

Advanced GIS

Raphaëlle ROFFO

Sciences Po - Urban School

Session 5

Multi-Criteria Decision Analysis in GIS

Today's plan

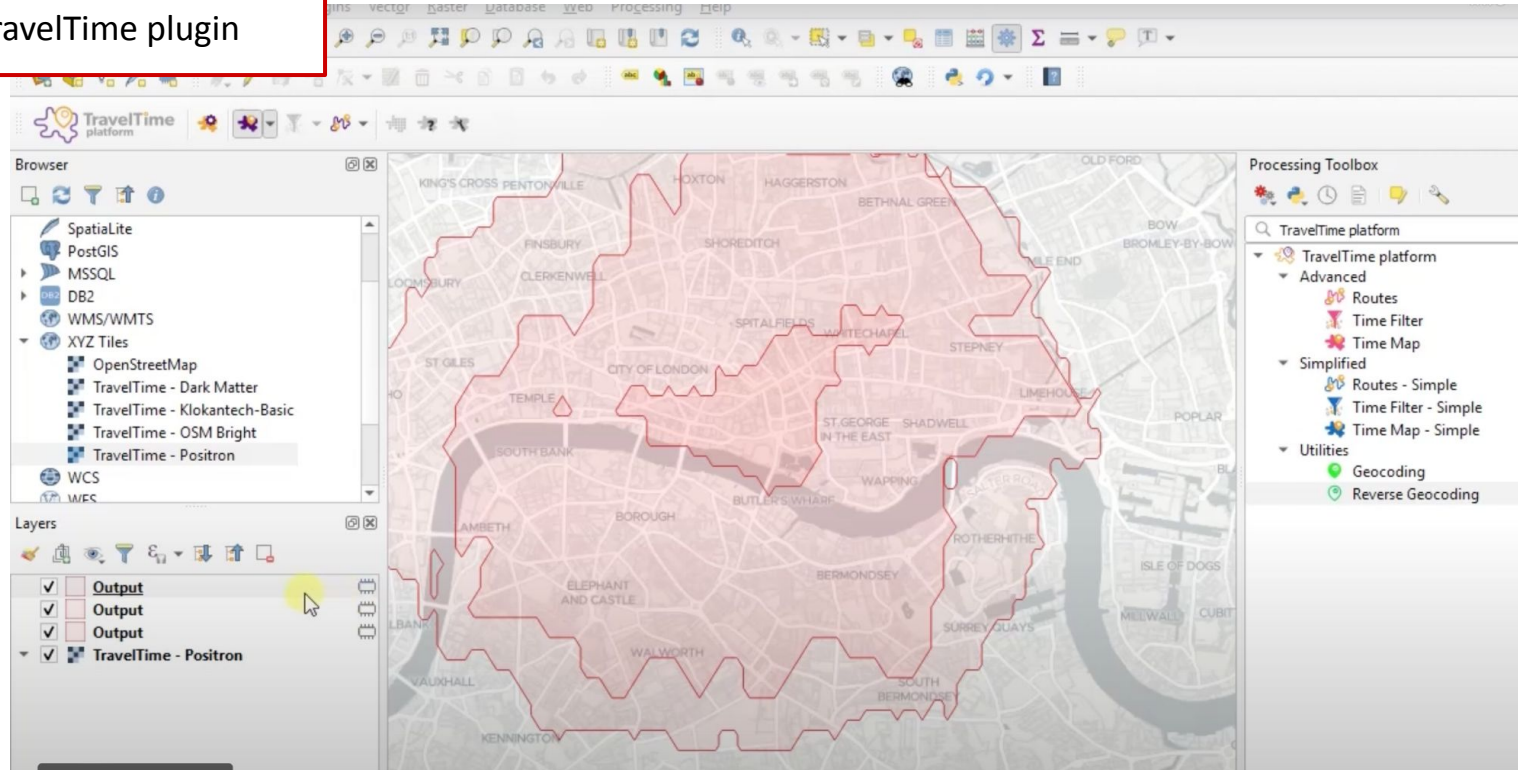
1. Isochrones / Cartogram tutorial: Feedback, Q&A
2. Environmental Justice in GIS
3. Multi criteria decision analysis



