MCA4climate

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MCA4climate: A practical framework for planning pro-development climate policies

Case Study:
Flood risks, Infrastructure Resilience and Climate Change Adaptation in Mumbai, India

Contribution to the MCA4climate initiative

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Final Report

June 2011

Available online at: www.mca4climate.info

Acknowledgements

The authors are very grateful to all workshop participants and those involved in the development of this case study:

Sophy Bristow (UNEP)
Zaid Chalabi (London School of Hygeine and Tropical Medicine)
William Cheung (University of East Anglia)
Jan Corfee-Morlot (Organisation for Economic Co-operation and Development)
Reinhard Mechler (International Institute for Applied Systems Analysis)
K. Narayanan (Indian Institute of Technology Bombay)

Practical Note

This case study represents an illustration of how the MCA4climate initiative may be applied under more realistic settings. Though it draws on real data, it does not represent a proper pilot application of the MCA4climate approach, but only a snapshot of how this may be applied in practice (the case-study was mostly centred around a two-day workshop at UNEP offices in Paris). For an overview of the general MCA4climate initiative please see the main MCA4climate report and other associated documents available on www.mca4climate.info. For further information, please contact the UNEP team, Serban Scrieciu, Sophy Bristow, Daniel Puig or Mark Radka at unep.tie@unep.org.

Introduction

The purpose of this case study was to illustrate the evaluation of climate adaptation policy options to increase infrastructure resilience in Mumbai – an Indian city covering more than 480 square kilometres with a population of 12 million (including the suburbs).(1)

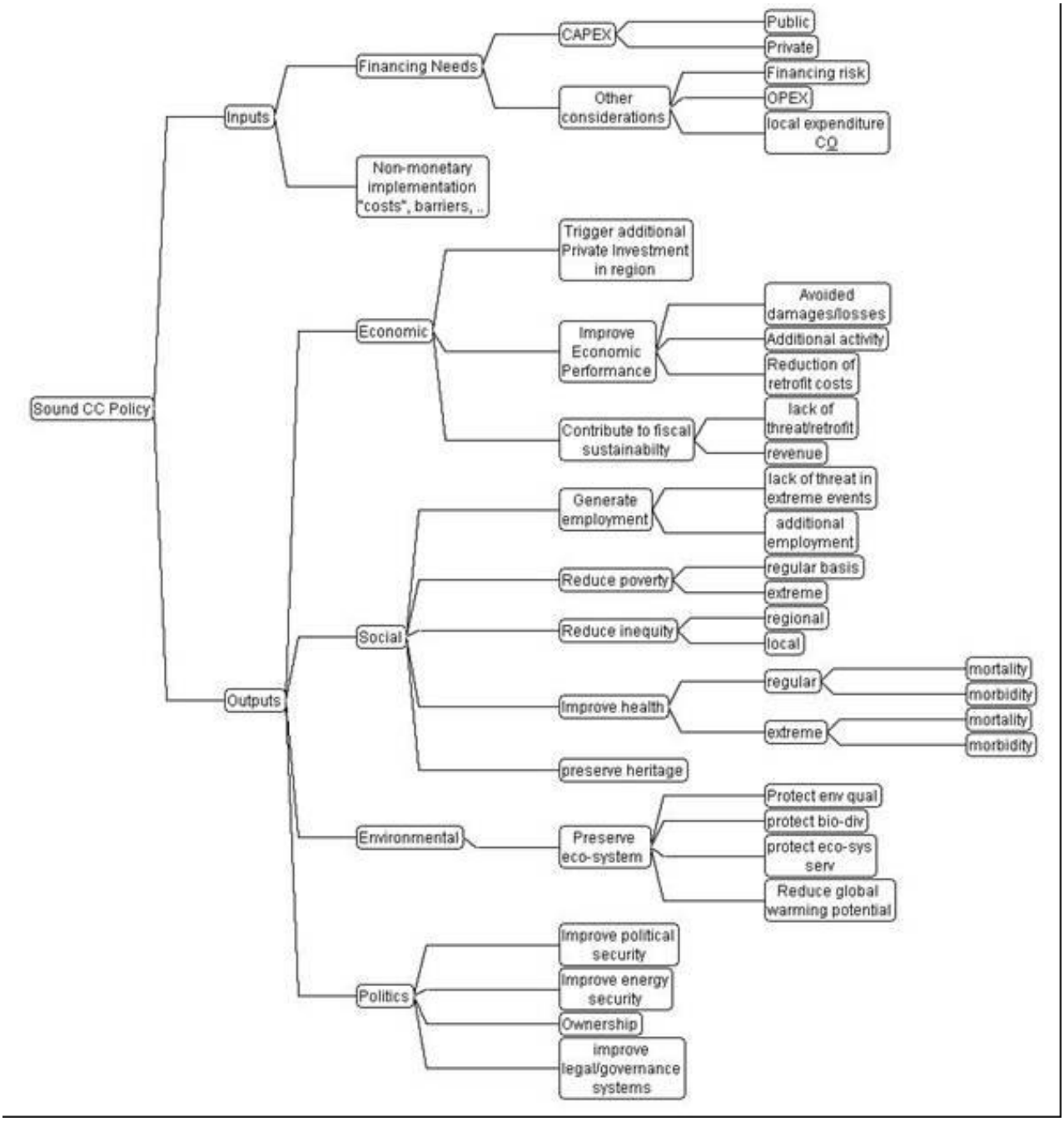
Mumbai is prone to severe flooding, which now occurs almost annually – the consequence of the climate and the way the city has developed. Climate change is expected to increase the severity and frequency of flooding. Strengthening the city's infrastructure to better resist flood risks is difficult for several reasons: land is scarce, making it hard to impose a zoning policy that allows construction only outside flood-prone areas; the population is still growing rapidly increasing demand on transportation, electricity and water services; most of the population still lives in informal settlements; institutions are weak and land tenure uncertain, making land-use or building regulations difficult to enforce; and the city is politically unstable, with latent conflicts between different population groups.

