GLOBAL ENVIRONMENT AND NATIONAL INFORMATION EVALUATION SYSTEM (GENIES) FOR URBAN IMPACT ANALYSIS

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Abstract

The urban areas of Asia are growing and will, in all likelihood, continue to grow at a rapid rate. This process could result in unprecedented risks to urbanized populations from climate change impacts, such as sea level rise, storm surge, extreme rainfall and temperature events, and cascading secondary effects.

A toolkit concept to support policy-making and planning based on a Global Environment and National Information Evaluation System (GENIES) has been developed that focuses on the core issues of adaptation, mitigation, risk, and economics of climate change and how they interrelate with aspects of water, energy, the built environment, transport, waste, and ecosystems. While recognizing the plethora of methodological perspectives that pertain to each sector, a system dynamics method is proposed, which lends itself to integrated assessment, given its flexibility and ease of extension and revision as new policy and planning questions emerge. The framework design starts with a clear definition of a problem and then draws together the appropriate models and data, to enable relationships to be defined and processed in a scientifically robust manner to evaluate adaptation and mitigation options.

The tool will be macro in its scale of engagement and represent a "first cut" method for conducting an indicative assessment of risks and potential costs and benefits of different adaptation options that could be applied to the risks posed by climate change. The tool development would have the highest chance for success if it were developed in a staged manner with an initial focus on one or two high priority issues in one or, at most, two cities. The political will of the pilot cities to engage in the process and carry it through to completion would be critical to the initial success of the project.

1. Introduction

The challenges facing Asia from urbanization are unprecedented—some 1.1 billion people could migrate from the countryside to the region's cities in the next 20 years. In addition, urban areas are becoming riskier owing to the threat of climate change, characterized by reduced agricultural productivity; urban, rural, and international migration; coastal inundation; and increasing vulnerability and damage from extreme climate events. Urban areas concentrate populations, economic activities, and infrastructure. These can be seen not only as vulnerabilities but also as opportunities to synergize resources for creating innovative risk management strategies. There is, however, a particularly urgent need to recognize such opportunities, develop them, and extend them to the wider urban community. Delays in incorporating climate change into urban development planning will reduce the efficient functioning of urban areas as centers of economic activity and aggravate the negative consequences of climate change.

There are barriers to making and implementing climate change policy in our rapidly growing urban centers. These include the lack of knowledge and uncertainties of climate change impacts and risks, and the absence of tools to guide decision making that integrate climate change considerations into overall urban development planning. This paper lays out the case for an urban policy-making support system to address the planning challenges related to the interplay of climate change, disaster risk management, and urbanization. By integrating various assessment models into a toolkit, a city can be in a better position to identify priority actions and, based on this information, implement policies to guide specific urban actions to improve resilience.

Currently, many models and tools are available related to climate change impact assessment, including risk and vulnerability assessment, and adaptation and mitigation tools. However, these models and tools mainly focus on (i) frameworks, lacking in-depth assessment models; (ii) a single sector, thus lacking integration; and (iii) sector processes, lacking a clear climate risk assessment component. None bring together local climate change projections, multisector impact analysis, and urban systems models to provide a set of integrated tools for urban decision makers to use in comparing adaptation and mitigation options in the context of local development

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plans in an open framework[3] that applies local, regional and global data. However, existing models do provide a basis for the development of an open framework system as a more comprehensive policy-making support toolkit that can provide an integrated and systematic assessment environment.

2. Objectives

The objective of the toolkit is to become an integrated climate change impact assessment tool for urban policy makers, which will allow them to assess the costs and benefits of mitigation and adaptation measures in light of the local development opportunities and constraints pertinent to the city, including for example, pollution problems and expected climate variability. The Asian Development Bank (ADB) proposes to develop this tool in partnership with international agencies and institutions with expertise in evaluating the environmental and socio economic impacts of climate change such as infrastructure, water security, and human health impacts due to air pollution and climate change, among others.

The deployment of the tool should speed up problem solving with pre-loaded data, models, rapid analysis functionalities, and a user-friendly interface; facilitate interpersonal communication and learning by allowing all groups to work with the same data, platform, and models; reveal new approaches to the formulation of problems and generate new evidence for decisions; and encourage exploration and discovery on the part of the decision maker. The features of the system include:

- modular design to build on and link to existing models and related applications;
- integrated analysis, enabling testing of adaptation and mitigation options against socioeconomic drivers, likely sectoral impacts, and existing goals for sustainable development;
- open framework, allowing multiscale, multidisciplinary impact assessment, which can be customized on a case-by-case basis to suit each city;
- climate change uncertainty analysis, building on General Circulation Model (hereafter GCM) and Regional Climate Model (hereafter RCM) climate change scenarios;
- geographic information system (hereafter GIS) integration, which is not heavily reliant on third-party software;
- visualization and further analysis options for the assessment of results; and
- Integration of risk analysis and cost-benefit analysis tools.

