7 Decision Support Tool Structure: Software options and methodologies

Chapter Summary

This chapter describes a distinct new class of scenario-modelling urban design tools, and it discusses a specific prototype tool generated as part of this research.

This chapter is drawn from the peer-reviewed paper "Prospects for scenario-modelling urban design methodologies" (Mehaffy, 2013). As noted previously, another section of that paper forms the conclusion of Chapter Two, "Counting Urban Carbon."

How can we develop a useful design decision support tool that can quantify the magnitude of GHG emissions through scenario-modelling? We now have some evidence about the factors that are likely to influence the results, which we can use as "Bayesian priors" within our methodology. We also have the elements of a methodology based upon existing scenario modelling and other approaches.

Clearly the contribution of the different factors will vary significantly based upon specific local conditions. Any modelling strategy will need the capability to express variations in these local conditions. More detailed research is needed to be able to account for these variations, and the ways that they interact. At the same time, some of this research will have to be highly localised (Johnston et al., 2000, Kates et al., 1998).

Moreover, a modelling tool will also have to account for the fact that these different factors do not merely aggregate, but also interact. Reductions from one factor, such as dwelling size, may then limit the available reductions from another factor, such as whether a dwelling is attached or detached. Some factors may also increase the available reductions from other factors. This means that the elements of the model will need to be able to interact with each other through mathematical functions operating not just in series, but within an interactive network. We discuss the strategy for developing such an interactive modelling structure below.

In spite of these variations, the evidence we have summarised does suggest that the total effect of such factors is likely to be a large one – taken together, perhaps in the range of one-third of all GHG emissions from human activity (Mehaffy, 2009). This helps to account for the actual observed difference in per capita emissions between cities, which is difficult to account for apart from urban morphology (World Resources Institute, 2009).

Of course, being able to account for and thereby model the relative reduction that is theoretically available between two theoretical urban morphologies is one thing. Actually changing the morphology of new urban developments to achieve significant reductions – let alone existing urban developments – is quite another challenge (Ewing et al., 2007). This will depend upon how much new development is occurring (a significant amount in developing countries like China and Brazil), and how much "retrofit" development is occurring elsewhere (and the extent of possible changes in morphology as a result). In any case, the first requirement is clearly the ability to account for and to model such a difference.

Also significant is that feedback from such a model can be tied to implementation strategies and incentives, which will make it more likely that the reductions shown in the model can actually be achieved. Various scenarios can be modelled, not only for their greenhouse gas reductions (and possibly other metrics of interest), but also for their feasibility. In this way, an optimum path can be identified through the testing of alternate "scenarios" in a stepwise, evolutionary process (Hopkins and Zapata, 2007).

There are two benefits from such a process. One, the alternatives identified by the model can serve to improve the likelihood that beneficial changes in morphology can in fact be made. And two, the outcome of such changes can itself be modelled, and the results can be used to fine-tune the model, and thereby improve its accuracy and usefulness (Condon, Cavens and Miller, 2009).

This situation presents a significant opportunity to develop new models that do just that. More specifically, they allow urban design scenario planning, with real-time evaluations of the various factors that might be able to be varied in the design. As we will discuss, such a methodology allows local evaluation, experimentation, and customised implementation. Over time, it allows the kind of evolutionary improvement of the model that we have described.

Moreover, such a system can itself be developed and improved by many collaborators, using so-called "open-source" collaborative methodologies. In such a system, different collaborators are able to make local incremental improvements, increasing the quality of the result. There are promising examples of such systems whose efficacy has been well demonstrated in the software development world, including software such as Linux and so-called "Wiki" systems such as Wikipedia. (von Hippel and von Krogh, 2003; de Laat, 2007; Voss, 2005).

Thus, such a modelling system, tied to a cycle of research feedback and empirical results, could in principle improve in accuracy and effectiveness over time: in effect, the system would "learn."

