UNIVERSITY OF CAMBRIDGE
Centre for Digital Built Britain

2017/18 Mini-Project

PolyChora Alpha: a new digital interface for interdisciplinary city design

Final Report

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Executive Summary

The aim of this project is to develop a new digital interface to integrate the data and visualisation of the designs of land use, buildings, transport infrastructure and associated urban services at both the neighbourhood and city scale. The interface can also be used to modify a range of aspects of such designs in the course of visualisations by non-specialists, with underlying building information data stored for feedback to the respective design teams. The focus of the work is the new method and tool for connecting digital data from multiple disciplines including architecture, city planning, transport planning, spatial economic studies and infrastructure investment.

In the past decade, a variety of data analytics and modelling techniques have been implemented in the planning and design of housing, offices, retail, public spaces, business parks, factories, logistics premises, mixed use neighbourhoods, road and rail projects, traffic control and regulation, emergency responses to events, terror-attack and natural disasters, etc. Each technique has been defined and applied with a specific disciplinary context. While BIM and associated standards are being implemented within each of the business sectors and disciplines a new challenge is emerging regarding the lack of connections and interface between the datasets. This has severely hampered the progress in co-design and coordination among the design disciplines, especially in fast growing cities where it is essential to join up the planning of business premises, housing and transport in the design of specific building or infrastructure.

The Cities and Transport Research Group led by Ying Jin at the Martin Centre for Architectural and Urban Studies, Department of Architecture is leading the world in connecting data and modelling among economists, transport and traffic engineers, housing and neighbourhood planners, urban designers and infrastructure investors in their integrated computer models of cities. Their models have been successfully applied around the world for predicting the joint effects of planning, design and infrastructure interventions. Ying Jin is currently leading a three-year 'Cambridge Futures 3' modelling study funded by Cambridgeshire and Peterborough Combined Authority and Cambridge Ahead to design and examine alternative scenarios of workplaces, housing and transport to 2031 and 2051. He is also an expert adviser for BSi and the International Organization for Standardization (ISO) for data standards including BIM at city scale.

In the existing models it requires specialist knowledge from each of the disciplines to specify and modify data inputs that represent alternative designs, and it is costly to produce 3D visualisation portraying the joined-up city design proposals. This means that only experts can work with the models at present, whilst the non-specialists are forced to consider the models as black boxes. Only on some rare occasions in the past (and with considerable expense) the model data was visualised in realistic 3D built form. Such visualisation that exists had proven extremely effective in helping policy makers and the public understand and contribute. However, so far there are no easy, repeatable methods and tools to achieve such visualisation or to record feedback during visualisation.

In this project we have been able to develop a pre-general release, alpha version of the visualisation tool through integrating both (1) data for land use, transport and buildings at the site level) and (2) modelling and visualisation tools for land use, transport and buildings at the site level. Its first applications in research on the Cambridge Futures 3 project and in MPhil teaching with a student project have proven to reduce the interaction time between the modelling specialists and non-specialists significantly, for data verification, validation, comprehension and scenario development.

In terms of policy impact the first results on the baseline scenarios have been used by the Cambridge and Peterborough Independent Economic Review (CPIER, 2018), with further outputs on radically different, alternative scenarios progressing in review pipeline.

Abstract

The aim of this project is to develop a new digital interface to integrate the data and visualisation of the designs of land use, buildings, transport infrastructure and associated urban services at both the neighbourhood and city scale. The focus of the work is the new method and tool for connecting digital data from multiple disciplines including architecture, city planning, transport planning, spatial economic studies and infrastructure investment. While BIM and associated standards are being implemented within each of the business sectors and disciplines a new challenge is emerging regarding the lack of connections and interface between the datasets. In this project we have been able to develop a pre-general release, alpha version of the visualisation tool through integrating both (1) data for land use, transport and buildings at the site level) and (2) modelling and visualisation tools for land use, transport and buildings at the site level. Its first applications in research on the Cambridge Futures 3 project and in MPhil teaching have proven to reduce the interaction time between the modelling specialists and non-specialists significantly, for data verification, validation, comprehension and scenario development. In terms of policy impact the first results on the baseline scenarios have been used by the Cambridge and Peterborough Independent Economic Review (CPIER, 2018), with further outputs on radically different, alternative scenarios progressing in review pipeline.

Research Question

The core research is how to develop a coherent visualisation tool through integrating both (1) data for land use, transport and buildings at the site level) and (2) modelling and visualisation tools for land use, transport and buildings at the site level. As the datasets that are held in each of the above disciplines grow, the inconsistencies and discrepancies among the datasets become a more apparent challenge that would potentially become detrimental to consider how to balance the development strategies in land use, transport and specific estate property and infrastructure projects.

