TV 0b0 still exist after 50 years.
    2- More than 95% of buildings constructed within TV 0b1 or TV 0b2 are reinforced concrete with infills.
    3- TV0b1 and TV0b2 do not feature any stone or adobe buildings.
    4- Buildings in TV0b1 and TV0b2 are either low-rise (1-4 storeys) or mid- rise (5-8 storeys).
    5- Distributions for Tomorrowville are given in table below:

Table 21: p(occ|polyt) distributions for Tomorrowville. Res: Residential; Com: Commercial; Ind: Industrial

$poly_t$	TV0			TV50		
	Res	Com	Ind	Res	Com	Ind
Agriculture	1.00	0.00	0.00	1.00	0.00	0.00
CommercialResidential	0.00	1.00	0.00	0.00	1.00	0.00
HistoricalPreservation	0.70	0.30	0.00	0.70	0.30	0.00
Industry	0.00	0.00	1.00	0.00	0.00	1.00
CityCentre	0.00	1.00	0.00	0.00	1.00	0.00
Residential (lowIncomeA)	0.90	0.10	0.00	1.00	0.00	0.00
Residential (lowIncomeB)	0.90	0.10	0.00	1.00	0.00	0.00
Residential (midIncome)	0.60	0.40	0.00	1.00	0.00	0.00
Residential (highIncome)	0.80	0.20	0.00	1.00	0.00	0.00

The algorithm requires various inputs that may be related to the entire urban area, the avgIncome value of the associated land-use zone (polygon), or the LuF value of the associated land-use zone. The input variables, their spatial scope of application and equations used for calculations are given in table below.

Table 22: Input variables and equations for the building data generation algorithm [11]

Variable explanation	Symbol	Applies to	Source
Current population	$P_{current}$	Whole area	User assumption
Projected population at t_f (i.e., 50 years in the future in this case)	P_{target}	Whole area	User assumption, consistent with densityCap field values
Current population	$P(poly)$	Each polygon	"Population" field values
Current population density	$d(poly)$	Each polygon	User assumption
Population density capacity	$d_{cap}(poly)$	Each polygon	densityCap field values
Area	$A(poly)$	Each polygon	Geometrical attributes of the land-use plan layer
Building footprint area probability distribution	$A_b(poly)$	Each polygon	User assumption
Pertinent characteristics (e.g., average, variance, ...) of $A_b(poly)$	$\bar{A}_b(poly)$; $\sigma^2(A_b)(poly)$	Each polygon	User assumption
Average number of storeys	$N_s(poly)$	Each polygon	User assumption
Average building area per household	$\bar{A}_h(poly)$	Each polygon	User assumption
Average household size	$\bar{N}_{hc}(poly)$	Each polygon	User assumption

$$d_{cap}^{eff}(poly) = d_{cap}(poly) - d(poly)$$

$$p_{alloc}(poly) = (P_{target} - P_{current})\frac{d_{cap}^{eff}(poly)A(poly)}{\sum_{poly} d_{cap}^{eff}(poly)}$$

$$h_{alloc}(bld) = \text{round}\left(\frac{A_b(bld)N_s(poly)}{\bar{A}_h(poly)}\right)$$

6.8.3 Household Layer

Information sources used to generate the household (and individual) data comprise a combination of expert judgement and geographically relevant literature and are described in [11] (which also provides the values for each variable).

Given the lack of detailed information, a straightforward Monte Carlo sampling strategy is used to sample uncertain household and individual attributes. It is assumed that the population across Tomorrowville (and each land-use zone that includes residential buildings) is evenly split between male and female genders, in the absence of more detailed data. nInd is first sampled according to a distribution conditional on the avgIncome field value of the land-use zone in which the household is located, *p(nInd|avgIncome)* (field:income is neglected in this case study, since household incomes are assumed not to vary significantly with respect to the corresponding avgIncome assignment). The head of each household is assigned a gender ($gender_{hh}$) according to the conditional distribution, p($gender_{hh}$|*avgIncome*). The age of the head of household (age_{hh}) is sampled according to the conditional distribution, $p(age_{hh}|avgIncome, gender_{hh})$, where age_{hh} accounts for only those old enough to be head of household. Each remaining person in a household is equally likely to be of either gender and has an age that is sampled according to the conditional distribution, *p(age|avgIncome, gender)*. Thus, there are no explicit dependencies between the age and/or gender of members of the same household. communityFacID is assumed to comprise the nearest hospital building.

6.8.4 Individual Layer

The age and gender field values are assigned as discussed above. The eduAttStat attribute (possible values are "none": no schooling, "primary": primary schooling only, "secondary": secondary schooling only, and "university": college- or university-level education) is sampled independently for all adults (i.e. for which age >= ageadult). Adults with eduAttStat = university less than or equal to the oldest age at which a person typically attends university (ageuniversity) are assumed to attend university or some other tertiary institute outside of Tomorrowville, and are therefore not included within the data. indivFacID covers workplaces and schools in this case study. All non-college-attending adults less than a retirement age that is specific to the avgIncome field value of the land-use zone in which they reside (i.e. age_{old}) are assigned a broad workplace location (wp) category (i.e. "polyt" value, but including the possibility of unemployment) according to distributions conditional on gender, the avgIncome field of the land-use zone in which they reside, and the educational attainment rate of the individual adult $p(wp|gender, avgIncome, eduAttStat, age_{adult} \leq age_{old})$. The individual is equally likely to work within any of the workplace buildings associated with the assigned workplace location category. Children of school-going age (i.e. individuals between $age_{schoolmin} \leq age \leq age_{schoolmax}$ that vary depending on the avgIncome field of the land-use zone in which they reside) are assumed to attend the nearest school according to gender-specific statistics that also change according to the the avgIncome field of the land-use zone in which they reside as well as the eduAttStat field value of their head of household $eduAttStat_{hh}$, $p(school|age_{schoolmin} \leq age \leq age_{schoolmax}, gender, avgIncome, eduAttStat_{hh})$.

6.9 EXERCISE

1. Connect to:

   https://uoe.sharepoint.com/:u:/r/sites/TomorrowsCities/Shared%20Documents/U.%20Risk%20Working%20Group/WP2%20Working%20Folder/SubWPs/WP2_2_SoftwareDevelopment/CodeRepo/Erdem/TCDSE_Exposure_Data_Generator_Matlab.zip?csf=1&web=1&e=RraYcC

   website and download the TCDSE_Exposure_Data_Generation_Matlab package.
2. Start Matlab.
3. Double-click on either TCDSE_Exposure_Data_Generator_v58b_win (for Windos/Linux) or TCDSE_Exposure_Data_Generator_v58b_mac (for MacOS).
4. Press the "Run" button.