§ 7.1 Computer modelling, open-source methodology and design patterns

Thus, there is considerable evidence to suggest that a computer-based scenario-modelling system is needed, and one that allows collaborative open-source development.

Among planners, the practice of using open-source software to develop and apply new methods of scenario modelling is already well advanced (Condon, Cavens and Miller, 2009; Holway, 2011). Modular software packages are being applied and developed further, including *Envision Tomorrow* by Fregonese Associates, and *UrbanFootprint* by Calthorpe Associates. These and other systems are explicitly written to work with "modules" written by others, which can be developed to model more specific or local features of the urban environment.

Such a modular approach is in fact a useful and often-used feature of software design, including software designed according to "design pattern" protocols (Gamma et al., 1995). As discussed in the previous chapter, design patterns are guides to software developers that provide information about the design elements that are most likely to be effective in a given context. Not only are there entire packages of software that function in this modular format, but even small parts of the software system consist of modular "patterns" that work together according to grammar-like rules (hence the term "pattern *language*"). This "object-oriented" flexibility provides much of the programming power for the methodology.

As noted previously, the development of design patterns also led directly to the development of Wiki, which can be thought of as a set of pages (originally, patterns) that can be collaboratively developed, edited and exchanged (Leuf and Cunningham, 2001). As the pages are developed, their information tends to grow more useful and (in the case of modelling information) more accurate. The best-known example of this phenomenon is the widely-used on-line encyclopedia, Wikipedia (Voss, 2005).

However, it is important to recognize that, under the right circumstances, Wikis are themselves capable of serving as modelling methodologies. In a sense, a page on Wikipedia is a model of a portion of human knowledge, expressed in relation to other knowledge via hyperlinks to other Wikipedia pages. Just as human knowledge can be refined, errors can be corrected, and more knowledge can be added, so Wikipedia is capable of refinement, correction and improvement. (This requires a degree of rigour in the methodology, as we discuss in the Appendix.) As we will see, this capability will prove useful in the software now under development.

§ 7.2 A scenario-modelling methodology based upon open-source software

Armed with these insights – and with the broader modelling methodologies previously specified in Chapter 6 – we are now ready to discuss the specific structural specifications of a scenario-modelling urban design methodology. The system will have the following attributes:

1. It is web-based, making it available to a wide community of users as well as developers;
2. It is simple enough to be user-friendly, but robust enough to be effective;
3. It is able to model different scenarios, with a range of input values, relatively quickly and effectively;
4. It is evidence-based and transparent – that is, the sources of evidence can be identified, further examined, and if superseded with new evidence, replaced;
5. It is developed and refined through an "open-source" process – that is, it is open to improvement by those who have the expertise or the evidence base on which to do so (this is particularly valuable in achieving refinements over time);
6. It has a capacity for interactive network modelling and whole-systems characteristics.

Such a technology would offer a notable advance in modelling capability. Most computer-based modelling systems today are "black boxes" – it is difficult or impossible to follow the calculation process, and there is typically no readily identifiable relationship to the research on which the calculations are based. Furthermore, even for open-source systems, the development of new features requires possession of the original source code as well as considerable programming expertise. Lastly, modelling systems typically require exceedingly complex calculations that are highly sensitive to initial conditions, which can produce erratic and unreliable results.

As we have discussed previously, software technologists have produced several innovations in recent years that are relevant to our needs:

