Participatory Modeling of Climate Change Impacts on Public Health in Long Beach, California

Discussion from a Workshop Hosted by the RAND Frederick S. Pardee Center for Longer Range Global Policy and the Future Human Condition

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Published by the RAND Corporation, Santa Monica, Calif.

Preface

On March 20, 2017, the RAND Frederick S. Pardee Center for Longer Range Global Policy and the Future Human Condition hosted a workshop called "Participatory Modeling Climate of Change Impacts on Public Health in Long Beach, CA." We assembled a diverse coalition of stakeholders from Long Beach, CA, including analysts, service providers, decisionmakers and interested community organization members. The workshop was designed to explore the potential of participatory modeling. Participants working collaboratively built causal loop diagrams, a tool that supports the conceptualization of policy problems spanning multiple sectors and engagement in long-range strategic thinking. The purpose of this exercise was to examine the systemic connections between climate change and public health issues to gain an understanding of potential impacts over coming decades.

These proceedings summarize the main discussions and final presentations given by participants at the end of the workshop. They will be of interest to anyone concerned with the long-term impact of climate change on public health issues, or more generally to anyone interested in the utility of systems diagramming for the study and practice of thinking and acting meaningfully over the long term, with particular reference to planners and policymakers.

About the RAND Frederick S. Pardee Center for Longer Range Global Policy and the Future Human Condition

The Pardee Center aims to enhance the overall future quality and condition of human life by aggressively disseminating and applying new methods for long-term policy analysis (LTPA) in a wide variety of policy areas in which they are needed most. There has been no shortage of past attempts to think globally about the human condition or the long-range future. What has been missing, however, is a means of tying those efforts systematically and analytically to today's policy decisions. This is the gap the Pardee Center seeks to address.

Questions or comments about these proceedings should be sent to the director of the Pardee Center, Robert J. Lempert (Robert_Lempert@rand.org). Information about the Pardee Center itself and its other projects and initiatives is available online (http://www.rand.org/pardee/). Further inquiries about Pardee Center activities and projects should be sent to the following address:

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This venture was made possible by a generous $5 million pledge from RAND alumnus Frederick S. Pardee. Through this gift, the RAND Pardee Center for Longer Range Global Policy and the Future Human Condition was established in 2001 to enhance the overall future quality and condition of human life by aggressively disseminating and applying new methods for long-term policy analysis in a wide variety of policy areas where they are needed most.

Contents

Figures

Project Description

The *Lancet* and University College of London's Institute for Global Health Commission have stated that climate change is the "biggest global health threat to the 21st century."[1] Climate change impacts on public health are likely to be both direct and indirect. An increase in extreme weather events, such as heat waves, drought, floods, and intense storms, may directly increase mortality and injury. Other environmental effects, such as sea-level rise and ecosystem degradation, may indirectly affect health outcomes through microbial proliferation, spread of allergens and vector-borne infectious disease, food insecurity or under-nutrition, and population displacement.[2,3] Human vulnerability to all weather- and health-related disasters is complex, with social, economic, health, and cultural dimensions.[4] Moreover, climate change is likely to interact with other drivers of change in a community in a systemic and nonlinear way. Adaptation and resilience requires local knowledge, skills, and capacity. Therefore, public health agencies are well positioned to identify local vulnerabilities and build community partnerships in an effort to mitigate the health effects of climate change.[5]

Participatory modeling aims to incorporate stakeholders, including decisionmakers and the public, into the process of developing models for the purpose of eliciting information from stakeholders, appropriately reflecting their interests and concerns, improving stakeholder understanding, and increasing their acceptance of the subsequent analysis. Causal loop diagramming (CLD) is a tool for achieving systemic understanding of a problem; it is commonly used in a participatory group-model building context, and may become the basis for a quantitative system dynamics model. System dynamics modeling is a modeling technique used since the 1960s to address problems that involve feedback, nonlinear dynamics, uncertainty, and time delays, all relevant to public health research.[6] In recent decades, system dynamics has been used in a participatory manner, involving stakeholders and local experts in the model-building

1 A. J. McMichael, R. E. Woodruff, and S. Hales, Climate change and human health: Present and future risks, *Lancet*, Vol. 367, 2006, pp. 859–869, doi:10.1016/S0140-6736(06)68079-3

2 N. Watts et al., Health and climate change: Policy responses to protect public health, *Lancet*, Vol. 386, 2015, pp. 1861–1914, doi:10.1016/S0140-6736(15)60854-6

