

Urban Simulation 3

The Family of Spatial Interaction Models Again, and General Urban Models

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Outline of Today's Lecture

First I will introduce the family of spatial interaction models that I did not finish last week

- Urban Models: Coupled Spatial Interaction
- Generalising the Model Adding Employment
- Building Spatial Interaction into the Economic Base
- Extending the Retail Model to Deal with Agglomeration and Scale
- Three Applications and a Fourth Next Time

An Important Note on Origin and Destination Attractors

In our spatial interaction models, we have variables on the right hand side of the model that pertain to origins and destinations. These are O_i and D_j . But when the model is unconstrained or singly constrained, then these same variables are attractors. That means that we can define them as anything that relates to the origin and/or the destination, such as F_i floorspace, say, or P_j actual population. When we define them as O_i and D_j then they can also be attractors but they are also the constraint variables that need to be met.

We will note again that we are going to drop the scaling of attractors not because we consider them irrelevant but because they are a complicating detail. We also note that we have variables on the RHS of the model that pertain to origins and destinations. These are O_i and D_j .

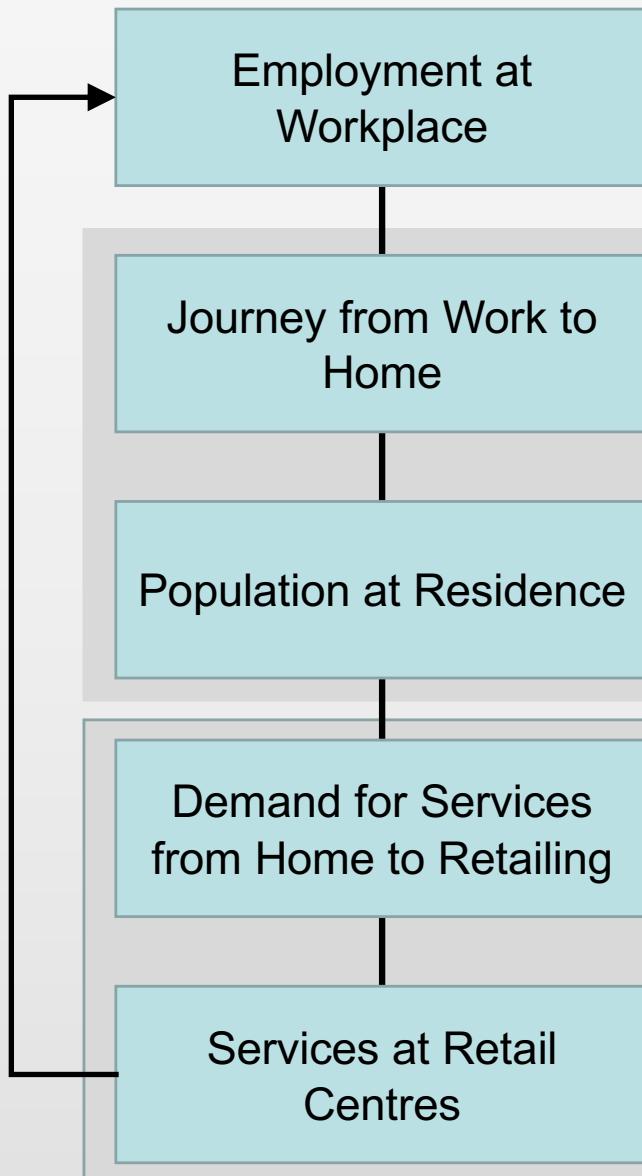
When the model is unconstrained or singly constrained, then these variables are **attractors**. We define them as anything relating to the origin and/or the destination, e.g. F_i floorspace or P_j population. If we define them as O_i and D_j , they can be attractors but also the **constraint variables** that need to be met.

Urban Models: Coupled Spatial Interaction

Ok – we have the building blocks of more comprehensive urban models now. Imagine we want to build a model of where people work, where they live and where they shop.

We first define where people work as employment at origins E_i and where they live as population at destinations P_j . This can be modelled as a singly constrained model where we predict P_j from E_i and then we predict where these people will shop which relates to the number of workers or size of the shopping centre S_i at the origins.

We thus start with journey to work model defined as



$$E_i (= X_i + S'_i)$$

$$T'_{ij} = A_i E_i P_j \exp(-\beta c_{ij})$$

$$P'_j = \sum_{i=1}^n T'_{ij}$$

$$S'_{ji} = B_j P'_j F_i \exp(-\eta c_{ji})$$

$$S'_i = \sum_{j=1}^m S'_{ji}$$

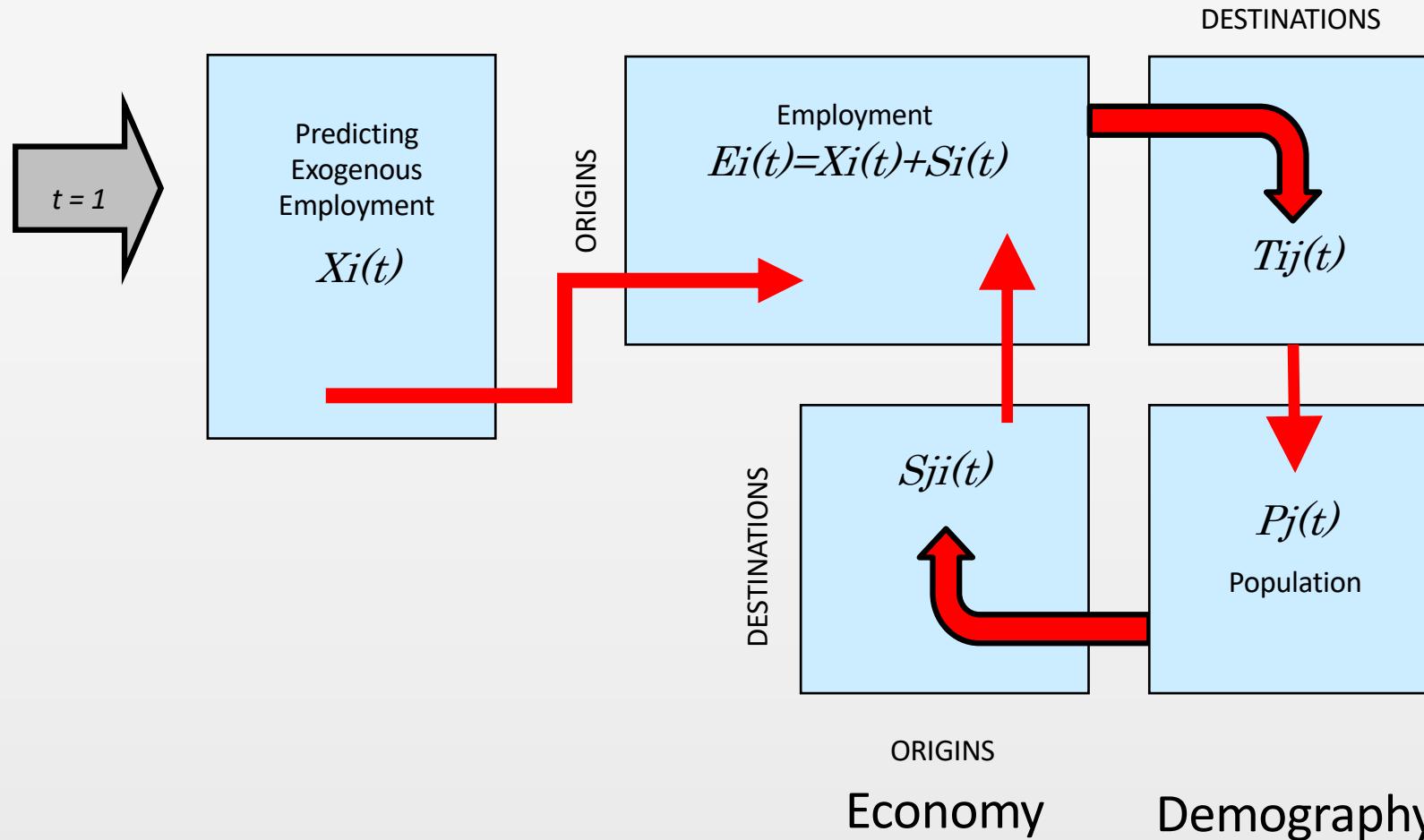
Generalising the Model Adding Employment

I am going to add a third sector – other employment to our model – sometimes it is called ‘basic employment’. So we have two kinds of employment –

- manufacturing and public service X_i
- retail and commerce S_i

where $E_i = X_i + S_i$ and we have of course population P_j .

