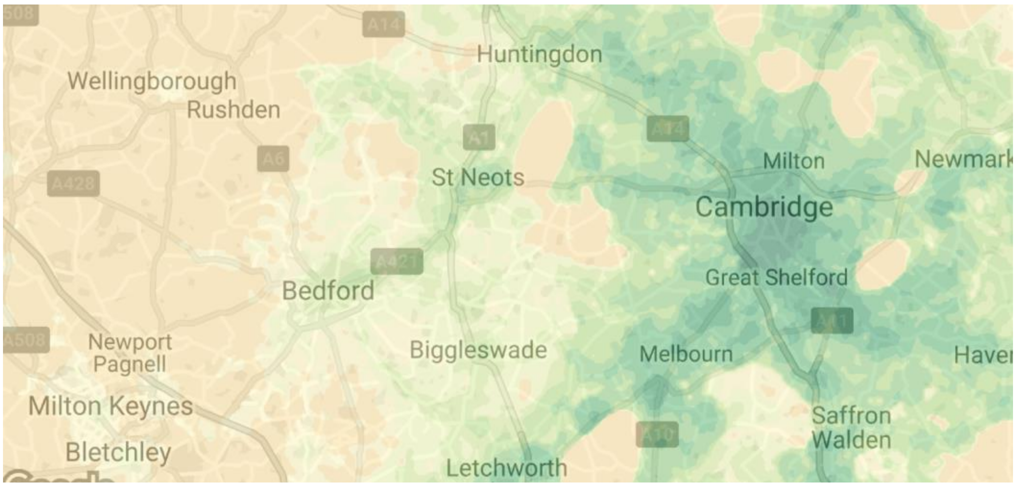
UNIVERSITY OF CAMBRIDGE
Centre for Digital Built Britain

2017/18 Mini-Project

Exploiting traffic data to improve asset management and citizen quality of life



Final Report

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Abstract

The main goal of this project was to demonstrate how large data sources such as Google Maps can be used to inform transportation-related asset management decisions. Specifically, we investigated how the interdependence between infrastructures and assets can be studied using transportation data and heat maps. This involves linking the effect of disruptions in lower-order assets to travel accessibility to private and public infrastructure. In order to demonstrate the viability of our approach, we conducted 5 case studies, 3 public and 2 private. On the public side, we collaborated with two county councils in the United Kingdom, specifically Cambridgeshire and Hertfordshire, and offered solutions to existing infrastructure-related problems proposed by them. For Cambridgeshire, we analysed the accessibility to Cambridge University's new research centers and the criticality of roads leading to Addenbrooke's Hospital in Cambridge. Similarly for Hertfordshire, the accessibility to different critical assets in the county were examined with the aim of supporting planning decisions. In addition, to highlight how our approach can bring benefits to private citizens, we solved two examples of commuting-related problems posed by students at the Institute for Manufacturing (IfM). We conclude that heat maps generated using the Google Maps API are powerful and efficient tools for use in infrastructure asset management. Our approach appears to be more cost-efficient and offers a higher quality of visualisation and presentation than other available tools. Furthermore, there exists the potential for a commercial spin-off: our approach can be employed in local, regional and national administrations to inform infrastructure-related decision-making, and can be used by commercial parties to improve employees' commutes, parking, et cetera.

Background

Asset management, criticality, and infrastructure

Infrastructure is key to the functioning of all modern societies. Networks of roads, bridges, pipelines, cables, water mains and other assets are critical to our economic, social and cultural well-being. However, these assets are often taken for granted, with people assuming they will continue to work without regular or extensive failures. Since infrastructure assets are continuously being updated and make increasing use of the digital technologies, the task of managing these assets is modernising, with researchers and practitioners continuously adapting to this modernisation. The proper management of infrastructure assets has thus become critical to providing economic services [1].

An important part of what we call infrastructure asset management is criticality analysis [2, 3]. Questions of criticality revolve around determining which assets are critical in a particular context: i.e. which assets will have a bigger effect in the performance of the system upon failure. Within the context of infrastructure asset management, criticality analysis could, for example, give insight into which roads or other transportation services are most important with regards to the accessibility of a certain asset, such as a hospital. Criticality analysis can also drive other asset management decisions regarding investment planning, maintenance prioritisation, and monitoring. However, carrying out an accurate criticality analysis is often hampered by the availability of good quality information. This project addresses this key issue by making use of a global data source: Google Maps and its API.

