Chapter 2
Towards the Development of a Monitoring System for Planning Policy

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Abstract Cities are constantly changing and growing. Planning regulation aims to guide the development of cities to provide the best possible quality of life for the people within them. Monitoring the effects of planning policy is an important step to improve decision-making but is often limited in practice. This study involved the construction of a browser-based mapping application as a prototype monitoring system. The study uses development permit, land use, infrastructure and service data from four case study cities—London, Chicago, Melbourne and Brisbane—to explore the mechanics and necessary prerequisites for ongoing automated monitoring. The selection of four cities allowed for comparisons to be made between the cities regarding planning system structure, data availability, suitable metrics and visualization techniques. The prototype is limited to residential land uses only but successfully demonstrates bringing together disparate datasets to communicate spatially-detailed information related to the success of planning objectives in an automated fashion.

Keywords Policy monitoring system · Urban plan evaluation · Planning support system · Digital innovation in planning

1 Introduction and Context

The role of monitoring has long been part of the theory of how the process of planning should be undertaken. The rational process view of planning, inspired by wider economic theories about rational decision-making in the 1960s and 70s, outlines a number of cyclical steps representing an idealised view of the planning process (Fig. 1) (Banfield 1959; Faludi 1973). These steps, or variations thereof, remain how the planning process is generally conceived, although with broader recognition of the inherently political and value-laden nature of planning (Forester 1989; Davidoff 1965;

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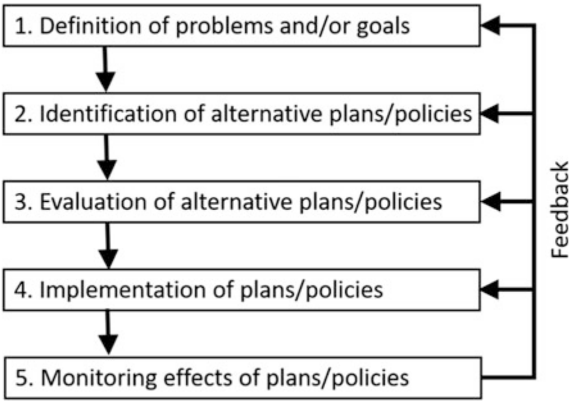

Fig. 1 Steps in the rational process view of planning (Taylor 1998, p. 95)

Friedmann et al. 1973) and importance of community involvement in decision-making (Arnstein 1975; Healey 2006). In this model, monitoring forms the final step, providing necessary feedback to restart the planning process or adjust the plan to account for new circumstances or shortcomings.

Monitoring of town planning policies can be defined as evaluating the extent of their implementation or impact. Nonetheless, although monitoring is broadly accepted in the planning profession as an important step to improve decision-making, it is often neglected. Instead, the bulk of evaluation efforts in planning are focused on the future of different plan alternatives, step three of the process in Fig. 1. Lots of work has been done on the development of urban-modelling techniques, which have been developed to examine scenarios and forecast future change. These include Land-Use Interaction Models (LUTI), Spatial Interaction Models (SIM), and more recently, Cellular Automata (CA) and Agent-Based Models (ABM) [see various overviews by Batty (2008, 2009, 2012)]. These and other forecasting techniques are frequently incorporated into planning support systems (see previous compendia, e.g., Geertman and Stillwell 2009; Geertman et al. 2015). The collection of tools that come from these techniques is sometimes referred to as urban analytics but in this chapter, the approach simply sets the context for the development of such analytics which are considered consistent and compatible with the mapping and monitoring approach proposed here.

A handful of empirical studies evaluating the effectiveness of past policies have been published. This literature is comprised of one-off studies such as Talen's (1996) publication, which evaluated the location of public facilities, and more recent articles relating to land use and growth control (Brody and Highfield 2005; Chapin et al. 2008; Alfasi et al. 2012; Long et al. 2015). Recent literature is largely silent on the concept of ongoing monitoring and, in particular, the use of computer software to complete monitoring tasks on an ongoing basis. Literature produced in the '50s, '60s and '70s in relation to the rational comprehensive planning process model indicates the need for ongoing monitoring in a new, more flexible policy environment, making reference to the maintenance of supporting information systems (see particularly

Meyerson 1956; Robinson 1965). Of this period, Calkins (1979) is perhaps the most explicit, expressing a theoretical monitoring system in a series of algebraic equations which track measurable attributes against explicitly enumerated planning goals.

Published studies providing evidence of how professional planners undertake monitoring in practice are very limited. Seasons (2003) is one of the few published who conducted surveys of officers in Ontario, Canada, to identify factors in planning practice that facilitate or impede monitoring and evaluation. The results of the interviews indicated a significant gap between ideal process theory and practice. The key reasons stated include:

- Resources: time, money and expertise—municipal resources are limited. The majority of municipalities focused resources into the review and facilitation of development proposals rather than policy research.
- Evaluation methods—evaluation methods lacked qualitative input. Methods also did not tend to allow for comparison with neighbouring municipalities to allow for meaningful benchmarking.
- Appropriate indicators—indicators tended to be linked to budgeting and resource efficiency rather than plan outcomes. There was also found to be a disconnect between the indicators used and planning policy objectives. Interviewees stated the need to be targeted and realistic with demands for monitoring data.
- Causality: linking goals and outcomes—many factors influence the built environment and it is often difficult to establish causality. Goals and objectives are often too vaguely worded to be conducive to evaluation.
- Political realities—planning goals are often seen to be less important than political exigencies.
- Organisational culture—attitudes from staff, management and political leaders varied in their support for monitoring and evaluation activities. Receptive organisations stressed the need for ongoing learning. Others saw monitoring as discretionary and yet others seemed to indicate resistance to the possibility of criticism.

Improved computing, new data sources and automation offer promising but previously unexplored solutions to many of these identified obstacles.

2 Aims and Objectives

The research looks into the pre-requisites and mechanics involved in bringing together existing datasets and methods to construct an automated monitoring system for the use of planning professionals. Through the construction of a working demonstration system, the research provides insights into data availability, data quality, system structure, useful metrics and methods of visualization but it is consistent with a wider array of urban analytics. The prototype is focused on residential land uses only, although it could be extended for other land uses using similar methods. The research is focused on four case study metropolitan government areas: London (Greater London Authority), Chicago (City of Chicago), Brisbane (Brisbane City Council) and Melbourne (City of Melbourne), for which disaggregated data on construction of residential dwellings could be sourced. The four case study cities allow comparisons to be made in the process required to transform available development data for each city into useful metrics for monitoring planning policy.