Criteria and policy options

The first step in the exercise was to identify sub-sets of theme-specific criteria for each of the 3rd-level criteria in the generic criteria tree.(2) This was achieved through wide-ranging discussion within the group of participants. The results are shown in Figure 1. Because of time constraints and since the purpose of the exercise was to demonstrate the applicability of the MCA4climate framework, operational indicators were not specified and the evaluation of the options was based solely on the criteria.

1 An OECD report on Yemen was used as the starting point for this case study (Hallegatte et al, 2010).
2 This process contributed to the set of indicators that were still being developed for the increasing infrastructure resilience theme, as well as to the development of the generic criteria tree. At the time of the workshop, an earlier version of the generic criteria tree was used for this analysis.

Figure 1: *Criteria tree for evaluating polices to increase infrastructure resilience in Mumbai (case study)*



The next step was to identify a set of policy options to be evaluated drawn from a larger set of possible options. The final set of five options was selected to represent a broad range of options that could be expected to have impacts that could be measured using the infrastructure theme-specific criteria (

Table).

Table 1: *Policy options to increase infrastructure resilience in Mumba*i

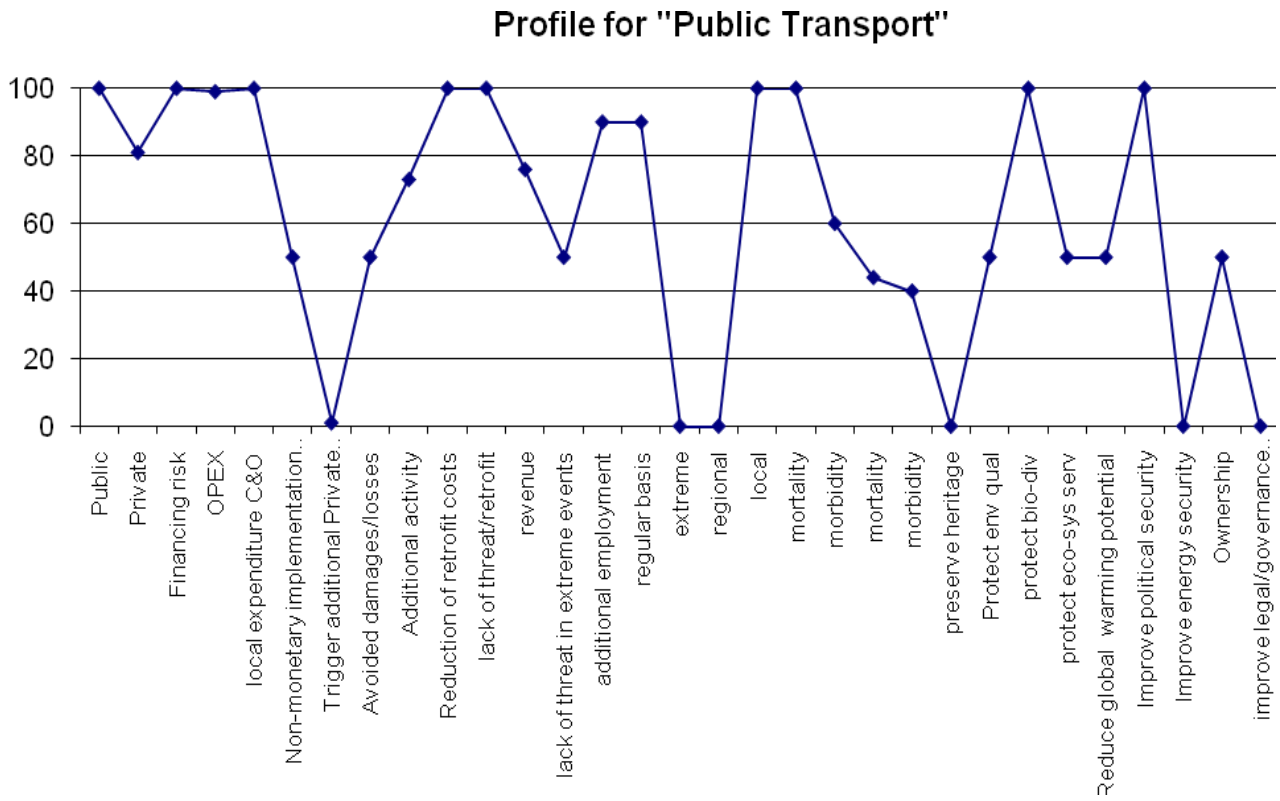
Policy	Instrument	Description
Public transport	Infrastructure development would be funded through a combination of taxation and public investment.	Build the planned transport link on stilts as opposed to underground (which represents a decrease in financial cost and an increase in co-cost like noise and views). Significant new infrastructure would be required to complete the project, which would bring the opportunity to link to the wider transport network (monorail and roads) creating better city-wide mobility.
Building Codes	Command and control type regulatory instrument.	Amend existing building regulations and introduce new regulations where necessary to ensure that in 20 years' time all floodplain buildings are on stilts, and earthquake-proof. Unauthorized colonies must be prevented and regulations enforced.
