ESRC Strategic Network:
Data and Cities as Complex
Adaptive Systems
(DACAS)

CASE STUDY REPORT

CASE STUDY 02.A
AIR POLLUTION AS AN EMERGENT PROCESS (INDIA)

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20–24 JUNE 2016

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CASE STUDY 02:

SUSTAINING THE TRANSITION – A TALE OF TWO CITIES

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Case Overview

This case contrasts the response to two health crises in India. One of the most recent outbreaks of pneumonic plague occurred in the city of Surat, Gujarat in 1994. A series of changes were made to the structural organisation of the city and improvements in sanitation brought many co-benefits. The city has gone from being one of the filthiest cities in India to being recognized as one of the cleanest. By contrast, Delhi struggles to manage ever increasing air pollution despite a raft of measures that have been introduced and constant legislative pressure. Why have measures worked in one case and not the other?

Problem Formulation

In the city of Surat, a serious health issue was tackled successfully with an approach based on 'localism'; and this approach seems to have had lasting benefits. In the city of Delhi, however, a range of approaches have been used to tackle what is arguably an equally serious health problem – that of air pollution – but with limited long term success. What has led to these markedly different outcomes?

Both cities chose to address the issues by changing existing governance processes and legislation. The changes were made against a background of the high levels of complexity inherent in today's large cities generally. The success of the changes will have been dependent to a large extent on how well they addressed the complexity of each city.

To some extent, Surat case is more straightforward than Delhi given the trigger for the plague was largely due to a single cause, in contrast to that of Delhi. It was concluded therefore, that attempting to identify the reasons for success in Surat, and then seeking to apply the lessons learned to air pollution control in Delhi would be the wrong approach; Surat's solutions were unlikely to address properly the complexity exhibited by Delhi. Instead, it was decided to concentrate problem formulation on consideration of Delhi itself.

Initially, problem formulation focused quite narrowly on thoughts of identifying the different types of pollutants, their relative importance in terms of the contribution they make to overall air pollution, and the sources of those pollutants; this approach seemed to have the benefit of being relatively tractable from a mathematically point-of-view. As policy and regulation is designed to incentivise changes in the point sources of various pollutants, such as large power plants or vehicles, evaluation of local polices normally begins with an understanding of the origin of the problem. As discussions progressed, however, it became clear that answering those questions was only a small part of the problem, and that the big issue was why steps taken by city government to tackle these pollutants had failed. From that the idea grew that the problem was one of governance, rather than chemistry (even if all air policy is based on the results of measuring the quality of the air), and that problem formulation should focus on that. The problem was then broadened to comprehensively take into account the various social and political factors that influence the degree to which governance action effectively decreases levels of pollutants that are a threat to human health

A wide range of governance strategies with the potential to influence the development of city air pollution policy and strategy, were identified. With globalisation in mind, it was recognised that actions to curb air pollution would have to take account of interests at global, national, regional, district and city scales. As there is a need for consensus among various stakeholders in designing and implementing action plans to address air quality, the importance of political cycles was also noted. This temporal element extended to consideration of horizon-scanning for emerging technologies that could have a beneficial effect and to the freedom of government to act quickly within the confines of existing supply chains. Alignment of physical/political boundaries was seen as important, with misalignment leading to conflicts in decision-making (either through overlapping jurisdictions or absence of control). Stakeholder identification was seen as a necessity, together with a clear understanding of the extent to which they were to be involved in establishing the ‘root definition’ of the problem, and arriving at a mutually acceptable accommodating solution. Linked with this was consideration of cultural issues such as local traditions and the likelihood of corruption; health, including physical and mental wellbeing; education; social standing and the power to influence; and existing transport and economic policies. Some of these factors are shown in the diagram in Figure 1.

Figure 1 indicates that problem definition must consider soft and hard systems: soft systems being those involving predominantly the actions of human beings, and hard systems being those involved in the design, construction and operation of infrastructure. Existing hard systems can be described through a process of reverse engineering aimed at eliciting system data for integration in system models. The level to which such systems should be defined is dependent on the question being addressed, and is something that would emerge in the course of an investigation. Soft systems, on the other hand, can be more difficult to describe for a variety of reasons, including difficulty in obtaining the necessary data. For soft systems the level of system definition again depends on the question being addressed: for example, from a quite detailed analysis of behaviour using agent-based techniques, to a higher level analysis employing heuristics of human behaviour.