The tool is intended to answer questions like:

- How to characterize the impacts of climate change?
- Which sectors are likely to be most affected?
- What actions could reduce the intensity of these impacts?
- How could cities evaluate the future costs of such impacts?
- Are other cities experiencing similar impacts and how are they responding?
- What are the expected benefits and co-benefits of an action plan?
- How can this information support adaptation funding and its prioritization?

3. How Can the Tool Help in the Policy-Making Process?

With the raised awareness of climate change challenges, top-down and bottom-up synergetic approaches are eventually adopted by countries (Pulhin 2010, 2011). Based on understanding the key vulnerability caused by climate change at different scales and correlation with other natural and socioeconomic contexts, climate policy can be made from the national to local, urban level. Through a synergetic process—including single and cross-sector assessment—financing, in alignment with the national and local development strategies, can meet the critical challenges (Lawler, *et al*. 2011).

Climate change issues can be addressed appropriately and be mainstreamed into the policy making and planning process for maximizing the values of human well-being (Figure 1). The notion of good governance is related to effective public institutions. At the local level, this involves the development of partnerships between top-down government initiatives and bottom-up local institutions and policies (Urich, Quirog and Granert, 2009). Empowering local citizens and community organizations in the decision-making processes not only increases efficiency but also provides a real possibility for individuals or groups to transform their choices into desired actions and outcomes

[3] Open framework is used here to describe a system that permits the end user to either select from a suite of models or add new models and to import local data to run the models in a system that evolves into a customised version of the toolkit for the particular urban environment.

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Figure 1: Top-Down and Bottom-Up Multi-Level Climate Change Policy-Making Support and Value Maximization

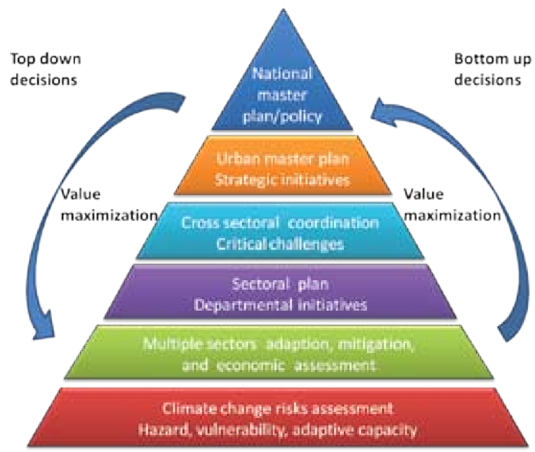
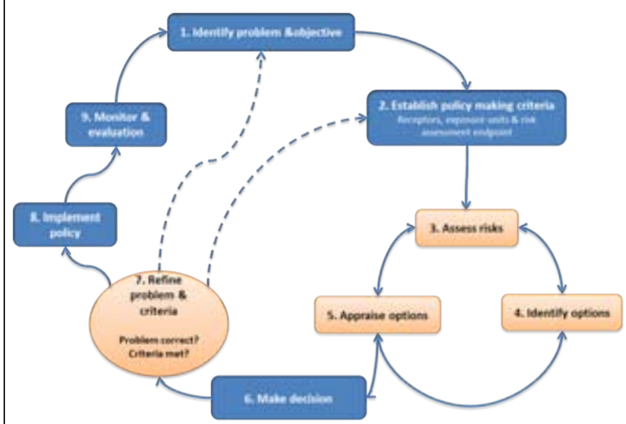


Figure 2: Risk, uncertainty and decision-making framework (Modified from Willows and Connell, 2003)



(Pulhin, 2011). The ultimate goal for adopting a synergetic approach is to strengthen the livelihood strategies of both national and urban communities.

Regarding the nature of climate change, for decision making on climate change adaptation actions, a risk, uncertainty, and decision-making framework (RUD) (Figure 2) can be deployed to explain how such a tool forms a decision support system (DSS). RUD enables decision makers to recognize and evaluate the risks posed by a changing climate, making the best use of available information about climate change, its impacts, and appropriate adaptive responses.