3 M. Franchini and P. M. Mannucci, Impact on human health of climate changes, *Eur J Intern Med*, Vol. 26, 2015, pp. 1–5, doi:10.1016/j.ejim.2014.12.008

4 M. E. Keim, Building human resilience: The role of public health preparedness and response as an adaptation to climate change, *Am J Prev Med*, Vol. 35, 2008, pp. 508–516, doi:10.1016/j.amepre.2008.08.022

5 A. Costello et al., Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission, *Lancet*, Vol. 373, 2009, pp. 1693–1733, doi:10.1016/S0140-6736(09)60935-1

6 A. Legasto, J. W. Forrester, and J. M. Lyneis, *System dynamics*, North-Holland Pub. Co.; Elsevier/North-Holland, 1980.

process. This technique has several advantages, including the incorporation of local knowledge into the model; achieving buy-in from stakeholders and policymakers who will be in charge of implementing the model's recommendations; and providing opportunities for social learning among the modelers and stakeholders as they jointly discuss complex problems in a systemic way.[7,8,9]

As an exercise in participatory modeling, RAND assembled a diverse coalition of stakeholders from Long Beach, CA, to construct CLDs depicting the impacts of climate change on public health. The purpose of this exercise was to (1) identify public health issues that might be caused or exacerbated by climate change; (2) examine the systemic connections between climate change and other drivers of public health/illness and mortality; and (3) identify feedback loops to gain an understanding of how climate change could impact public health over coming decades. This workshop follows a recent report designed to assess the resilience of the city of Long Beach to climate change in multiple domains.[10] Public health was one topic discussed in this report.

This workshop was part of a participatory short course offered by Dr. Schmitt Olabisi, a visiting scholar at RAND. Students from the Pardee School were involved in planning, facilitating, and analyzing the output from the workshop.

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[7] M. Van den Belt, *Mediated modeling: A system dynamics approach to environmental consensus building*, Island Press, 2004.

[8] L. Schmitt Olabisi et al., Using Scenario Visioning and Participatory System Dynamics Modeling to Investigate the Future: Lessons from Minnesota 2050, *Sustainability*, Vol. 2, 2010, pp. 2686–2706.

[9] K. A. Stave, Using system dynamics to improve public participation in environmental decisions, *System Dynamics Review*, Vol. 18, 2002, pp. 139–167, doi:Doi 10.1002/Sdr.237

[10] AOP, City of Long Beach Climate Resiliency Assessment Report, prepared by the Aquarium of the Pacific (AOP), for the City of Long Beach, California, Aquarium of the Pacific, Long Beach, CA, 2015.

Workshop Description

Workshop participants gathered at the Aquarium of the Pacific in Long Beach, CA, on March 20, 2017, for the causal loop diagramming workshop. Working in groups of five, they were tasked with depicting the impacts of climate change on public health in Long Beach. Groups were encouraged to designate a key health outcome of concern on a citywide scale, but were asked to include critical drivers of the outcome at higher and lower scales if necessary (e.g., state laws, or household-level decisions that affect health outcomes in the aggregate). Social, environmental, political, and economic variables were all considered as part of the exercise. After the small group diagramming exercise, groups presented their diagrams to other participants, and the discussion around the diagrams was recorded with written notes. The research team then digitized the diagrams using Vensim® software, and generated a combined diagram from all six small groups. These diagrams are presented later in this section, as Figures 1 through 7.

To enhance interpretation of the diagrams, the two kinds of feedback represented in a CLD should be explained. A loop in which the initial action is reinforced is termed *reinforcing*, and tends to lead to runaway growth or decline. A loop in which the initial action is opposed or dampened is called *balancing*, and tends to exhibit stabilizing or equilibrium-seeking behavior. Many complex systems contain both types of feedback loops, and the behavior of the system depends on which loop dominates. A quantitative simulation is necessary to determine loop dominance; this information is not contained in a CLD. The six causal loop figures generated by workshop participants are detailed in Figure 7.

Figure 1 identifies heat-related illness as the central variable of concern. There are two feedback loops: one reinforcing (+) and one balancing (-). As heat-related illness rates increase in Long Beach, social vulnerability also increases (because residents spend more money and time on health care, for example). This, in turn, can exacerbate pre-existing health conditions through stress, leading to increased susceptibility for heat-related illness in a reinforcing pattern. One way to address heat-related illness is through providing cooling centers. As more people use cooling centers, demand for these services should drive increased access to alternative cool spaces in the community (green spaces and air-conditioned residences, for example). With access to alternative cool spaces, cooling center use should decrease, in a balancing loop.