In this project, the research aim is to leverage the computer simulation models for land use, transport and buildings and decompose the data and tool integration question into a series of feasible stages of data definition, visualisation and consultation, first through effective visualisation of each of the component datasets, and then integrate them through 2D and 3D visualisation of the complete urban systems.

The proposed project is well aligned to the Centre's aim to develop and demonstrate policy and practical insights, leading to standards and guidance in the UK and internationally. More specifically, the project leverages the new and emerging BIM research and technology, track capabilities in Cambridge to develop commercial exploitation of our integrated urban modelling capabilities, and magnify their policy and social impacts, and fills a gap in implementing BIM levels 3 and 4 by connecting BIM data among multiple business sectors and disciplines. The outcomes of the research are made available to local and regional governments, and national and international standard bodies

More specifically, the proposed project builds an alpha version (i.e. a pre-general-release, researcher version) of a new digital interface software for visualising in 3D animation the combined urban land use, buildings, transport infrastructure and associated urban services. The emphasis is placed on interfacing the above 3D data and model with non-specialist users – it is expected that the users will be able to use an easy and intuitive interface (e.g. through sliding bars) to modify some aspects of the 3D datasets for revised visualisation, using common equipment such as a laptop computer and an iPAD tablet.

The project aims to build this tool for use at the scale of a city region, i.e. not only the densest core but also the faster changing periphery of the city. The short name of the project is therefore PolyChora (meaning a city region supported by multiple data sources and to undergo multiple alternative design scenarios) rather than focusing on a city alone (in which case the name would be PolyPolis).

Methodology

In the project we start from a fully fledged integrated city-scale computer simulation model which provides the digital datasets for urban land use, buildings, transport infrastructure and associated urban services – the first part of the datasets are city design inputs, such as the layout, density and building design of housing, workplaces, public spaces, roads, transit lines, etc; the second part are model outputs such as predictions of the occupancy of the buildings, traffic flows, congestion, prices and rents. At present no easy user interface exists and specialists have very limited means (such as via CAD and GIS tools) to interrogate and revise the data. This process is time-consuming and inefficient, and above all cannot involve non-specialist users in an easy way.

In the design of the tool, we envisage that the tool's structure and data flow will be flexible enough to interface with a full range of BIM, GIS and augmented reality (AR) softwares, both those currently in use and those emerging in the foreseeable time horizon. It will also be flexible enough to allow the integration of multiple data formats (linear, areal, volume, agent). It is hoped that the flexibility of the tool will make it resilient and adaptable to the rapidly changing technical scene of the underlying software tools.

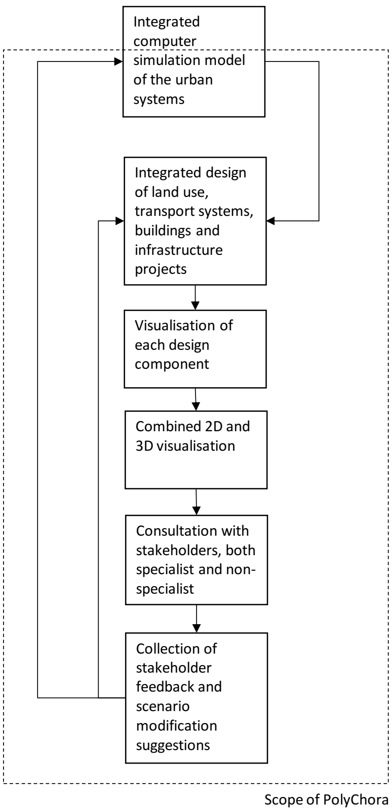

Figure 1. PolyChora: Scope and Flow Chart

Figure 1 presents the scope and flow chart of the PolyChora tool. First of all, PolyChora is supported by and interfaced with an integrated computer simulation model of the urban systems (which in turn consist of urban land use, transport buildings, infrastructure facilities and their use by citizens). Its main use is currently envisaged to be supporting the integrated design of alternative scenarios of urban land use, transport systems, buildings and infrastructure projects. A first stage of PolyChora's use is to visualise each design component, and once the design and configuration of each of the components are verified and confirmed by stakeholders, PolyChora produces combined 2D and 3D visualisation of the complete systems that consist of interconnected components. Such visualisation of complete systems are then shown to both specialist and non-specialist stakeholders, and feedbacks and scenario modification suggestions collected from them (either directly via the user interface as a data input, or verbally if a qualitative comment). Such stakeholder feedbacks are then used to modify both the model and integrated scenario design.