Session 5 Tutorial

Isochrones using TravelTime

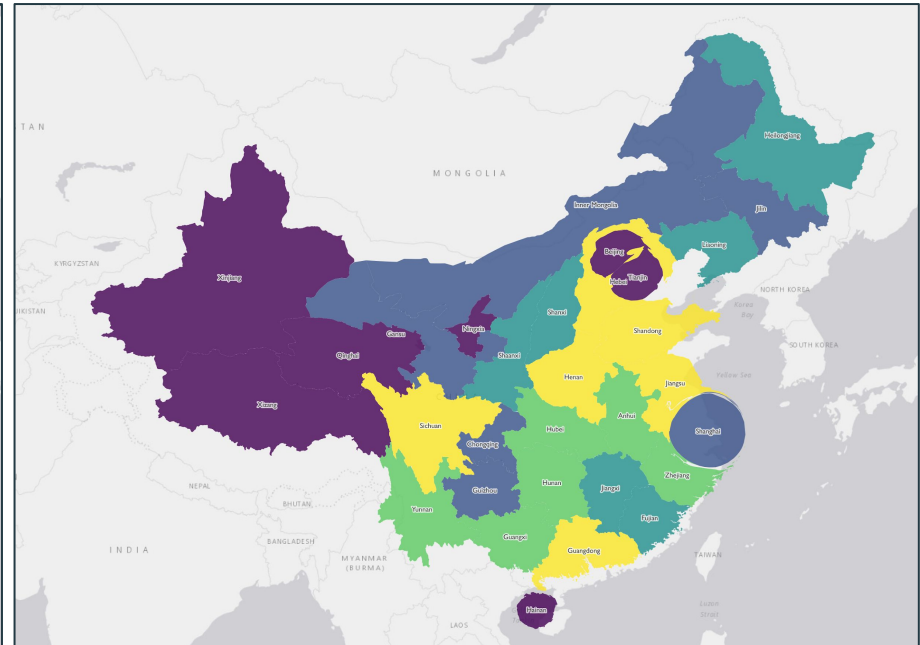
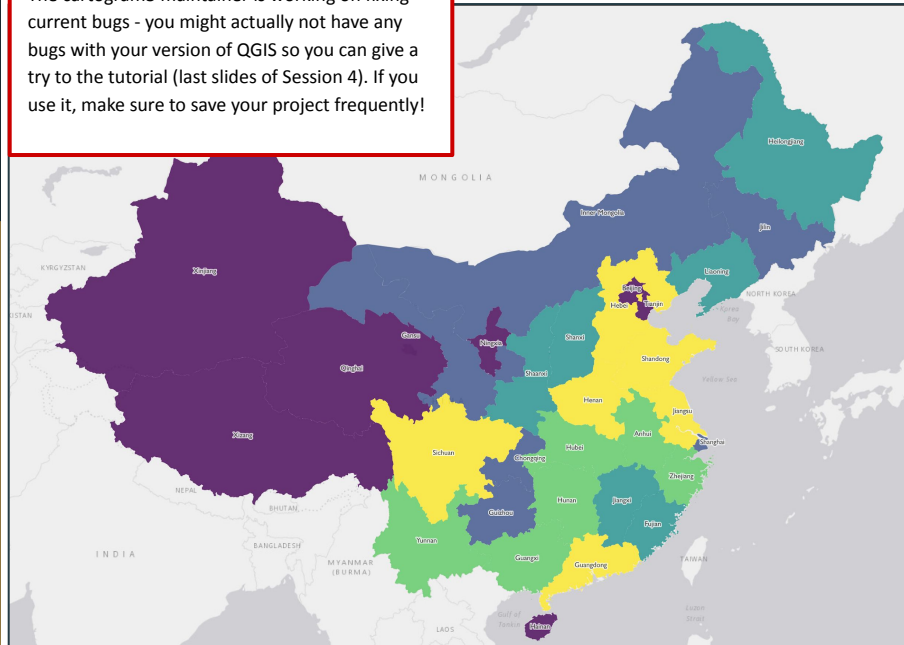
TravelTime plugin



Population density cartogram

You can now see how combining a **cartogram of population density** with a **choropleth of absolute population numbers** can provide a finer understanding of population trends across China (look at large metropolitan areas such as Shanghai, Beijing, Tianjing, Hainan!)

The cartogram3 maintainer is working on fixing current bugs - you might actually not have any bugs with your version of QGIS so you can give a try to the tutorial (last slides of Session 4). If you use it, make sure to save your project frequently!



Questions



Environmental Justice & GIS

Environmental Justice in GIS

GIS provides powerful tools to question the links between social and environmental variables, especially under an environmental justice framework.

By now you have acquired enough skills to be able to combine social and environmental datasets, and explore their spatial patterns.

Asthma and air pollution in the Bronx:
Methodological and data considerations in using
GIS for environmental justice and health research

Juliana Maantay  

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<https://doi.org/10.1016/j.healthplace.2005.09.009>

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Abstract

This paper examines methods of environmental justice assessment with Geographic Information Systems, using research on the spatial correspondence between asthma and air pollution in the Bronx, New York City as a case study. Issues of spatial extent and resolution, the selection of environmental burdens to analyze, data and methodological limitations, and different approaches to delineating exposure are discussed in the context of the asthma study, which, through proximity analysis, found that people living near (within specified distance buffers) noxious land uses were up to 66 percent more likely to be hospitalized for asthma, and were 30 percent more likely to be poor and 13 percent more likely to be a minority than those outside the buffers.