3 Introduction to Case Study Cities

Planning systems vary from city to city. The underlying regulatory framework is important in the design of a monitoring system as it will determine the form of planning outputs, including policies, development-approvals data or monitoring reports. Four case study cities were selected to allow comparisons to be made regarding planning system structure, data availability and the extent to which metrics can be generalized for different cities.

The planning system in London and the UK can be described as a 'plan-led discretionary system' (Carmona et al. 2003) with strategic plans and written objectives. At the other end of the spectrum, Chicago has a strict regulatory system centered around a zoning ordinance; although a strategic plan exists for the region, it does not have statutory weight in the consideration of development applications. The two Australian systems lie somewhere in between.

Each city has one or more strategic plans which contain objectives for the development of the city (see Brisbane City Council 2014; Chicago Metropolitan Agency for Planning 2010; City of Melbourne 2016; Greater London Authority 2016; State Government Victoria 2014). All of the four cities are growing in population and have a surprisingly similar set of objectives for residential development indicating that similar metrics could be used to measure policy success across the four cities. These objectives can be summarized as follows:

- regulations should ensure that they are not so limiting that they do not provide developable areas to accommodate population growth;
- development must provide a mix of housing sizes and types to accommodate increasing variety in family structures and living arrangements;
- a proportion of development should be affordable housing;
- high-density development should be located in special areas mapped for growth, with the amenity of established areas, marked to be retained as low-density, to be protected; and
- residential development, especially high-density development, should be conveniently located and well integrated with other land uses, within walking distance of public transport infrastructure and community facilities.

For London and both Australian cities, two separate permit systems exist for the regulation of development and construction, for buildings regulations approval, to check conformance with various building safety codes, and planning approval, which primarily considers wider impacts of development. In Chicago, only a single system exists for building permits, and for large projects the local authority also checks the application for compliance with the zoning ordinance.

Of the four systems, only the UK was identified to have legislated mandatory monitoring requirements for planning in the form of an annual monitoring report. The Greater London Authority (GLA) has some very specific objectives in its London Plan which it measures using 24 indicators. Most of the indicators relevant to residential land use are non-spatialized, based on counts of approvals with statistics aggregated by year and borough.

4 The System

4.1 Structure of the System

The task was approached using the following conceptual system structure with four stages, identified in Fig. 2.

The first component is to establish the location and density of residential dwellings in the city at a point in time. Establishing a base case is essential in order to gauge the relative magnitude of changes identified in component two. Component three involves the development of metrics to measure the relative success of policy objectives. The fourth component involves the visualization and communication of measurements.

In terms of practical program structure, the prototype utilises popular web-based visualization tools Google Maps API, HTML, JavaScript and MySQL. Scripts process the raw data and export it to an SQL database. Additional scripts then pull the clean data from the database, calculate metrics, produce and send calculated values and semi-transparent image tiles to the server for viewing in a browser-based mapping application. The program structure is outlined in Fig. 3.

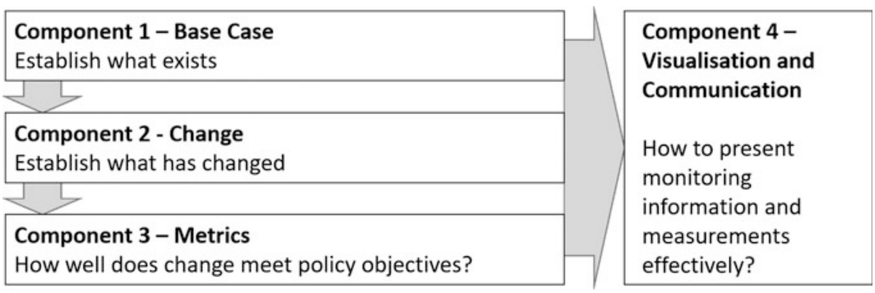

Fig. 2 Conceptual framework for monitoring system

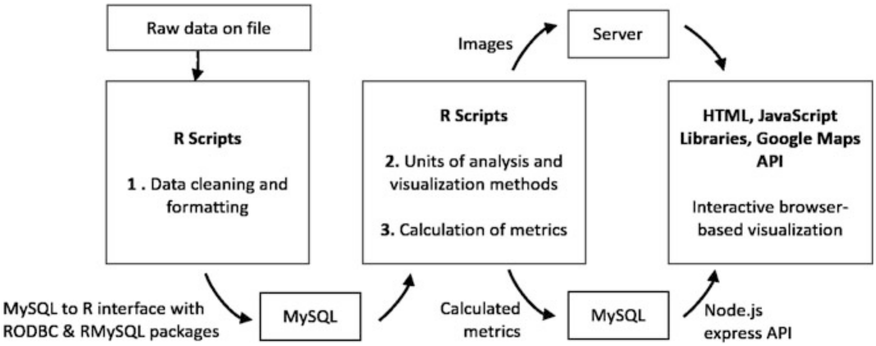

Fig. 3 Flow diagram representation of prototype monitoring system program structure

4.2 Data

4.2.1 Availability

Three types of administrative datasets are used as the foundation for the monitoring system, with each type key to one of the first three conceptual components:

- Existing land-use data—component 1 (base case)
- Development approvals or construction data—component 2 (change)
- Infrastructure and service location data—component 3 (metrics).

The land-use and development datasets and their relative levels of detail are outlined in Table 1.

Spatial datasets relating to infrastructure and service location are available from a variety of different sources with varying degrees of accuracy and coverage. For the prototype, road network and open space data was sourced from OpenStreetMap. Public transport data was downloaded from the various city transit agencies in General Transit Feed Specification (GTFS) format. Additional open space data was sourced for London from the 'Greenspace information for Greater London' (GiGL) dataset, and Chicago parks from the city's open data portal.

4.2.2 Processing Requirements

Scripts were developed to reformat data into a consistent format for programming metrics as outlined in Table 2.

Most data processing involved simple but extensive sub-setting to reach the point outlined in Table 2. This task, exhausting when done manually, is accomplished through scripts which perform tasks automatically, such as removing irrelevant records, applying consistent field names and translating coordinate reference systems for web mapping.