Heat maps

A heat map is a visual representation of data on a geographical map using colours [4] to help differentiate a key variable of interest. They are used in a wide variety of contexts ranging from visualising weather and climate models to understanding house foreclosures and consumer demand for certain products [5]. This makes heat maps a tool relevant to administrators, asset managers, as well as citizens' everyday lives. When it comes to infrastructure asset management, particularly for public administrations, heat maps also have myriad potential applications as they can be used to visualise the effects of particular assets within the geographical landscape of a country or region. They also have potential for use in criticality analysis, as they present an intuitive way to visualise the importance of certain assets.

However, heat maps are only as good as the data used to create them. This is often one of the problems with transportation time and criticality visualisation tools: they tend to have limited data to work with (for example when it is provided by a local, regional or national government), and it can be difficult to find applications outside of a very specific context. Existing tools that serve the above purpose, such as TRACC (developed by BaseMap)[1], Transit Time NYC[2] and Mapnificent[3] are often geographically constrained, struggle to achieve good resolution at small scales and fail to connect the concept of heat map visualisation to asset management. Clear and trustworthy transportation time maps are also key to understand public servicing inequalities and inform future policy aiming to bridge this gap.

Goal of the project

This project aims to demonstrate the utility of transportation time data to generate tools capable to inform public policy by providing logistic (location) recommendations for the management of public assets such as hospitals, schools, et cetera. We seek to show the potential for highlighting different transportation metrics in the world's urban areas, which at the same time is key to evaluate future infrastructure investments and bridge possible inequalities in public transport and road servicing. In addition, this project helps outline the positive impact of infrastructure data on citizen well-being by showcasing examples where an everyday situation, such as choosing the right house to move into vis-à-vis the travel options to one's place of work, can be informed by new digital technologies and techniques.

Research Question

The asset management group at the Institute for Manufacturing (IfM) at the University of Cambridge has long been interested in infrastructure criticality questions and geographical asset analysis. The tools used in this endeavour are often geographically constrained, suffer from low resolution, and are not targeted to asset management. This prompted us to ask the question of whether a tool that had already been developed could be informative for transportation and infrastructure asset management. The main question that guided this project is therefore:

How can publicly available datasets be effectively exploited for carrying out infrastructure criticality analysis?

In particular, this project answers this question by addressing it in the context of transportation infrastructure and criticality based on travel times through the analysis of Google Maps data.

[1] http://www.basemap.co.uk/tracc/
[2] https://project.wnyc.org/transit-time/
[3] www.mapnificent.net

Methodology and approach

We make use of data obtained through the Google Maps API. An API, or “Application Programming Interface”, is a set of protocols and tools that developers can use to build software based on existing software. The Google Maps API can be used by developers for a wide range of implementations and applications. Google encourages developers to create their own tools and solutions by making use of their API.

Google has a wide set of APIs that can be accessed online, each with a different purpose. For this project we are particularly interested in the Directions API and the Static Maps API. The Directions API can be used to obtain directions between two geographical points, and the Static Maps API provides high-quality maps for practically any region of the planet.

The Directions API

The Directions API gives access to an online data generator that responds to individual calls. These calls have the following inputs:

- Position of origin and Position of destination: by coordinates, address or name of point of interest.
- Mode of travel: driving, walking, cycling or public transit. Here, “transit” includes combinations of public transportation (bus, subway, train or tram) and walking.
- Time of departure, or time of arrival.
- Additional specifications: for example, requiring the API to provide alternative routes and not only the fastest option from A to B.

The Directions API then returns the following outputs (summarised):

- Detailed directions from the origin to the destination. This includes roads traveled, public transportation lines used, detailed directions for walking or cycling, warnings (for example, with regards to dangerous traffic), and a geometrical poliline of the trajectory between the two points.
- Information about transportation time, and the total distance.

The Static Maps API

The static maps API provides high resolution maps of the earth’s surface tailored to the user’s demand. Here, the input to Google and subsequent output are much simpler. The user inputs the centre of the map, its extension and style, and Google generates it from its dataset of geographical data. The style, content and scope of such maps is broad, as Google allows users to generate their own map-generating instructions.