So we can now extend our model as follows – were we have other employment, population and retail employment in that order – our model equations begin with employment



We can keep on extending the model in this way with different sectors but let us look at a simple application for the London region but before this let us demo the extensions

Building Spatial Interaction into an Economic Base

Ok, we will now examine the sequence of operations from with respect to employment. Let us first divide our employment into two types; $E = X + S$

- external or exogenous employment we call **basic** X
- endogenous employment called **non-basic** S

Basic is employment that drives the system, non-basic is dependent employment like retail and services, sometimes called service employment

Our general model reflects this already

Now let us first restate the identity that total employment is equal to basic and non basic as

$$E = X + S$$

And then we scale total employment to population using an activity rate α to get

$$P = \alpha E = \alpha(X + S)$$

Note that $\alpha = P/E$

Now service or non-basic employment is a function of population – it depends on population and this ratio is called the population serving ratio defined as β

Now we can generate this services or non-basic from

$$S = \beta P = \beta \alpha(X + S)$$

Multiplying this out we get

$$S = \beta\alpha X + \beta\alpha S$$

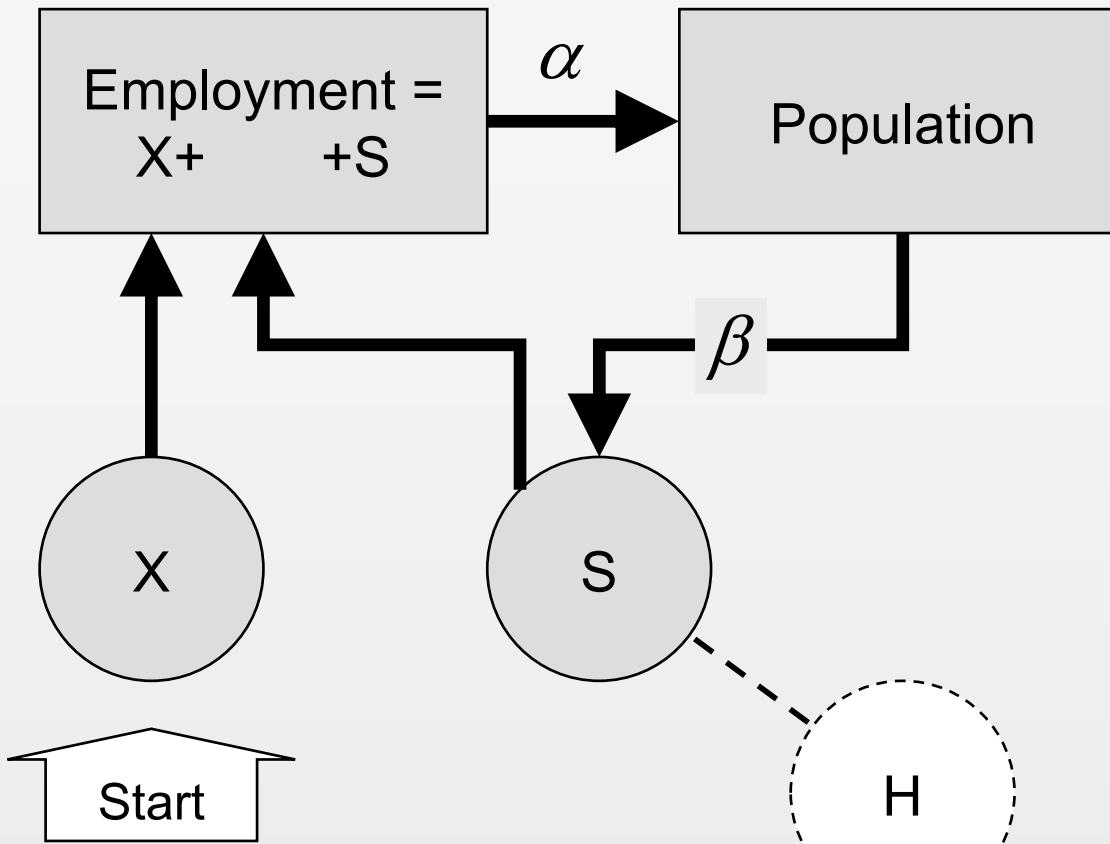
And we can then simplify this by bringing terms to the LHS of the equation as

$$\left. \begin{aligned} S(1 - \beta\alpha) &= S - \beta\alpha S = \beta\alpha X, \quad \text{and} \\ S &= \beta\alpha X(1 - \beta\alpha)^{-1} \end{aligned} \right\}$$

So given basic we can get non-basic and these are related by the multiplier

$$(1 - \beta\alpha)^{-1}$$

Now we can draw a block diagram of this so we can see how we can generate it in the following sequence of operations – or ‘workflow’ if you like.



I am not going to detail all these previous models and elaborate the equations but you can see that this is the structure they can fit into – this essentially is the Lowry model framework

Employment: X=Exogenous; S=Service;

Extending the Retail Model to Deal with Agglomeration and Scale

Here is the shopping model that we stated last time:

$$S_{ij} = A_i e P_i F_j \exp(-\beta c_{ij}) = e P_i \frac{F_j \exp(-\beta c_{ij})}{\sum F_j \exp(-\beta c_{ij})}$$

Now we can extend it in two ways – first we can add a scaling factor to the attraction on the assumption that as a centre gets bigger, then it has economies of scale. The assumption in economics is that as things get bigger other quantities grow more than proportionately – superlinearly. Thus we can replace

$$F_j \rightarrow \overrightarrow{\dots} F_j^\alpha$$

The model thus becomes

$$S_{ij} = eP_i \frac{F_j^\alpha \exp(-\beta c_{ij})}{\sum_j F_j^\alpha \exp(-\beta c_{ij})}$$

And in fact your assignment exercise has this kind of scaling factor which we introduced in this and the last lecture. To estimate it you would need some form of multiple regression because there are two parameters – in fact three including the intercept,

Now we don't calibrate it this way as we will show in a minute but first we need to add an even more appropriate agglomerative effect by taking account of local economies of scales inside a retail centre

We can argue that local shops in a centre exert a positive effect on agglomeration by assuming that the attraction of the centre takes account of these local shops. If we now think of F_j^α as a shop not a set of shops and note that there are other shops F_k^α in the centre j then we can add up the effect of these shops on the attraction using a similar deterrence effect as

$$A_j = F_j^\alpha + \sum_{k \in \Omega_j} F_k^\alpha \exp(-\phi c_{jk})$$

Note we are summing over all the k located shops in the centre j and assuming a deterrent effect – i.e. closer shops exert of a positive effect