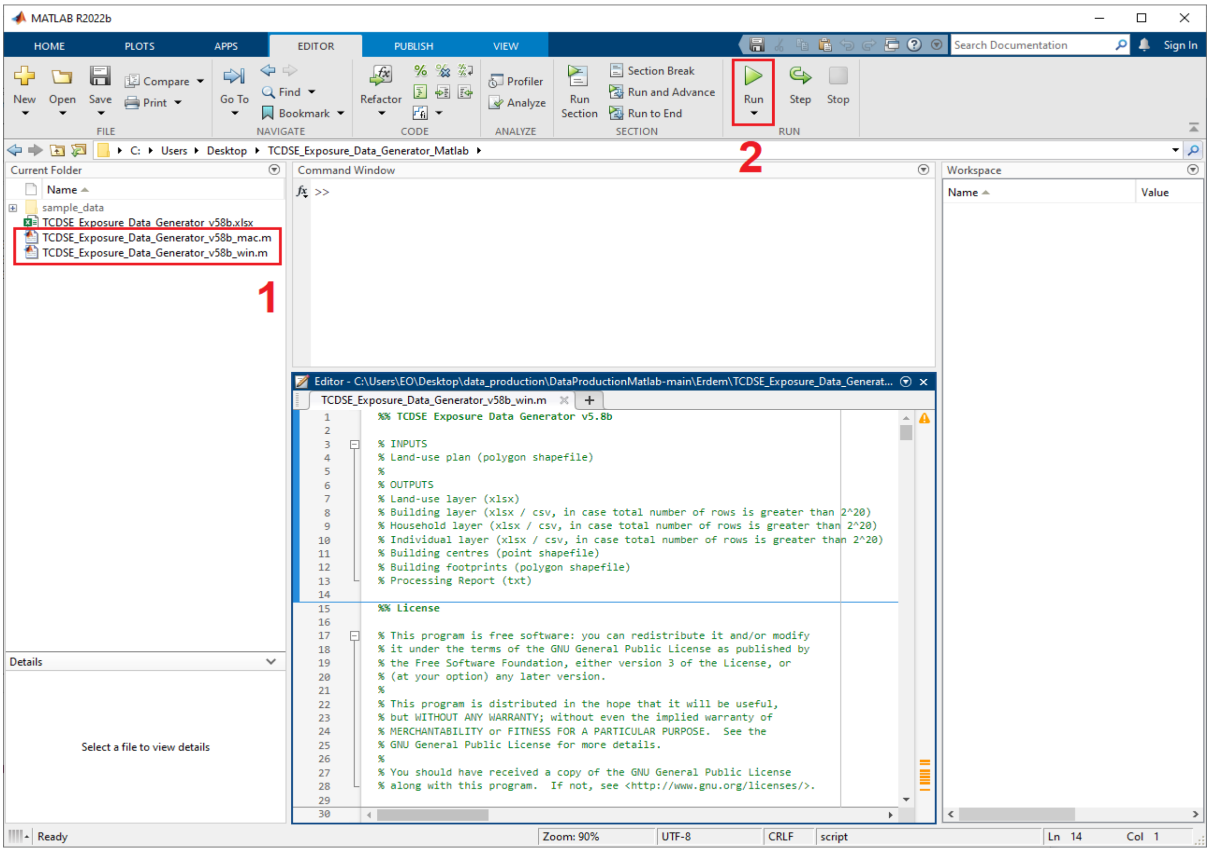


Figure 29: **Matlab Layout**

5. The code will ask to select the input land-use shapefile. Please enter the sample_data folder and select the “tomorrowville_test1” shapefile.

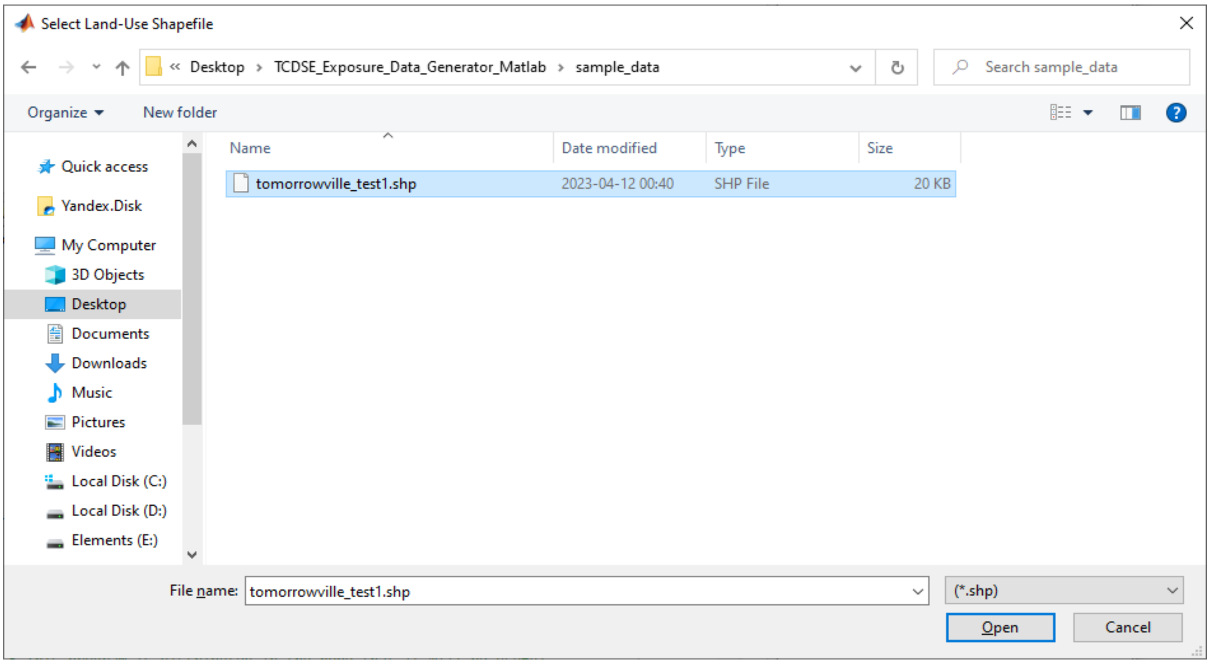


Figure 30: **Input Window-1**

6. Once the shapefile is selected, another window asking to select the Assumptions/ Distributions file will pop up. Please select the "TCDSE_Exposure_Data_ Generator_v58b_ tomorrowville_test1.xlsx" file in the sample_data folder.

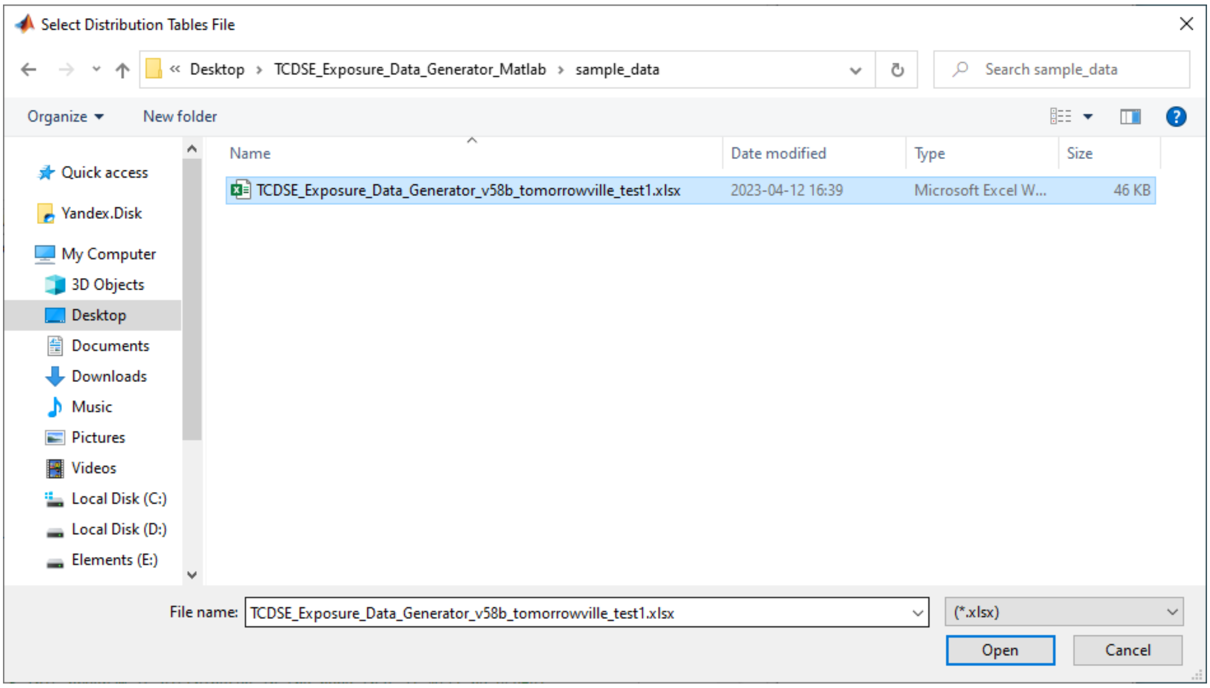


Figure 31: Input Window-2

7. The code will produce four Excel files, two shapefiles and a text file under the "_outputs" folder where the input shapefile is located.