While the use of an integrated urban systems simulation model provides direct support in coordinating the interfaces of the distinct datasets, PolyChora provides an effective mechanism to design and modify the stakeholder inputs for the simulation model. The urban systems simulation model and PolyChora therefore complement each other.

Case Study

To illustrate the use of PolyChora, we have applied a pre-general release, Alpha version of the tool to our current Cambridge and Peterborough Futures (CPF) modelling study which is funded by Cambridgeshire and Peterborough Combined Authority and Cambridge Ahead. The use of the tool to design and examine alternative scenarios of workplaces, housing and transport to 2031 and 2051 has proven the efficacy of this 2D and 3D visualisation approach. The CPF study has already produced the main datasets for use in economic, social and environmental assessment. However, the CPF modelling study does not cover the scope of visualisation nor non-specialist user interface. The PolyChora tool in its current form has greatly improved the efficiency for engaging with policy makers and non-city-planners in the planning and design.

As the CPF scenarios are still being checked and modified in the review process (which remains highly sensitive among the stakeholders until the review is complete), we present a summary with public material plus a MPhil student project that has been carried out using the tool. Figures 1-10 below presents the main stages of the 2D and 3D mapping for the tool:

1) Define model and presentation zoning (Figure 2)
2) Define land use zone at the UK national level (so that the tool becomes applicable nationally; Figure 3)
3) Mapping land use inputs – example 1 (housing supply 2011-2031 under the Baseline Scenario in and around Cambridge, Figure 4)
4) Mapping land use inputs – example 2 (business floorspace supply 2011-2031 under the Baseline Scenario in and around Cambridge; Figure 5)
5) Mapping land use inputs – example 3 (housing supply 2011-2031 under an alternative planning scenario 'Transport Corridors' in and around Cambridge; Figure 6)
6) Mapping land use and transport inputs – example 4 (jobs growth and transit lines 2011-2031 under an alternative planning scenario 'Transport Corridors' in and around Cambridge, Figure 7)
7) 2D and 3D representation for the existing situation and model simulation results under the 'Transport Corridors' scenario for the Waterbeach area, to the north of Cambridge (Figure 8-10).

Figure 2 Cambridge and Peterborough Futures Computer Simulation Model – Model Zone Plan (Source: CPF Model)