Environmental Justice in GIS

A GIS–Environmental Justice Analysis of Particulate Air Pollution in Hamilton, Canada

Michael Jerrett, Richard T Burnett, Pavlos Kanaroglou, . . . , more...

Show all authors ▾

First Published June 1, 2001 | Research Article

<https://doi.org/10.1068/a33137>

Article information ▾



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Using GIS to Assess the Environmental Justice Consequences of Transportation System Changes

Jayajit Chakraborty, Lisa A. Schweitzer, David J. Forkenbrock

First published: 17 December 2002 | <https://doi.org/10.1111/1467-9671.00020> | Citations: 31

Abstract

The authors address two research questions: (1) Are populations with lower socioeconomic status, compared with people of higher socioeconomic status, more likely to be exposed to higher levels of particulate air pollution in Hamilton, Ontario, Canada? (2) How sensitive is the association between levels of particulate air pollution and socioeconomic status to specification of exposure estimates or statistical models? Total suspended particulate (TSP) data from the twenty-three monitoring stations in Hamilton (1985–94) were interpolated with a universal kriging procedure to develop an estimate of likely pollution values across the city based on annual geometric means and extreme events. Comparing the highest with the lowest exposure zones, the interpolated surfaces showed more than a twofold increase in TSP concentrations and more than a twentyfold difference in the probability of exposure to extreme events. Exposure estimates were related to socioeconomic and demographic data from census tract areas by using ordinary least squares and simultaneous autoregressive (SAR) models. Control for spatial autocorrelation in the SAR models allowed for tests of how robust specific socioeconomic variables were for predicting pollution exposure. Dwelling values were significantly and negatively associated with pollution exposure, a result robust to the method of statistical analysis. Low income and unemployment were also significant predictors of exposure, although results varied depending on the method of analysis. Relatively minor changes in the statistical models altered the significant variables. This result emphasizes the value of geographical information systems (GIS) and spatial statistical techniques in modelling exposure. The result also shows the importance of taking spatial autocorrelation into account in future justice – health studies.

PDF TOOLS SHARE

Abstract

Although environmental justice research has typically focused on locations of industrial toxic releases or waste sites, recent developments in GIS and environmental modeling provide a foundation for developing measures designed to evaluate the consequences of transportation system changes. In this paper, we develop and demonstrate a workable GIS-based approach that can be used to assess the impacts of a transportation system change on minorities and low-income residents. We focus specifically on two adverse effects: vehicle-generated air pollution and noise. The buffer analysis capabilities of GIS provide a preliminary assessment of environmental justice. We integrate existing environmental pollution models with GIS software to identify the specific locations where noise and air pollution standards could be violated because of the proposed system change. A comparison of the geographic boundaries of these areas with the racial and economic characteristics of the underlying population obtained from block level census data provides a basis for evaluating disproportionate impacts. An existing urban arterial in Waterloo, Iowa, is used to illustrate the methods developed in this research.

Environmental Justice in GIS



NIH Public Access

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Mapping Urban Risk: Flood Hazards, Race, & Environmental Justice In New York”

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^bResearch Fellow, NOAA-CREST, Lehman College, City University of New York, The Graduate Center, City University of New York

Abstract

This paper demonstrates the importance of disaggregating population data aggregated by census tracts or other units, for more realistic population distribution/location. A newly-developed mapping method, the Cadastral-based Expert Dasymeric System (CEDS), calculates population in hyper-heterogeneous urban areas better than traditional mapping techniques. A case study estimating population potentially impacted by flood hazard in New York City compares the impacted population determined by CEDS with that derived by centroid-containment method and filtered areal weighting interpolation. Compared to CEDS, 37 percent and 72 percent fewer people are estimated to be at risk from floods city-wide, using conventional areal weighting of census data, and centroid-containment selection, respectively. Undercounting of impacted population could have serious implications for emergency management and disaster planning. Ethnic/racial populations are also spatially disaggregated to determine any environmental justice impacts with flood risk. Minorities are disproportionately undercounted using traditional methods. Underestimating more vulnerable sub-populations impairs preparedness and relief efforts.