1. ***Wiki.*** As we have seen, this web-based content-sharing platform is simple and powerful, and applications like Wikipedia (perhaps the best known example) are able to evolve rapidly through open-source development. Hyperlink capability allows elements to be networked, and provides the capacity to link to citations of peer-reviewed research and other evidence for examination and possible revision.
2. ***Data interchange and calculation plug-ins.*** Web pages can now handle relatively sophisticated calculations with new modular data-interchange formats like Javascript Object Notation (JSON).
3. ***Federated open-source.*** Instead of open-source development on a single master copy (like the centralized copy of Wikipedia) federated open-source is a "next-generation" innovation that allows simultaneous development and differentiation of multiple local copies. Beneficial developments can be re-migrated to other copies, or back to the original. New applications can be quickly developed that do not just explore new uses of the original source code, but alter it. The result is faster and more diversified development of innovations.
4. ***Design patterns and pattern languages.*** As discussed in Chapter 6 and further in Appendix 1, pattern languages can be thought of as modular elements of design that have been shown to be effective within a definable context, and that can be combined more quickly, easily and reliably into a relational network. Wiki is itself an elementary form of pattern language structure, developed as part of the larger development of design patterns in software

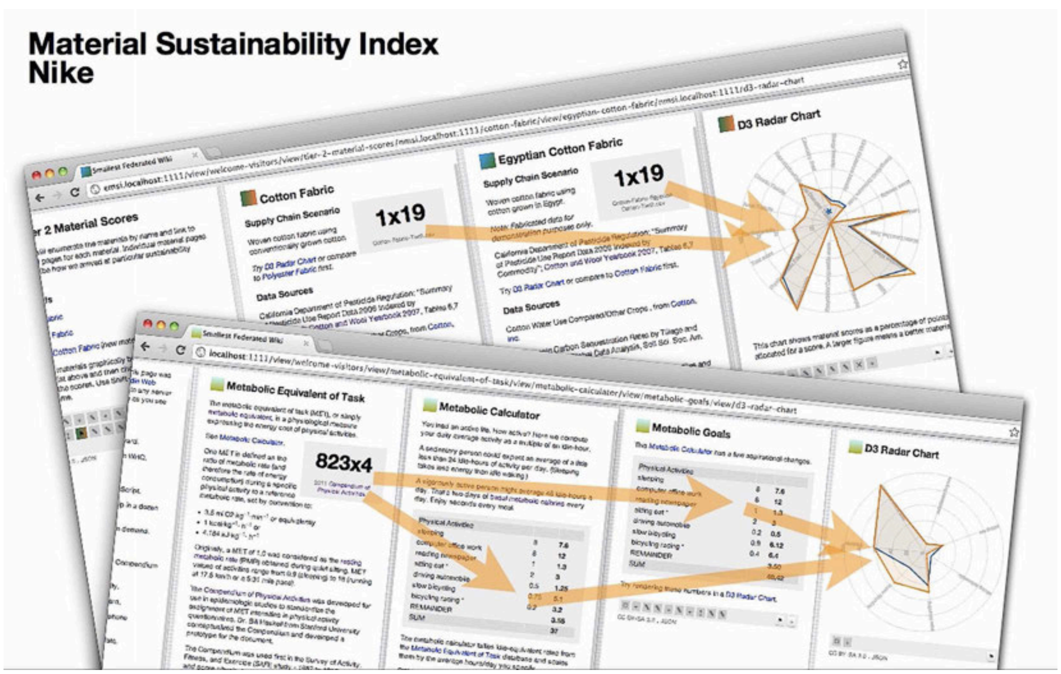

FIGURE 7.1 Ward Cunningham's "Federated Wiki" as developed to provide design outcome scenario-modelling for Nike apparel designs. [Source: Cunningham (2012a).]

§ 7.3 Federated Wiki – a promising new scenario-modelling technology

The research herein has been conducted in collaboration with the software engineer Ward Cunningham, who is the original developer of Wiki as well as a co-developer of design patterns. Cunningham has developed a new generation of Wiki with data exchange and calculation capabilities, the goal of which is, as Cunningham states, "to do for numbers what the first Wiki did for words."

A second crucial innovation is that the new Wiki has a federated structure, allowing faster and more differentiated open-source development. In practice this means that a scenario-modelling system like WikiPLACE that is altered by one user can be shared and altered by another user, and any useful innovations can be migrated back to the first user.