Warning Systems and Emergency Response	A combination of public investments (e.g. setting up of new centres and services) and information-based instruments (targeted education and communication).	The formation and coordination of a 'disaster management' cell – including government, emergency services, logistics and weather-forecast services. It would also involve the building of designated safe shelters, as well as targeted communication and education to relevant sectors of the population.
Insurance	Public investment since this is a government financed	A government scheme aimed at low-income households and the informal

	scheme (although there is the potential to support this through taxation).	sector. The insurance would be compulsory. The aim of this policy option is to achieve 80% coverage within ten years.
Enforced Retreat	A command and control regulatory instrument.	The definition of high-risk priority areas, the enforced movement of people living in those areas, the location and development of alternative settlements and the restoration of vacated areas. The target would be up households and small businesses. Although this would be government supported policy, the opportunity for public/private partnerships would be promoted in the development of new settlements.

Scoring the options

Scoring involved direct rating of options against a 0 to 100 'locally defined' scale. In other words, the scale was defined for each infrastructure theme-specific criterion by the 'best' and 'worst' of the five options, which were positioned at 100 (best) and 0 (worst) on the scale. The other options were then scored according to their performance relative to these two reference points, the position of each being determined by relative difference between it and the reference points. Thus, scoring option X at 50 means that the value-added by moving from the worst option to option X (50 points) is judged to be equivalent to the value added in moving from option X to the best option. The results are shown graphically in Figures 2 to 6 for the profiles of each of the five policy options considered in this case study.