- layer_building.xlsx
- layer_household.xlsx
- layer_individual.xlsx
- layer_landuse.xlsx
- inputfilename_building_centres.shp
- inputfilename_building_footprints.shp
- processing_report.txt

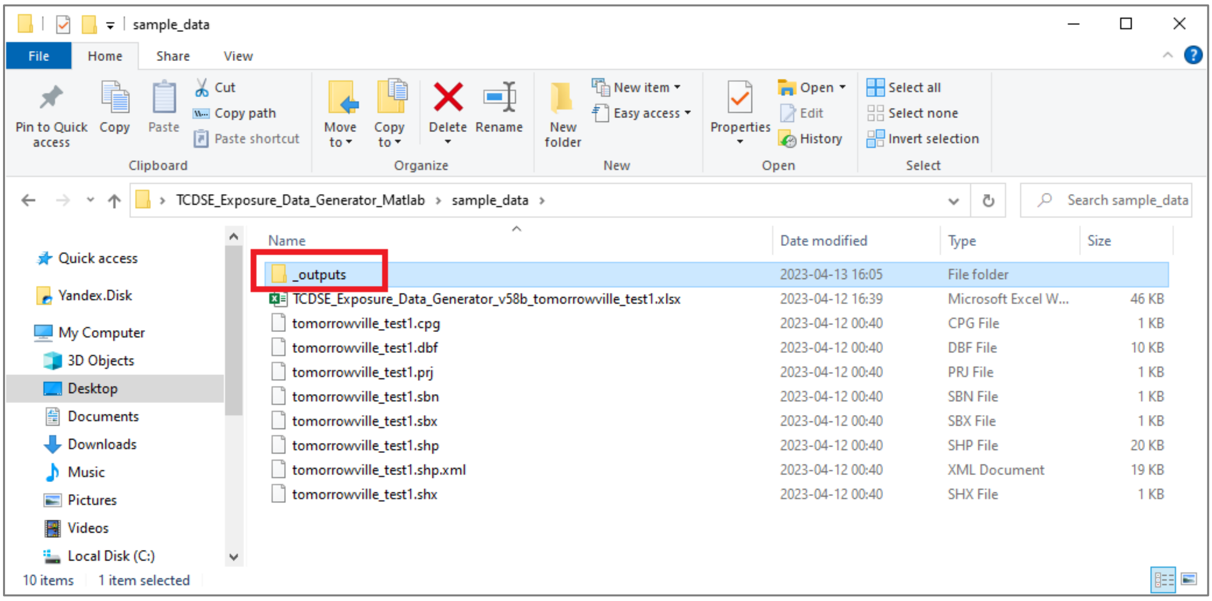


Figure 32: Location of _outputs folder

8. Go over each file considering the exposure data structure already explained.
9. Start a GIS software of your choice and add the input land-use file together with the building footprints and centres outputs.

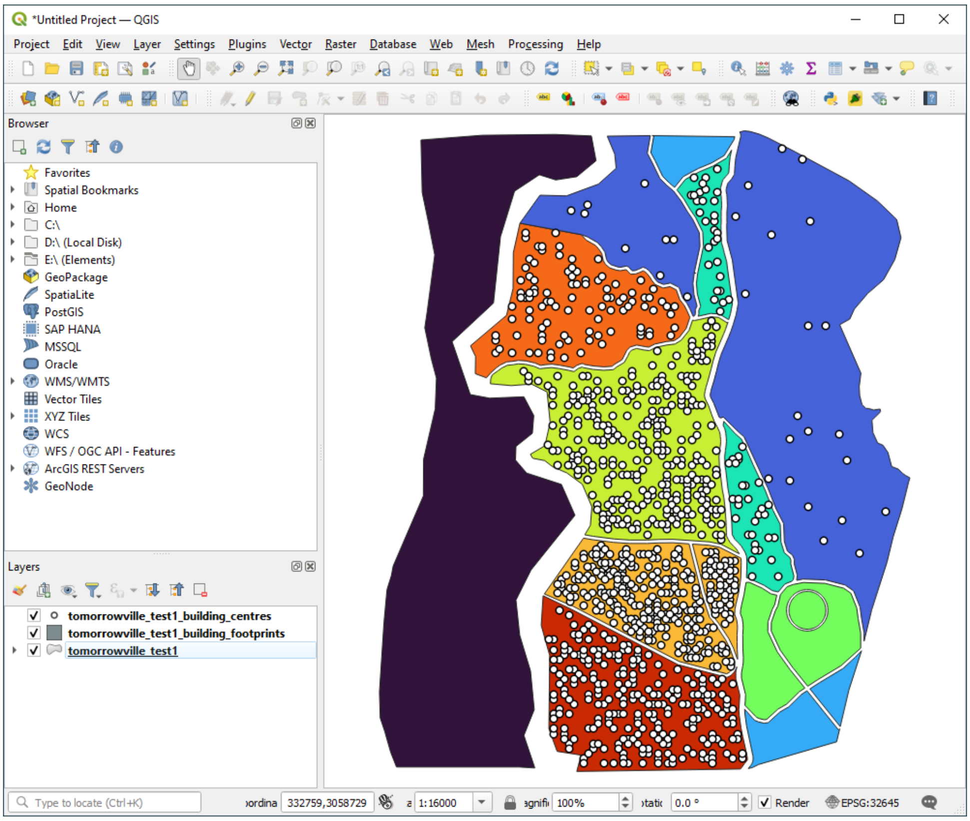


Figure 33: Visualisation of generated building footprints over input land-use file

10. Discuss the outputs.

6.10 Annexes

6.10.1 Annex 1: SPATIAL DATA SOURCES

i. Copernicus Land Monitoring Service

(https://land.copernicus.eu/)

Copernicus is the European Union's Earth observation programme. Information from this programme is provided through six thematic services: land, marine, atmosphere, climate change, emergency management and security. All information is free and openly accessible to all users [62]. The Land Service is divided into four main components:

Global: The Copernicus Global Land Service (CGLS) is a component of the Land Monitoring Core Service (LMCS) of Copernicus, the European flagship programme on Earth Observation. The Global Land Service systematically produces a series of qualified bio-geophysical products on the status and evolution of the land surface, at global scale and at mid to low spatial resolution, complemented by the constitution of long-term time series. The products are used to monitor the vegetation, the water cycle, the energy budget and the terrestrial cryosphere.

Pan-European: The pan-European component is coordinated by the European Environment Agency (EEA) and produces CORINE Land Cover datasets, High Resolution Layers, Biophysical parameters and European Ground Motion Service.

The CORINE Land Cover is provided for 1990, 2000, 2006, 2012, and 2018. This vector-based dataset includes 44 land cover and land use classes. The time-series also includes a land change layer, highlighting changes in land cover and land-use.