Table 1 Comparison of land-use and development datasets for each case study city across key dimensions

		Brisbane	London	Chicago	Melbourne
Land-use datasets	Source	Brisbane City Council 'Land Use Activity Dataset'	Ordnance Survey 'Address Base Plus'	Chicago Metropolitan Agency for Planning 'Land Use Inventory'	Melbourne City 'Census of Land Use and Employment'
	Open	No	No	Yes	Yes
	Spatial resolution	Site polygon	Address point	Merged site polygon	Site polygon
	Updates	Every six months	Every six weeks	Every five years	Every two years
Development datasets	Source	Brisbane City Council 'Building Completions Certificates'	Greater London Authority 'London Development Database'	City of Chicago 'Building Permits'	Melbourne City 'Census of Land Use and Employment'
	Open	No	No	Yes	Yes
	Spatial resolution	Site polygon	Address point	Address point	Site polygon
	Period	2010-2015	2006–2015	2006–2015	Difference between 2011 and 2015

Table 2 Input data requirements for prototype monitoring system

Land-use data	Development data	Infrastructure and service location data	
		Public transport	Other
Unique identifier (parcel/property) Date of inventory Number of dwellings Location of dwellings Information on dwelling type	Unique identifier (development project) Date of development Number of dwellings Location of dwellings Information on dwelling type	Location and ID of stops Location and ID of routes Timetable data associated with each route and stop	Location, extent and ID of public parks Location of roads

Some datasets required more complex processing. For example, small-area census data on dwelling numbers and a land-parcel spatial dataset was used in conjunction with the land-use dataset for Chicago to approximate the number of dwelling per parcel. In addition, details relating to the type of development in Chicago were found in a text description field and required parsing as shown in the example in Fig. 4.

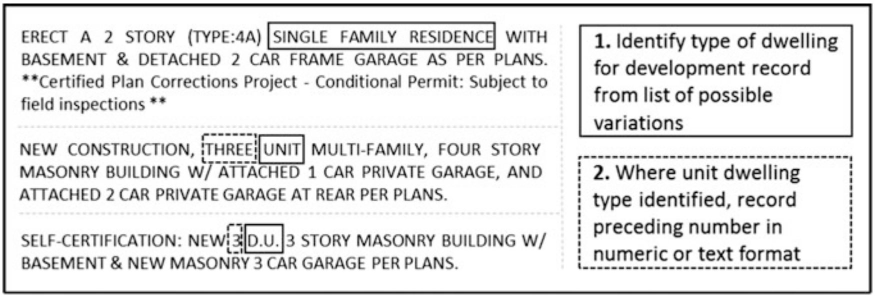

Fig. 4 Text parsing procedure for Chicago development dataset

4.2.3 Key Data Quality Issues and Limitations

Temporal resolution is a key limitation of the datasets. For instance, the land-use dataset sourced for Brisbane is dated 30 June 2014, resulting in just over a year in which change can be monitored in the prototype system. Whilst characteristics of recent development may be measured independently, they are less meaningful without the context of the previous land use. This is a limitation for cities without a land-use inventory or that have only just begun to assemble one.

Alongside temporal resolution there is a large difference in the attribute resolution between datasets of similar types for different cities. Data attributes often reflect the administrative procedures required to process an application and are not necessarily the best for ongoing monitoring purposes. For instance, in Chicago's building approvals dataset, 119 of the 131 fields were devoted to information such as contractor identification and fee payment.

A development approval usually denotes permission to undertake a specific construction or development project and does not guarantee that the project will go ahead. The procedure for tracking completed development varied for each city. In Brisbane, a building completion certificate is issued upon the completion of a project and a mandatory recording system is in place. Although a similar system exists in the UK, it is not mandatory for building inspectors to record their final checks with councils and separate surveys often have to be made with completion dates often approximated to the end of financial year, as shown in Fig. 5. Some of these limitations may be mitigated in practice with greater access to internal data sources.

4.3 Aggregation and Visualization

Aggregation and visualization of data is required in order to reveal patterns and relationships between measures for the disaggregated development data. Four

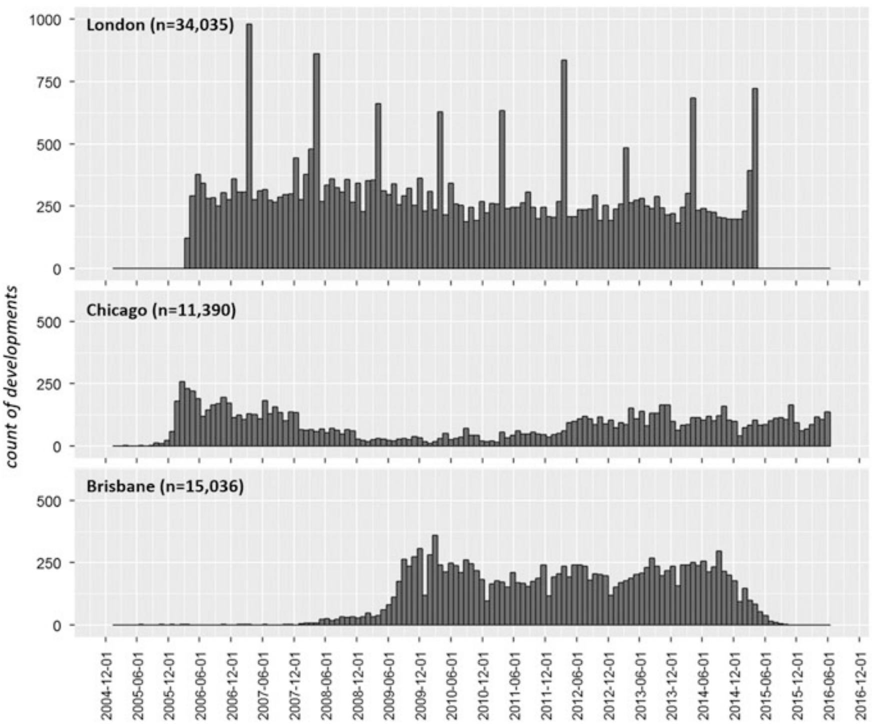

Fig. 5 Histograms showing number of developments per city over time (30 day intervals; no temporal data available for Melbourne)

methods were tested: point mapping, choropleth mapping, cluster identification and mapping, and kernel density mapping, in order to compare the processing requirements and output of each.

4.3.1 Point Mapping

A simple map showing the locations of development sites. Point symbols may differ by category or the size and colour may be graduated according to value of indicator (Fig. 6).

4.3.2 Choropleth Mapping (Administrative Areas)

Data may be aggregated to the administrative level and displayed as a choropleth map of aggregate or average values (Fig. 7).