Figure 2: Scoring of policy options to increase infrastructure resilience in Mumbai: Profile for “Public transport”



Note: The scale was defined for each infrastructure theme-specific criterion by the ‘best’ and ‘worst’ of the five options, which were positioned at 100 (best) and 0 (worst) on the scale. The same applies for Figures 3, 4, 5 and 6 below.

Figure 3: Scoring of policy options to increase infrastructure resilience in Mumbai: Profile for "Building Codes"

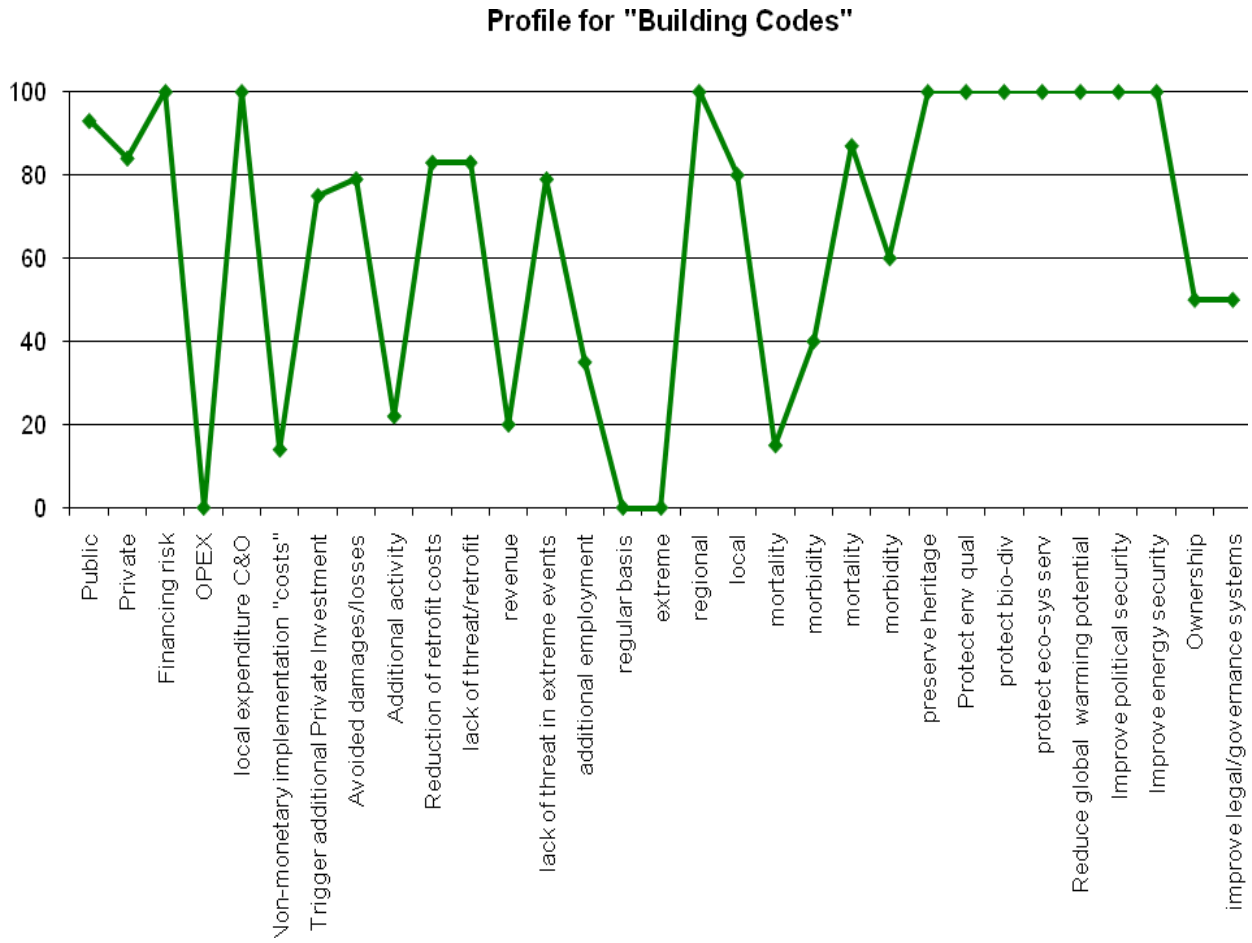


Figure 4: Scoring of policy options to increase infrastructure resilience in Mumbai: Profile for "Warning systems and emergency response"