A third key innovation is that the new Wiki exists entirely on the web, in a contextual "drag and drop" page format. Elements from one Wiki page can be quickly and easily dragged to another page. Its hyperlinks function contextually on the web, and they will update in response to the context in which they are placed.

The central importance of this innovation must be emphasized. The pages and elements exist within a language-like web that depends upon their context, just as natural languages do. The elements are not fixed, but depend upon their context, without which they can be ambiguous. This key point warrants explanation by an example.

In a natural language, if one speaker uses the term "she", speaking to another, the intended referent of the term will likely be understood even though it is structurally ambiguous and entirely dependent on context. It could be that "she" is a person previously identified in the conversation, or, alternatively, "she" might be a new referent in the discussion. The person spoken to will look for an identifying context for the person to whom the speaker is referring. If there is no new identifying information, the context will imply that "she" is the person to whom the speaker previously referred.

This ambiguity and flexibility is in fact a powerful capability of language (Chomsky, 2002). It allows the network of references to become infinitely extensible, forming an open-ended modelling system that can include many different aspects of interest. We can speak of "she," and also "her briefcase," and subsequently "it," and so on – ultimately encompassing an infinite web of entites and sub-entities within our descriptions.

By contrast, a linguistic system that lacked this flexible ambiguity would be very limited in its usefulness. We would have to re-state with monotonous precision every term and every relation – e.g. Mary who has the briefcase that contains the letter, and so on – greatly limiting the flexibility and agility of the language.

There is a strong corollary with the agility of Federated Wiki. The simple but powerful use of contextual variables places a given element within an ultimately infinite web of contextual relationships – just as natural languages do.

Contrast this structure with, say, the structure of spreadsheet data, where the failure to precisely specify the location of even a single point of data, or its operation, can cause the entire spreadsheet to malfunction. This failure of rigid specification systems is a key driver of innovations like wiki, by Cunningham and others, leading to the development of what has come to be known as Agile Methodology. (See the Appendix section for more on this subject.)

Of course there is a risk with such a language-like flexibility, as ambiguity can cause its own kinds of failures in data. However, the benefits are much more significant than the limitations, as several examples will demonstrate.

In fact, as we shall see, the scenario-modelling capability of such a system is very well suited to the Bayesian approach that we discussed in Chapter 6.

§ 7.4 Federated Wiki and the Nike sustainability rating system

Many current-generation environmental design sustainability assessment systems (such as BREEAM and LEED-ND) rely on a "checklist" format, and there has been criticism of the weak correlation between the points awarded and actual performance (Humbert et al., 2007, Abdalla et al., 2011). Indeed, criticism of such assessments' arbitrary construction and weak basis in evidence has grown in recent years (Tolksdorf, Peterson and Ulferts, 2014).

In product manufacturing, there has been a similar effort to account for environmental as well as social impacts from materials and manufacturing choices, which often occur across the lifecycle of the materials. One typical response was developed by the footwear manufacturer Nike, their "Nike Materials Sustainability Index" (or Nike MSI). A key aim of the index was to allow apparel designers to compare choices of design elements, and to produce comparative design scenarios in which the impacts of materials production from "cradle to gate" (that is, from extraction to product delivery) could be identified (Nike, 2012).

The Nike report describes the process as follows:

> "Nike MSI calculates relative material scores for each of the more than 80,000 materials available to Nike product creation teams from 1,400 suppliers. These scores then feed into the Nike Apparel and Footwear Sustainability Indexes, helping designers to select materials with lower environmental impacts, as measured by Nike MSI."

In essence, designers were being asked to construct scenario models of various materials choices, and identify a more optimum mix of materials choices. However, with 80,000 materials the process was a complex one, and not particularly user-friendly. In addition, updates to the database were limited by the number of people who had access – in practice, very few. This was in spite of the fact that Nike had decided to open the data to inspection and review by third parties. This meant, in principle, that the data could be revised, corrected and extended by a larger community of users.