The process is circular, emphasizing the importance of the adaptive approach to managing climate change problems and implementing response measures. Decisions should be revisited in the light of new information on climate change and its impacts; for instance, when new climate scenarios are published.

Feedback and iteration are encouraged, so that the problem, objectives, and decision-making criteria can be refined (stages 1 and 2), and further options identified and refined to better reduce and manage climate change risks (stages 3, 4, and 5). Iteration is important to achieving robust decisions.

Certain stages (3, 4, and 5) are tiered. This allows the decision maker to identify, screen, prioritize, and evaluate climate and non-climate risks and options before deciding whether more detailed risk assessments and options appraisals are required.

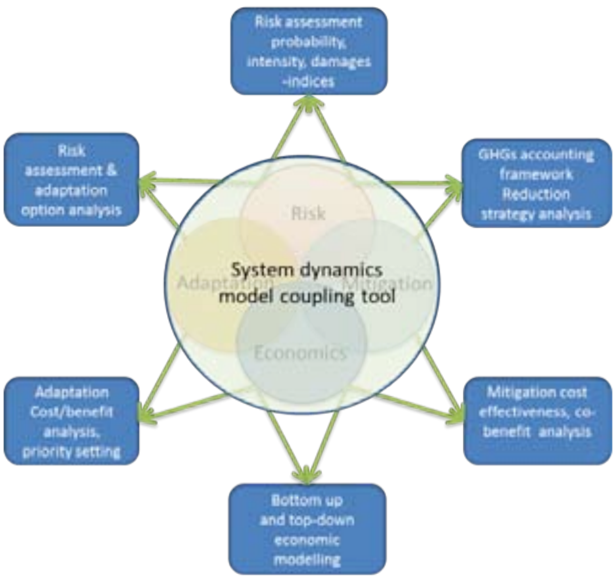
4. What Methodologies can Help Simplify Complicated Systems?

Climate change can affect every sector of an urban system with varied extent and intensity. A decrease in precipitation but increase in extremes can have a series of impacts on water, transport, energy, health, buildings, and other sectors. And by the urban system's nature, all sectors are closely correlated and working as a human life-supporting system. Therefore, for policy and decision making regarding climate change, the sectors also need to be seen systemically. However, to a large extent, climate change is still viewed as an add-on component to the routine of traditional policy making with its management of uncertainty, challenge, and opportunities.

Different from other sectoral DSSs or models, a Global Environment and National Information Evaluation system (hereafter GENIES) is framed by climate change issues, including risk, adaptation, mitigation, and related economic analysis, with a clear expression of urban planning and policy making; all sectors link to climate change issues, although each sector has a potentially long list of risks and opportunities.

During the last few decades, many modeling methodologies and tools have been developed for each climate change topic (i.e., risk, adaptation, mitigation, and economics). Many combined modeling methodologies also have been explored for the relationship among topics. The main quantitative modeling methodologies can be summarized as follows (Figure 3 and Table 1).

Figure 3: Structure of the Modeling Methodology



Other than quantitative modeling approaches, guidance or instructive tools have also been developed by various agencies, including ADB, Clean Development Mechanism, Inter-American Development Bank, international and national nongovernment organizations, the United Nations system, and World Bank.

5. Model Integration Tool

Given the large number of existing but independent models and tools, GENIES would act as a harvesting system that can integrate the existing and emerging technologies to make them work together as a system to provide better climate change policy-making support. A system dynamics approach and object modeling system (OSM) can serve this purpose effectively (Box 1), although GENIES would not be a typical system dynamics software system.

There is a need for a new framework of model development that can integrate existing and future natural resource models into a common, collaborative, and flexible system. Such a system will maintain modularity, reusability, and interoperability or compatibility of both science and auxiliary components. The system will also recognize the fact that different categories of applications may require different levels of scientific detail and comprehensiveness, driven by problem objectives, scale of application, and data constraints. These functionalities of the system will be obtained by establishing standard libraries of interoperable science and auxiliary components or modules that provide the building blocks for a number of similar applications. Module libraries have been successfully used in several domains, such as the manufacturing, transport, and other systems. The development of an individual model will follow the standard of OpenMI (http://www.openmi.org/).