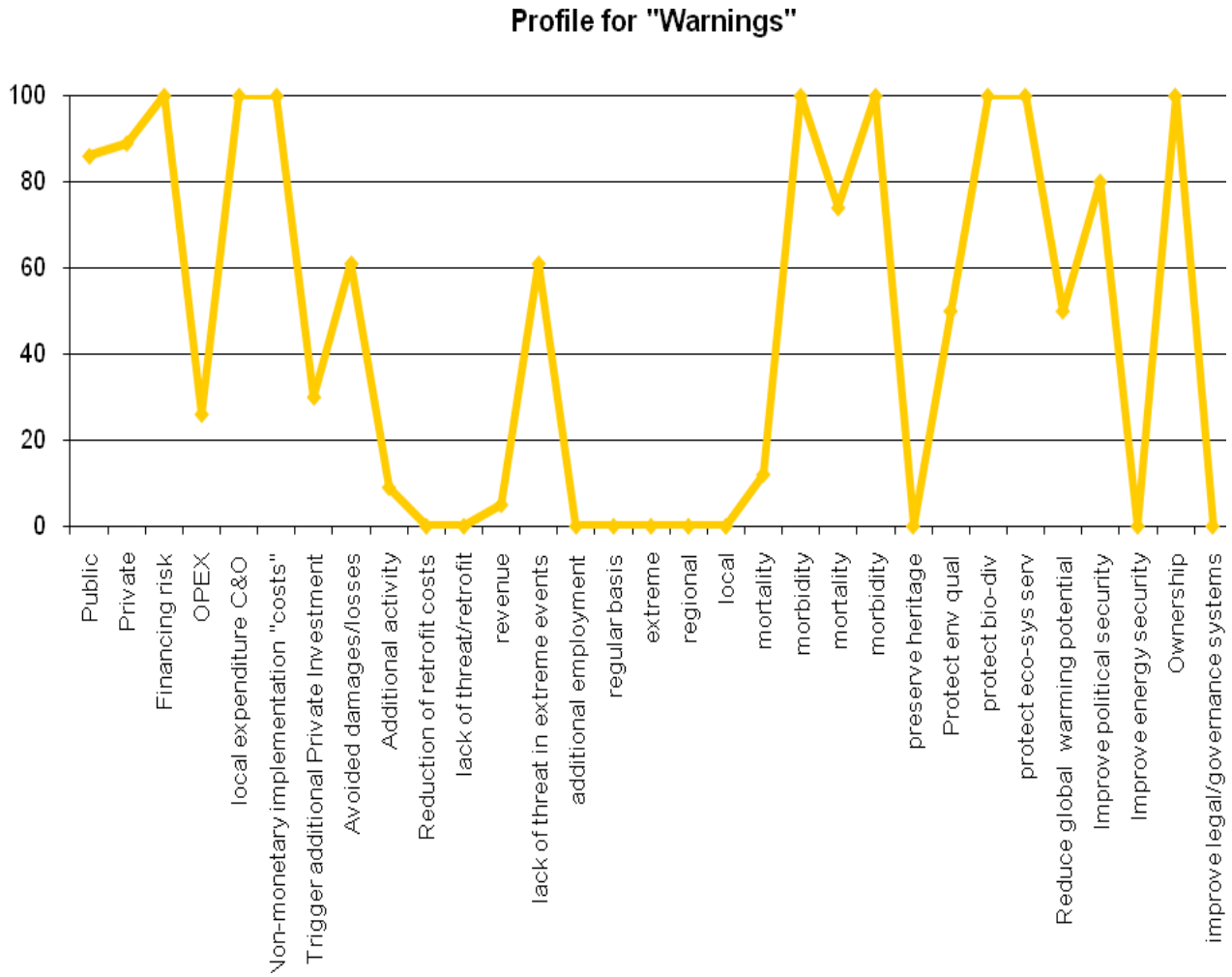


Figure 5: Scoring of policy options to increase infrastructure resilience in Mumbai: Profile for “Insurance”