In addition, a second generation CORINE Land Cover (CLC) has been developed, with a geospatial component (CLC+ Backbone (BB) raster and vector product), and a database/web application component (CLC+ Core). CLC+ BB raster data will be made available here shortly. For more information about CLC+ Core database/web application please check (https://land.copernicus.eu/pan-european/clc-plus).

The High-Resolution layers (HRL) are raster-based datasets which provide information about different land cover characteristics and are complementary to land-cover mapping (e.g. CORINE) datasets. Five HRLs describe some of the main land cover characteristics: impervious (sealed) surfaces (e.g. roads and built up areas), forest areas, grasslands, water & wetlands, and small woody features. Most of the HRLs are available for 2006, 2009, 2012, 2015 and 2018.

The systematic monitoring of biophysical parameters consists of a set of bio-geophysical products on the status and evolution of the land surface. These high spatial resolution products are used to monitor dynamics of the vegetation, the water cycle, energy budget and terrestrial cryosphere variables. The products are continuously produced at a European extent. Currently two products are implemented, the 'High Resolution Vegetation Phenology and Productivity' and the 'High Resolution Snow and Ice monitoring'.

The European Ground Motion Service (EGMS) provides consistent and reliable information regarding natural and anthropogenic ground motion over the Copernicus Participating States and across national borders, with millimetre accuracy.

Local: The local component is coordinated by the European Environment Agency and aims to provide specific and more detailed information that is complementary to the information obtained through the Pan-European component. The local component focuses on different hotspots, i.e. areas that are prone to specific environmental challenges and problems. It will be based on very high-resolution imagery (2,5 x 2,5 m pixels) in combination with other available datasets (high and medium-resolution images) over the pan-European area. The three local components are:

- **Urban Atlas:** EU regional policy justifies the production and maintenance of detailed land cover and land use information over major EU city areas. The Urban Atlas provides pan-European comparable land cover and land use data covering a number of Functional Urban Areas (FUA). In 2012, an additional layer (Street Tree Layer - STL) was produced for a selection of FUA's as well as a building height dataset covering, originally, only the capital cities but now extended to additional 870 cities. The latest update refers to the 2018 reference year and accounts for the update of the land cover and land use product (including a revision of the 2012 reference year) as well as an update of the Street Tree Layer.
- Riparian Zones: The next local component addresses land cover and land use in areas along rivers, i.e. the riparian zones. The rationale for this local component is provided by the need to monitor biodiversity at European level, amongst other in the framework of improving the "green" and "blue" infrastructures in the European Union.
- Natura 2000 N2K: The Natura 2000 (N2K) areas are also important hotspots to have in consideration. The aim of the first N2K project was to assess whether Natura2000 sites are effectively preserved and whether a decline of certain grassland habitat types is halted.

Imagery and Reference Data: Copernicus land services need both satellite images and in-situ data in order to create reliable products and services. Satellite imagery forms the input for the creation of many information products and services, such as land cover maps or high-resolution layers on land cover characteristics. Having all the satellite imagery available to cover 39 countries of EEA (EEA39), the individual image scenes have been processed into seamless pan-European ortho-rectified mosaics. The Copernicus Land Monitoring Service also provides access to Sentinel-2 Global Mosaic service. EU-DEM is a pan-European digital surface model and EU-Hydro provides a photo-interpreted river network and a modelled drainage network for EEA39 countries. Many in-situ data are managed and made accessible at the national level. However, due to issues such as data access and use restrictions, data quality and availability across EEA39 countries, Copernicus services and particularly Copernicus Land Monitoring Service also relies on pan-European in-situ datasets created and/or coordinated at European level. The LUCAS database is one such longstanding European database coordinated by DG ESTAT, which used for verification and validation of several information services in the Copernicus Land Monitoring Service portfolio.

ii. OpenStreetMap (https://www.openstreetmap.org/)

OpenStreetMap is a free, editable map of the whole world that is being built by volunteers largely from scratch and released with an open-content license. The OpenStreetMap License allows free (or almost free) access to the map images and all of the underlying map data. The project aims to promote new and exciting uses of this data [63].

OpenStreetMap (OSM), also known as the Wikipedia of maps, constitutes a new open geographic database and a community mobilisation initiative with the potential to serve as a source of information for the called-for "data revolution". The potential of OSM to harness the power of new information and communication technologies in support of disaster risk reduction has been recognised by several authors. The past decade has seen the emergence of an ecosystem composed of volunteer mapping communities, corporations, and governmental & humanitarian organisations which contribute to and use the open geographic database of OSM for various purposes. While initially, the term' disaster mapping' has been introduced to describe the "ability for volunteers to assist in disaster response situations via mapping and other spatial analysis", since 2010, the broader term' humanitarian mapping' has evolved. It refers to collaborative mapping in OSM for both humanitarian relief responses and humanitarian purposes in general.

This activity is also referred to as remote mapping or digitisation and consists of generating geographic data based on satellite imagery. Since contributors do not need to be at the place of mapping physically, the efforts are collaborative and distributed to volunteers around the world [64].

iii. Copernicus Open Access Hub

(https://scihub.copernicus.eu/dhus/#/home)

The Open Access Hub provides complete, free and open access to Sentinel-1, Sentinel-2, Sentinel-3 and Sentinel-5P satellite data products [65]. The Open Access Hub provides *synchronous* access to the latest data, and *asynchronous* access to the historic data. Access is via https in all cases. The Open Access Hub maintains at least the latest month of products for *synchronous* access, immediately available for download via the product URL via https. The Open Access Hub provides *asynchronous* access to all historic data, which are restored for download within 1 hour of their request and available for download via https for the subsequent 3 days at least. The product catalogues of the Data Hub services provide seamless access to the full set of data, searchable via the Graphical User Interfaces as well as the OData and OpenSearch APIs. Data that are available for asynchronous access are flagged as "offline". An attempt at downloading these "offline" products, will trigger their retrieval. Following their retrieval, the requested products will be available for download through the original URL. The Data Hub Graphical User Interface (GUI) can be used to identify and order offline products.

iv. US Geological Survey (https://earthexplorer.usgs.gov/)

Created by an act of Congress in 1879, the U.S. Geological Survey has evolved over the decades, matching its talent and knowledge to the progress of science and technology [66]. The USGS is the sole science agency for the Department of the Interior. It is sought out by thousands of partners and customers for its natural science expertise and its vast earth and biological data holdings. The vision of the entity is to lead the nation in 21st-century integrated research, assessments, and prediction of natural resources and processes to meet society's needs. The USGS monitors, analyses, and predicts current and evolving Earth-system interactions and delivers actionable information at scales and timeframes relevant to decision makers. The USGS provides science about natural hazards, natural resources, ecosystems and environmental health, and the effects of climate and land-use change. As the Nation's largest water, earth, and biological science and civilian mapping agency, USGS collects, monitors, analyses, and provides science about natural resource conditions, issues, and problems. The diverse expertise enables large-scale, multidisciplinary investigations and provides impartial scientific information to resource managers, planners, and other users.

v. Digital Elevation Models

Space Shuttle Radar Topography Mission (SRTM)

NASA only needed 11 days to capture Shuttle Radar Topography Mission (SRTM) 30-meter digital elevation model [67]. Back in February 2000, the Space Shuttle Endeavour launched with the SRTM payload. Using two radar antennas and a single pass, it collected sufficient data to generate a digital elevation model using a technique known as interferometric synthetic aperture radar (InSAR). C-Band penetrated canopy cover to the ground better but SRTM still struggled in sloping regions with foreshortening, layover and shadow. In late 2014, the United States government released the highest resolution SRTM DEM to the public. This 1-arc second global digital elevation model has a spatial resolution of about 30 meters. Also, it covers most of the world with an absolute vertical height accuracy of less than 16m. The SRTM DEM data is being housed on the USGS Earth Explorer as well as 30-Meter SRTM Tile Downloader (https://dwtkns.com/srtm30m/).