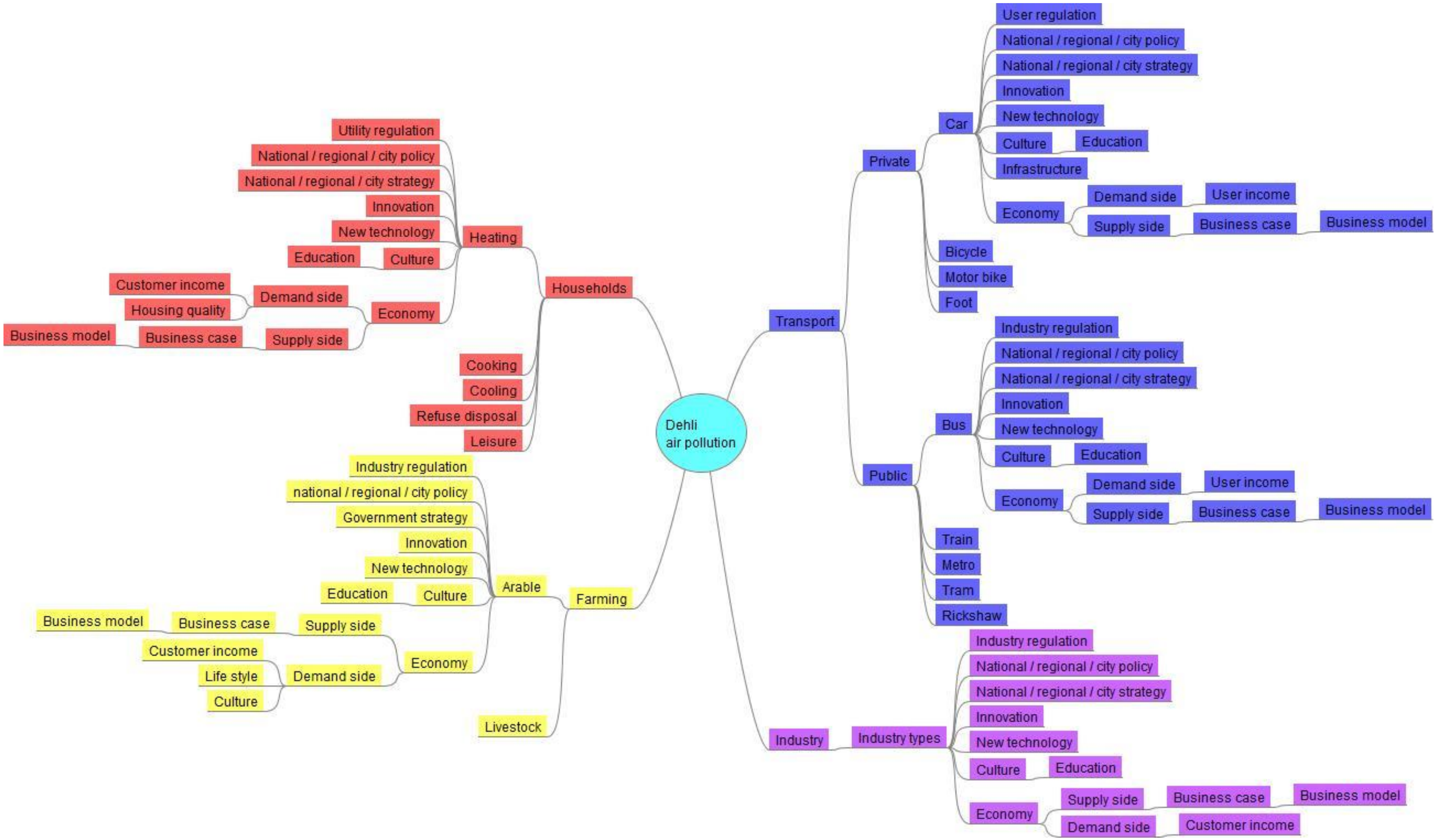

Figure 1. Factors with the potential to influence governance actions to tackle air pollution in cities.

Concept Transferability

During the discussions, several concepts, elements and methods of systems and complexity sciences stood out, suggesting that these two fields can offer helpful insights and approaches to deal with the air pollution issue in Delhi.

Phase transitions

Can phase transition analysis techniques from chemistry and biology be used to predict sharp changes in policy, as generally arising from a change of government following an election? As suggested above, positive alignment of government policies across national, regional and city scales is helpful to successful implementation of government initiatives. Alignment can change for better or worse during elections, with changes often being sudden and unexpected. Viewing these phase transitions may help generate knowledge that could be used to promote positive change, or militate against negative change (though this latter option may be seen as undemocratic).