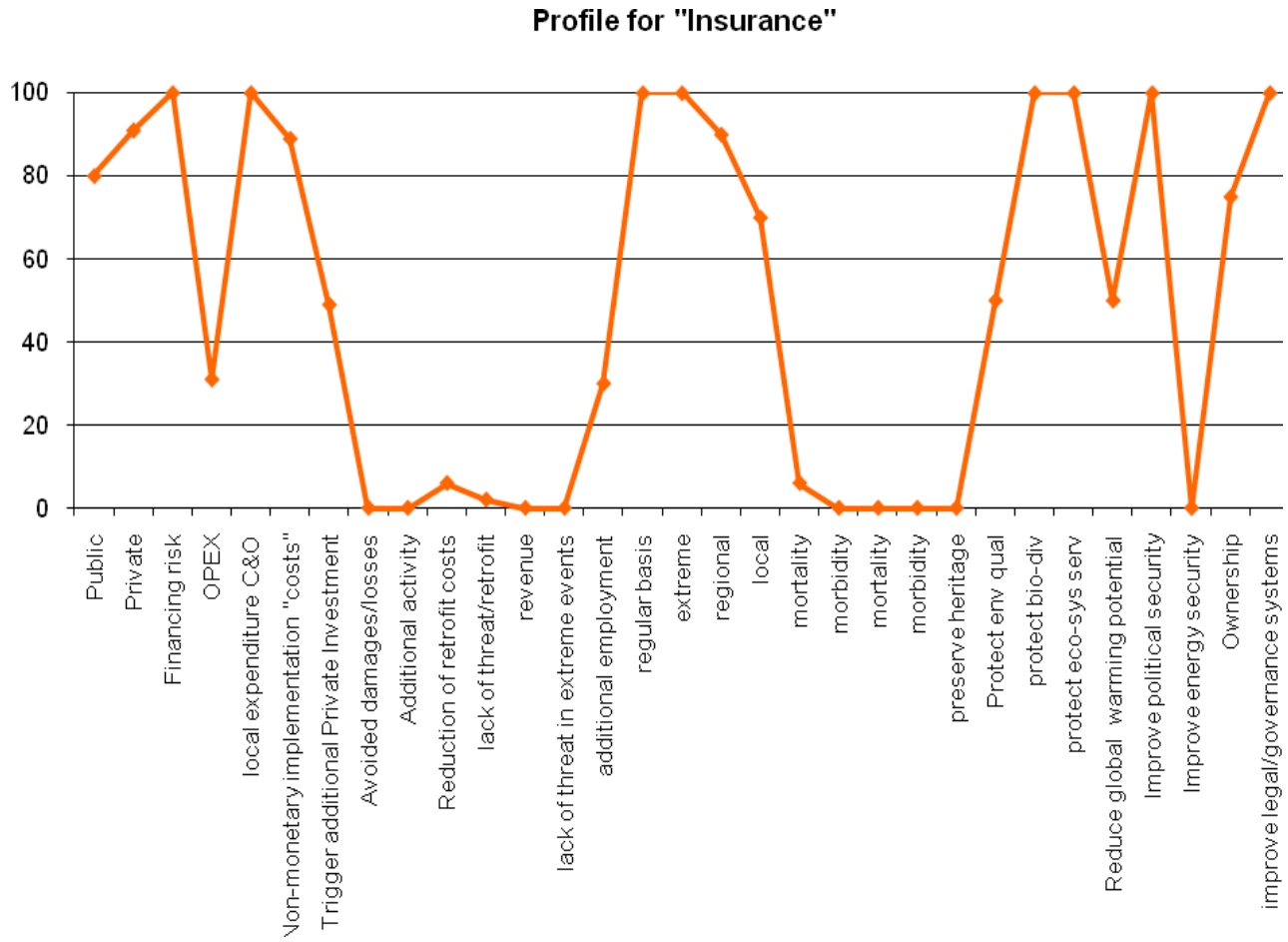