In 2012 Nike hired Ward Cunningham as their "Open Data Fellow" and asked him to develop a Wiki system that would allow greater collaboration, sharing, and user-friendly use of the Nike MSI system. As an outgrowth of that system, Cunningham developed a new generation of Wiki which he called "Federated Wiki." This research has been carried out in part on behalf of Nike corporation, with potential application to its apparel manufacturing systems. (Cunningham, 2012a; Zaino, 2012).

In the Nike model, Wiki pages (scaled to be used easily on a handheld device) could be quickly combined and substituted to construct scenario models of different materials for a design (say, a shoe design). The metrics of those materials – cost, energy in manufacturing, water use, GHG emissions et al. – could be quickly tracked and displayed. The different variables could be coordinated with each other, and even correlated (for example, cost of energy correlated with GHG emissions). In this way, users could quickly explore a number of components through scenario planning, and assess their impacts in each case. (Cunningham, 2012b)

Just as important, the Federated Wiki makes it easy for a community of users to develop, refine and improve both the system, and the underlying data on which it relies. Because of the hyperlink structure of the data, it is possible to examine the source of a given piece of data, refine it, correct it, or add more data.

It is also possible to re-write small elements or even entire portions of the Wiki, which will appear on the local copy of the "federated" original. If these improvements are seen as valuable by the original user or by other users, they are also available to be re-incorporated.

This "federated" approach bears further explanation. It has become common in open-source software development, where it has proven effective. Although the approach is decentralised, it is nonetheless highly structured, following specific protocols of refinement. While anyone is free to "fork" their own copy of a software program (or in this case a wiki) from elsewhere, and make whatever changes they care to, those changes cannot be "pulled" back to the original unless the original author agrees.

There is also a function of "curation" – that is, a host organisation can ask trusted individuals (known as "committers") to peer-review content for its accuracy and suitability. This is how Wikipedia, for example, maintains and improves the quality of its content. (While Wikipedia is not a federated wiki, its curation function works in roughly the same way.)

Toward an urban design decision support tool based on Federated Wiki

Conceptually, it is not a large leap to envision a system that does the same thing for urban design. The components of a shoe (fabric, sole, laces etc) might simply be replaced with the components of a development (homes, commercial spaces, etc). The modular "pattern language" approach means that each of these can be further broken down into smaller components, with modelling of their interactions. An element of say, GHG modelling information, could form a "pattern" that could then be combined with other patterns (say, other GHG inputs) within a larger set of modular and coordinated tools, or a "pattern language."

The critical function is the passing of metrics from one pattern (or page) to the next, together with the appropriate function as indicated by the research – for example, attaching dwellings will result in a predictive delta of reduced emissions, as will higher density. Because the system is open-source and Wiki-based, it is relatively easy for different users to test, refine and exchange improvements, and build up the base of information to become more reliable and more useful. As we discussed previously, just such an evolutionary improvement is what has in fact occurred with Wikipedia (see also the discussion in Appendix 1).

The advantage of such a system, then, is precisely what we seek: the ability to easily and rapidly model different scenarios, analysing variables that facilitate implementation; and the ability to use such a process to make further refinements in the result, to improve accuracy and usefulness. This is therefore, we conclude, a most promising new research agenda.