Similar to Figure 1, deaths and hospitalizations from extreme heat are the public health variable of interest in Figure 2, which contains two reinforcing feedback loops and two balancing feedback loops. As deaths and hospitalizations from extreme heat rise, household income is affected through lost work days. This, in turn, increases vulnerability to extreme heat through the range of mediating mechanisms listed by the group in the center of the diagram—linguistic and social isolation, occupation (access to quality jobs), lack of access to cooling centers, air conditioning, transit, healthcare, or parks, homelessness, and health (il)literacy. All these

Figure 1
Heat-Related Illness

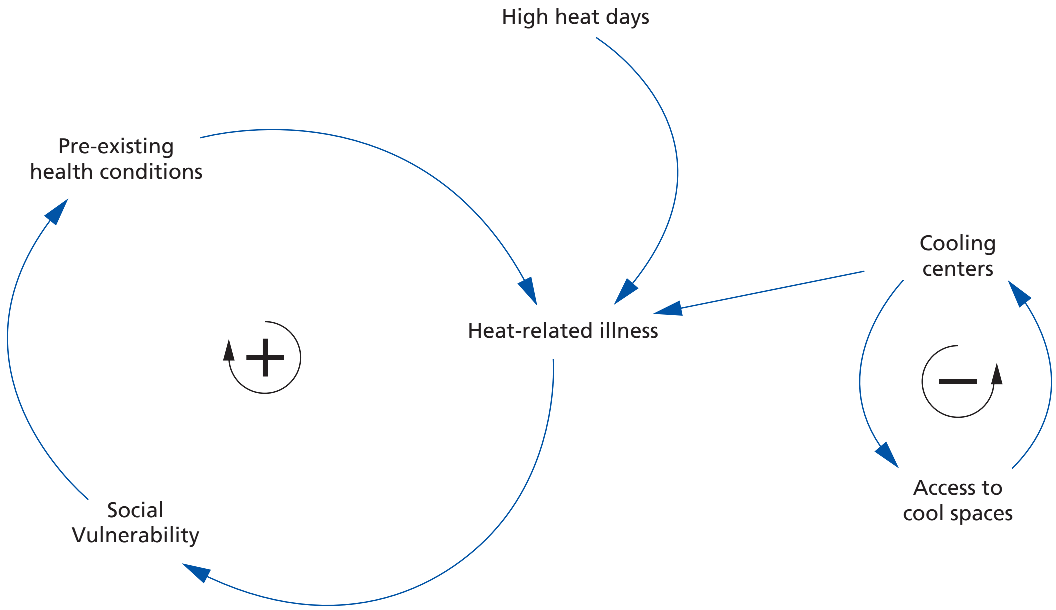

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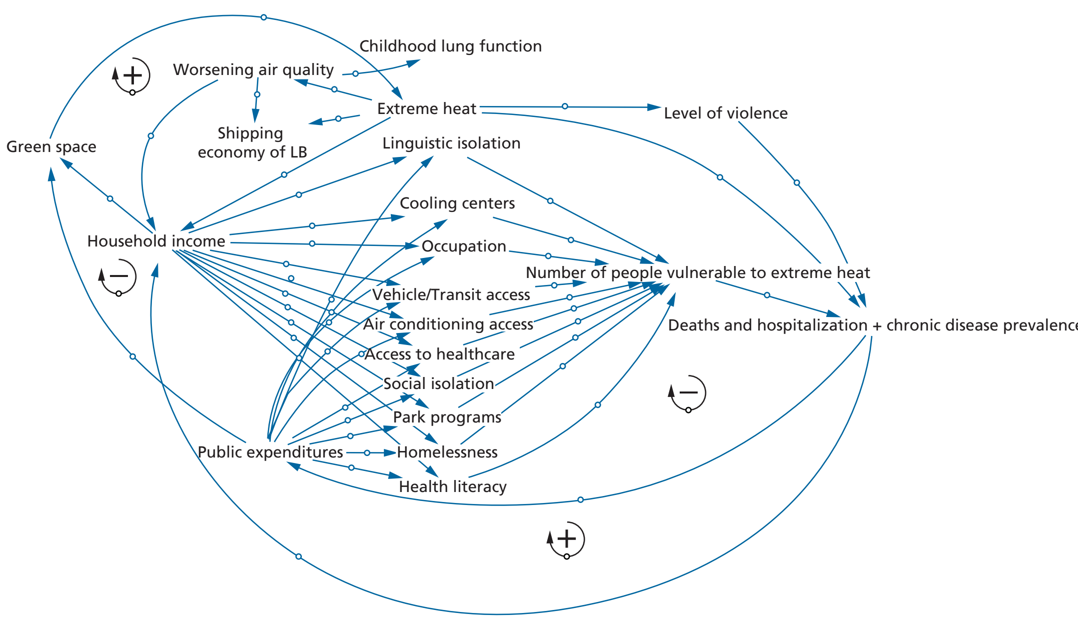
Figure 2
Deaths and Hospitalizations