Keywords

dasymeric; population mapping; environmental justice; flood hazard; New York City; cadastral; urban; 100-year flood

Quantitative Limits to Qualitative Engagements: GIS, Its Critics, and the Philosophical Divide*

Agnieszka Leszczynski

University of Washington

Heated exchanges between critical theorists and GIScientists over geographic information systems (GIS) in 1990s geography gave rise to calls for increased communication between critics and practitioners of the technology and most recently for “hybrid” qualitative-quantitative GIS practices. Although GIS scholars have successfully addressed mid-1990s critiques of the technology by developing a series of critical GIS practices that involve nuanced and reflexive deployments of GIS and assessments of its visual products, theoretical critiques of GIS remain fixated on the epistemological deficiencies of the technology. Despite references to loosening metaphysical tensions across the discipline, this difference in assessments reveals the discourses of critical-theoretic geography and GIScience to remain separated by a trenchant philosophical divide, across which ontological and epistemological commitments are inviolable. The inability to fully reconcile a critical-theoretic epistemology with the explicitly ontological metaphysics of GIS further complicates qualitative engagements with the technology by addressing a series of inconsistencies into GIS praxis arising from the quantitative limits to representation encountered in the formal universe of computing. The persistence of metaphysical tensions in critical engagements with the technology questions the degree to which qualitative methods can be seamlessly hybridized with the quantitative architectures of GIS. **Key Words:** critical geography, formal ontology, GIS, hybrid geographies, philosophical divide.

Environmental Justice in GIS

1 hour Webinar by the Tishman
environment & design centre

[Who Does Mapping Serve? GIS in
Environmental Justice and
Climate Change Research](#)

MAPS AS CASE MAKING: COMMUNITY-BASED ENVIRONMENTAL JUSTICE RESEARCH

Community-based Environmental Justice Research is situated in the context of local circumstances and “local knowledge” (Sze, 2007).

It can use mapping as a way of critiquing traditional risk assessments by exposing outcomes of racist social processes (Bryant, 1995; Checker, 2007).

WEACT
NORTHERN MANHATTAN
EAST HARLEM

LEGEND

- NYC HURRICANE EVACUATION ZONES
- ZONE 1
- ZONE 2
- ZONE 3
- ZONE 4
- ZONE 5
- ZONE 6
- NYC Community Districts
- Water Bodies
- Parks
- Open Spaces
- Publicly Accessible Interiors (PAIs)
- Subway Station
- Subway Route
- NYC Hurricane Evacuation Center
- Accessible Hurricane Evacuation Center

FEATURES

- EDUCATION
- THEATERS
- SWIMMING POOLS
- BOCCAS & FOOTBALL FIELDS
- PARKS
- POLICE PRECINCT
- BAR STATION
- HEALTH
- SOCIAL CARE CENTER
- CHILD CARE
- SENIOR CITIZEN CARE
- CHURCH & COMMUNITY
- TRANSPORTATION

26:44 / 1:19:31
(WE ACT, 2015. Northern Manhattan Climate Action Map)

Context

[Climate change](#)