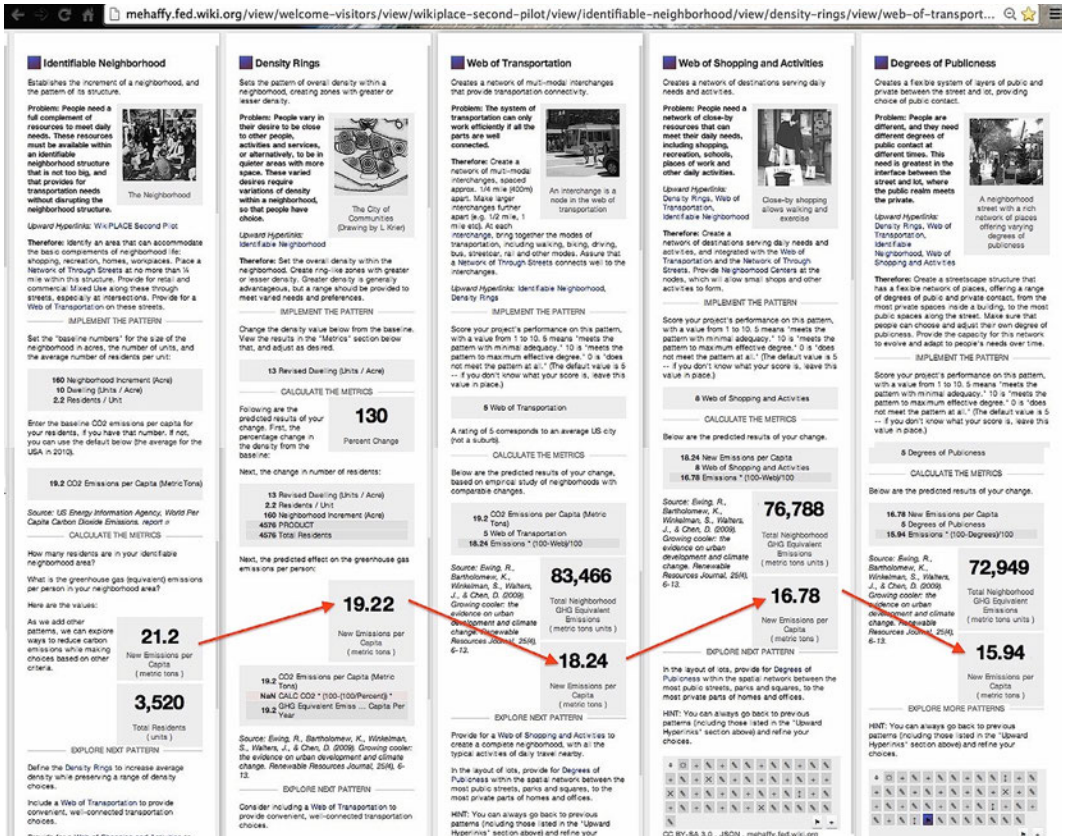

FIGURE 7.2 Early demonstration by Cunningham and Mehaffy of WikiPLACE, a scenario-modelling tool based upon the Smallest Federated Wiki architecture. Such a tool could in principle fit as a module within other scenario-modelling tools. [Source: the author.]

The example above (Figure 7.2) shows a nominal neighbourhood of 100 residential units, and other metrics of baseline GHG emissions per person, number of persons per household and so on. Additional "patterns" (urban design elements) are chosen (via hyperlinks at the bottom of each page) to assemble the full scenario model: in this case single family detached residences, attached residences, increasing density, etc. As these and many other patterns are chosen, the model applies a predictive calculation at each step, acting as a "delta" on the metric with each new pattern. The challenge for the accuracy of the model is to ensure that the delta follows empirical research, and accounts for potential interactive effects.

The links to such research are given, as are all calculations. The point of the process is that it is transparent and accessible, allowing other collaborators to spot errors, add more accurate data, and improve the model over time. For specific user communities, it is also easy to substitute specific local information for the broader baseline information, thus "calibrating" the scenario-modelling to local conditions.

Cumulative effects are relatively easy to model – as for example, the cumulative sources of emissions, or the average deltas of a given design pattern. More difficult to model are interactive effects, which will require more complex and carefully constructed functions (as we discuss below).

In this way, a group of users can develop and test alternative urban designs relatively quickly, manipulating the parameters of building type, density, network, orientation and many others to produce an increasingly accurate predictor of GHG emissions. In principle, it would be relatively straightforward to use a software module to analyse a specific design drawing, and report back on its predicted performance.