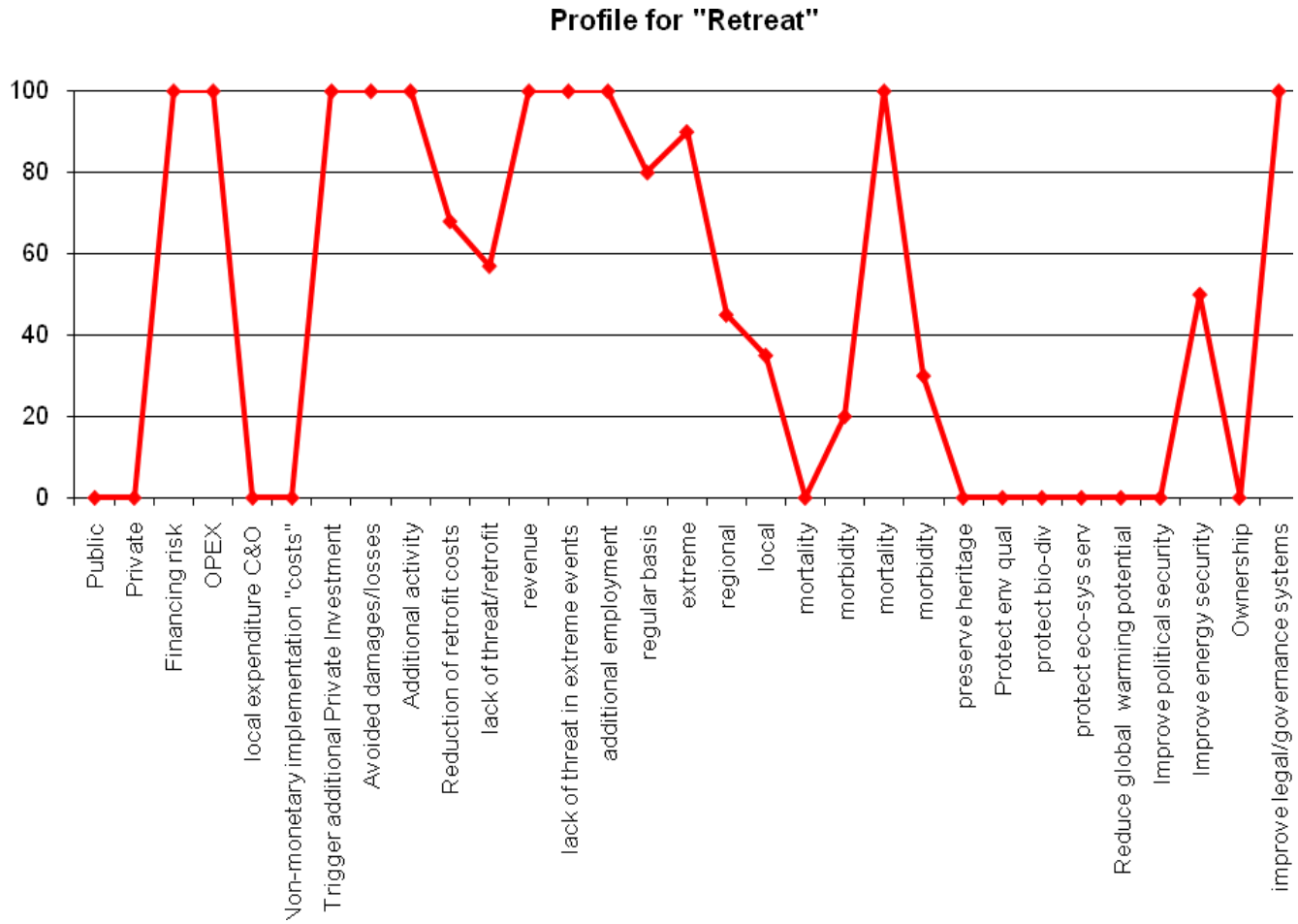