Putting this into the model, we get an augmented retail model with three scaling parameter and of course some sort of constants to ensure normalisation. The model now looks like this F_j^α

$$S_{ij} = \eta P_i \frac{A_j \exp(-\beta c_{ij})}{\sum_j A_j \exp(-\beta c_{ij})} = \eta P_i \frac{\left[F_j^\alpha + \sum_{k \in \Omega_j} F_k^\alpha \exp(-\phi c_{jk}) \right] \exp(-\beta c_{ij})}{\sum_j \left[F_j^\alpha + \sum_{k \in \Omega_j} F_k^\alpha \exp(-\phi c_{jk}) \right] \exp(-\beta c_{ij})}$$

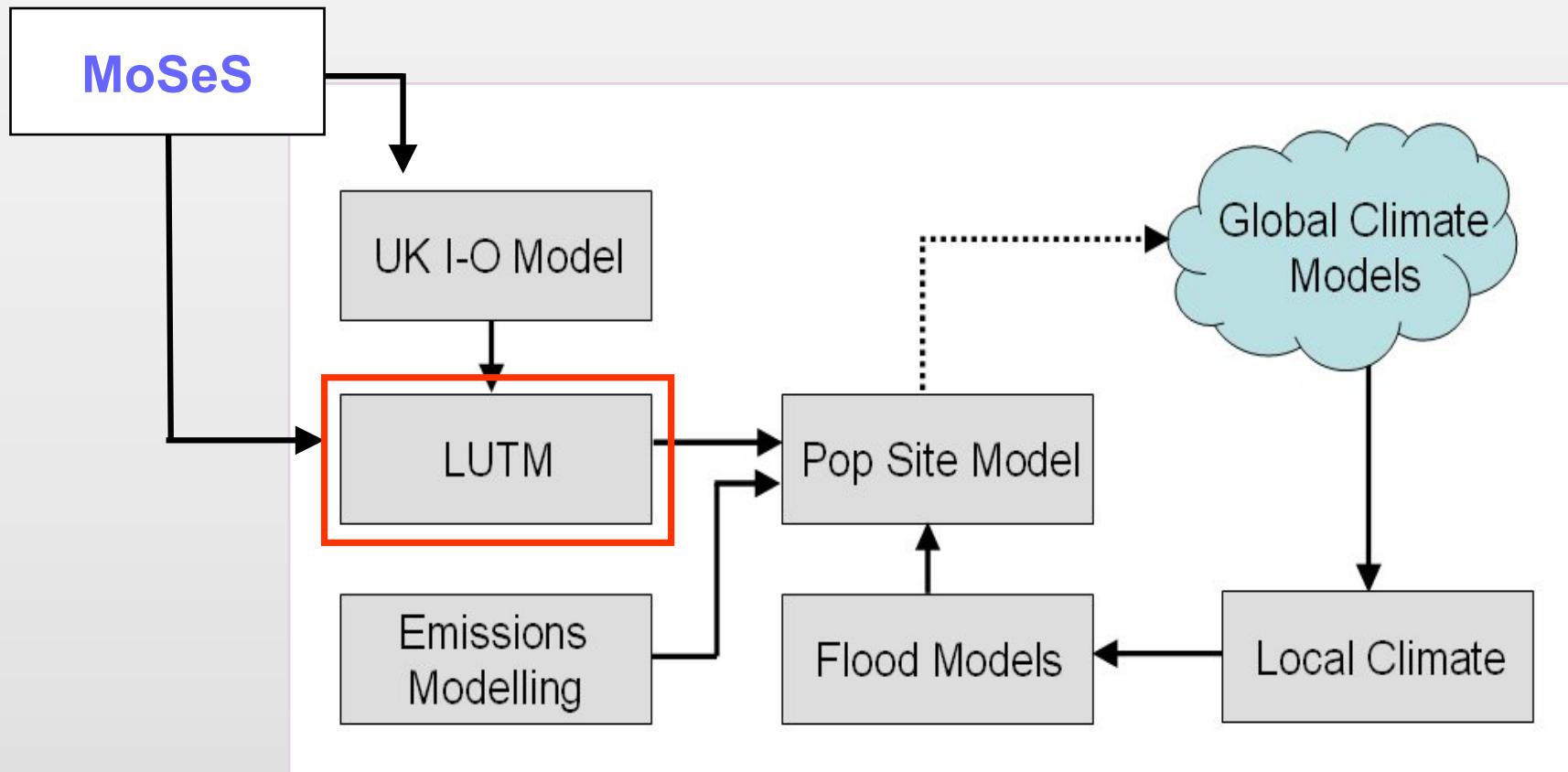
Of course we don't know what sign these parameters can take and it may be that the local effect is truly agglomerative and the parameter is positive

Three Applications and a Fourth Next Time

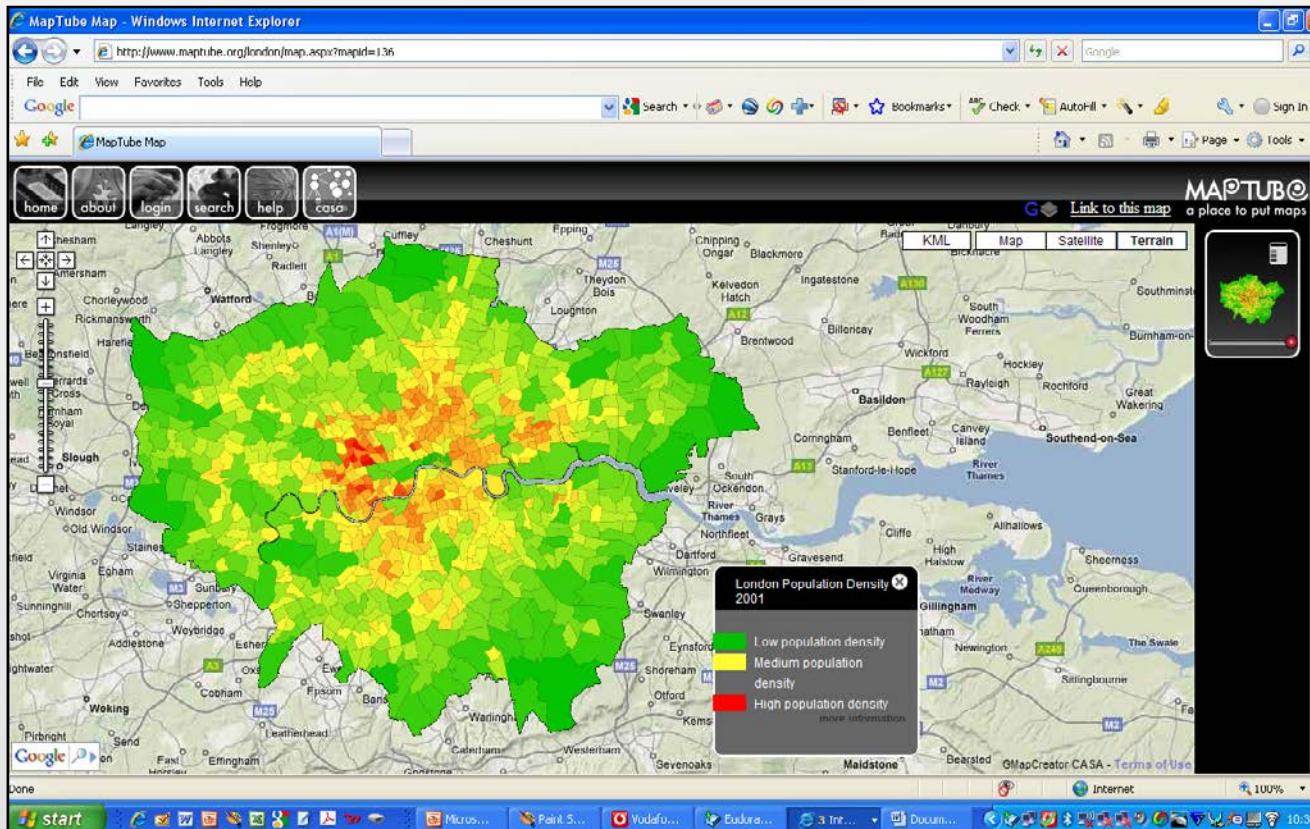
1. A simple gravitational model for Greater London – linked to other models focussed on integrating different infrastructure and economic models
2. The extended model for Greater London and the outer metropolitan area – three sector urban model called SIMULACRA
3. A simple model built rapidly in a two days - a demo for Dubai based on data extracted from the web
4. A large scale LUTI land use transportation interaction model for the UK called QUANT – we will talk about this next time in our fourth lecture

1. The London Tyndall Model Applications

This is an integrated model as shown in the block diagram below. Our focus is on integrating a singly constrained residential local models into the framework.