Python as a plotting and data manipulation tool

In this project, we used a Python framework previously scripted by Jon Roozenbeek and Adrià Salvador Palau to demonstrate the usefulness of Google’s data services. This framework was developed by us prior to commencing the CDBB project. The main libraries of reference are matplotbib and googlemaps, the latter being an official library by Google that gives online access to its API services.

Discussion

Approaching potential partners

In order to demonstrate the viability of our tool, we looked for companies and local and regional administrations to explain what our tool can do and explore its applications. First, we contacted a number of city- and county councils in the south of England. We also contacted a number of private and semi-private companies. These are the following:

- Polly Williams, Travel Plan Coordinator at Travel4Cambridgeshire, a (private) sustainable travel membership organisation that is part of Cambridgeshire County Council [6].
- Dan Clarke, Smart Cambridge Programme Manager at Cambridgeshire County Council [7].
- Jennifer Sibley, Principal Policy Officer for Transport, Infrastructure and Environment at London Councils [8].
- Chris Faires, Technology and Information Manager for Highways at Hertfordshire County Council [9].
- Norfolk County Council's Roads and Transport department [10].
- Suffolk County Council's Roads and Transport department [11].
- Transport for London, London's integrated transport authority [12].

Within the time span of this project, we received positive replies from Travel4Cambridgeshire, Smart Cambridge and Hertfordshire County Council. All three indicated that they were interested in our project's potential applications and requested a meeting. During each of these meetings, we explored what transportation- and infrastructure-related issues these organisations were facing and how our tool might help solve them. Hertfordshire and Cambridgeshire agreed to provide us with a number of specific and clearly defined problems that we could solve within the time span of the CDBB project. Travel4Cambridgeshire, which is a privately run section within the Cambridgeshire County Council, was also interested, especially in matters related to parking. Specifically, it asked us to look at how companies in Cambridgeshire could optimise their employees' ways of getting to work and alleviate Cambridge's congestion problems. However, Travel4Cambridgeshire required more time to draft a case study than what was available during the span of the project.

Project feasibility testing and results

As mentioned above, we conducted activities for Hertfordshire County Council, Smart Cambridge and Cambridgeshire County Council. This section will detail our activities for them. Where appropriate, we show indicative examples of the maps we produced.

Hertfordshire County Council

Hertfordshire County Council asked us to do two things:

- To compare the heat maps tool to the transportation maps that the Council has been using thus far which were developed by BaseMap. Specifically, they asked us to create a number of maps displaying the travel times from a central point in Hertford for different modes of transport: walking, bicycle, bus and train. Figure 1 shows BaseMap on the left, our map using the same resolution as the BaseMap heat map in the middle, and our high-resolution map on the right. Note the difference in shape of the travel time cutoff zones; while the BaseMap heat maps and our maps overlap to some extent, there is a difference in how fine-grained the maps are. .

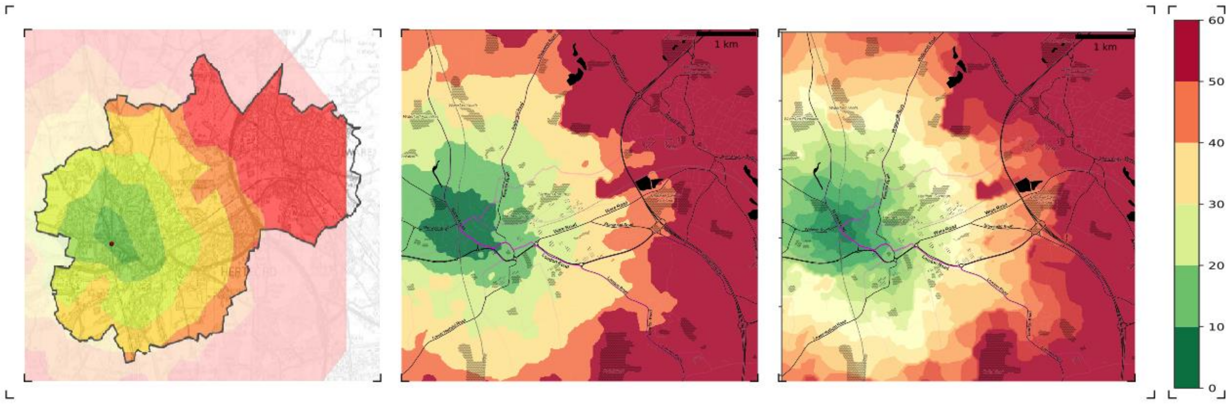

Figure 1: Pedestrian accessibility to Hertford North railway station (located in the middle of the greenest area on the maps). The bar on the right indicates the number of minutes of walking time.