ASTER Global Digital Elevation Model

NASA and Japan's joint operation was the birth of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) [68]. As part of this project emerged the ASTER Global Digital Elevation Model (GDEM). This is also a 1-arc second global digital elevation model. Each scene consists of 4,100 samples by 4,200 lines corresponding to about 60 kilometres (km) by 60 km ground area. Despite its high-resolution and greater coverage (80% of the Earth), dissatisfied users expressed issues with its artefacts often in cloudy areas. ASTER GDEM used stereoscopic pairs and digital image correlation methods. Based on two images at different angles, it used stereo pairs and photogrammetry to measure elevation. However, the amount of cloud cover affected the accuracy of ASTER which wasn't the case for SRTM DEM. Because of how passive and active sensors work, this had the most significant effect on the quality of DEM. But over time, ASTER DEM data has improved its products with artefact corrections of their own. In October 2011, ASTER GDEM version 2 was publicly released, which was a considerable improvement. Despite its experimental grade, ASTER GDEM-2 is considered a more accurate representation than the SRTM elevation model in rugged mountainous terrain. The ASTER DEM data can be downloaded for free from the USGS Earth Explorer, NASA Earthdata (https://search.earthdata.nasa.gov/search/) and Japan Space Systems (https://www.jspacesystems.or.jp/ersdac/GDEM/E/).

JAXA's Global ALOS 3D World

ALOS World 3D is a 30-meter resolution digital surface model (DSM) captured by the Japan Aerospace Exploration Agency (JAXA) [69]. Recently, this DSM has been made available to the public. The neat thing about is that it is the most precise global-scale elevation data now. It uses the Advanced Land Observing Satellite "DAICHI" (ALOS) based on stereo mapping from PRISM. The users register online through the JAXA Global ALOS portal to download it (https://gportal.jaxa.jp/gpr/index/index).

vi. World Bank Infrastructure Data

(https://datacatalog.worldbank.org/infrastructure-data)

INFRADATA is a data platform with an aim to improving the availability and quality of data on existing infrastructure assets and service delivery to support better investment, policy-making and research. INFRADATA has been developed with an intention of making available high-quality information on the location, quality, efficiency and price of infrastructure networks to allow financiers to investors to identify financing opportunities, and policy makers to design more effective interventions, and researchers to understand where investments can generate most impact. INFRADATA is a unified repository and one-stop shop for the infrastructure data resources of the World Bank, serving both internal and (where intellectual property allows) external clients. It includes a wide range of indicators that are relevant to the economic analysis of infrastructure. These range from highly granular project-level country-specific databases created during the course of the World Bank's operational engagement, to regional and global databases created in the context of the World Bank's analytical engagements, to subscription data services where the custodianship may lie with a particular unit within the World Bank.

Esri Open Data Hub (https://hub.arcgis.com/search)

The Esri Open Data Hub comprises a huge amount of free GIS data. It houses over 250,000+ open data sets from 5,000+ organisations worldwide. It allows users to make categorical search such as infrastructure, boundaries and transportation.

Diva-GIS Free Spatial Data (http://www.diva-gis.org/)

DIVA-GIS is a free computer program for mapping and geographic data analysis. It also provides free spatial data for the whole world such as for any country in the world: administrative boundaries, roads, railroads, altitude, land cover, population density.

6.10.2Annex 2: NON-SPATIAL DATA SOURCES

i. National Statistics Bureaus

https://www.ons.gov.uk/, https://cbs.gov.np/

https://www.ecuadorencifras.gob.ec/

https://www.knbs.or.ke/

https://www.tuik.gov.tr/ etc.)

Agencies responsible for generating official statistics for decision making in public policy (i.e. conducting census) in each country.

ii. ESRI Demographics

(https://www.esri.com/en-us/arcgis/products/data/data-portfolio/demographics)

Demographics are available both globally and locally, with access to over 15,000 ready-to-use demographic data variables from more than 170+ countries around the globe. Dive deep into demographic trend analysis on topics such as world population growth, birth and mortality rates, and populous countries.

iii. World Bank Databank

(https://data.worldbank.org/)

DataBank is an analysis and visualisation tool that contains collections of time series data on a variety of topics. The users can create their own queries; generate tables, charts, and maps; and easily save, embed, and share them.

iv. World Development Indicators

World Development Indicators (WDI) is the primary World Bank collection of development indicators, compiled from officially recognised international sources. It presents the most current and accurate global development data available, and includes national, regional and global estimates.

v. Statistical Capacity Indicators

Statistical Capacity Indicators provides information on various aspects of national statistical systems of developing countries, including an overall country-level statistical capacity indicator.

vi. Education Statistics

The World Bank EdStats Query holds around 2,500 internationally comparable education indicators for access, progression, completion, literacy, teachers, population, and expenditures. The indicators cover the education cycle from pre-primary to tertiary education. The query also holds learning outcome data from international learning assessments (PISA, TIMSS, etc.), equity data from household surveys, and projection data to 2050.

vii. Gender Statistics

Data on key gender topics. Themes included are demographics, education, health, labor force, and political participation.

viii. Health Nutrition and Population Statistics

Key health, nutrition and population statistics gathered from a variety of international sources.

ix. International Database IDB (https://www.census.gov/data-tools/demo/idb/)

The Census Bureau is the U.S. government's source of population estimates and projections (E&Ps) for over 200 countries and areas of the world to the year 2100. These data have been produced since the 1960s, and the results have been published in the International Database (IDB) since 1996.

x. United Nations Statistics Division (https://unstats.un.org/UNSDWebsite/)

The United Nations Statistics Division is committed to the advancement of the global statistical system. It compiles and disseminates global statistical information, develops standards and norms for statistical activities, and supports countries' efforts to strengthen their national statistical systems. It facilitates the coordination of international statistical activities and supports the functioning of the United Nations Statistical Commission as the apex entity of the global statistical system.

6.10.3 Annex 3: APPLICATION PLATFORMS

i. Open source

- **QGIS**

Quantum GIS is an Open Source Geographic Information System [70]. The project was born in May 2002 and was established as a project on SourceForge in June the same year. A great effort was made to enable GIS software (which is traditionally expensive proprietary software) available to anyone with access to a personal computer. QGIS currently runs on most Unix platforms, Windows, and macOS. QGIS is developed using the Qt toolkit (https://www.qt.io) and C++. This means that QGIS feels snappy and has a pleasing, easy-to-use graphical user interface (GUI).

QGIS aims to be a user-friendly GIS, providing common functions and features. The initial goal of the project was to provide a GIS data viewer. QGIS has reached the point in its evolution where it is being used for daily GIS data-viewing needs, for data capture, for advanced GIS analysis, and for presentations in the form of sophisticated maps, atlases and reports. QGIS supports a wealth of raster and vector data formats, with new format support easily added using the plugin architecture.

QGIS is released under the GNU General Public License (GPL). Developing QGIS under this license means that user can inspect and modify the source code, and guarantees that the user will always have access to a GIS program that is free of cost and can be freely modified.

- **GRASS GIS**

GRASS GIS, commonly referred to as GRASS (Geographic Resources Analysis Support System), is a free and open source Geographic Information System (GIS) software suite used for geospatial data management and analysis, image processing, graphics and maps production, spatial modelling, and visualisation.

GRASS GIS offers powerful raster, vector, and geospatial processing engines in a single integrated software suite [71]. It includes tools for terrain and ecosystem modelling, hydrology, visualisation of raster and vector data, management and analysis of geospatial data, and the processing of satellite and aerial imagery. It comes with a temporal framework for advanced time series processing and a Python API for rapid geospatial programming. GRASS GIS has been optimised for performance and large geospatial data analysis.