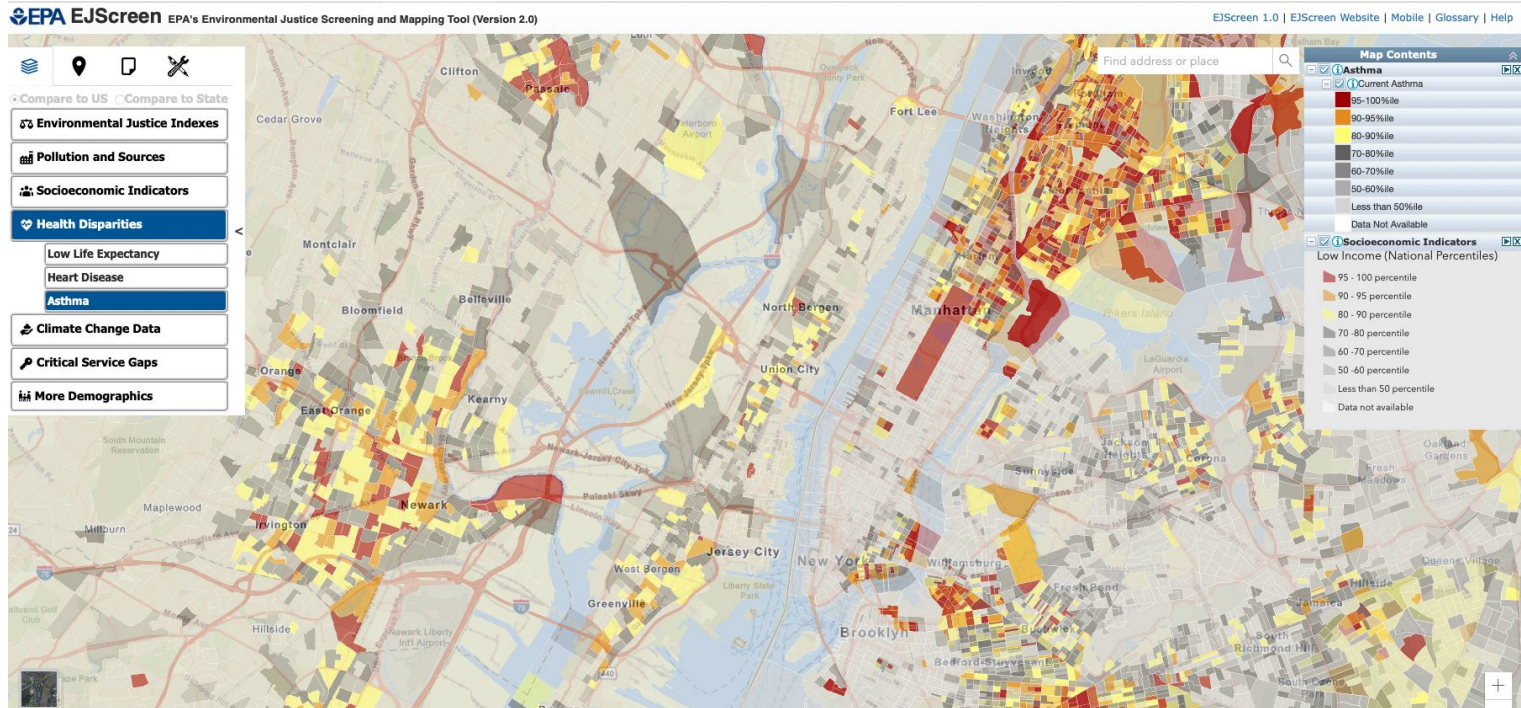
United Nations

Climate change refers to long-term shifts in temperatures and weather patterns, mainly caused by human activities, especially the burning of fossil fuels.

Who Does Mapping Serve? GIS in Environmental Justice and Climate Change Research

Environmental Justice in GIS

EPA Environmental Justice tool



Environmental Justice in GIS

Mapping for Change UK Project



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Citizen Science Used to Map
Community Air Quality

Completed

In 2009, Mapping for Change supported communities across London to measure and map local air quality. Use of a 'citizen science' approach meant local residents in seven locations were able to collect data, then see the real results of their monitoring activities, and subsequently embark on a campaign to see the serious results addressed.



Local Schools for Local
Children

Completed

A group of parents from East Finchley were frustrated with the lack of good community secondary schools in their area and decided to unite and demand for a change. The group, Local Schools for Local Children, expanded, and has now more than 1,000 supportive local parents, who are campaigning for a new Free School – The Archer Academy.