- To analyse which roads and other infrastructure assets are critical for the accessibility of Princess Alexandra Hospital in Harlow. This hospital is considering moving to a different location, and the Council indicated that an analysis of several potential new locations' accessibility would be useful for determining the new hospital's optimal location. Since Hertfordshire County Council preferred not to make the results of our analysis public, we are unable to show the results in this report.

Cambridgeshire City Council and Smart Cambridge

Smart Cambridge provides "a 'digital' platform to support the transport infrastructure investments taking place in [Cambridgeshire]" [6]. Smart Cambridge asked us to look at the accessibility of the Cambridge Biomedical Research Centre and to the Babraham Research Campus, specifically when it comes to bus schedules and travel time, and to analyse critical infrastructure assets for Addenbrooke's Hospital. We will briefly discuss both case studies below.

Accessibility of the the Biomedical and Babraham Research Campus

Figure 2 shows the results for the Biomedical Campus, and figure 3 for Babraham.

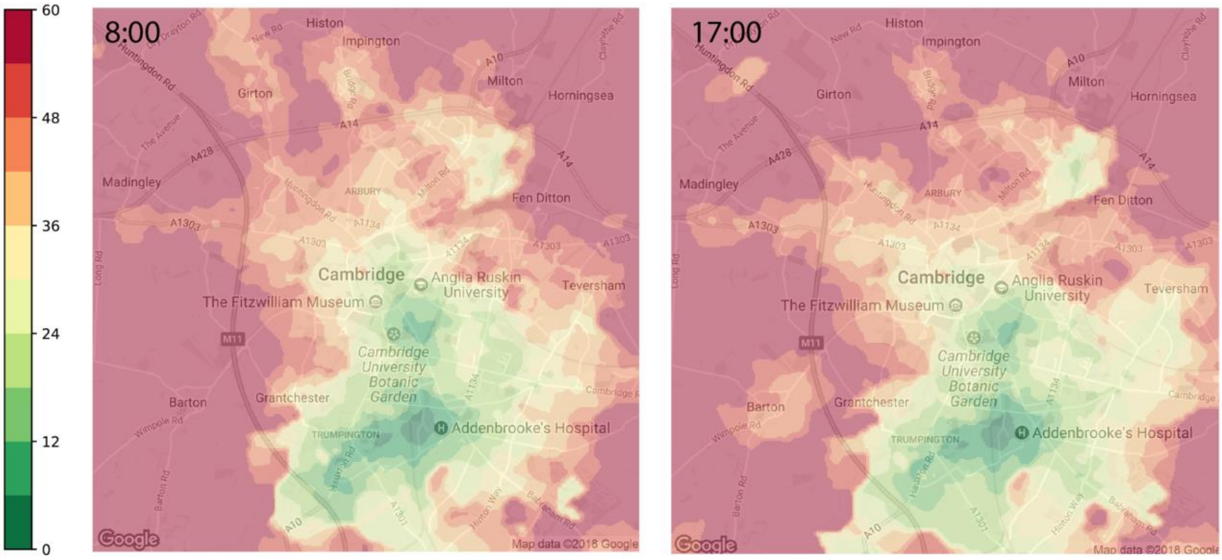

Figure 2: Transportation times by public transport to the Cambridge Biomedical Campus / Cambridge Biomedical Centre (just west of Addenbrooke's Hospital on the map), city level, at 08:00 and 17:00.

As we can see, the area roughly between Trumpington and Hills Road/Babraham Road has the best accessibility to the campus. Here, the average travel time is approximately 5-10 minutes. Trumpington is especially well-connected through the A1134. Most of the city centre is roughly 20-30 minutes away from the campus.