To summarize, an approach for GENIES is needed that will

- reduce duplication of development effort and improve the quality and currency of model codes;
- make natural resource models much easier to build, access, understand, and use;
- facilitate long-term maintainability of existing and new natural resource models;
- lead to greater consistency of modeling for particular problems and scales;

Table 1: Summary of Quantitative Modeling Methodologies

Topic	Methodologies
Risk Assessment	Vulnerability and risk indicators and profiles; past and present climate risks; probability analysis; livelihood analysis; agent-based methods; narrative methods; risk perception, including critical thresholds; relationship of adaptive capacity to sustainable development.
Risk and Adaptation	Cross-sectoral interactions; integration of climate with other drivers; linking models across types and scales; combining assessment approaches/methods; adaptation option analysis; cost-benefit analysis, cost effectiveness, priority setting, and ranking.
Mitigation	Top-down models are most useful for studying broad macroeconomic and fiscal policies for mitigation, such as carbon or other environmental taxes. Bottom-up models comprise three basic types: optimization, simulation, and accounting frameworks. There are various hybrid models that combine elements of these three approaches.
Economics	Top-down and bottom-up economic modeling; integrated assessment models simulate the process of human-induced climate change, from emissions of greenhouse gases to the socioeconomic impacts of climate change; cost simulations across the widest range of possible impacts, taking into account the risks of the more damaging impacts suggested by new scientific evidence; analyzing changes to economies and societies that are large, uncertain, unevenly distributed, and that occur over a very long period of time.

Box 1: System Dynamics Approach

System dynamics is a computer-aided approach for policy analysis and design that applies to problems arising in complex social, managerial, economic, or ecological systems. The approach is appropriate for any dynamic system characterized by interdependence, mutual interaction, information feedback, and circular causality. It emphasizes wholes rather than parts, and stresses the role of interconnections, including the role each person plays in the systems at work in our lives. It emphasizes circular feedback (for example, A leads to B, which leads to C, which leads back to A) rather than linear cause and effect (A leads to B, which leads to C, which leads to D, etc.). It contains special terminology that describes system behavior, such as reinforcing process (a feedback flow that generates exponential growth or collapse) and balancing process (a feedback flow that controls change and helps a system maintain stability).

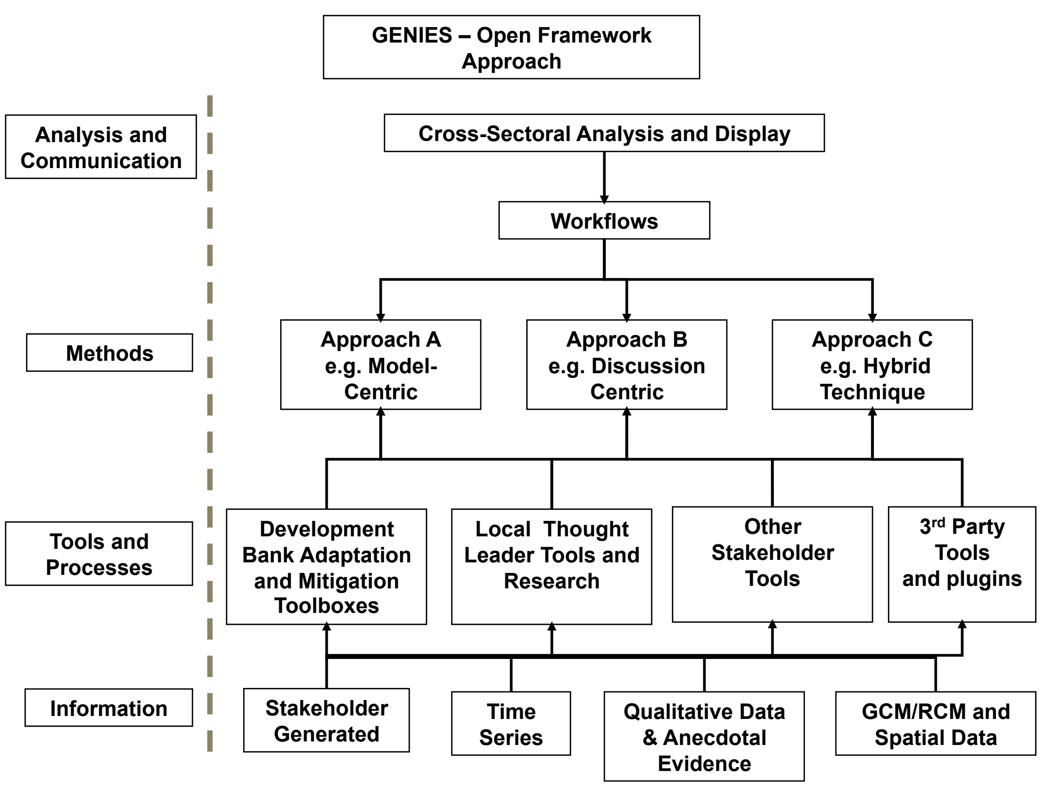
Source: http://www.systemdynamics.org/what_is_system_dynamics.html

- improve response and delivery times in scientific modeling projects; and,
- ensure credibility and security of model implementations.