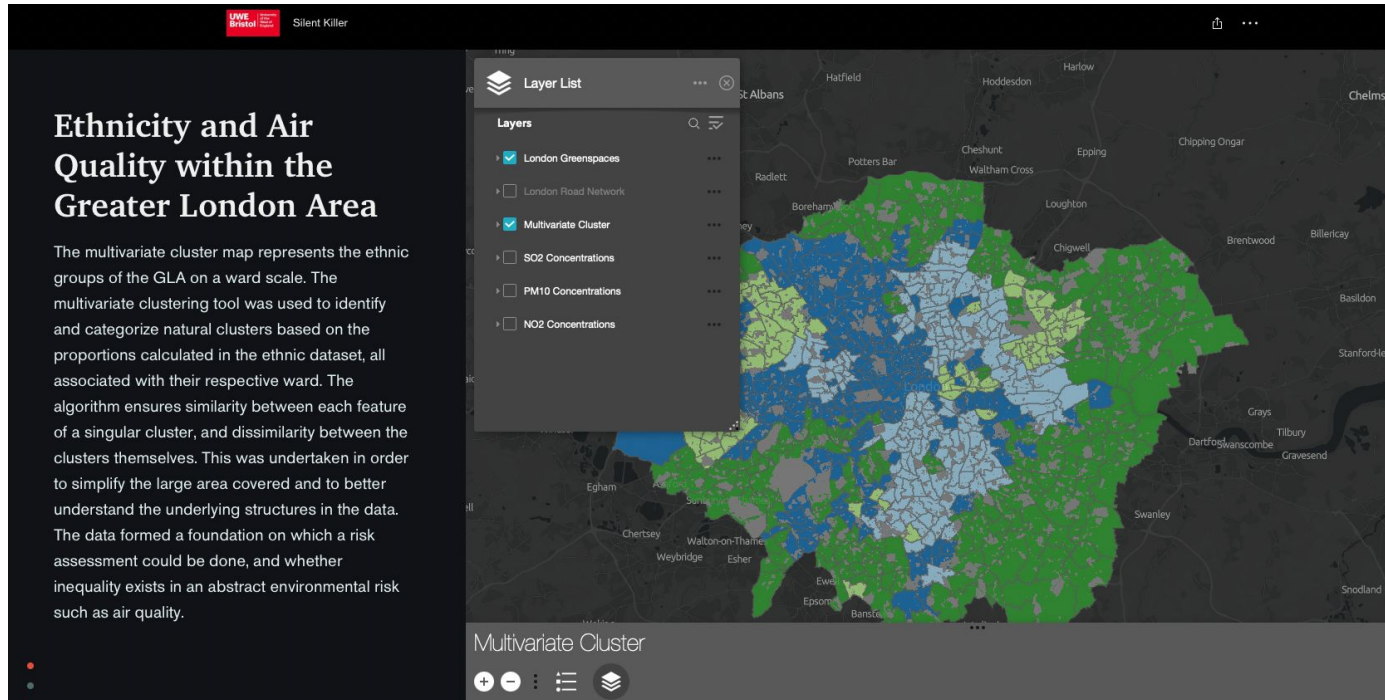
UK Climate and Community
Action Map

Completed

Mapping for Change produced a Climate and Community Action Map, to inform people about initiatives happening in their local area. As there are thousands of organisations and projects that could be displayed, there is no one organisation that has a comprehensive list so any mapping will need to rely on local people's knowledge and readiness to add their work to the map.

Environmental Justice in GIS

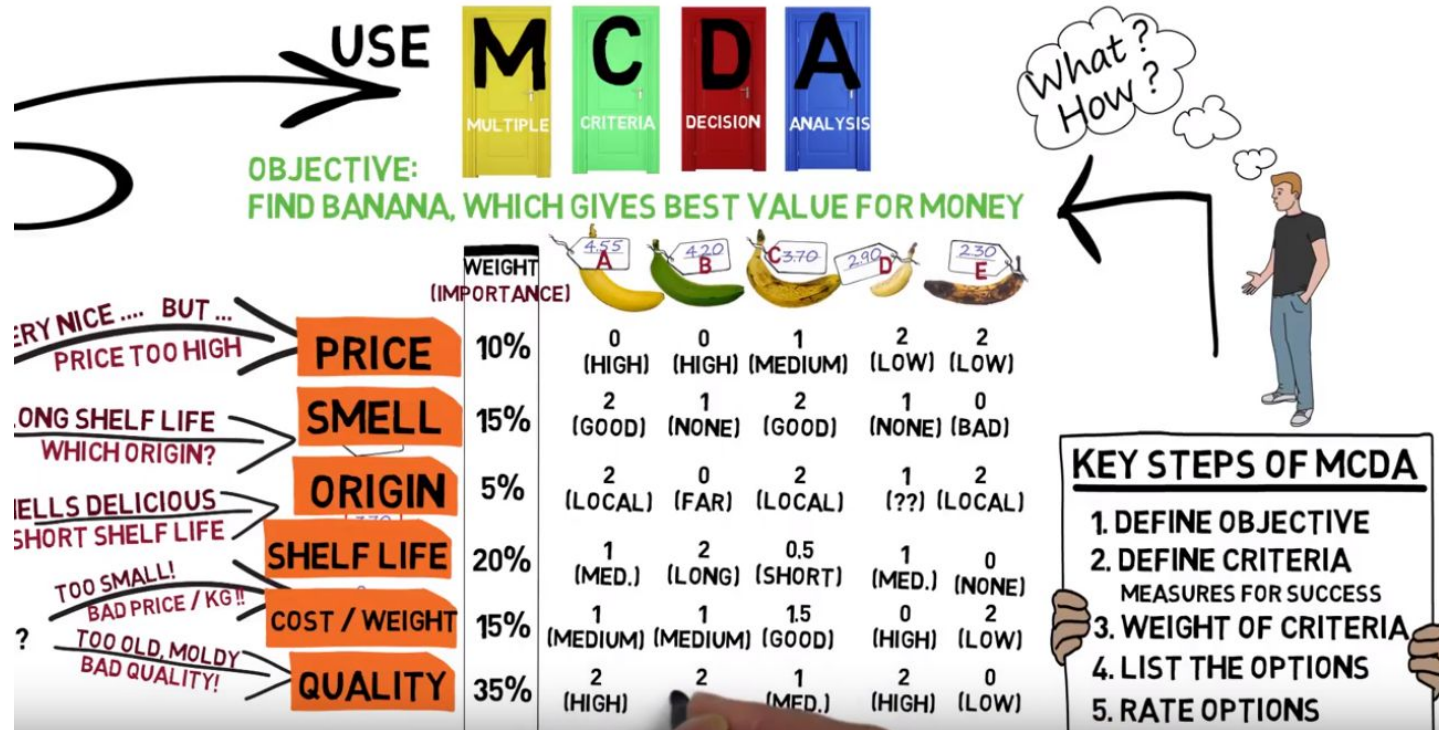
Air pollution in London: silent killer





Multi Criteria Decision Analysis & Weighted Overlays

Multi-Criteria Decision Making (MCDM)