A number of areas are rather less well-serviced than one might expect. First, the area around Mill Road (south-east of Anglia Ruskin University on the map) is on average almost 30 minutes away from the campuses, despite the fact that the A1134 provides a direct route between these two places. Right now, bus lines do not use the A1134 directly to go between the Mill Road area and the Addenbrooke's area. Considering that a substantial number of Mill Road area residents working in and around Addenbrooke's, it could be worthwhile thinking about how to improve travel times here.

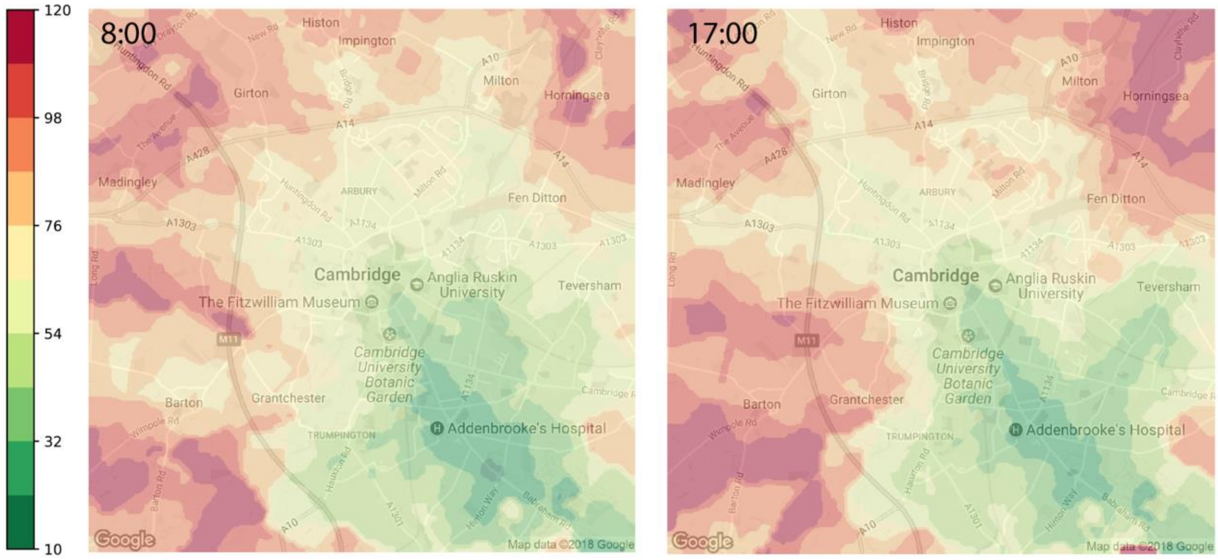

Figure 3. Transportation times by public transport to the Babraham Research Campus at 08:00 and 17:00. Babraham can be found on Babraham Road, just south-east of Addenbrooke's Hospital on the map.

We observe that the entirety of Babraham Road, between Babraham and Cambridge city centre, is well-connected to the campus. Travel times generally do not exceed 40 minutes in most areas around this road. Hinton Way, which leads towards Great Shelford (not visible on the map) is also well-connected, as is Cherry Hinton Road, which leads towards Teversham.

As with the Biomedical Research Campus, some areas in the centre of Cambridge are less well-connected than one may expect from such a central location. Once again, the area around Mill Road (close to Anglia Ruskin University on the map) is underserviced based on its location and importance as a residential area. Furthermore, the areas around Barton, Grantchester and Trumpington, in the south-east of the map, are especially poorly serviced. The same goes for the area around Madingley. From here, travel times to Babraham can run up to about 2 hours. This might be mitigated by installing a bus route that goes along the M11 and connects to Addenbrooke's and Babraham.

Critical infrastructure around Addenbrooke's Hospital

Smart Cambridge also asked us to look into critical infrastructure assets for Addenbrooke's Hospital, in order to find out which assets are critical to its accessibility, and in which order. This may help administrators determine, for example, when and where to conduct road works.

We calculated criticality by weighting the appearance of different bus routes in the transportation recommendations from the Google API. Concretely, we perform a random sample of destinations of origin and count how many times each route appears in the recommendations. These routes are then overlaid on the map with a colour scale proportional to the times that they have appeared in Google's recommendations.