- **SAGA GIS**

System for Automated Geoscientific Analyses (SAGA) is a Free Open Source Software (FOSS), which generally means that the users have the freedom [72]:

  - to run the program, for any purpose,
  - to study how the program works and to modify it,
  - to redistribute copies,
  - to improve the program, and release the improvements to the public.

Except for the SAGA Application Programming Interface (API) most SAGA source codes have been licenced under the GNU General Public Licence or GPL. The GPL requires derived works to be available under the same or a comparable licence, with other words derived works have to become Open Source as well. For a few reasons the SAGA creators decided to use a less restrictive licence for the SAGA API. The API uses the GNU Lesser General Public Licence or LGPL, which permits use of this library in proprietary programs, i.e. SAGA modules, which always base on the API, have not automatically to be published as Open Source too.

- **Commercial**
  - ArcGIS (ESRI), Geomedia (Hexagon Geospatial), MapInfo Professional (Precisely)

6.10.4Annex 4: CODING PLATFORMS

i. Open-Source

- Python
  - It is important to select an appropriate Python tool for the kind of data required to be generated. The following figure highlights available Python libraries for specific tasks [73].

Purpose	Python Library
Increasing data points	DataSynthesizer, SymPy
Create fake names, addresses, contact, or date information	Fakeer, Pydbgen, Mimesis
Create relational data	Synthetic Data Vault (SDV)
Create entirely fresh sample data	Platipy
Timeseries data	TimeSeriesGenerator, Synthetic Data Vault
Automatically generated data	Gretel Synthetics, Scikit-learn
Complex scenarios	Mesa
Image data	Zpy, Blender
Video data	Blender

Figure 34: **Python data generation libraries**

All these libraries are open-source and free to use with different Python versions. This is not an exhaustive list as newer tools get added frequently.

- GNU Octave (MATLAB compatible) , Scilab, JavaScript, Java, PHP, C, C#, C++, R

ii. Commercial

- MATLAB, Statistical Package for Social Sciences (SPSS)

6.10.5Annex 5: database management systems

i. Introduction

A **database** is a collection of data, typically describing the activities of one or more related organisations. For example, a university database might contain information about the following:

- Entities such as students, faculty, courses, and classrooms.
- Relationships between entities, such as students' enrolment in courses, faculty teaching courses, and the use of rooms for courses.

A Database Management System (DBMS), is software designed to assist in maintaining and utilising large collections of data. The need for such systems, as well as their use, is growing rapidly. The alternative to using a DBMS is to store the data in files and write application-specific code to manage it. The use of a DBMS has several important advantages, as given below [74].

ii. Advantages of DBMS

Using a DBMS to manage data has many advantages:

Data Independence: Application programs should not, ideally, be exposed to details of data representation and storage. The DBMS provides an abstract view of the data that hides such details.

Efficient Data Access: A DBMS utilises a variety of sophisticated techniques to store and retrieve data efficiently. This feature is especially important if the data is stored on external storage devices.

Data Integrity and Security: If data is always accessed through the DBMS, the DBMS can enforce integrity constraints. For example, before inserting salary information for an employee, the DBMS can check that the department budget is not exceeded. Also, it can enforce *access controls* that govern what data is visible to different classes of users.

Data Administration: When several users share the data, centralising the administration of data can offer significant improvements. Experienced professionals who understand the nature of the data being managed, and how different groups of users use it, can be responsible for organising the data to minimise redundancy and for fine-tuning the storage of the data to make retrieval efficient.

Concurrent Access and Crash Recovery: A DBMS schedules concurrent accesses to the data in such a manner that users can think of the data as being accessed by only one user at a time. Further, the DBMS protects users from the effects of system failures.

Reduced Application Development Time: Clearly, the DBMS supports important functions that are common to many applications accessing data in the DBMS. This, in conjunction with the high-level interface to the data, facilitates quick application development. DBMS applications are also likely to be more robust than similar stand-alone applications because many important ta.'3ks are handled by the DBMS (and do not have to be debugged and tested in the application).

iii. Components and Interfaces of DBMS

A database management system involves five major components: data, hardware, software, procedure, and users [75]. These components and the interface between the components are shown in the figure below.

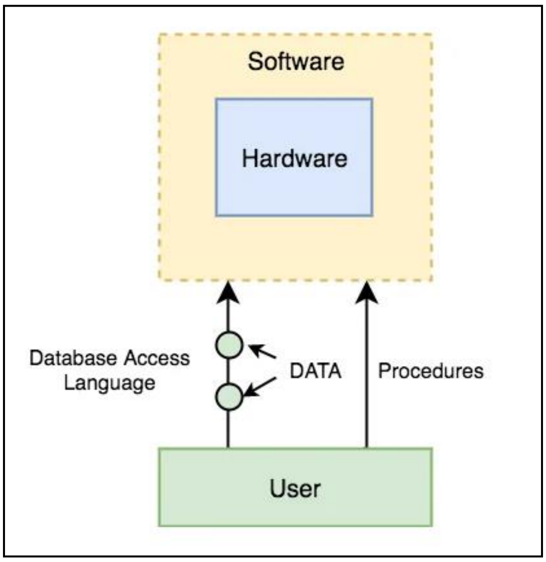


Figure 35: **DBMS components and interfaces [76]**

iv. Existing Database Management Systems

i. Open-Source

- MySQL, PostgreSQL, SQLite, Maria DB, MongoDB, Cassandra, Altibase, Cubrid, Redis, Commercial, Oracle, Microsoft SQL Server, IBM DB2, Microsoft Access

SESSION 7: VALIDATING VISIONING SCENARIOS

Author of the Chapter: Dr. Emin Yahya Mentese

7.1 Objectives

The objective of this session is to:

- Discuss the logic behind validation process.
- Design and deploy a validation workshop that will be used to revise the Visioning Scenarios.

7.2 Structure of Session 2

The structure of Session 7 is as follows:

Structure
1. Summary and way forward
2. Validation Workshop: Design and Deploy

7.3 Summary and way forward

This module described in detail the second Work Package of Tomorrow's Cities Decision Support Environment, which focuses on producing Visioning Scenarios based on the Future Visions (WP1) produced by different disaggregated stakeholder groups. Session 1 introduced the scope and aims of Tomorrow's Cities, the framework of the TCDSE and the role and focus of the Visioning Scenario work. By and large, this session explained how the deliverables from Future Visioning Workshops do – a people-centred work package – should be processed by the expert team. The following sessions unpacked the key components of Visioning Scenarios: (a) Policy Bundles (Session 2 on policy development) and (b) Spatial Urban Plans (Session 3 on land use plans and Session 4 on future exposure data generation).

The policy development session described how the team produces an assessment which connects policy expectations from stakeholders to the policy context, adding to such assessment a consideration on external factors (political, socioeconomic, and hazard-related). The session on land use plans in turn described how sketched plans from 'co-mapping exercises' (part of Future Visioning) are processed into GIS and connected to the local urban planning context and its planning standards. Finally, the session on future exposure data generation explains how aspirations from Future Visioning (what do people expect to see in the future spatially) are mixed with trends and forecasting related to urban and population growth.

It is worth noting however that all of the above processes happen at the 'backend', that is, drawing on stakeholders' inputs but without their direct participation. Considering Tomorrow's Cities commitment with co-production, it becomes then crucial that the groups that produced future visions (and the deliverables they entail) have a chance to verify expert-driven interpretations and comment or challenge such interpretations. Further, because future trends were added into Visioning Scenarios, groups should also have an opportunity to refine their visions and understand the trade-offs that come with them – both in relation to policy and spatial components. This follow-up interactions between the Tomorrow's Cities team and participants happen during 'Validation Workshops', to be briefly described in this session.