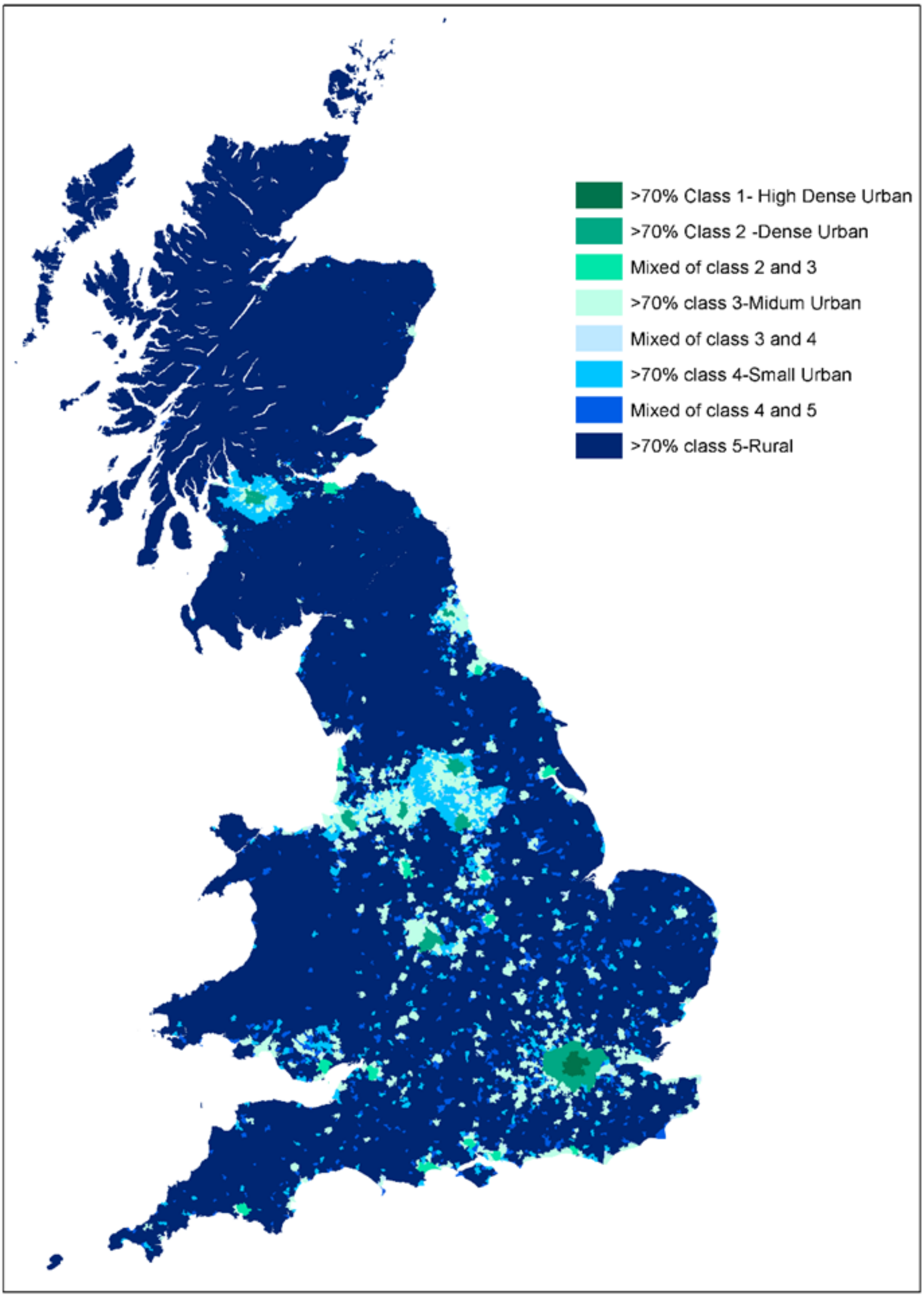

Figure 3 Mapping of the Land Use Zone Classification based on National Travel Survey Data (Source: Jin et al, 2018)

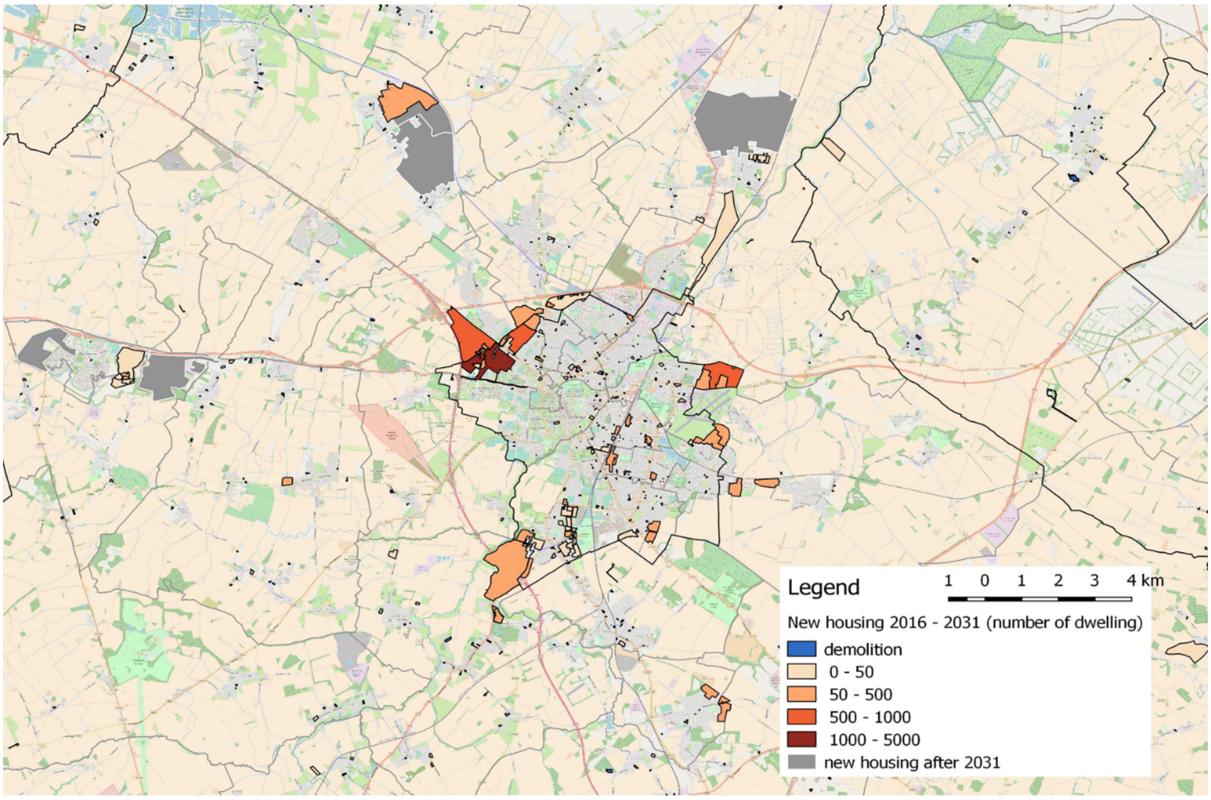

Figure 4 Mapping Housing Development Plans 2011-2031 as the Baseline Scenario, based on local plan data