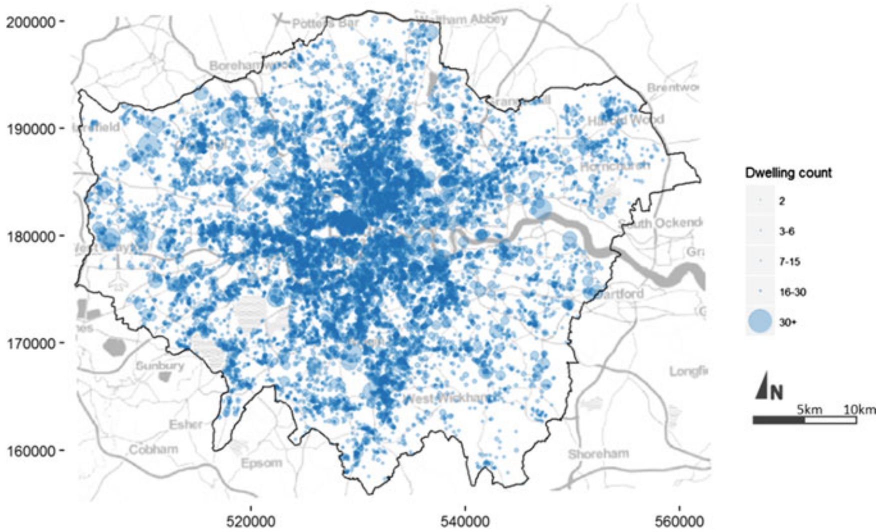

Fig. 6 Point map of completed development records in London, size by number of dwellings (April 2011–2015)

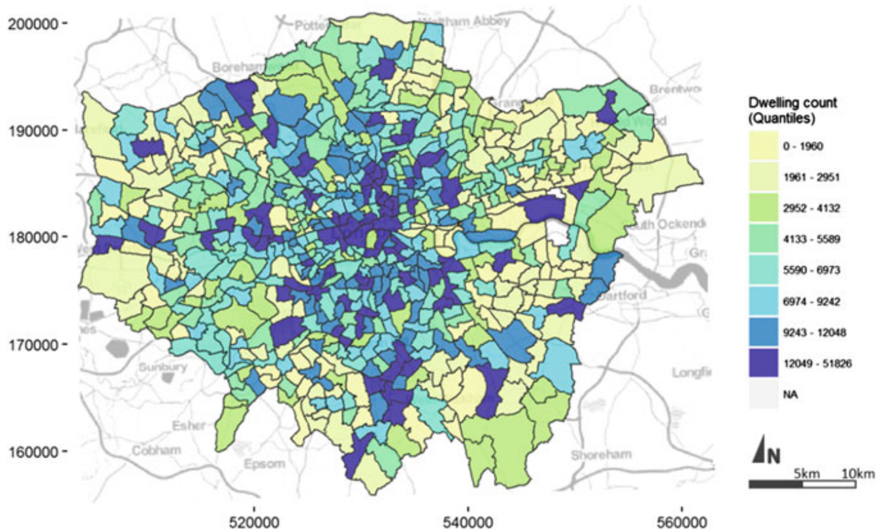

Fig. 7 Choropleth map of completed development records in London coloured by number of dwellings per electoral ward (April 2011–2015)

4.3.3 Cluster Identification and Mapping

An agglomerative hierarchical clustering algorithm was used to define regions for aggregation, based on the spatial distribution of the development sites. For the

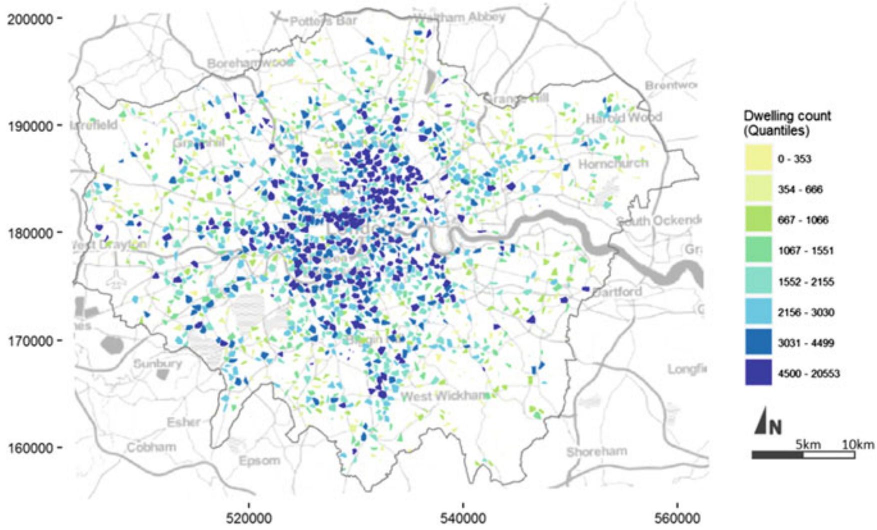

Fig. 8 Convex hull map of clusters of completed development records in London coloured by number of dwellings (April 2011–2015)

prototype the algorithm was defined so that the furthest distance between points in each cluster did not exceed 800 m (Fig. 8).

4.3.4 Kernel Density Mapping

Kernel density mapping (commonly referred to as 'heat mapping') is a standard technique for mapping density of point objects whilst avoiding the need to assign the points to a zone. In essence, it is a method for smoothing data according to its variation and density. For the prototype system, a custom conic kernel was used with values decreasing from the centre according to a simple linear function of the height of each kernel (number of dwellings) to the edge of the kernel (bandwidth of 800 m) (Fig. 9). The pixel values of the Kernal Density Estimation (KDE) may also be combined to produce a 'density profile' allowing for comparison between any desired geographic units. In addition, different raster surfaces can also be combined in the calculation of metrics, using any desired equation across the values of the corresponding cells.