Whilst Tomorrow's Cities is divided in research work packages, there are other ways to look at how the project operates. In terms of stakeholder interactions, it could be said that there are five moments in which community groups, urban authorities and others engage with the TCDSE. The below timeline illustrates this process, and it starts with moment '0' - numbered as such because of its political nature when there are no actual research and practical deliverables. Moment 1 consists of Future Visioning workshops, extensively described in this document.

Figure 36: TCDSE In terms of stakeholder interactions

Moment 2 is the abovementioned Validation Workshop, which this session is further unpacking. After the validation of Visioning Scenarios, the package of spatial urban plans and policy bundles – one per stakeholder group – runs through a computational modelling process, aimed at simulating future multi-hazards onto the spatial urban plans (with the policy bundles functioning as mitigating factors). The modelling work (formally called Work Package 3 in the TCDSE) ultimately delivers 'impact metrics' – objective measures of risk such as the number of casualties after a hazard, the number of families displaced, the number of children without access to schools, and so on. Whilst the choice of hazard and event scenarios can count of stakeholders' inputs, the overall calculations are highly technical and not participatory in nature. Hence, after Work Package 3, it is necessary to hold yet another workshop where stakeholders learn about the results of calculations and understand better how their choices (spatial- or policy-related) led to risk-related outcomes. They also get to discuss how their 'impact priorities' (captured during Validation workshops) led to more subjective understandings of risk. Such collective learning happens during 'Risk Assessment' workshops, also called 'Risk Agreement' in the TCDSE. Finally, once stakeholders have learned about how their choices lead to objective impacts and subjective risk, they have a chance to test other choices over and over in a somewhat circular process called 'Reiteration'.

The above description summarises the participatory engagements in Tomorrow's Cities. Roughly, it consists of understanding the urban context to be worked (usually through a pilot area), gathering people's expectations (from a community-oriented approach), detailing such expectations in the form of Visioning Scenarios, and validate. In a way, the reiteration is a form validation which happens repeatedly in a circular fashion. Theoretically, three rationales are mixed; future visioning focuses on a normative rationale, which aims at finding desired outcomes and pathways; the stage of visioning scenarios focuses on an exploratory approach, focuses on looking at multiple future options; and throughout all of the TCDSE there is a concern with understanding trends from a quantitative perspective, which therefore falls under a predictive rationale.

Having presented this short summary, this session now moves to a detailing of the process of validating Visioning Scenarios, the key co-production activity of Work Package 2 which gives a final stage to policies and urban plans, therefore allowing the TCDSE to progress.

7.4 Validation Workshop

In simple terms, Validation Workshops consist of three stages: 'understanding', 'discussing', 'revising'. Yet, these three stages apply to both spatial urban plans and policies and are further mixed with a notion of 'prioritisation of impacts' which will be used to bridge Work Package 2 (Visioning Scenarios) with Work Package 4 (Risk Agreement).

In terms of methodological design, Validation Workshops follow a similar rationale to Future Visioning engagements, as the former is a follow-up to the latter. Both engagements ultimately aim at democratising the process of urban planning with an injection of information and awareness about hazards. Also, both aim at making local voices heard, particularly those of hitherto poor and marginalized population.

Yet, Validation Workshops go a step further; they are less 'participatory' (from a superficial sense) and more focused on co-production. That is, they aim to promote a deeper engagement between communities, researchers, and policy makers, so future visions are more realistic, data- and hazard-conscious, and better aware of trends and trade-offs related to equity.

The image below summarises this transition – from Future Visions to validated Visioning Scenarios:

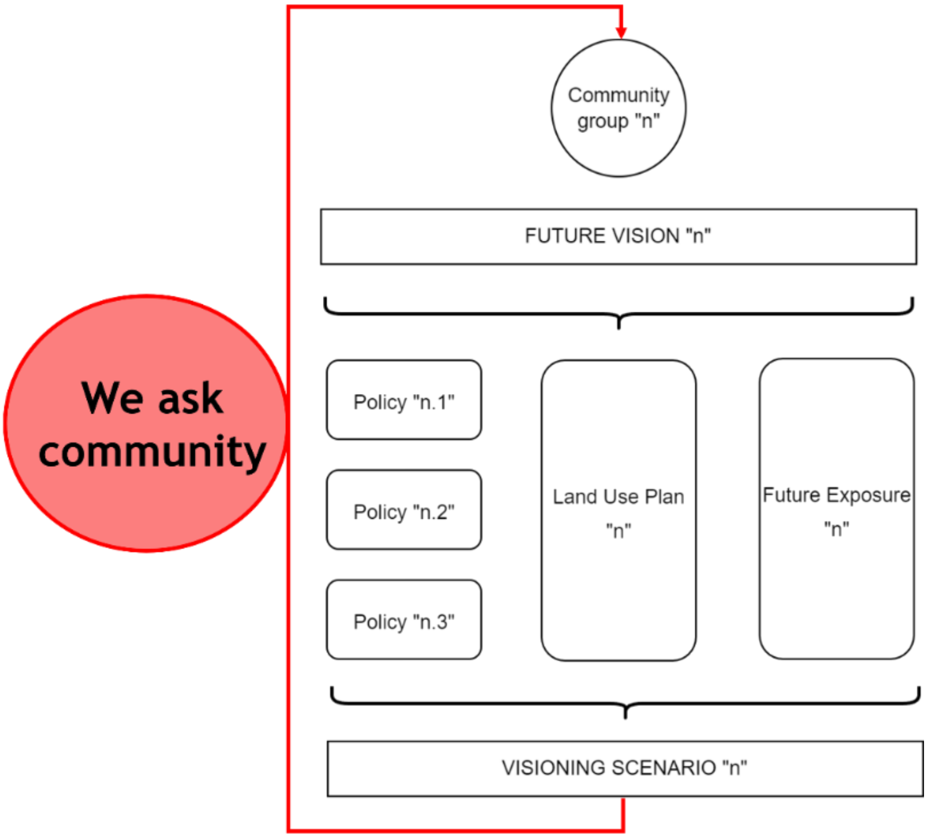


Figure 37: **Transition from Future Visions to validated Visioning Scenarios**

In terms of timing, Validation Workshops are divided into three stages: (1) understanding GIS interpretations of land use plans; (2) brainstorming hazards and prioritising impacts; and (3) defining policy bundles. All these three moments develop under the rationale of 'understanding', 'discussing', and 'revising', albeit in different ways.

7.4.1 Understanding GIS interpretations of land use plans

Co-mapping is one of the key exercises of Future Visioning, so during Validation Workshops a considerable amount of time is spent on understanding how the Tomorrow's Cities team translated spatial expectations (usually sketches) into GIS. Those can be more or less sophisticated depending on how complex is the land in question and how much detail have groups put into their co-maps. Participants are not only asked to understand the map, but also to discuss and revise it. They are given their own 'wheel of urban assets' from future visioning and their own visioning statement. They have a chance to check if all aspirations are indeed materialised, if something was forgotten or misinterpreted, and if something must be added given post-future visioning reflections. Importantly, this is a moment when the Tomorrow's Cities team also explains the trade-offs that the visions entail. For instance, expectations for low-density visioning scenarios are often unrealistic once the future exposure data generation is added onto the land use. This would lead to further discussions about what are the core aspirations to be pursued and which groups is a visioning scenario really benefiting.