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things increase the number of people vulnerable to extreme heat, leading to more deaths and hospitalizations (reinforcing). However, deaths and hospitalizations from extreme heat may also prompt higher public expenditures toward the mediating mechanisms listed, which would reduce the number of people vulnerable to extreme heat and reduce deaths and hospitalizations (balancing). Public expenditures could also go toward creating and maintaining green space, which would reduce the impact of extreme heat on vulnerable populations, thereby reducing deaths and hospitalizations (balancing). Finally, as extreme heat worsens air quality, household income is impacted through missed work. This reduces household access to green space (assuming lower-income families live in neighborhoods with less green space), thereby reinforcing the impacts of extreme heat on these families (Figure 3).

Figure 3 centers on respiratory problems and cardiovascular diseases as the critical health outcomes driven by urban heat. However, flooding is also included as a climate change impact that could affect health outcomes indirectly. Figure 3 contains three reinforcing feedback loops. Cardiovascular disease affects job performance through missed work days, etc., leading to increased vulnerability of those who suffer (reinforcing). A similar dynamic holds for vulnerable populations who suffer from respiratory problems (reinforcing). Finally, vulnerable populations are typically less able to access quality health care, which may lead to more respiratory problems and cardiovascular disease (reinforcing).

As with Figure 3, cardiovascular and respiratory health are the health outcomes of interest in Figure 4. The figure contains two reinforcing feedback loops: first, respiratory disease and cardiovascular disease exacerbate one another. This cycle is fueled directly by poor air quality and indirectly by extreme heat days, exacerbated by climate change. Second, neighborhood walkability affects property values, improving the socioeconomic status of residents, thereby reducing crime, which leads to better walkability (reinforcing).

Heat-related illness is the key variable of concern in Figure 5, with seven reinforcing feedback loops and three balancing feedback loops. Each of these loops is in a tightly coupled dyad: social capital/money (that is, income); awareness of heat risk and the Long Beach alert system; Alert Long Beach and communication resilience; communication resilience and trust in government; trust in government and risk awareness; social vulnerability and homelessness; and, finally, a reinforcing feedback loop encompassing pre-existing health conditions, home-