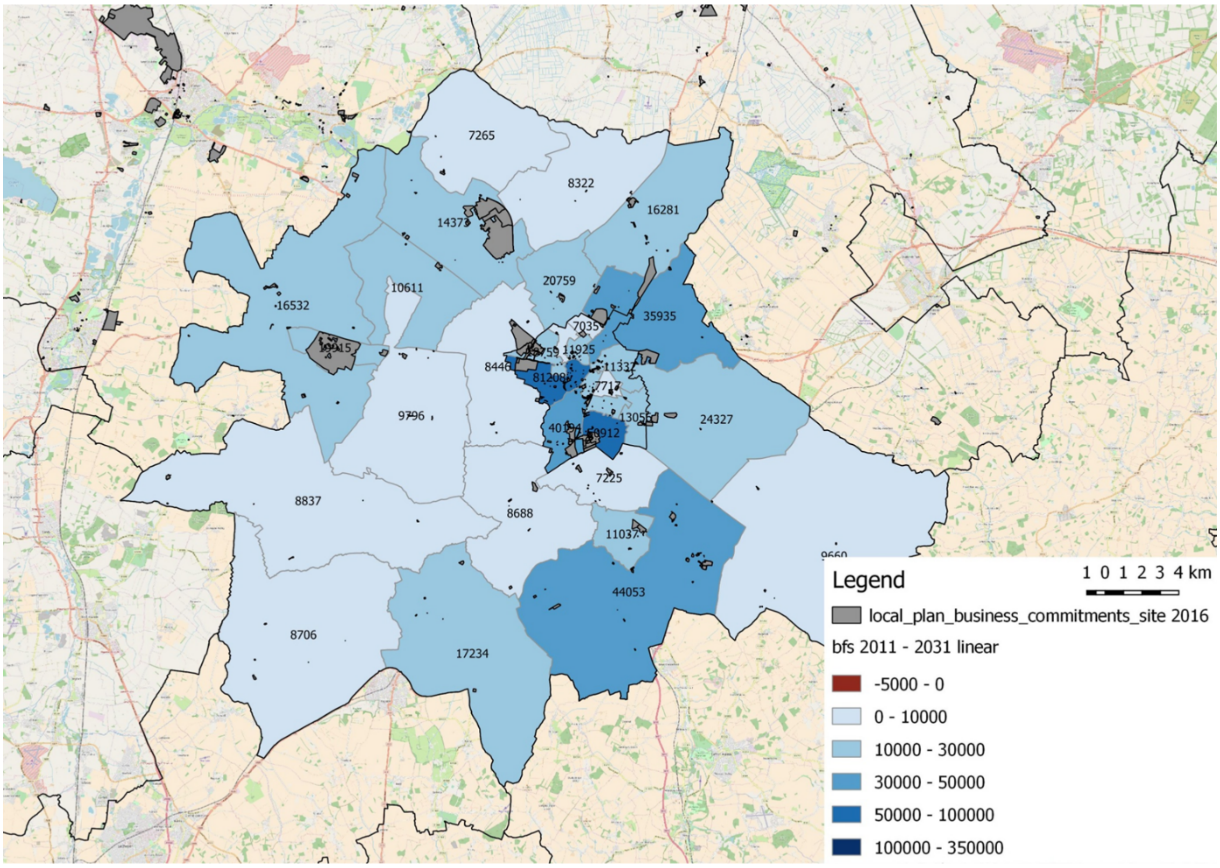

Figure 5 Mapping Business Floorspace Development Trends 2011-2031, based on projection of trends 2011-2016