Climate change planning can, and should, augment and be integrated with existing planning and development activities across all sectors. All the features of a system dynamics approach can make climate change issues clearer in urban planning and can help us see how to change them effectively with the aim of overcoming the complexities of decision making.

A unique advantage of applying system dynamics models is the ease of extension and revision as additional questions arise. The system could allow users to add models, input and output of the model, use a visual coupling tool for data conversion, and define, run , and monitor workflows. Figure 4 illustrates the inclusive open framework of GENIES.

Figure 4: GENIES Open Framework Approach



The inclusive framework of GENIES information and model/tools has (i) a layer of different methods or approaches to problem solving—probably tailored to each individual sector (water, transport, health, etc.); hence, they do not need to be generic, and can be different for each outcome; (ii) a layer of tools, in which again each tool is sector and process specific. Where we do not have a tool, one can be built; and (iii) a layer of information.

6. How Will the Toolkit be Developed?

The toolkit needs to focus only on climate change related issues, through a case study approach to define the audience and learning by doing (i.e., not in a one-off project; continuous support from commercial operations is needed). Many attempts to develop integrated climate change impact assessment tools stopped at the blueprint or pilot stage because of the loss of focus and continuous support. The development methodologies and operational approach for this project need to be clearly defined to ensure its completion.

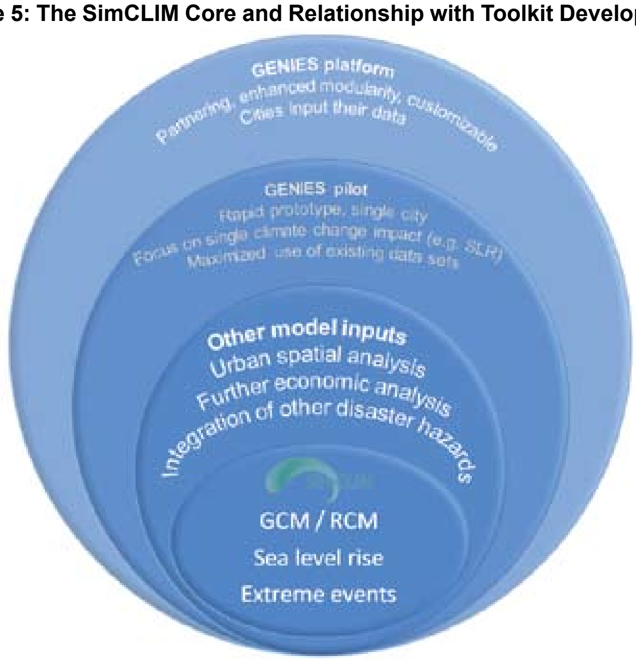
The foundational pieces of this toolkit are the existing integrated climate change impact assessment software SimCLIM (Figure 5) (Warrick, 2009a; Warrick and Urich, 2011). The integration of data, graphic user interface, impact models, and open framework makes SimCLIM a co-evolutionary decision support system that can be upgraded and improved through the interaction between end users and toolkit developers (Li., *et al*. 2009; Li, Ye and Yan, 2011). The main features of SimCLIM are that it allows for multi-scale, multi-disciplinary impact assessment; climate change scenario uncertainty analysis; and, with a built-in GIS tool, visualization and further analysis of the assessment results. A series of models, tools, and datasets have been integrated into SimCLIM (Masike and Urich, 2008; Masike and Urich, 2009; Warrick, 2009b).

7. Agile Development Methodologies

Given the complexity of the toolkit, it needs to be a test-driven development process. We need to release workable software regularly using a staged approach with prompt stakeholder/end-user/developer communication, quickly adapted to new demands/changes, and the process repeated until the strategic goal is fulfilled (Box 2). The stages are as follows.

Stage 1: Develop a broad framework and core models as the foundational piece in the primary stage. SimCLIM and its impact model library already provide a unique platform for the development of GENIES. The methodologies and functionalities that are important but not existing or inadequate can be prioritized for the first stage development. Some of the development needs have already been identified, such as the enhancement of economic analysis, including cost-benefit, co-benefit,

Figure 5: The SimCLIM Core and Relationship with Toolkit Development



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cost effectiveness analysis, and development of integration tools using the system dynamics approach. An international technical support group needs to collaborate closely with the policy-making group. Scientists, modelers, and software developers need to work seamlessly with their counterparts in urban policy-making groups. This stage also needs to be relatively short in order to provide workable software for the user to evaluate and to attract funding.