- essentially we have built this model for Greater London which is divided into 633 zones (wards) – the area has 7.7m population and about 4.3m jobs –
- we have four modes – road (car), heavy rail, light rail and tube, and bus – walk/bike is a residual mode.



To give a flavour of the LUTI/LUTM model, I will show some screen shots first

The screenshot shows a Windows application window titled "London and the Thames Gateway Land Use Transportation Model". The interface includes a map of the London area with a color-coded population density heatmap. The Tyndall Centre logo is prominently displayed, along with logos for CASA UCI, Newcastle University, and the Cities Research Programme. The main text area describes the model as a rudimentary land-use transportation model built along classical lines, allocating population and employment to small zones of the urban system using spatial interaction principles. It mentions the model's focus on Greater London and the Thames Gateway at ward level, and its role in integrated assessment for climate change impacts. A separate text block explains the programme's purpose as a sketch planning tool for scenarios from 'business as usual' to radical changes. At the bottom right, there are buttons for "GO!" and "Program Manual".

This program is a rudimentary land-use transportation model built along classical lines which allocates population and employment to small zones of the urban system. It uses spatial interaction principles which bind the population sector (residential or housing) to employment sector (work or industrial and commercial) through the journey to work (work trips) and the demand from services (which loosely translate into trips made to the retail and commercial sector).

The model is being built for Greater London and the Thames Gateway at ward level - 633 in all - so that it can be used in a wider process of integrated assessment focussed on assessing the impact of climate change on small areas in this metropolitan region. In particular rises in sea level and pollution are key issues, and as such the model sits between aggregate assessments of environmental changes associated with global and regional climate change models and environmental input output models, and much more disaggregate models related to the detailed hydrological implication of long term climate change.

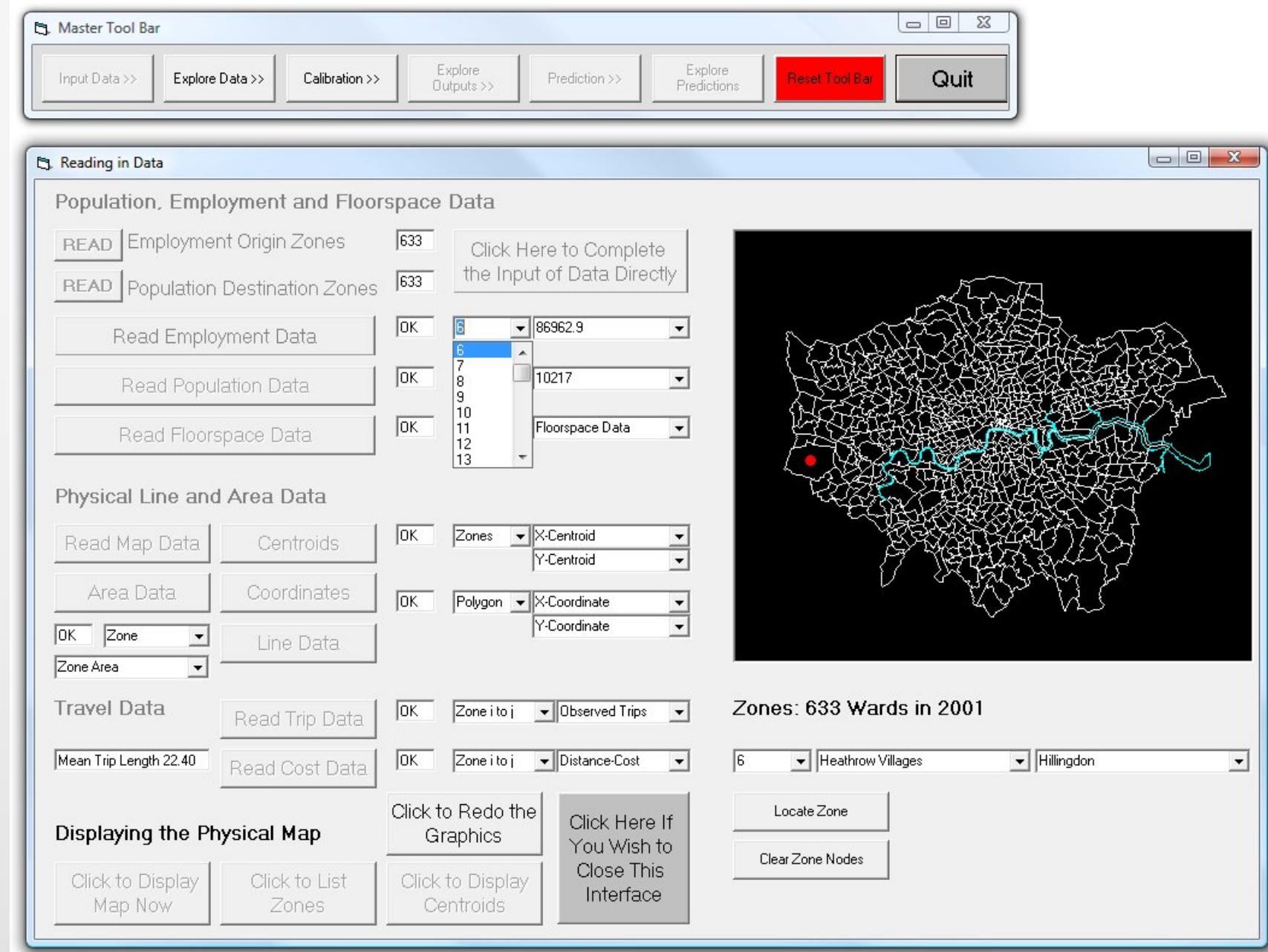
The programme enables the user to read in the data and explore it spatially, to calibrate the parameters of the model and explore its outputs spatially and to engage in various predictions ranging from the typical 'business as usual scenarios' to much more radical changes posed limits on spatial behaviour which either result from climate change and, or mandated by government. The predictions and scenarios are intended to go out to 2100 and thus the model is largely designed as a sketch planning tool.