For retaining spatial detail, it was found that point mapping was most appropriate for categorical variables and for measures applicable to each development site in isolation. Where relationships between points is relevant, or the concept 'density' or 'intensity' needed to be conveyed, the kernel density map display was chosen as the best method for the display and aggregation of data. This method has the advantage of its ability to preserve the detail of spatial distribution whilst

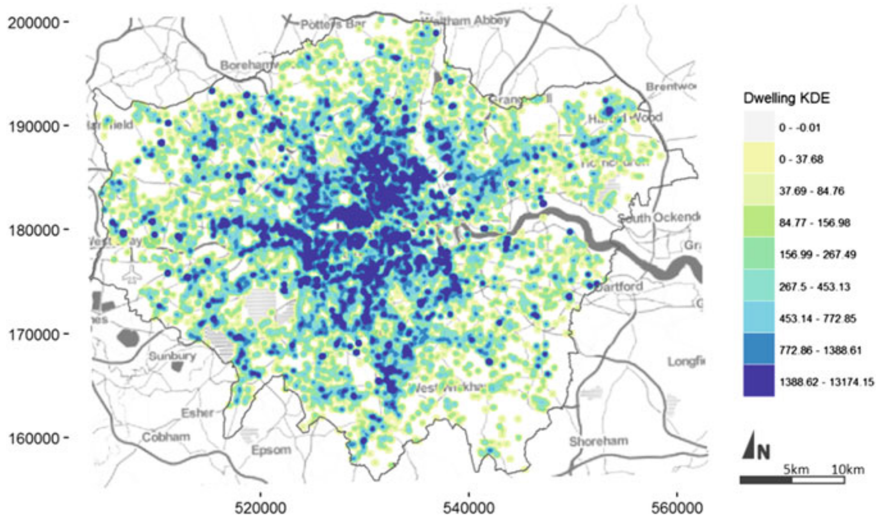

Fig. 9 KDE map of completed development records in London coloured by dwelling intensity (April 2011–2015)

displaying information about the spatial relationship between points, with the value of each pixel a result of aggregated scores for overlapping kernel neighbourhoods.

4.4 Metrics

Choosing what to measure is the greatest challenge for the development of a monitoring system. The strategic plan for the city is very broad and the potential combinations of measurements stretch into the thousands. In the end, it was decided to restrict metrics to three common residential planning objectives identified in the review of policies of all four cities to serve as a 'demonstration' project.

- Mix of housing types—development should provide a mix of dwelling types and sizes to cater for demographic diversity and change.
- Access to public transport and services—residential dwellings should be located within walking distance of frequent public transport and facilities such as public open space. The denser the development, the more convenient the location should be.
- Conformity with spatial plan—planning policies identify specific areas of the city where development is encouraged and other areas where development should either be limited or prohibited.

Table 3 Chosen metrics

	Objective 1—Mix of dwelling types	Objective 2—Access to public transport and services	Objective 3—Conformity with spatial plan
Simple	Ratio between numbers of detached dwellings and residential apartments	Number of facilities within 800 m buffer of new development site	Whether development site falls inside or outside identified strategic growth areas
Complex	Diversity index based on numbers of bedrooms provided in each newly developed dwelling	Distance to nearest facilities along road network	Whether development site is appropriate with regards to fine-grained spatial development plan (zoning)

A very simple measurement and a slightly more involved measurement were chosen for each as an example of what is possible (Table 3). In practice, subtleties around measurement decisions could be chosen to align most closely to goals and objectives specific to the particular city.

4.4.1 Mix of Dwelling Types

The development data available for most cities limited options for the measurement of housing diversity to a simple ratio of attached and detached housing. The metric has been designed to combine two dwelling total KDE surfaces for attached and detached housing types. A value of '1' indicates all detached dwellings and a value of '2' indicates entirely attached dwellings, as shown in Figs. 10 and 11.

$a_{x,y}$ - Attached dwellings, value for pixel in location x, y in dwelling density KDE

$b_{x,y}$ - Detached dwellings, value for pixel in location x, y in dwelling density KDE

$c_{x,y}$ - Derived house type ratio surface, value for pixel in location x,y

$$c_{x,y}\begin{cases} (a_{x,y}=0)\wedge(b_{xy}=0)\rightarrow 0 \\ (a_{x,y}=0)\wedge(b_{xy}>0)\rightarrow 1 \\ (a_{x,y}>0)\wedge(b_{xy}=0)\rightarrow 2 \\ (a_{x,y}>0)\wedge(b_{xy}>0)\rightarrow 1+a_{x,y}/(a_{x,y}+b_{x,y}) \end{cases} \quad (1)$$

Fig. 10 Housing type ratio equation for combining attached and detached dwelling total KDEs

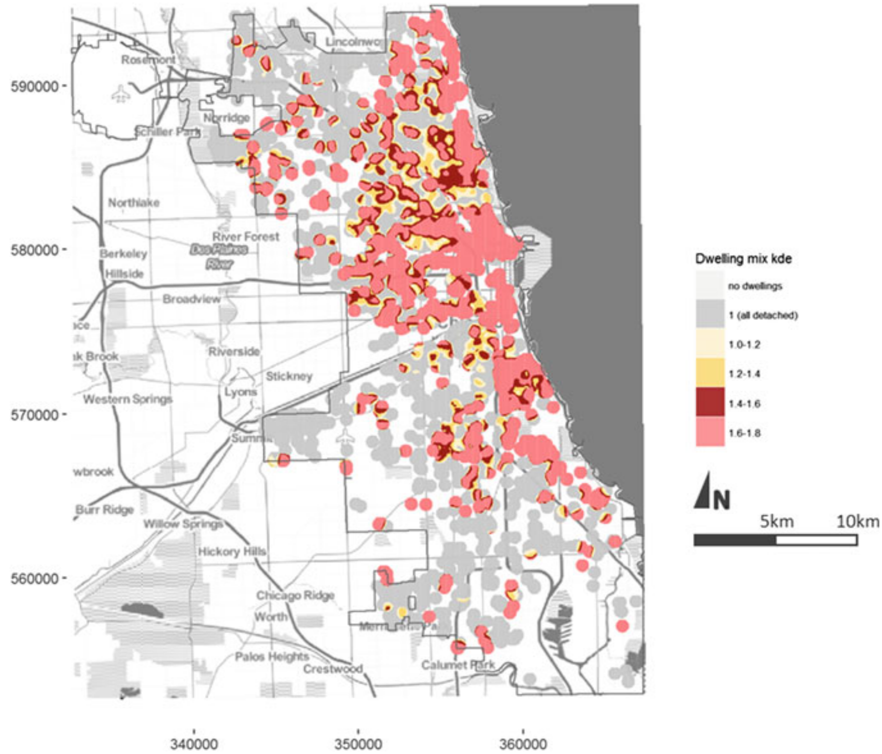

Fig. 11 Housing ratio combined KDE for Chicago building permits

$a^{n}_{x,y}$ - Dwelling density KDE for dwellings of type 'n' number of bedrooms, value at location 'x, y'

$c_{x,y}$ - Derived diversity index surface, value for pixel in location 'x, y'

$$c_{xy} \begin{cases} (\sum a^{n}_{x,y} = 0) \rightarrow 0 \\ (\sum a^{n}_{x,y} > 0) \rightarrow 1 - \sum (a^{n}_{x,y} / \sum a^{n}_{x,y})^2 \end{cases} \quad (2)$$