Figure 4 shows the results. In the figure, purple routes are considered critical. The higher the criticality, the larger the influence of these bus routes on travel times to the hospital. The more intense the colour is, the more critical they are.

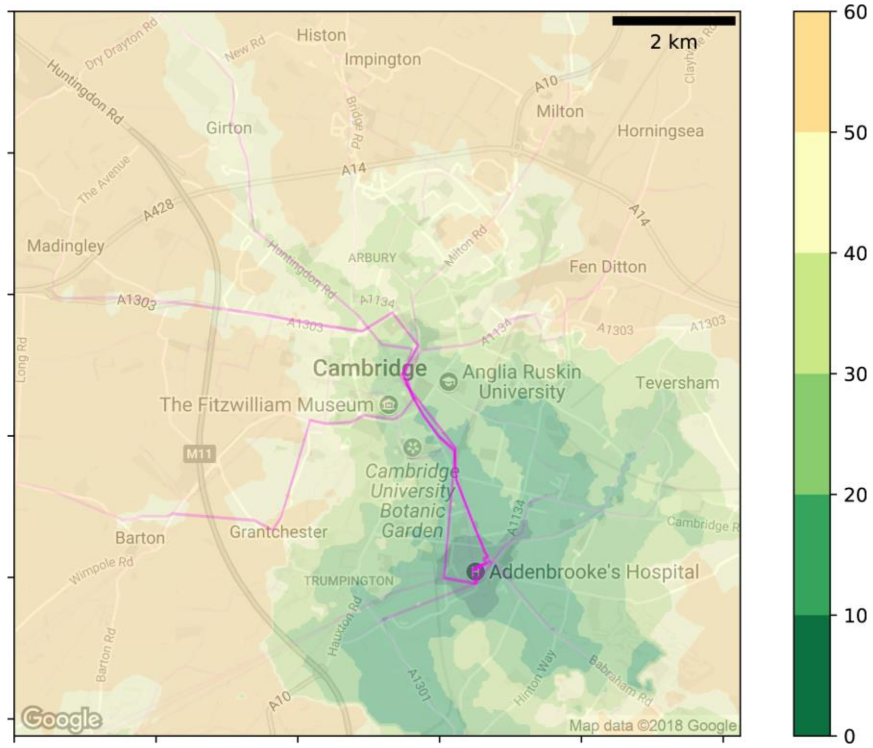

Figure 4. Transportation times and most critical public transportation routes servicing Addenbrooke's Hospital.

The map shows that the Busway Route (routes A and U) between the Cambridge Railway Station and Addenbrooke's Hospital is by far the most critical infrastructure asset. Robinson Way, which curls around the hospital, is also highly critical. Other critical assets are the bus routes along the A1307 between the station and the city centre, Babraham Road and Hills Road (but only up until Hinton Way), and the A603 between the centre and the M11, which also connects Grantchester and Barton.

Private citizens' case studies

In addition to the above mentioned public case studies, we conducted two studies that investigate problems more attuned to private citizens' daily lives.

First, we investigated how one might use our tool to find the optimal location for a place to live in terms of travel time. A student of the University of Cambridge came to us with the following problem: locate the ideal renting area in Cologne, Germany, according to his daily commute (to the Westviertel area of Essen (marked as position 1 in Figure 5)). He was concerned about his CO_2 footprint and wanted to use public transportation only. Figure 4 shows the results.

Figure 5: Map showing the position to which the student of the University of Cambridge had to commute (1) from the city of Cologne (2), commute times were calculated for the area marked in blue (see Figure 6).