Behavioural heuristics and game theory

Can human behaviour heuristics emerging from studies of psychology and behavioural economics help provide a better understanding of the decision-making processes around air pollution, and about how the population will respond to them? What sort of ‘hard-wired’ decision-making heuristics do humans use, and do these heuristics come with probability distributions? An example of such a heuristic is the ‘hot hand syndrome’, which takes its name from basketball. Basically, it is saying that if people observe a number of successful actions, they will expect subsequent actions to be successful as well. Can these heuristics be used to inform decision-making based on game theory?

Collective behaviour

To what extent can existing knowledge about the behaviour of large groups (for example, swarms and flocking) be applied to predict the response of city populations to actions aimed at curbing air pollution?

System dynamics and causal loops

Soft systems methodology has identified the importance of understanding how a system works as a first step towards improving things. Can the reverse engineering techniques of systems engineering help in this area? Can causal loop diagrams developed through reverse engineered models involving the stakeholders provide a framework for identifying sources of system value, which might help to promote adoption of better air pollution control measures?

Agent-based modelling

To what extent can agent-based modelling be used to tie all these approaches together? Work on collective behaviour etc. can contribute to development of the rules governing agent behaviour.

Morphogenetic engineering and urban metabolism

What can we learn from the way in which cells deal with waste management that could be applied to cities? To what extent does this tie in with the science of urban metabolism – particularly Pincetl's 'expanded', holistic view of urban metabolism, which takes account of politics etc.?

Appropriate Methods

As we advanced the discussions, it became more clear to us that the solution for the air pollution issue in Delhi should pass through to re-organizing the system, to better implement and operationalize schemes to lower pollutant emissions. That is, the several different sectors and stakeholders involved in the problem might reconcile or steer their individual goals and actions, and the best level of governance for critical points in the system might be found in order to deal with the problem.

The best course of action for us was, then, to use soft systems methodologies, which would help stakeholders (1) to have a broader sense of the systems' dynamics and structure, (2) to understand their role in the system and (3) to think of strategies to change the whole system to a more desirable state.

Bringing stakeholders together to discuss the air pollution issue in Delhi using soft systems methodologies would allow them to put their perspectives on the table, moving from individual mental models to a collective understanding about the problem. It is also an important empowerment exercise, as those involved in the problem would contribute to its solution, re-orienting the systems goals and functions.

Additionally, this approach would rely less on the knowledge we have about the India and Delhi context (governance structure, cultural context, legal issues etc.) and the scarcity of data to build a simulation model – two important limitations to adequately solve the problem – and more on shared knowledge and information by those within the system.

Model Typology

We suggest a three-step community-based participatory modelling. First, we would develop a causal loop (influence) diagram to map the elements and relationships, within and across levels of governance, involved in the air pollution issue in Delhi. Key sectors and stakeholders must be identified and invited to participate. The diagram would be constructed collectively by the stakeholders in two or three half-day workshops. These workshops would introduce the process of modelling and symbolism of a model to participants, create a shared vision of a modelling project and lead to the elaboration of a causal loop diagram. More details can be found elsewhere (see the Hovmand's works on 'Bibliography').

In the second step we would build a systems dynamics model based on the casual loop diagram and inputs from other stakeholders about the real system. This model would have an educational and experimental purpose. It would be a tool that allows stakeholders to test and 'play' with different decisions, strategies and governance levels in order to broaden the understanding of what factors influence the actual functioning of the system (pathways, delays, feedbacks, flows of information, bottlenecks etc.) and to gain insights into how to achieve more desirable outcomes.

Finally, further workshops with stakeholders would take place to allow them to put their hands on the systems dynamics model and facilitate the co-creation of a new governance architecture to tackle the air pollution issue in Delhi.

Conclusion

This case study showed us that successful experiences are not always fully transferable to other contexts, as from Surat to Delhi. Sometimes, the systems' structures and dynamics are too different and a fresh look is needed. Important lessons are often learnt the hard way.

Not all complex problems must rely only on mathematical and simulation methods. In complex social systems, the observed systemic resistance to changes comes, many times, from opposite goals and actions among stakeholders, each one pushing in a different direction. In these situations, a soft systems methodology would have great potential to solve these antagonisms and bring the whole system to a more desirable state for everyone.

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