Fig. 12 Simpson's Diversity Index equation for combining dwelling total KDEs for different dwelling types

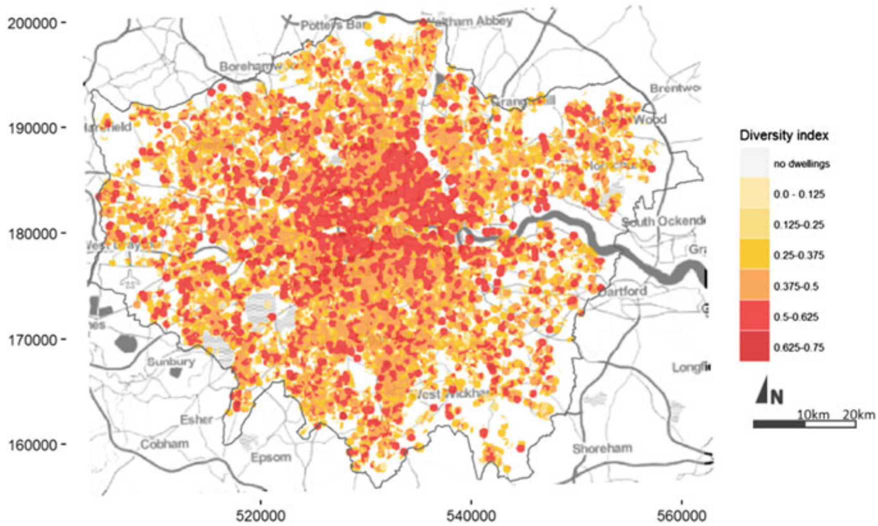

Fig. 13 Diversity surface for completed residential development in London (2006–2016) by number of bedrooms

Unlike other cities, the London Development Database provides information on the number of bedrooms for most complete development records. Dwelling total KDEs were calculated for each dwelling type and combined using the Simpson's Diversity Index equation outlined in Fig. 12. This calculation reflects the 'evenness' of dwelling numbers in each category by calculating the probability that, if chosen randomly, two development records would be of a different type. The scale ranges from zero (least diverse) to one (most diverse) (Fig. 13).

4.4.2 Access to Public Transport and Services

In order to calculate the frequency of service at a stop during peak hour (Fig. 14), the following process was undertaken using GTFS data:

1. Specify a single representative weekday.
2. Get the ID of all services that run on that day from the calendar file.
3. Get the IDs of all trips associated with services that run on that day.
4. Subset stop times data frame to include only those trips.
5. Define peak times and further subset stop times dataset.
6. Group stop times subset by stop ID.
7. Sum the number of trips per stop.

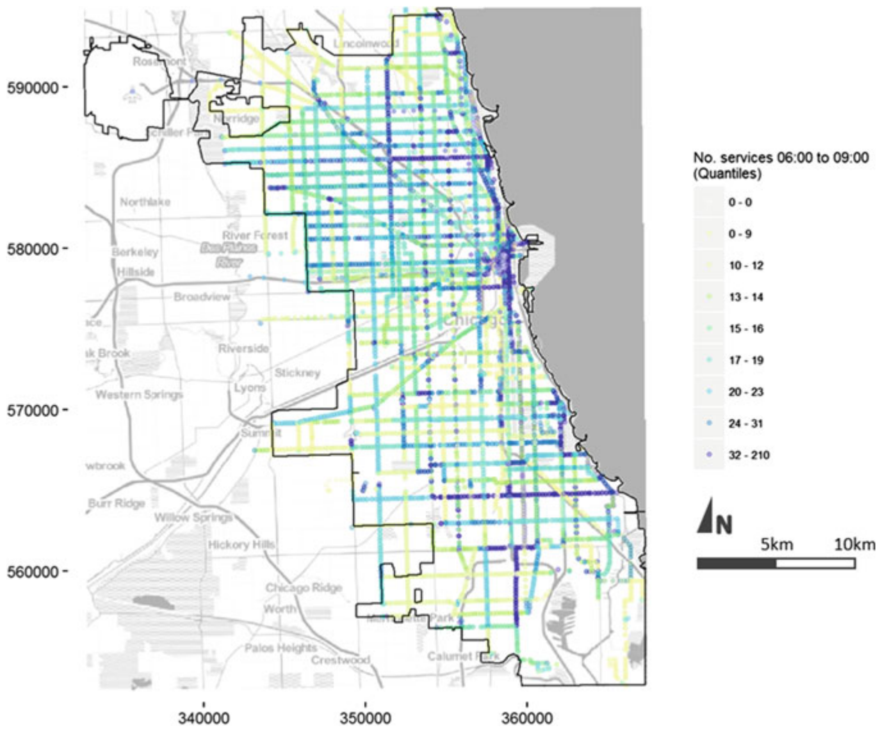

Fig. 14 Number of public transport services per stop from 06:00 to 09:00 on a Wednesday, City of Chicago

As a simple measure, spatial buffer overlay functions were used to determine whether stops serviced on average every ten minutes during peak hour fell with the 800 m radius of development records. As a more complex measure, road network spatial data from OpenStreetMap was converted into a network using the iGraph package and used to calculate distances (Fig. 15).

4.4.3 Conformity with Spatial Plan

Spatial buffer and overlay functions were used to determine whether development records fell within areas defined in the spatial plan for the city at a strategic level and, where relevant, at a more detailed zoning level. Compliance and non-compliance can be shown with point symbols, similar to above.