Accessibility calculations support such discussions and inject equity (pro-poor thinking) into visioning scenarios. Such calculations will point out if future residents will have access (being more or less distant) to key services such as schools and hospitals, as well as to jobs and greenspaces.

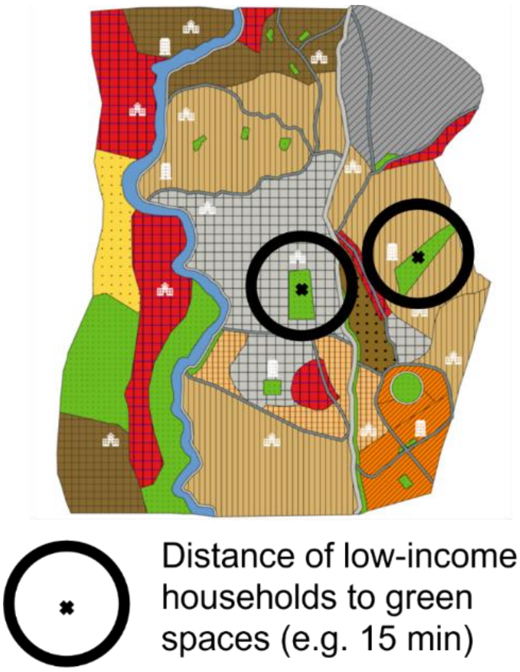


Figure 38: **Tomorrow ville**

7.4.2 Brainstorming hazards and prioritising impacts

Once GIS interpretations of spatial urban plans are understood, discussed, and revised, it will be soon time to do the same with policies. But before that happens, participants must go through a 'bridging exercise' called hazard brainstorm. Such exercise exists because, whilst spatial urban plans can be conscious of hazards but are ultimately expressions of aspirations, policies must be necessarily oriented at reducing, mitigating, or compensating the potential negative impacts of future hazards. Simply put, policies might be emerging from aspirations, but their design must embed a narrative that is hazard conscious. Their primary function in the TCDSE is to make urban plans perform better in the event of a future hazard. Brainstorming hazards helps this movement from aspirations to impact reduction and mitigation, while also opening an opportunity to slowly learn about how impact metrics work. Further, participants get to discuss what do they prioritise in the event of a hazard, which later in the TCDSE will help to reach at a score of risk for each stakeholder group.

In practice, the exercise is divided into two stages: (a) brainstorming hazards and their potential negative impacts and (b) prioritising impacts. Stage A consists of offering a scenario and instigating thinking on potential effects - e.g., 'imagine a major flood or earthquake. What could happen to your future city, its infrastructure, resources and inhabitants?'. At a fast pace (brainstorm-like), participants will identify impacts – many of those which could become real impact metrics to be calculated in Work Package 3. The image below shows how this happened in the case of Nairobi. Whenever possible, participants will provide links between their imagined impacts and the dimensions of the wheel of urban assets. This will make easier to grasp the notion that diverse impacts can be 'clustered' under one dimension of the wheel. Stage B consists of discussing which 'clusters of impacts' are seen as priorities by each group. This is a discussion that progresses slowly and as previously mentioned, will support the calculation of different risk scores in further moments of the project.

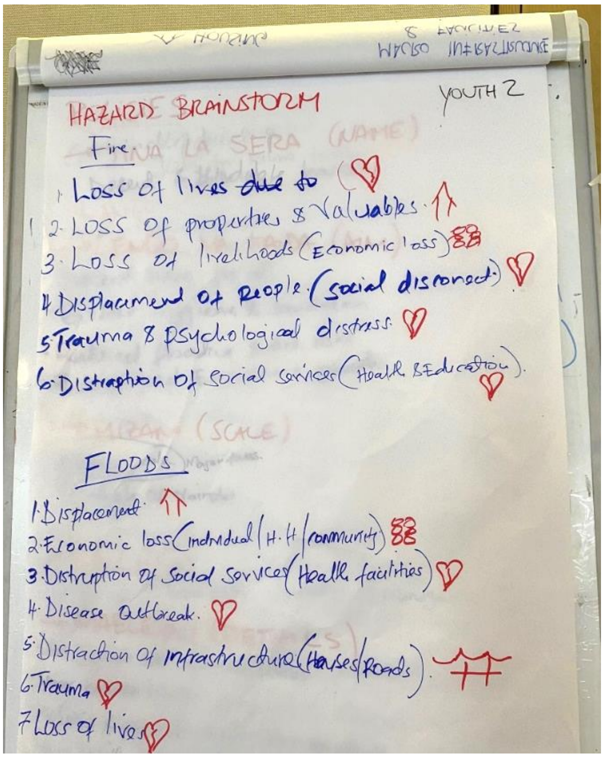


Figure 39: **Hazard Brainstorming Example**

Figure 40: **Participants displaying their impact priorities in Khokana, Kathmandu**

7.4.3 Closing Policy Bundles

Once spatial urban plans are revised and impacts are brainstormed and prioritised, participants should be in the appropriate headspace to refine their policy options and arrive at the final shape of their policy bundles. It is worth reminding here that during Future Visioning workshops they will have already discussed few policies priorities and will also have been reminded of the project's focus on disaster risk reduction. Yet, at this stage participants will also have an 'expert-led assessment' of at least three policy expectations, which could lead to richer discussions about how policies could eventually reduce, mitigate, or compensate future risk.

What is the name of the policy?	Potentials: will it likely impact exposure? Why? How?	Potentials: will it likely impact vulnerability? Why? How?	How does this policy relate to the scoping conducted in WP0?	What are the main political or governance factors that could prevent that policy from being effective?
As WP1	If yes: briefly justify If no, write no	If yes: briefly justify If no, write no	Is the policy (a) an exact match, (b) similar with adaptations (c) new alternative?	political will/corruption/data scarcity or unavailability

Are there any physical, infrastructural or natural constraints for implementation/activation?	What are the main socioeconomic factors that could prevent that policy from being effective?	Do you have any equity concerns for that policy?	Any additional notes?	What is your overall constructive assessment?
Hazard(flood,landslide), land uses (agriculture, landfills), topography(slope)	budget concerns, issues of knowledge, awareness or social conflict	housing/land affordability, access to critical infrastructure, services & green or recreational areas?)	comments that emerged during interviews or desktop research	recommendation to make policy effective for tackling the constraints

Figure 41: **How expert- driven assessments inform the discussions in validation workshops**

Different from Future Visioning, Validation Workshops aim at a more realistic discussion on policies – one that ties expectations to context, and that invites local policy makers to contribute more explicitly to enable community aspirations. In practice, this means that, whilst policies are still representing the vision of a group for the future, choices will be conscious of enablers and constraints highlighted by local experts and the tomorrow's cities team.

Usually, the product is a bundle with at least three policies that contain precisely details and notes on enablers and constraints. That is, groups are reflecting themselves about (a) which groups each policy benefits, (b) what are the possibilities for it to reduce the potential negative impacts of future hazards, and (c) what are the constraints for implementation – or what needs to change for that policy to be created, activated, or implemented.

In an ideal situation, this will foster not only plans and policies which are both desirable and realistic, but also community groups and urban authorities which are better able to dialogue and reach compromises and agreements. In many cities, it might be that policy discussions need to be continued between smaller groups of residents and policy makers. Also, given that high profile policy makers are unlikely to attend long workshops, it is advisable that the policy discussion is the last element of workshops, so that policy makers engage once communities feel better confident and capable to arguing for their visions.

Once the Validation Workshop ends, the Tomorrow's Cities team revises the plans and policies again, and inputs the results into the project's computational platform, which will allow for the conduction of multi-hazard simulations and the calculation of impact metrics.

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