Figure 3
Urban Heat

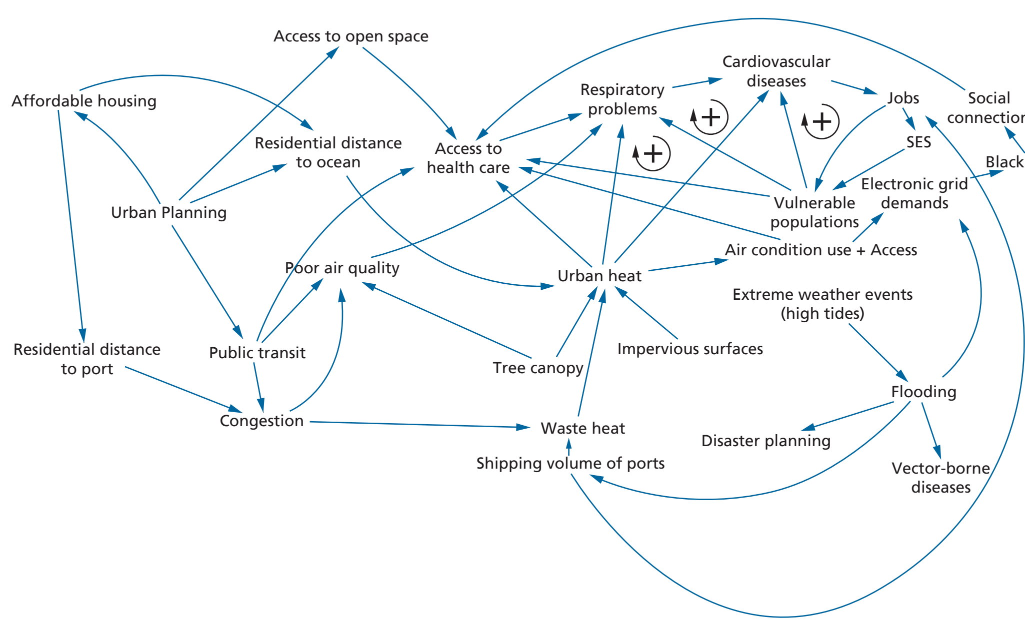

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Figure 4
Cardiovascular and Respiratory Health

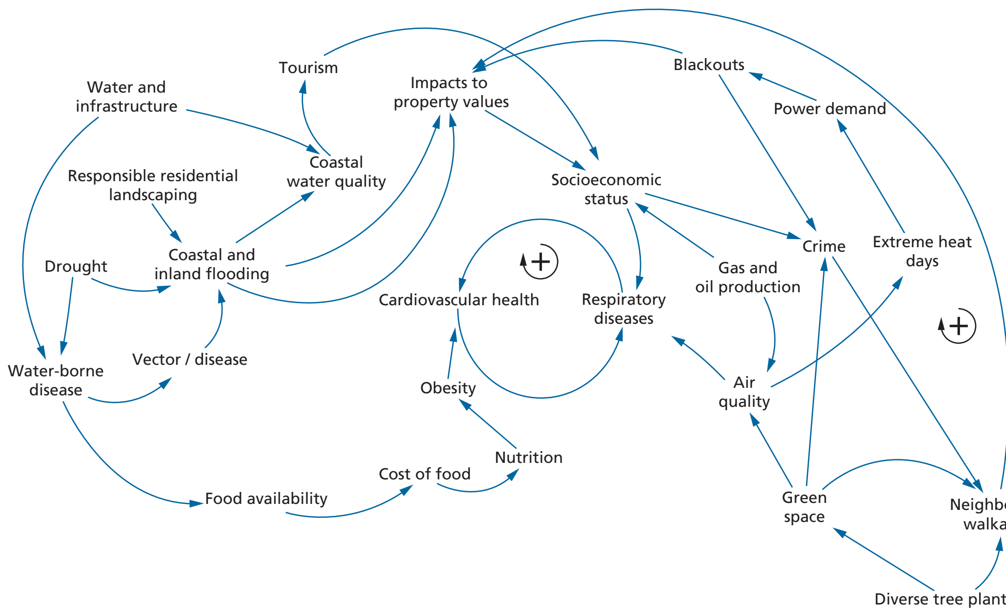

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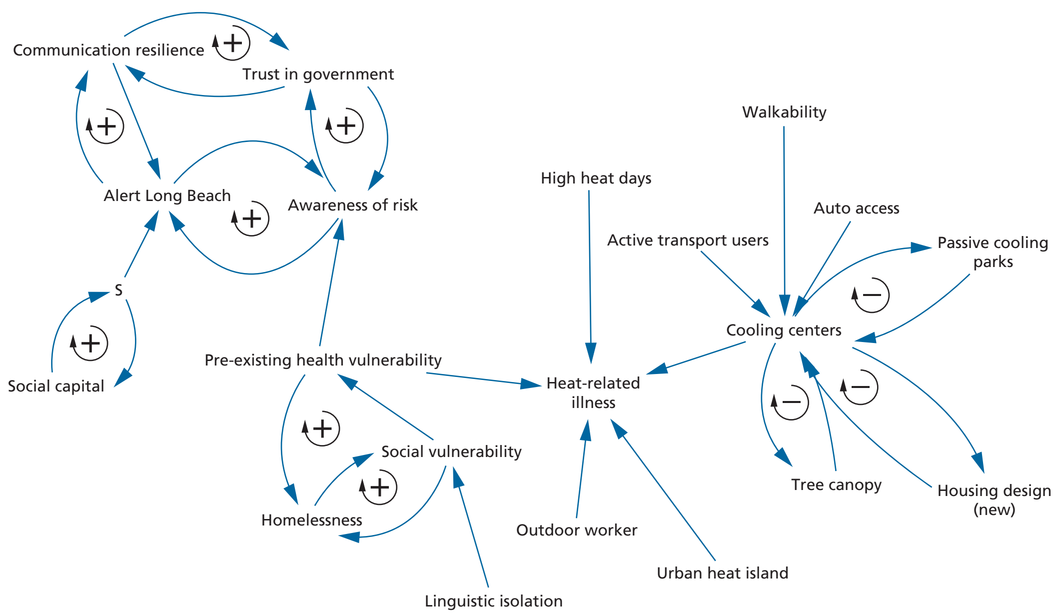
Figure 5
Heat-Related Illness