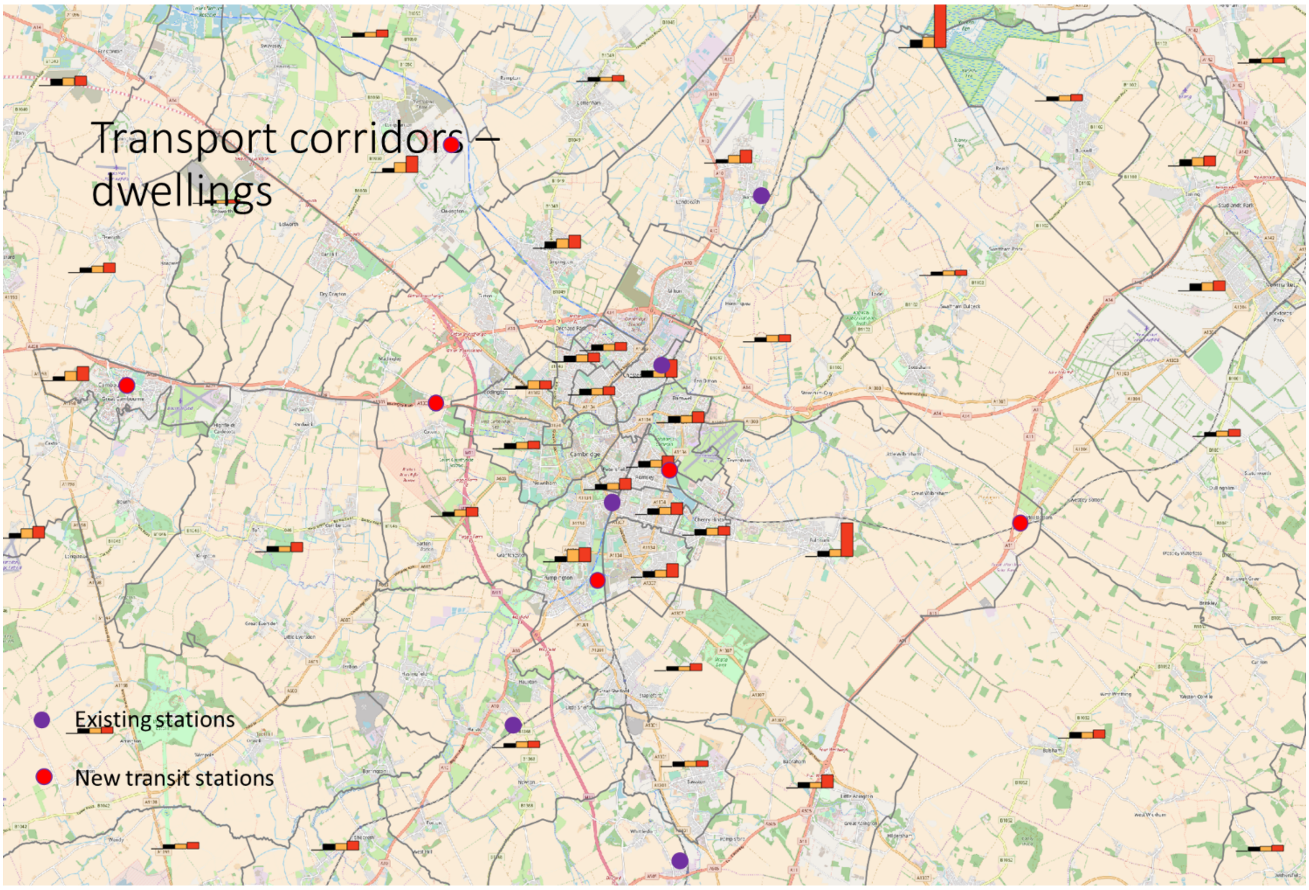

Figure 6 Mapping Alternative Housing Development Plans, Under the 'Transport Corridors' Scenario