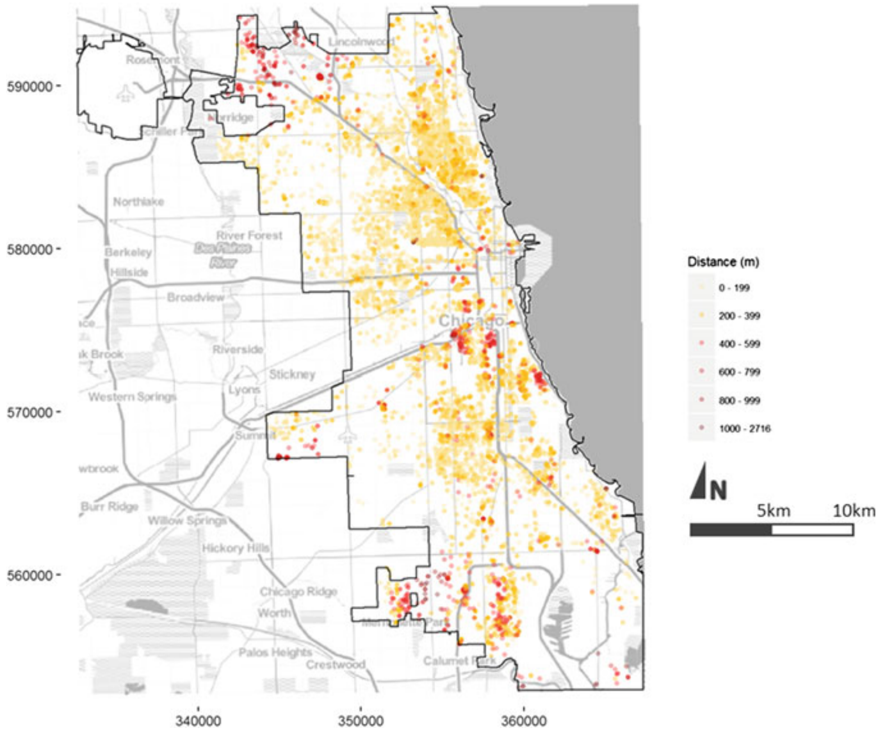

Fig. 15 Distance along road network to a public transport stop serviced on average at least every 10 min or more during morning peak hour

4.5 Website Format and Design

Figure 16, 17, 18 outline the relevant features of the website which displays the outputs of the prototype monitoring system, drawing data both from the API to the database on the server and to the semi-transparent image tiles which display the outputs of calculated metrics.

Browser-based visualization was found to be superior to the static map outputs, with the primary advantage of the web-based system being the ability to interactively pan and zoom to areas of interest with the context of a detailed map or satellite imagery. Graphic buttons organize the information, and provide clear and efficient means of sorting through and exploring available information to a degree that is impractical for a print-based system, with each component of the monitoring system including display options for four different map types, three colour schemes, three classification schemes, as well as various additional options.

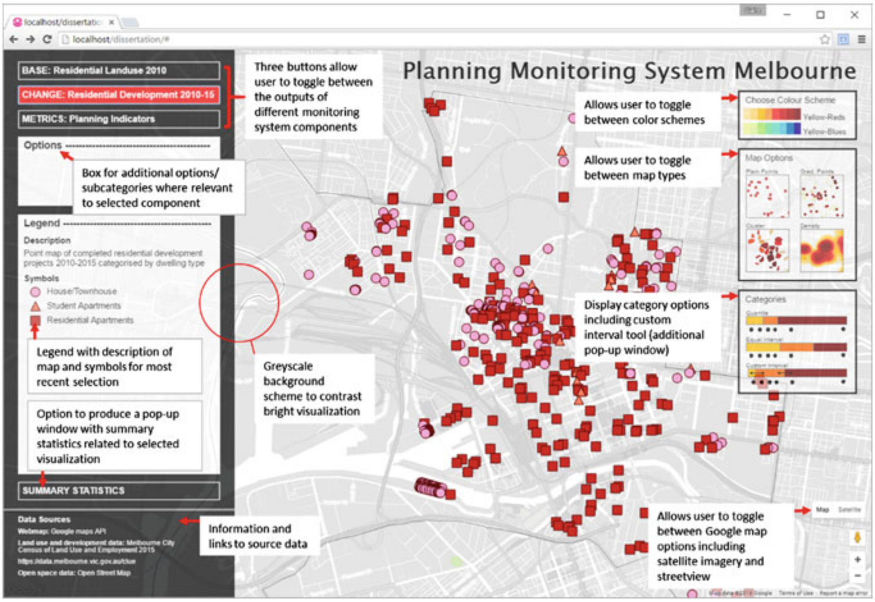

Fig. 16 Website features

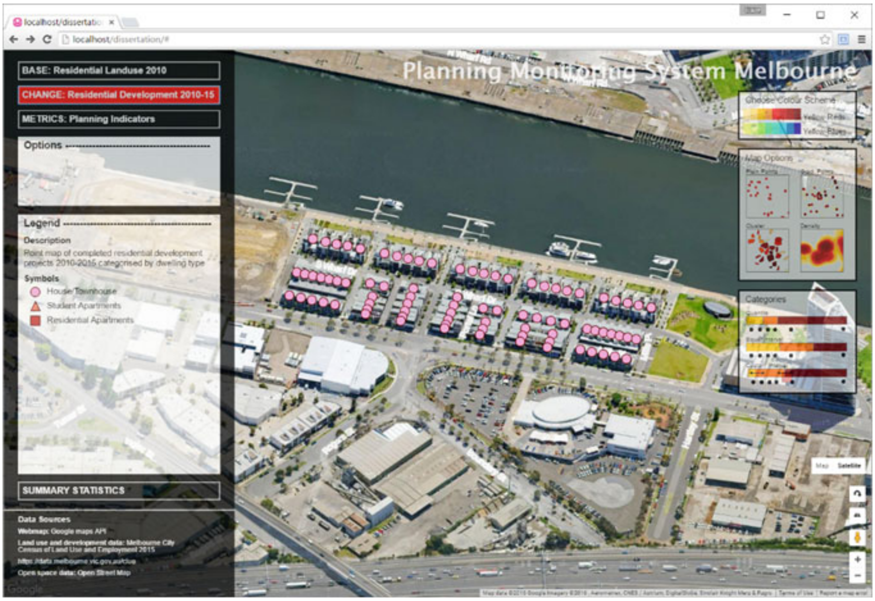

Fig. 17 Google satellite imagery visualization option allowing detailed picture of a new development site in South Melbourne