Stage 2: Build up more new models through a co-evolutionary process, projects, and end user demand. Provide inclusive linking methods for other models following the OpenMI standard. The software needs to be developed continuously and maintained efficiently; therefore, funding for such a toolkit needs to be well sourced, including projects from international financing institutions, and international and national agencies. GENIES has to be a collaborative development initiative of interested stakeholders. Stakeholder engagement needs to be stressed from the beginning. Table 2 provides an example of a stakeholder engagement approach.

Stage 3: The further development and application of the toolkit extends to a broader scope to fulfill the strategic goal of this initiative.

Table 2: Stakeholder Engagement Approaches to GENIES Development

Stakeholder Identification and Analysis	Invest time in identifying and prioritizing stakeholders and assessing their interests and concerns.
Information Disclosure	Communicate information to stakeholders early in the decision-making process in ways that are meaningful and accessible, and continue this communication throughout the project life.
Stakeholder Consultation	Plan each consultation process, consult inclusively, document the process, and communicate with stakeholders.
Management Functions	Build and maintain sufficient capacity within the provider to manage the process of stakeholder engagement, track commitment, and report on progress.
Reporting to Stakeholders	Report back to stakeholders on environmental, social, and economic performance, both to those consulted and those with more general interest.
Discussion and Partnership	For controversial and complex issues, enter into open discussions that satisfy the interests of all parties by forming a strategic partnership.
Concerns Management	Establish accessible and responsive means for stakeholders to raise concerns and demand changes about the project throughout its life.
Stakeholder Involvement in Project Monitoring	Involve directly affected stakeholders in monitoring project impact, mitigation, and benefits, and involve external monitors where they can enhance transparency and credibility.

Box 2: Agile Software Development

Agile development is a different way of managing software development projects. Ten key principles of agile software development illustrate how it fundamentally differs from a more traditional waterfall approach to software development, and are:

1. Active user involvement is imperative.
2. The team must be empowered to make decisions.
3. Requirements evolve but the time scale is fixed.
4. Requirements are captured at a high level; lightweight and visual.
5. Develop small, incremental releases and iterate.
6. Focus on frequent delivery of products.
7. Complete each feature before moving on to the next.
8. Apply the 80/20 rule.
9. Testing is integrated throughout the project lifecycle— test early and often.
10. A collaborative and cooperative approach between all stakeholders is essential.

Source: http://www.allaboutagile.com/10-key-principles-of-agile-software-development/

8. Conclusion

A framework for GENIES uses a system dynamics-like approach. It acts as a combined harvesting system that can integrate existing and emerging technologies to make them work together as a system to provide climate change policy-making and planning support. The integrated toolkit will provide an opportunity to maximize the co-benefits of mitigation actions and location-specific adaptation policies at the local level, keeping in mind interactions between sectors. Given the complexity of the toolkit, it needs to be a test-driven development process. We need to release workable software regularly using a staged approach with prompt stakeholder/end user/developer communication, agilely adapted to the new demands and changes in need and climate science. This process needs to be repeated until the strategic goal is fulfilled.

An investment will need to be made to develop the tool to attain its maximum utility, building on existing resources and initiatives, to enable enhanced applications for urban impact analysis. This investment will need to be extended to improve data collection and build local capacities for analysis and planning.

The tool will be macro in its scale of engagement and represent a "first cut" method for conducting an indicative assessment of risks and potential costs and benefits of different adaptation options that could be applied to the risks posed by climate change. The tool development would have the highest chance for success if it were developed in a staged manner with an initial focus on one or two high priority issues in one or, at most, two cities. The political will of the pilot cities to engage in the process and carry it through to completion would be critical to the initial success of the project.

A more global perspective for development and deployment of the software toolkit could be explored with the World Bank,Inter-American Development Bank and African Development Bank. Further sharing of perspectives and tools and integration with programs currently being run by other international financial institutions would be desirable to avoid duplication in such an important area of tool development.

The first steps involve discussing needs of urban policy makers, mapping existing tools, and resources, undertaking a high-level functional design, developing the integrated tool, identifying pilot cities for initial application, and supporting the ongoing development and use of the system by a growing number of interested cities.

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