GIS Multi-Criteria Decision Making

- Multi-Criteria Decision Making (MCDM), also known as Overlay Analysis, Multi-Criteria Decision Analysis (MCDA) or Multi-Criteria Analysis (MCA), is a framework for taking multiple variables into account when making a decision. It can be applied to spatial decisions using GIS-MCDM methodologies.
- The basic logic is that *“Many decisions depend on identifying relevant factors and adding their appropriately weighted values.”* ([Longley, Goodchild et al, 2015](#)). Obviously, different stakeholders will have different perspectives on which factors to take into account and their importance. In policy-making, public consultations can help determine the perspective of each stakeholder, and come up with a set of weights that is acceptable to all parties.
- GIS-MCDM method is especially useful when trying to solve problems such as land use suitability, site selection, etc. Please note that *“suitability analysis”* can also be carried out using vector geoprocessing (buffers, intersection tools, clipping etc), but typically when we talk about GIS-MCDM or Overlay analysis we refer to a raster data analysis method.

Suitability analysis: Vector vs Raster

The following table summarizes the main geoprocessing stages, advantages, and pitfalls of suitability assessment with vector and raster data:

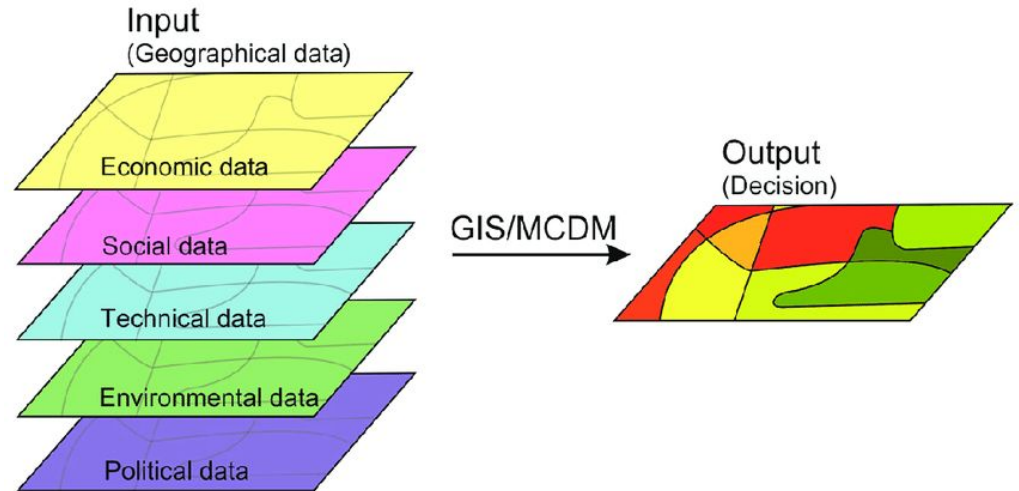
	Vector data	Raster data
Main geoprocessing and analysis operations	<ul style="list-style-type: none"> ➤ Buffering ➤ Clip overlay ➤ Intersection overlay ➤ Union overlay 	<ul style="list-style-type: none"> ➤ Vector data rasterization ➤ Proximity raster creation ➤ Raster reclassification ➤ Raster algebra addition ➤ Raster algebra multiplication ➤ Raster algebra subtraction

Advantages	<ul style="list-style-type: none"> ➤ Workflow quickness ➤ Workflow simplicity ➤ Good representation of man-made features 	<ul style="list-style-type: none"> ➤ Simple data reclassification ➤ Good representation of continuous features ➤ Crisp and fuzzy classes are possible ➤ Possibility to weigh different coverages according to their importance ➤ Various assessments are possible, such as binary, ranked, and weighted
Limitations	<ul style="list-style-type: none"> ➤ Provide only crisp classes ➤ Usually provides binary (yes/no) assessments only 	<ul style="list-style-type: none"> ➤ Reclassification and ranking subjectivity ➤ Workflow complexity

Source: Bruy, A. and Svidzinska, D., 2015. *QGIS by Example*. Packt Publishing Ltd.

(GIS) Multi-Criteria Decision Making

Applied to GIS, MCDM consists in crossing different variables to determine an output (the decision).