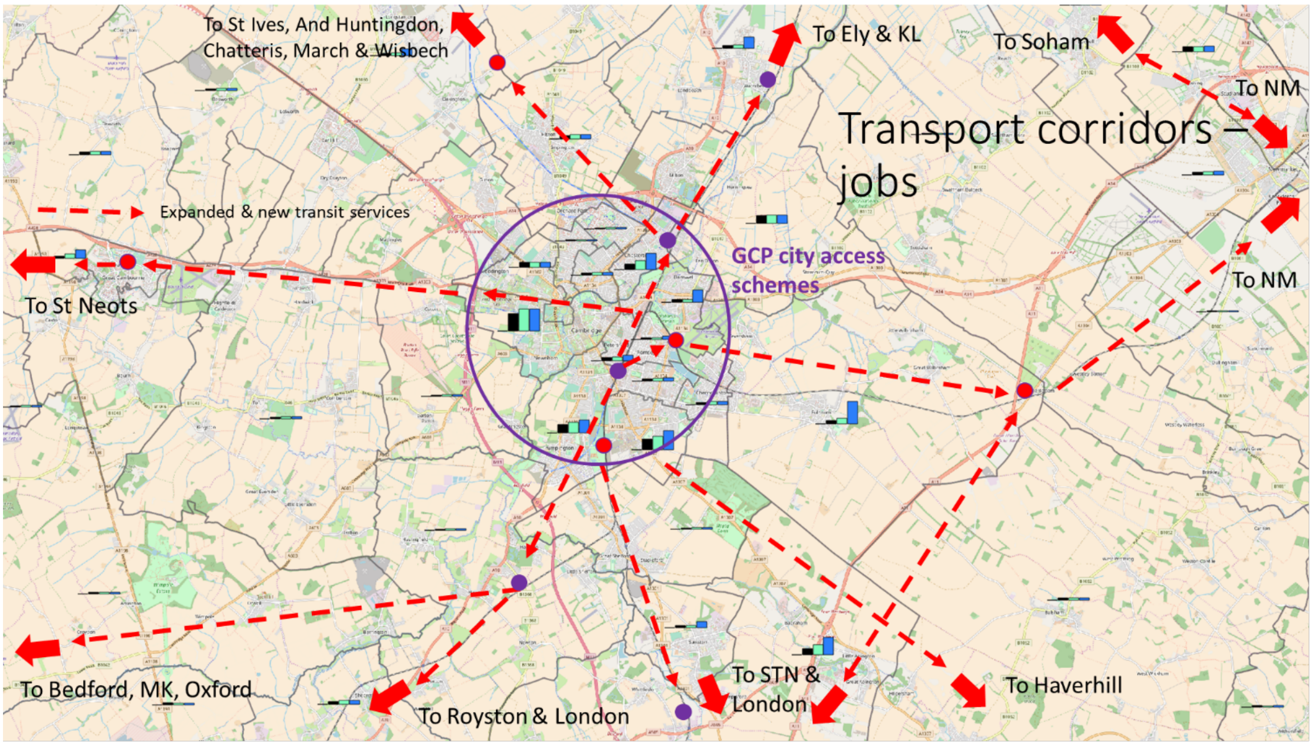

Figure 7 Mapping Alternative Job Growth and Transit Corridors, Under the 'Transport Corridors' Scenario

Figure 8 Mapping Integrated Land Use, Transport and Buildings Under the Transport Corridors Scenario for the Waterbeach Urban Extension (2D)

(Note: Light pink: Existing Buildings; Deep pink: Housing and Community Facilities to Be Built Within Time Horizon; Blue: Future Reserved Land)

Figure 9 Waterbeach: existing land use, transport links and buildings (3D using Rhino-Grasshopper visualisation)