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lessness, and social vulnerability, which all reinforce one another. The balancing feedback loops all involved cooling centers. As cooling center demand goes up and they become crowded, alternative means of keeping cool would be sought out, including parks, tree canopy, and passive cooling housing design. All these things would reduce the need for cooling centers, generating a balancing effect on cooling center use.

Heat vulnerability, leading to heatstroke, is the health outcome variable in Figure 6. There are two reinforcing feedback loops: homelessness leading to a lack of access to infrastructure, reinforcing homelessness; and education and climate change awareness reinforcing one another.

The composite diagram generated by combining all the small group diagrams is pictured in Figure 7. All feedback loops included in the original diagrams are depicted. Outcome variables

Figure 6
Heat Vulnerability

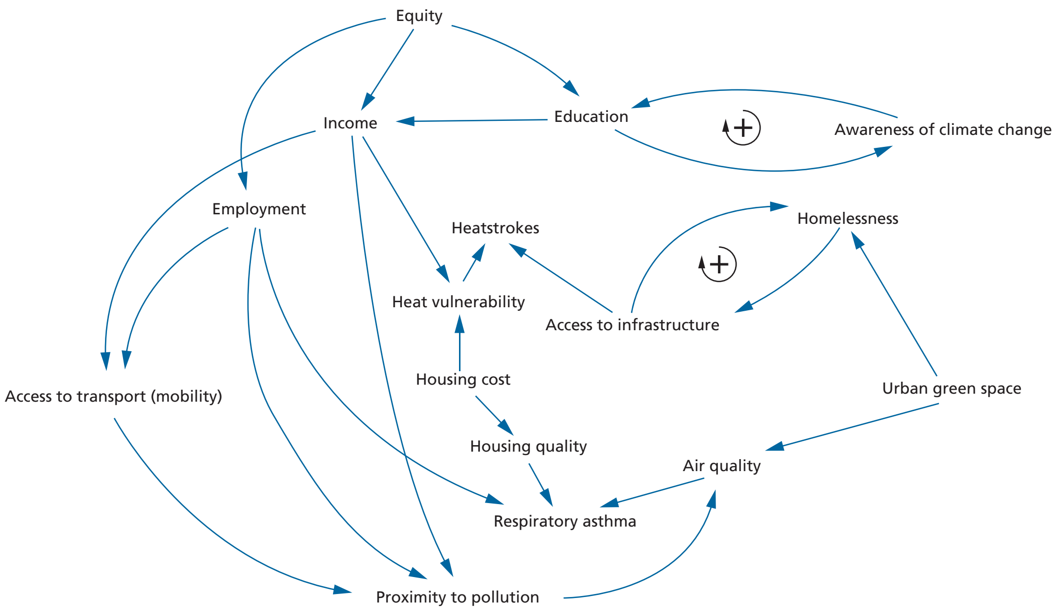

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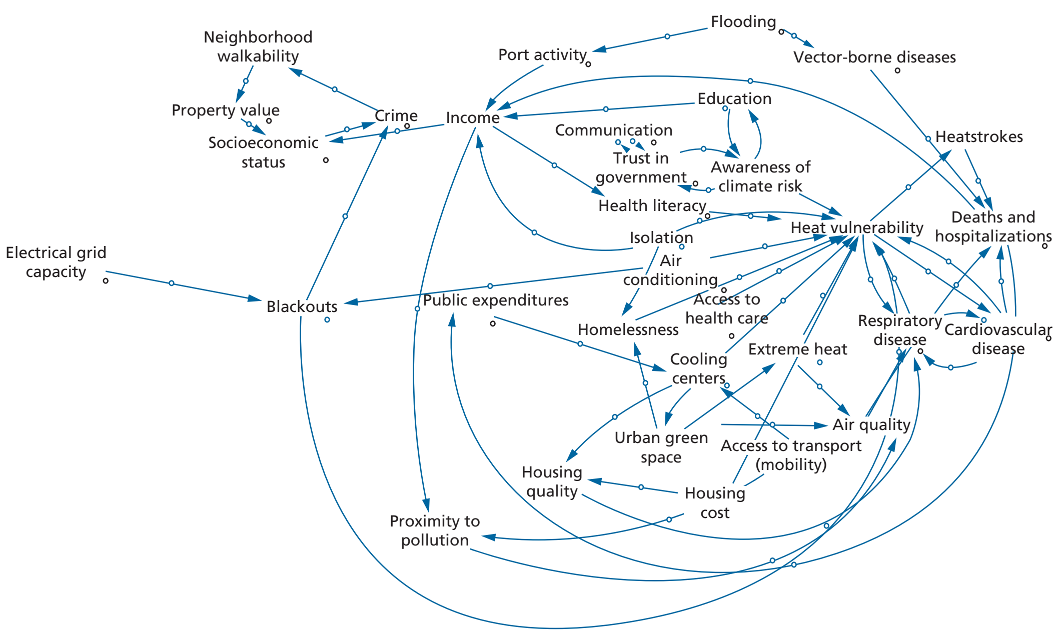
Figure 7
Six Causal Loops Composite Diagram



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are pictured toward the right of the diagram, while contributing variables are pictured on the left. Some arrows were left off for legibility; particularly, connections between income and all the variables in the center of the diagram (from top to bottom, health literacy through access to transportation) are not present, nor are connections between public expenditures and these variables. Climate impacts described in the workshop—extreme heat and flooding—are outlined in red. Ultimate variables of concern are deaths and hospitalizations. The health conditions that lead to deaths and hospitalizations are vector-borne diseases, heatstroke, respiratory disease, and cardiovascular disease. These are outlined in blue.

Discussion and Conclusions

Each of the groups quickly focused on health conditions caused or exacerbated by extreme heat, indicating that this is the most immediate and concerning health-climate linkage for Long Beach stakeholders. Groups pointed out that extreme heat both exacerbates underlying conditions, such as asthma and other respiratory illnesses, and compounds the effect of these illnesses on the vulnerable by worsening air quality. This could lead to a downward health spiral for vulnerable populations as extreme heat events become more common. Potential interventions could be sorted into short-term (cooling centers, hydration stations) versus long-term (tree cover, access to better quality housing).