A key benefit is that the process is real-time and relatively user-friendly. The tool could be used in a group setting such as a collaborative workshop or charrette, or a public involvement design process. As the demand for public involvement grows, this potential benefit should not be underestimated. (Indeed, it represents a tantalising opportunity for further research.)

It is also important to note that, using the same conceptual approach, other metrics besides GHG emissions can be modelled instead, or in addition.

§ 7.5 Beyond aggregations: Towards modelling (and capturing) the synergetic effects of whole-systems networks

As should now be evident, the evolutionary capability of such a model, with its ability to progressively incorporate more successful strategies based upon tighter feedback cycles with empirical results, offers a tantalizing capability: to gradually evolve functional models of dynamic interactions that are effective and useful resource toward achieving a given goal within a highly complex and uncertain system (such as the reduction of greenhouse gas emissions from urban sources).

It bears stressing that, based on the findings discussed previously, this outcome should be possible with such a methodology *even if the set of mechanisms is not well understood beforehand.* As the model is adjusted to correspond with such observations, it can in principle grow more accurate in its capacity to represent the complex dynamics that are characteristic of urban systems – perhaps even before a theoretical model of the mechanism at work has been abstracted. (Such a process could even hasten the identification of new and more detailed theoretical models, thus serving as an important research tool.)

One such promising dynamic may be in the cyclical flows of resources that capture synergetic effects, greatly increasing the efficiency of a resource system. Such a dynamic is well understood within "metabolic" systems in biology, and promising strategies have been developed to capture them within the growing field known as "industrial ecology." The essence of such strategies is to plug resource flows into cyclical networks, to maximise their synergetic recombinations. Though it is beyond the scope of this research, we believe it is important to note including that the same opportunity may well exist for urban resource networks (Codoban, 2008).

In this light it is also important to recognise that a design pattern is, in essence, an element of a whole-systems network, which is more completely modelled by its larger pattern language. There is a close correspondence to the way that a natural language can serve as a useful model of a part of the world,and it does so in part as a whole-systems network whose parts are interdependent. In both cases the network is capable of redundant relationships, which are not accidental features but in fact crucial to the dynamics of the system as a network.

A scenario-modelling system that utilises design patterns will consider each pattern as a scenario element, and then the assembly of patterns is the larger scenario. If the system is able to handle quantitative data and its transformations (as indeed we must seek) then it is simply necessary that the transformation of data between patterns is also a model of what is happening in the phenomenon in question – for example, a decrease in greenhouse gas emissions per capita. (We will discuss this in more detail in Chapter 8, where we present the actual scenario-modelling software and its functioning.)

§ 7.6 Conclusion

As we discussed in Chapter 6, the challenge of urban design decision support goes to the heart of modelling methodology, and the nature of modelling processes in a complex and uncertain context – an inevitable characteristic of almost any urban system. If we are to avoid the problems we discussed of "whack-a-mole" (solving one problem only to see another one produced) then it seems clear that we must develop a new generation of tools that are suited to the whole-systems nature of our challenges.

Indeed it is not too much to say that the question goes to the methodologies of science itself, and how scientific findings can be translated into efficacious designs. It seems clear that this must be done pragmatically and iteratively, following Bayesian logic, and without the expectation of linear precision.

As with the process of scientific discovery and refinement as a whole, this is not, and cannot be, an automated technological process. Rather, it must be a process of "curation" of knowledge – that is, an ability to review and evaluate information as it is generated, and to test and adjust the result accordingly. The ability to improve accuracy depends upon this curation. The same principle of curation must apply to open-source software technologies – including wiki – if they are to grow more useful and accurate.

In the present challenge of urban form and greenhouse gas emissions, by following such a methodology, we may begin to tease out very important factors within the patterns of consumption and waste, that do in fact relate directly to urban morphology. Such a modelling process would be an extremely helpful guide in both evaluating design scenarios, and in establishing the policies, tools, incentives and practices needed to implement them. This is the tantalizing research and development opportunity ahead.

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