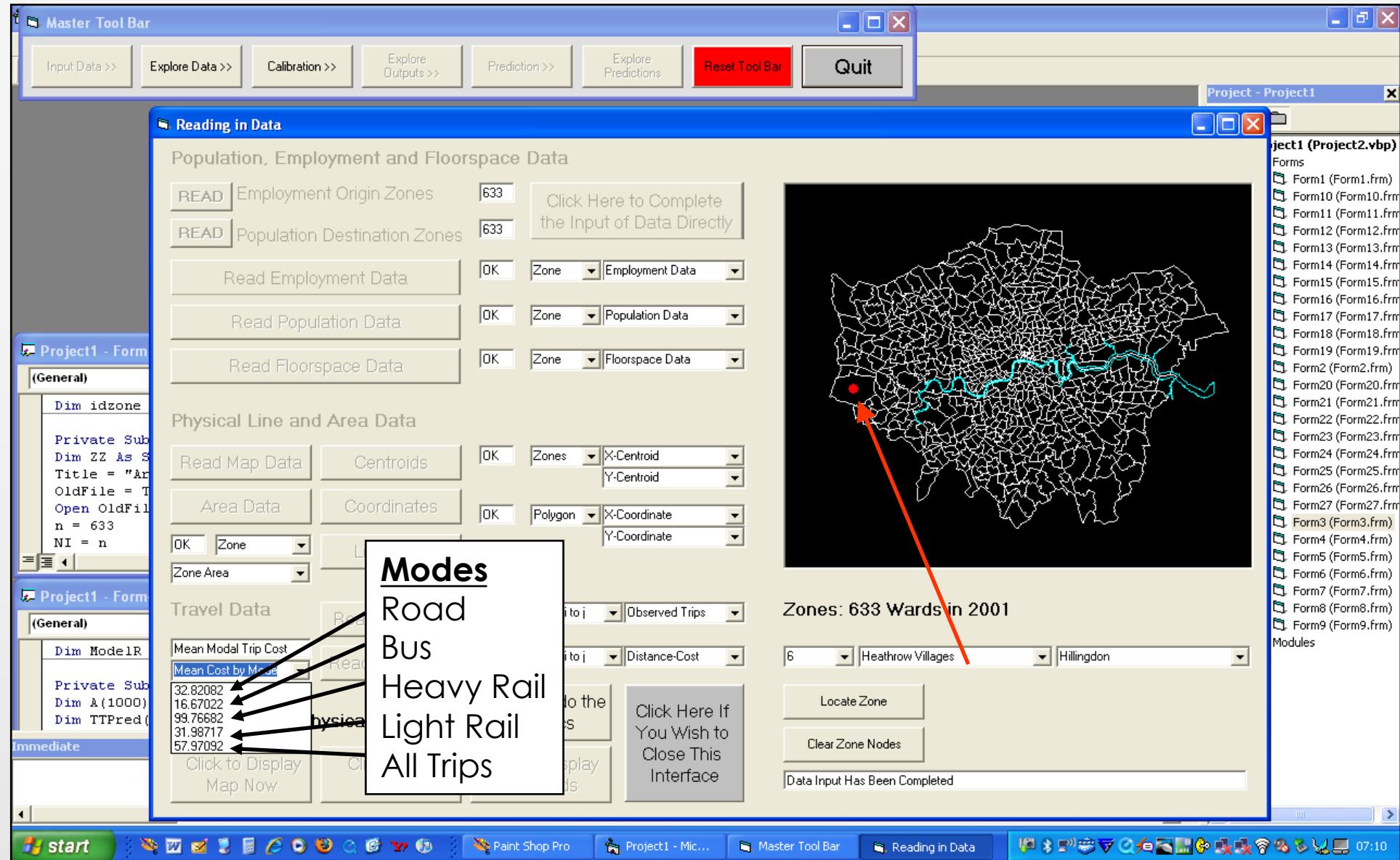
These various stages of the model contained in a master tool bar which is activated when the GO! button is pressed on this screen. The master tool bar enables the users to proceed through the various stages indicated and to display outputs in map and statistical form at any stage.

with **GLAECONOMICS
LONDON**

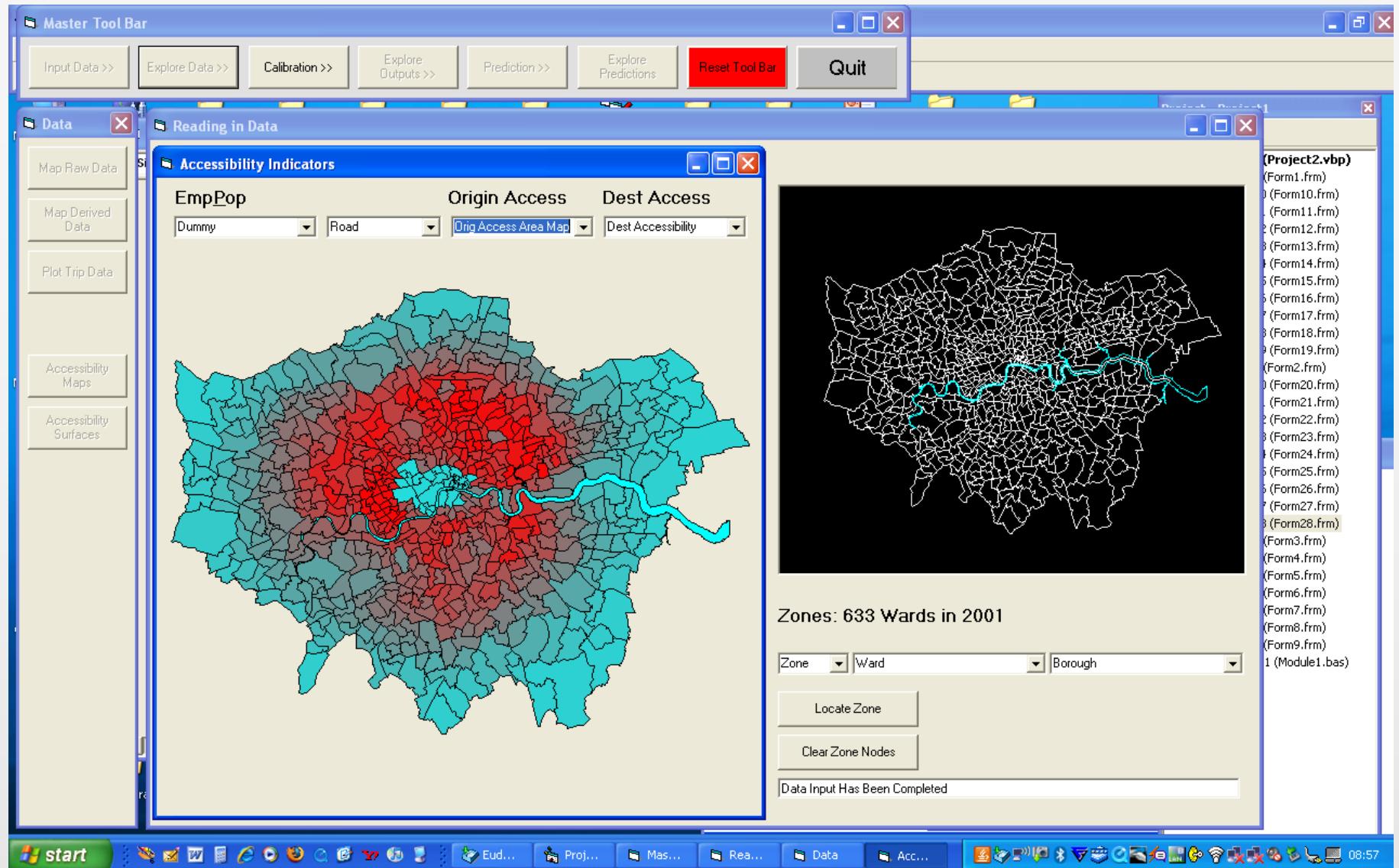
GO!