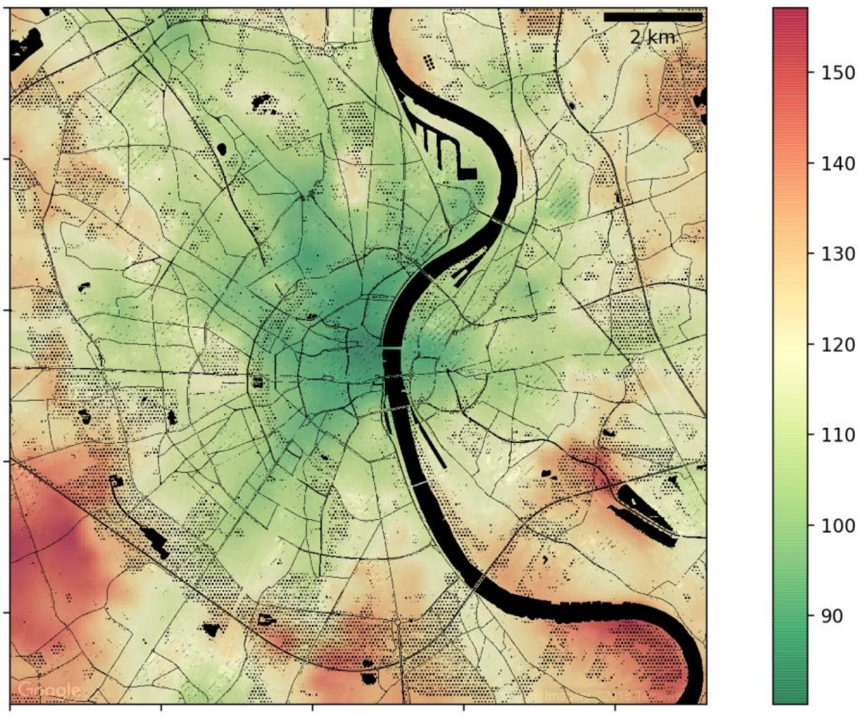

Figure 6: Weighted transportation times by public transportation to a place of work outside Cologne. The scale bar on the right shows the number of minutes spent on average to commute to the Westviertel area of Essen.

Second, we looked at a similar problem for finding a place to live in New York. One of the researchers working on this project was expecting to undertake an exchange in New York, where he would commute to two locations:

- Two days a week to IBM' Thomas J. Watson Research Center in Yorktown Heights (Position 1 in figure 7).
- Three days a week to Rutgers University in New Jersey (Position 2 in figure 7).

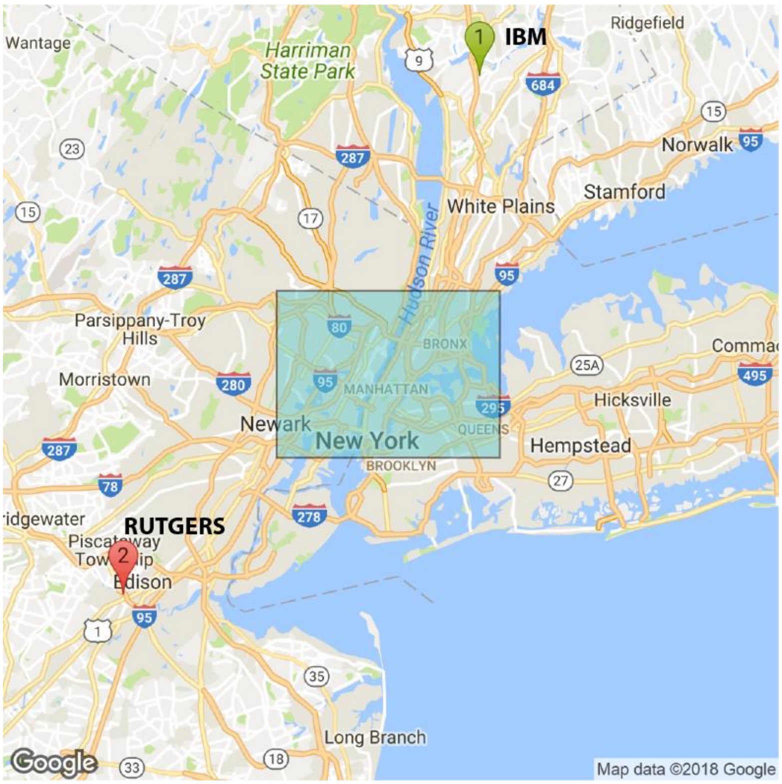

Figure 7: Map showing the two positions to which the researcher in this project had to commute during his stay in New York. The studied area shown in Figure 8 is marked in blue.

Commuting times to both places were calculated and weighted according to the time frequency. The result showed a map of the new-york are with the best places to live. The map was used to inform the location of the flat that was eventually rented.