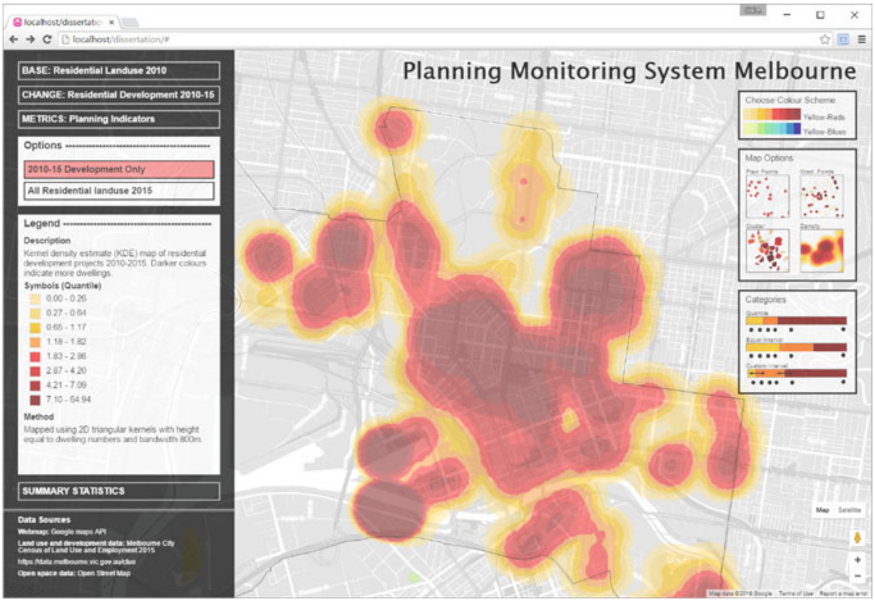

Fig. 18 Density map display option, number of dwellings recently developed

5 Potential for Practical Application

Where they exist, current monitoring outputs from planning authorities tend to use simple measures, summarized annually, for the entire authority area. This has limited use for planning regulations, which operate down to the scale of a neighborhood or individual block of land. This monitoring system proposes a platform to visualize indicators at temporally and spatially disaggregated scales.

This tool will help address many of the identified obstacles for monitoring in professional town planning practice. Foremost, automation of tasks reduces a lot of the effort involved in compiling indicator measurements. The prototype system shows that although the resolution and quality of available data varies, it is possible to turn raw data from four separate planning administrative systems into a meaningful and comparable web-visualization with minimal human intervention. As outlined above, in some cases improvements could be made to the way input data is collected and published by city authorities to make this process easier. Examples of improvements include ensuring essential attributes such as the number of dwellings are recorded in different fields, recording dates in development datasets as the actual day the construction completion certificate is issued and recording greater detail in attributes, such as number of bedrooms as is the for the London Development Database.

As in other areas of local government, the availability of open data, the potential of crowdsourced data and web-scraping may change political realities in the reluctance to adopt monitoring for fear of criticism in urban planning. The prototype systems for Melbourne and Chicago have been built using entirely public data, sourced from their respective open data portals.

It is now more than two decades since quantitative evaluation and modelling methods, proposed in the '60s and '70s by authors such as McLoughlin (1969), Chadwick (1971) fell out of favour with the planning profession. New sources of disaggregated data about the city are now available in digital format alongside increased storage space and computer processing speed to handle it. The existence of tools to assist with quantitative monitoring does not make the need for qualitative and community feedback any less important. Indeed, outputs from the prototype system are produced in standard spatial data formats that could easily be integrated into other planning support systems or participatory GIS system for public consultation.

The prototype system does not entirely ameliorate challenges regarding the complexity of planning objectives and defining success. It is, however, able to demonstrate the potential for the automated calculation of a range of spatial metrics related to planning objectives, highlighting areas of new dwellings that are relatively better or worse measured against any indicator. The minimum value which is considered 'acceptable' then becomes a political decision, depending on local context and trade-offs between other perceived benefits of the development location.

Similarly, the prototype monitoring system is, in itself, unable to determine cause-and-effect relationships between planning policy and development outcomes. The sheer complexity of city systems means it remains extremely challenging to isolate factors sufficiently to make definitive statements in almost any context. In addition, due to data limitations, the time period within which city change could be measured is very short and did not readily line up with most plan implementation dates. What the monitoring system provides is a platform that, if updated with data over a sufficient period of time, can be used to compare outcomes before and after the implementation data of a specific policy and between areas in the city where a specific policy applies or does not apply.

6 Further Work

User testing is an essential step in making the prototype system operational which was outside the scope of the study. Previous research into the development and use of planning support systems shows that adoption rates still remain low (Geertman et al. 2015). Many urban planning professionals, whilst experts in regulatory and administrative systems, are not specifically trained in statistics, and testing the system for usability is essential, particularly in relation to the proposed kernel density surface metrics.

The system currently has a limited scope but has the potential to be expanded to other types of development and metrics can be customized almost infinitely. Again, user testing is critical to define how well the selected policy priorities for the prototype system fit professional practice and what priorities should be given to possible extensions. Further technical improvements should also be explored, especially improvements to program efficiency and processing speed.

The scope of this research regarding generated outputs was largely descriptive as the study focused on the mechanics of system development. Nevertheless, through the unique combination of multiple datasets and definition of standard metrics, the outputs of the prototype system have the potential to provide comparative insights into the recent growth of all four cities. Development approvals and completions data has rarely been used in previous studies but has the potential to provide interesting insights into urban change.

7 Conclusions

This study investigated the data, measurement and visualization requirements for the construction of a prototype monitoring system as a necessary prerequisite for measuring the success of planning policy in an ongoing and automated fashion. A review of the literature found that, whilst the importance of monitoring is not disputed in planning theory, it is largely neglected in both academic studies and planning practice. The study fits neatly within this gap.

The prototype system is programmed as an interactive web-mapping application utilising Google Maps API, HTML, SQL and R Scripts. The system combines existing land-use, development, infrastructure and services data to visualize indicators of change and compliance with policy objectives. Four case study cities—London, Chicago, Brisbane and Melbourne—allowed comparisons to be made in the process required to transform available development data for each city into useful metrics for monitoring planning policy. A small number of indicators were developed to serve as a demonstration of potential measures that could be calculated using the available datasets for each city. These measures focused on three of the identified common planning-policy objectives: promotion of a mix of dwelling types; access to public transport and facilities; and conformity with spatial land-use or growth plans. Visualization methods that preserved the greatest level of spatial disaggregation were favoured for the prototype system, being point mapping for categorical and isolated metrics, and kernel density mapping for metrics requiring aggregation or to convey information on relative intensity.

The chosen metrics, combined with the visualization outputs, provide a successful demonstration of how planning objectives can be measured in a standardized and ongoing fashion. The prototype system can help to address many of the identified obstacles for monitoring in professional town-planning practice, foremost the automation of tasks required to clean data and compile indicator measurements, but also by extending current techniques to preserve information at a spatially disaggregated scale and in an accessible format, and future work should be directed to user testing and extending current capabilities in association with user feedback. Monitoring the actual effects of policy has long been an ideal of planning, being necessary to improve decision-making, but is often limited in practice. This project demonstrates the potential of bringing together new sources of data and technology as a tool to bring the profession a few steps closer to this ideal.

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