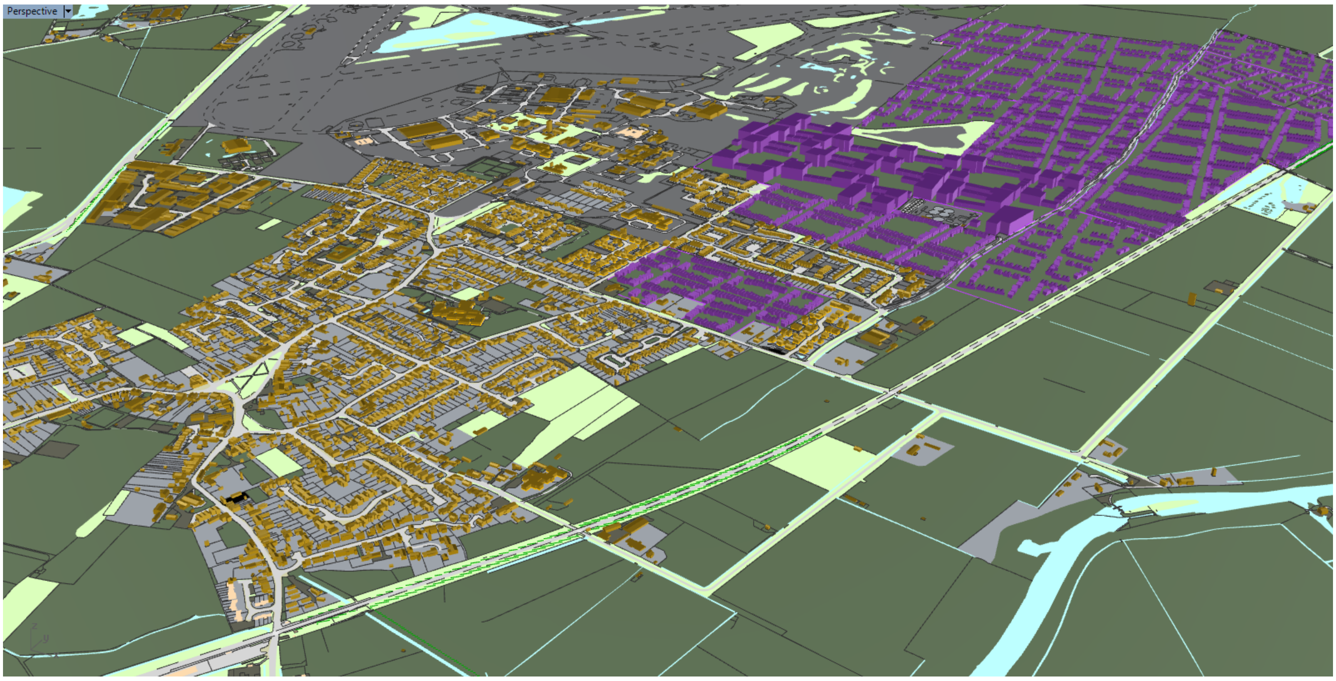

Figure 10 Waterbeach: existing and planned land use, transport links and buildings (3D using Rhino-Grasshopper visualisation)

Discussion

The development of the alpha (i.e. pre-general release) version of PolyChora has already made it much more efficient to discuss and modify the computer simulation model inputs, which according to our estimates has doubled the rate in the production of the simulation runs. As the tool is refined we expect the efficiency gains will become greater. More importantly, the 2D and 3D visualisation has made it straight-forward to discuss and define the scenario model inputs. So far in the CPF work five variants of the Baseline scenario and four further alternative scenarios have been developed and tested this way.

What is quite surprising in the tests so far is that the local government officials, local planners, designers, the business community and the charity organisations (such as Cambridge-Past-Present-Future) appear to favour working with the numbers and 2D visualisation, rather that the 3D which we thought would be more popular. This is in part because so far the discussions have been carried out within a quite small group of highly skilled people. As the presentation is rolled out to the wider public this may well change. We have also noted the comments and suggestions for improving the 3D presentation so that it carries with it more precise tabulation and presentation of data along the lines of AR, and this is also expected to improve the use of the 3D outputs in the future.

Conclusions

In this project we have been able to develop a pre-general release, alpha version of the visualisation tool through integrating both (1) data for land use, transport and buildings at the site level) and (2) modelling and visualisation tools for land use, transport and buildings at the site level. Its first applications in research on the Cambridge Futures 3 project and in MPhil teaching with a student project have proven to reduce the interaction time between the modelling specialists and non-specialists significantly, for data verification, validation, comprehension and scenario development.

In terms of policy impact the first results on the baseline scenarios have been used by the Cambridge and Peterborough Independent Economic Review (CPIER, 2018), with further outputs on radically different, alternative scenarios progressing in review pipeline. We have also initiated the discussion with the British Standards Institution (BSi) on producing a Publicly Available Specification (PAS) for interdisciplinary city design modelling, and the concept of PolyChora will become a key part of this PAS.

Acknowledgements

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References

CPIER (2018). The Cambridgeshire and Peterborough Independent Economic Review – Interim Report. Study Funded by the Cambridgeshire and Peterborough Combined Authority.

Hagen-Zanker, A and Y Jin (2015). Adaptive zoning for efficient transport modelling in urban models. 15th International Conference on Computational Science and Its Applications (ICCSA 2015). Banff, AB, Canada, June 22–25. Best Paper Award. Published as Gervasi, O, B Murgante, S Misra, ML Gavrilova, AMAC Rocha, C Torre, D Taniar and BO Apduhan (eds.) (2015). Computational Science and Its Applications – ICCSA 2015 Proceedings Part III, Springer, Heidelberg, pp673-687.

Jahanshahi, K and Y Jin (2017). Mapping interdependencies surrounding car ownership and travel choices in Britain through integrating structural equation modelling with latent class analysis, Full paper peer reviewed and accepted (18-06746) the US Transport Research Board (TRB) for its Annual Meeting.

Jin Y, M Echenique and A Hargreaves (2013). A recursive spatial equilibrium model for planning large-scale urban change. Environment and Planning B: Planning and Design, Vol 40: pp1027-1050 (doi:10.1068/b39134).

Jin, Y, K Jahanshahi, L Wan and X Rong (2018). Novel applications of structural equation models for car ownership and travel choice forecasting. Report funded by the UK Department for Transport T-TRIG Grant. Department for Transport, London.