GIS MCDM models: mathematical framework

Let's say you want to identify the zones that are most vulnerable to flooding in a given region.

- A number of factors influence vulnerability **I**, denoted by **X1** through **Xn**. For instance slope, land use, distance from water stream.
- The impact of each factor on vulnerability is determined by a transformation of the factor **f(X)**. For example, the factor distance would be transformed so that its impact decreases with increasing distance, whereas the impact of slope would be increasing.
- Then the combined impact of all of the factors is obtained by weighting and adding them, each factor *i* having a weight **w_i**, which is determined by the GIS specialist, based on stakeholders' inputs.

$$I = \sum_{i=1}^n w_i f(x_i)$$

Table 15.1 An example of the weights assigned to three factors by one stakeholder. For example, the entry "7" in Row 1 Column 2 (and the 1/7 in Row 2 Column 1) indicates that the stakeholder felt that Factor 1 (slope) is seven times as important as Factor 2 (land use).

	Slope	Land use	Distance from stream
Slope		7	2
Land use	1/7		1/3
Distance from stream	1/2	3	

GIS MCDM Steps

1. **Define the problem/research objective:** this would typically include literature review to understand the domain and the local context.
2. **Definition of criteria and constraints,** based on literature research, analysis of historical data and potentially interviews with domain experts and stakeholders
3. **Reclassify/Transform the values** onto a relative scale to ensure the criteria can be comparable. For instance, transform a vector layer of a road into a raster layer of distance ranges to the nearest road.
4. **Weight the criteria:** think about each criteria's relevance to the final result, and it's importance compared to the other criteria.
5. **Combine the criteria** into a single layer.
6. **Results analysis** and validation, leading to the decision

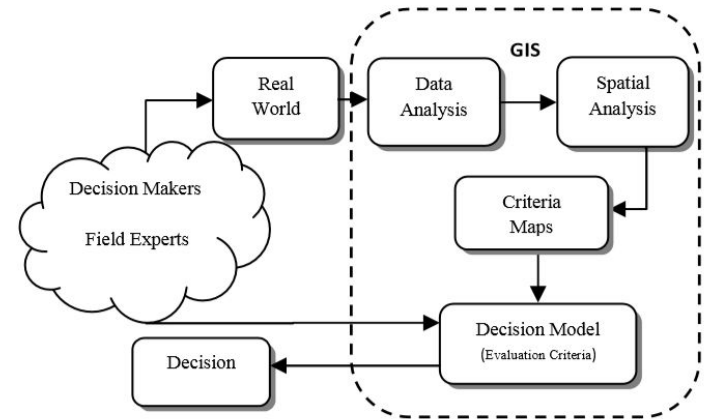
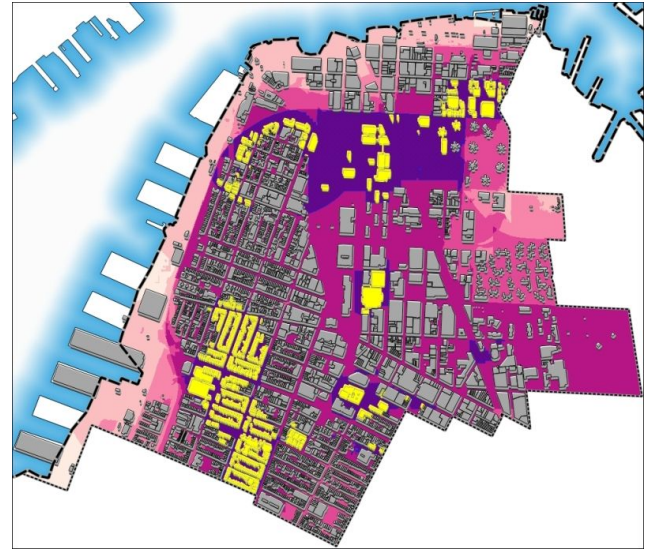


Figure 1. Integrated GIS/ MCDA approach

Extra readings on MCDM / weighted overlays

Please read these three resources to have a better understanding of the MCDM / overlay methodology

1. The [ESRI page on overlay approaches](#)
2. [This tutorial](#), which covers an entire workflow for identifying buildings suitable for a family to move in, based on their preferences (close to green spaces, to primary schools, well-connected by public transport, etc.)
3. This research poster on [agriculture in Vermont](#)





Homework

Next session in 2 weeks (March 7th) in person



Homework for 07/03/2022

1. Do the [QGIS tutorial](#) on MCDM
2. Use Slack if you have questions (#help).
3. Spend time on your final coursework - next session is your last chance to share progress / concerns / challenges with the class!