Figure 6: Scoring of policy options to increase infrastructure resilience in Mumbai: Profile for "Enforced retreat"



Some patterns emerge from this analysis, which confirm the complementary nature of the policy options selected for analysis:

- Against the input criteria, the *Retreat* option (in red) clearly fares badly compared with the other options for financial inputs, as this option would obviously be very expensive to implement. Against the output criteria, the performance of this option is extreme in that it is, or is close to, the best or the worst of the options considered on the majority of the criteria: it performs particularly badly against the environmental criteria but is the best option on some other criteria, notably economic impacts.

- The *Warnings* (yellow) and *Insurance* (orange) options have similar performance profiles across the input criteria and the economic, environmental and political output criteria, mostly contrasting with that of Retreat. Their performances diverge with respect to the social output criteria.

- The *Building Codes* (green) option preforms in a similar way to *Warnings* and *Insurance* on the input criteria; on the output criteria, it performs strongly with regard to the environmental and political criteria.

- The profile of the *Public Transport* (blue) option is distinct from the others, performing generally very well on the input criteria and showing some strengths and weakness within each of the four second-level output criteria.

None of the five options dominates or is dominated by any of the other options at this level of analysis.

Weighting the Criteria

The next step was to determine weights for each of the criteria to enable the combination of the scores to reflect the aggregate performance of options at higher levels of the criteria tree. The weighting of sub-criteria within each of the five criteria families/groups (Inputs, Economic, Social, Environmental and Governance), was carried out by the relevant theme expert using the swing-weighting method. These values were then processed using the V.I.S.A (Visual Interactive Sensitivity Analysis) software – a web-based multi-criteria decision-making tool to enable further analysis.(3) Higher level criteria were not assigned weights by the group as they did not have enough information about the likely preferences of the main stakeholders to be able to make this judgment. Instead, extensive sensitivity analyses were carried out to explore the impact of different weightings of the input criteria.

A real benefit of the use of this type of software is the ability to play with the assigned criteria weights in order to understand the impact of changing these – small changes reflecting the consequences of imprecision in their specification and large changes potentially reflecting differing stakeholder perspectives, or changing priorities in different scenarios. This process enables us to identify any 'tipping points' – points at which the definition of the efficient frontier is changed.

Results and sensitivity analysis

The scores assigned to options for each of the infrastructure theme-specific criteria were then aggregated using the criteria weights to determine the overall performance of the options at higher levels of the value tree. The results of the weighted scoring of the five options (shown in

Figure 7) revealed the following:

- *2nd level:* the pattern of performance against the six 2nd-level criteria is markedly different for each of the options: the Retreat option, again, exhibits the biggest range, performing very well on economic criteria but badly on non-monetary implementation costs. The range of scores is narrowest for Public Transport. But no one option stands out as performing consistently better than any other.

3 More details about the software and how it works can be found at www.visadecisions.com

- *1st level:* Retreat clearly perform less well than the other options at this level, while Public Transport performs better on both input and output criteria than Insurance and Warnings (though less well than Building Codes on output criteria). The efficiency plot, which gives equal weighting to the overall scores on the inputs and output criteria, suggests that Public Transport and Building Codes are the best options, as they are the most efficient in terms of the level of output generated for a given input. The most efficient options are closest to the top right-hand corner of the plot.

Figure 7: Results of the scoring of policy options to increase infrastructure resilience in Mumbai for a particular set of weights

Notes: The two top-left corner pink bar-charts display the set of weights chosen for the 2nd level input and output criteria. The two top right-hand corner charts show the scores for the 2nd level input and output criteria. The bottom input-output chart shows the performance of each of the five infrastructure policy

options against aggregated inputs and aggregated outputs: this efficiency plot suggests that Public Transport and Building Codes are the best options.

Sensitivity analysis was performed using different weightings for the 2nd-level output criteria. The outcome was that all of the policy options appeared on the efficient frontier in at least one of the cases examined. In the case of the Retreat option, this only happened when the economic criterion was given a bigger weight. The Building codes and Public transport options were robust to changes in weights and were close to or on the efficient frontier in all the cases. The Warnings option, which had an aggregate input score very close to Public Transport stayed close to the efficient frontier, but was just 'dominated' by Public Transport (i.e. the latter had a slightly higher score) except when a bigger weight was given to the environmental criterion. The Insurance option also had an input score close to Warnings and Public Transport; it was dominated by Public Transport when a bigger weight was given to the economic or social criteria, but was otherwise on the efficient frontier.

The impact of changing the relative weights of input criteria, with the same set of output criteria weighting considered above, was also examined. Generally, the positions of Building Codes and Public Transport improved slightly (i.e. they were more efficient relative to the other options as a consequence of their consistently good performance on the financial input criteria). When the emphasis was reversed and a bigger weight was given to non-monetary inputs, the aggregate input scores of Building Codes and Public Transport, which did not perform well on this criterion, were significantly lower.