Program Manual





Road: 38%; Bus: 12%; Heavy Rail: 12%; Light Rail 19%; Other (Walk, Bike): 19%



MASTER TOOL BAR: The London and Thames Gateway Land Use Transportation Model

Tyndall® Centre CITIES

Data

Reading in Data

Mapping Location Data

Employment Population Work Trips

Employment Maps Population Maps Trip Maps Choose Mode
 Employment Density Population Density Trip Density Choose Origin
 Pop-Emp Count Maps
 Pop-Emp Density

Zones: 633 Wards in 2001

Zone Ward Borough

Locate Zone Locate Borough Colour Boroughs
 Clear Zone Nodes Clear Boroughs

Data Input Has Been Completed

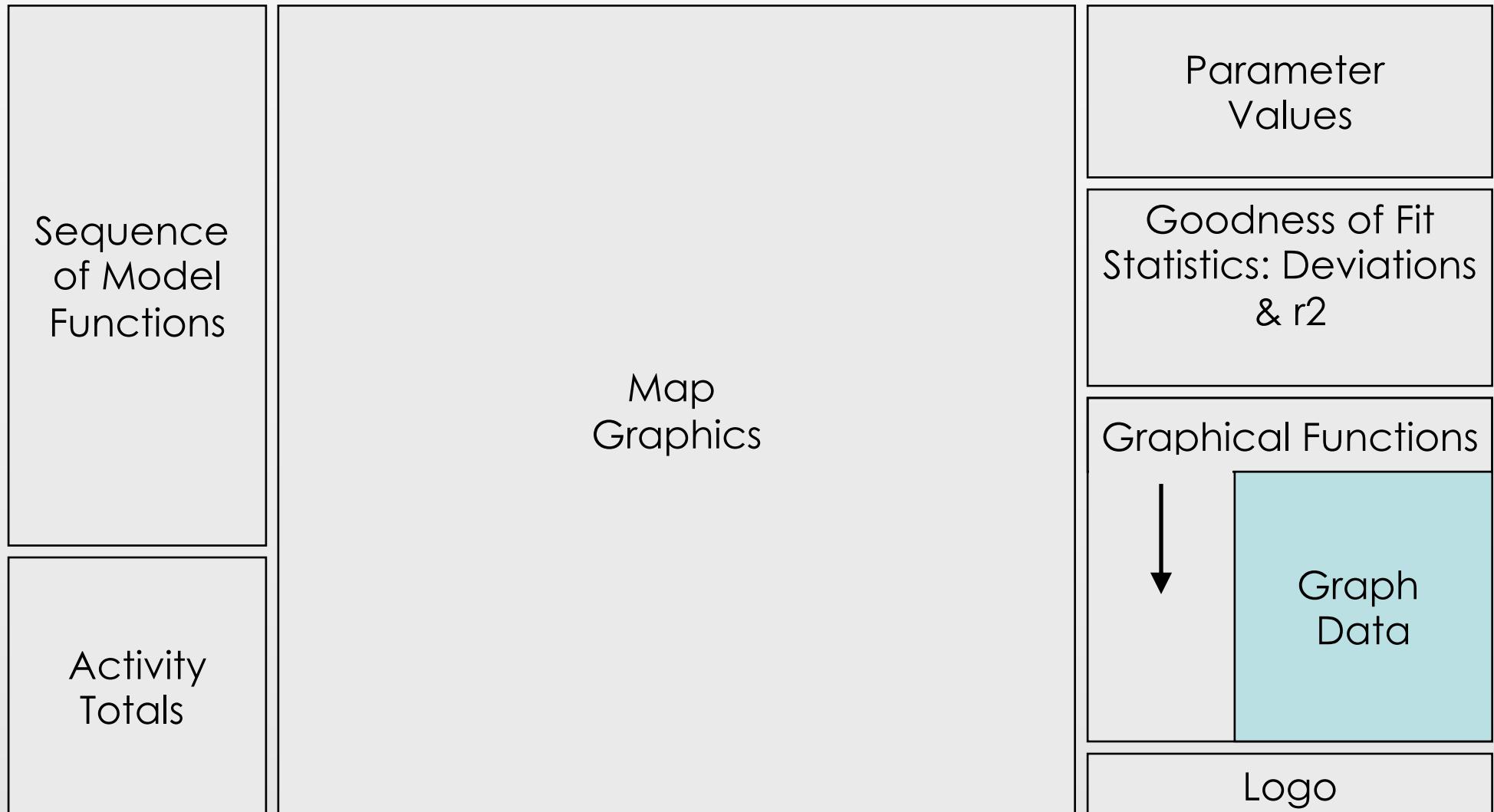
Modular Modelling: Coupled Spatial Interaction

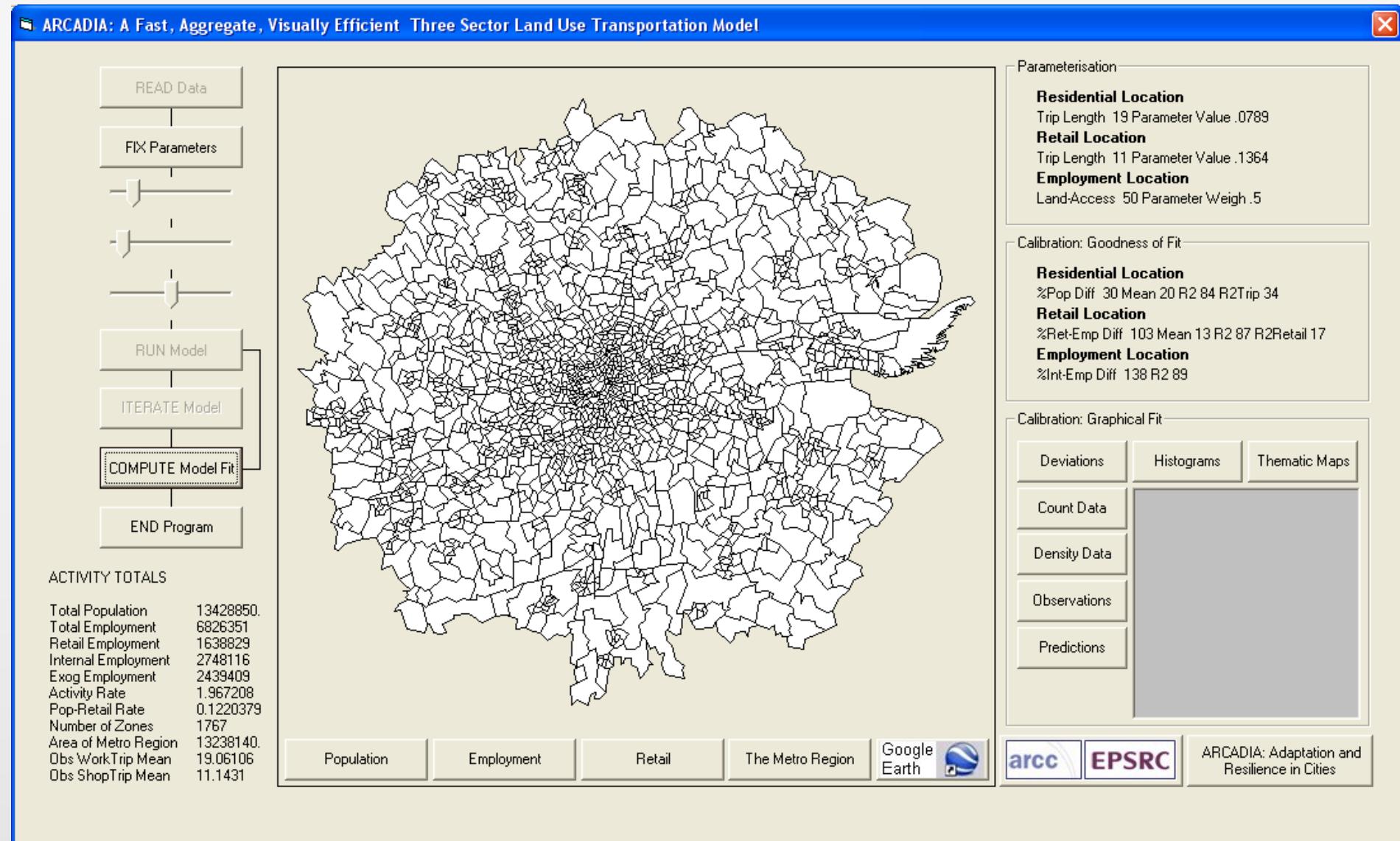
So far we have just singled out a module for one kind of interaction – based on a variant of the gravity model – consider stringing these together as more than one kind of spatial interaction: Model 1 → Model 2 → Model 3 →