Multiple socioeconomic factors contribute to the vulnerability of Long Beach residents to climate-related health impacts, according to workshop participants. These include health literacy, access to health care, homelessness and housing quality, access to transportation, etc. Household income and public expenditures act on these socioeconomic variables and make up reinforcing feedback loops with health outcomes, as described. This implies that increasing household income and public expenditures would have more of a multiplier effect on reducing deaths and illnesses than interventions like providing cooling centers, because they are involved in multiple feedback loops. There is an interesting trade-off with low-income groups in Long Beach: living closer to the water has a protective effect on high heat days, but waterfront properties are more susceptible to flooding. This implies that potential impacts of climate change are highly site-specific, emphasizing the need for local consultation.

Efforts to reduce deaths and hospitalizations related to extreme heat and flooding should also consider the feedback effects that could counterbalance those efforts. For example, increasing air conditioner use in an attempt to combat heat vulnerability—at private residences or cooling centers—could overload the electrical grid, leading to more blackouts, and, therefore, more heat vulnerability. Workshop participants also mentioned that blackouts perpetuate crime sprees, which also have negative effects on health.

Overall, this exercise clarified the systemic nature of the public health impacts of climate change in Long Beach by revealing potential policy tradeoffs, as well as underlying socioeconomic drivers of vulnerability to extreme heat, as described above. While the stakeholders present represented a diverse cross-section of decisionmakers affiliated with the public health sector, the voices of those most vulnerable to climate change impacts (e.g., the poor, elderly, and those with chronic health conditions) were not represented in the workshop. This is one limitation of the exercise; another is the qualitative nature of the diagramming exercise, as time did not allow for quantitative simulation of the conceptual models developed by the stakeholders. Future development of this work could include a quantitative model based on the CLDs, and data collection around some of the key variables in the model.