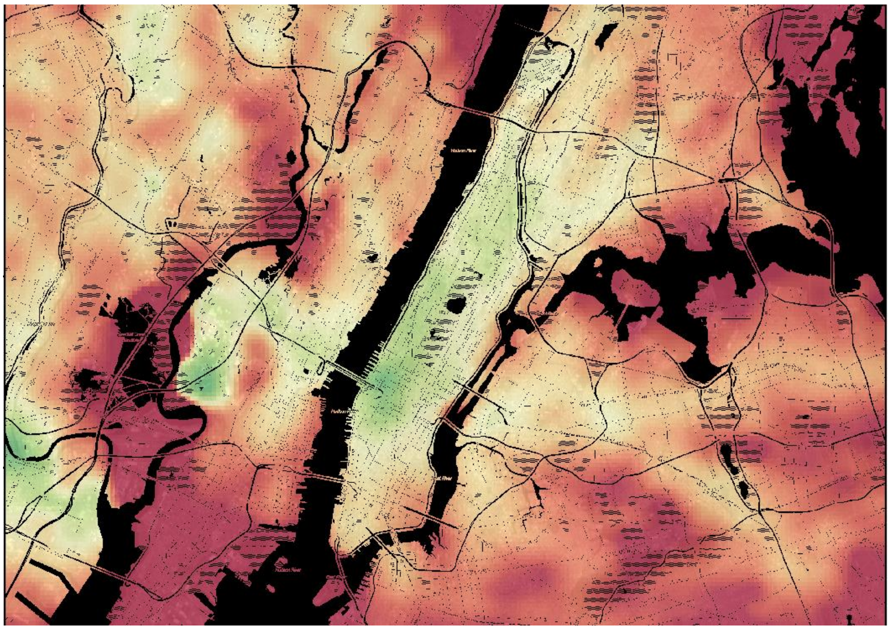

Figure 8: Weighted transportation times by public transportation to IBMs Thomas J. Watson Research Center in Yorktown Heights, and Rutgers University. The areas marked in greener colours correspond to a shorter commute. Note how non-trivial local minima appear in Manhattan and in New Jersey.

Conclusion

Our project has two main components: testing the utility of using Google API data to inform asset management decisions, and assessing the demand for the range of solutions that it can provide.

With regards to the usefulness of the Google API data, our final assessment is positive. We wanted to see whether large-scale data repositories like Google Maps could be used within asset management solutions and criticality analysis. Considering the range of identified problems and the solutions that we managed to provide, this appears to be the case. We are confident that we are capable of solving a large number of problems related to criticality, transport and infrastructure, both for private companies and local or regional administrations.

With regards to demand, our final assessment is also positive. Our exploration of what problems and issues both the private and the public sector are currently facing in the United Kingdom showed that both companies and local governments have questions about transportation, criticality and infrastructure, and that they see our contribution as a useful addition to their existing applications.

Related and Further Work

This project sought to demonstrate the utility of transportation time data (specifically: data obtained via the Google Maps API) to generate tools capable to inform public policy by providing logistic (location) recommendations for the management of public assets such as hospitals, schools, et cetera. The project also aimed to show the potential for highlighting different transportation (in)efficiencies in the world's urban areas, which at the same time is a key metric to evaluate future infrastructure investments and bridging possible inequalities in public transport and road servicing.

Thus far, we have explored a subset of the capabilities of the Google Maps API with regards to criticality and transport and infrastructure asset management. However, there are many questions that have remained unaddressed in our report. First, our work has thus far mostly remained limited to the United Kingdom. Since Google is a global company, there are many possibilities for implementing solutions outside of the UK and even Europe.

Second, we have focused mostly on transportation-related questions raised by public administration officials. There are, however, many possible implementations for the private sector as well. For example, large employers around Cambridge are experiencing problems finding ample parking space for their employees. Our tool can provide solutions to this problem by investigating where best to run a shuttle service, or by pointing out areas with less congestion. This warrants further exploration.

Third, the problems we have solved so far were relatively straightforward compared to the much more complex issues that companies and administrations have indicated. Our tool is in theory capable of also solving such complex problems, but this will have to be tested.

Fourth, our tool has shown potential for both commercial and academic exploitation. Commercially, we want to use the tool in consultancy services for administrations and private companies. Academically, DIAL could use this tool as a baseline for conducting criticality analysis; this would require overlaying the tool's maps with other data relevant to the research.

Acknowledgements

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