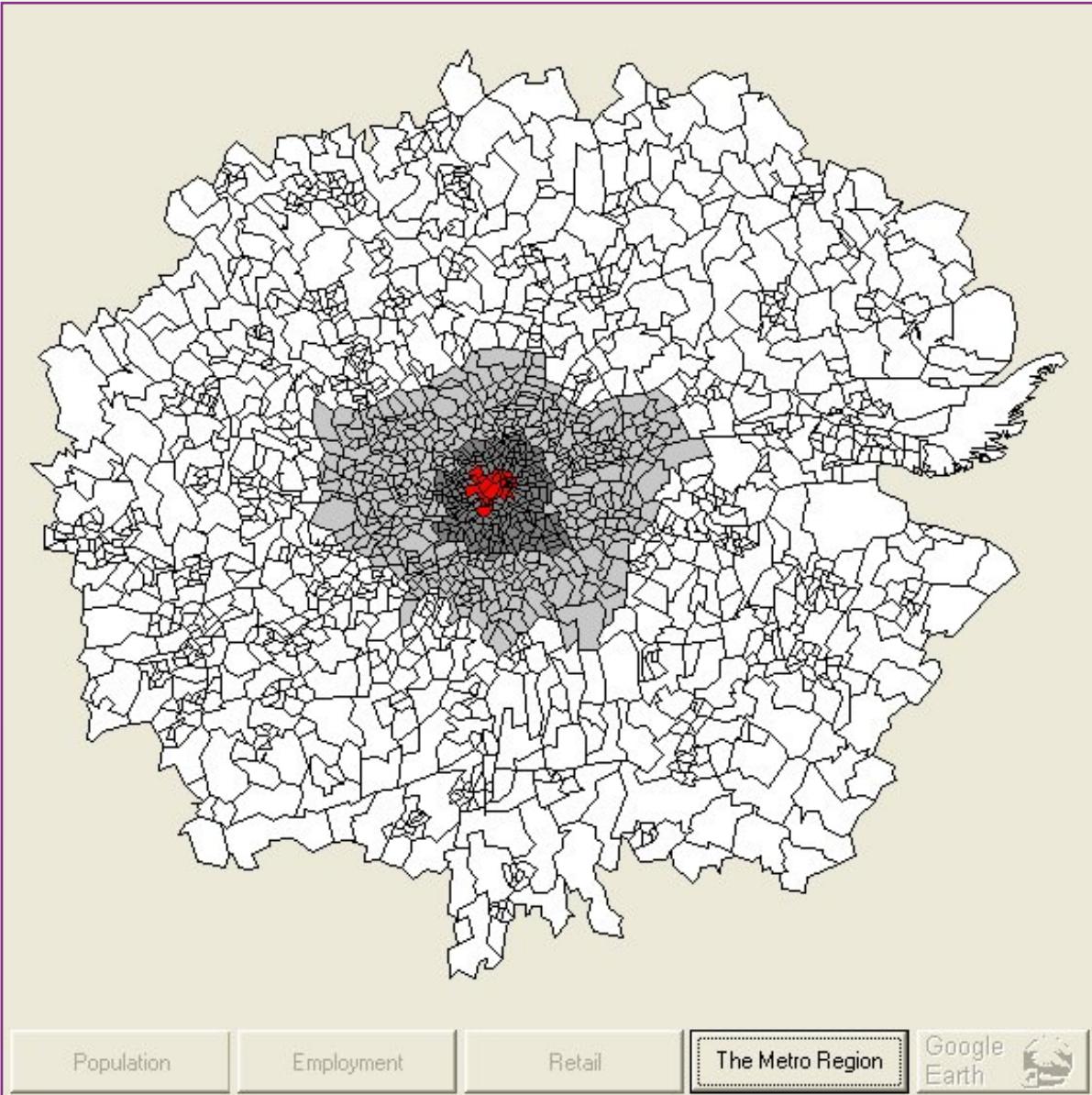
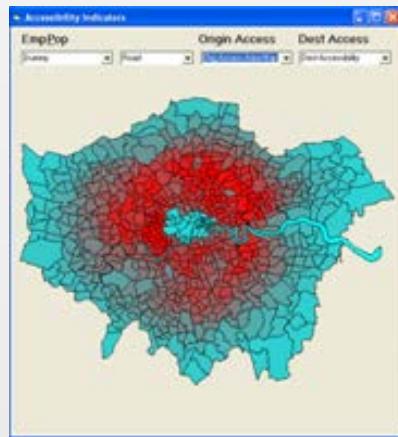
Classically we might model flows from home to work and home to shop but there are many more and in this sense, we can use these as building blocks for wider models. This is for next time too

What we will now do is illustrate how we might build such a structure taking an Exogenous Employment accessibility model linked to journey to work model from Employment to Population and then to Shopping which we structure on the desktop as

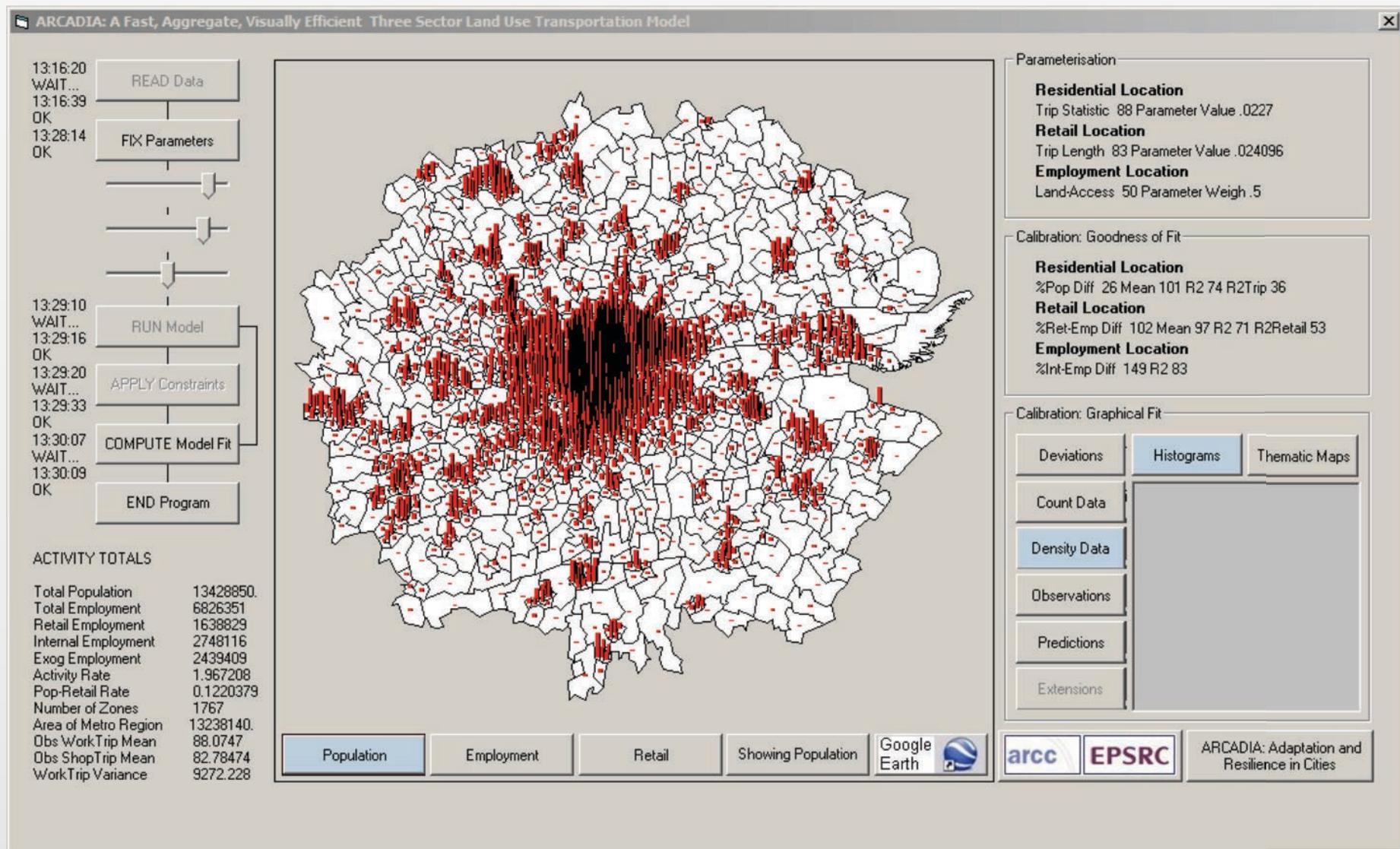
This is the order in which the operations take place

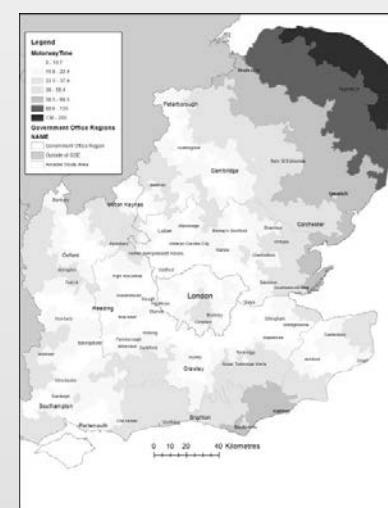
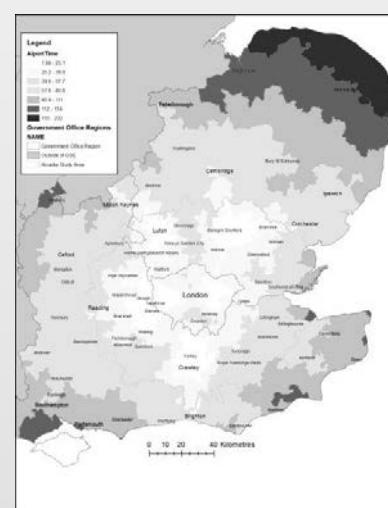
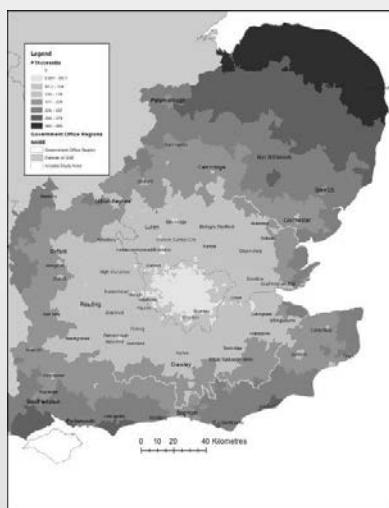
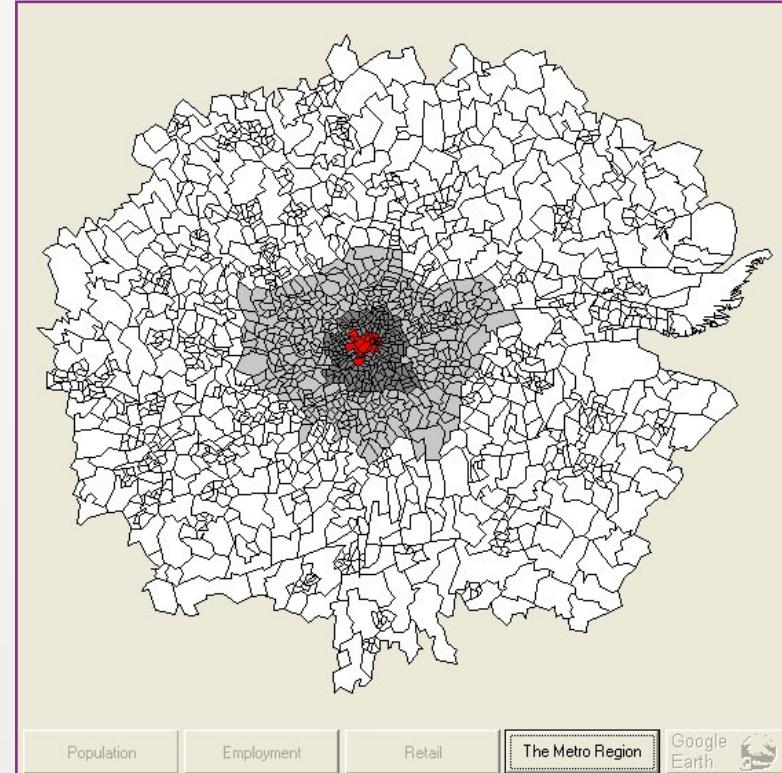
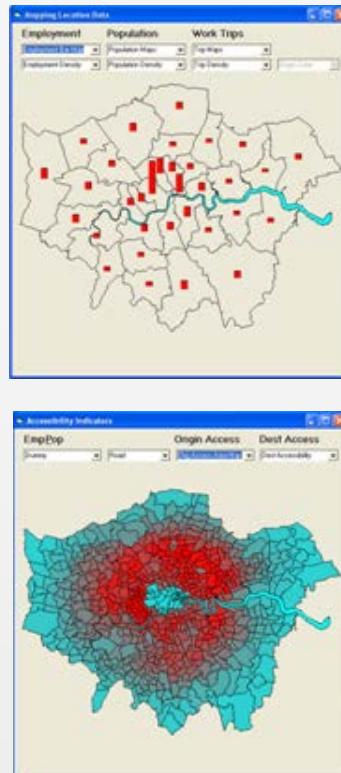
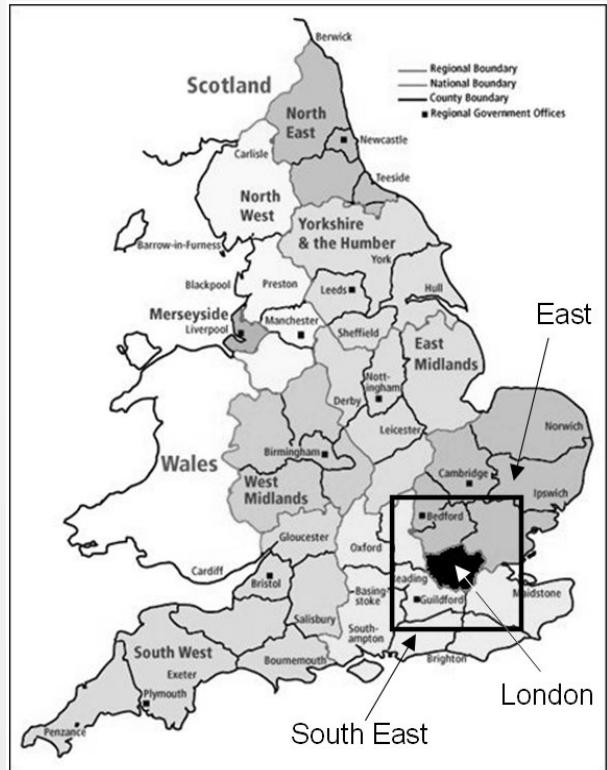






The Family of Spatial Interaction Models Again and General Urban Models

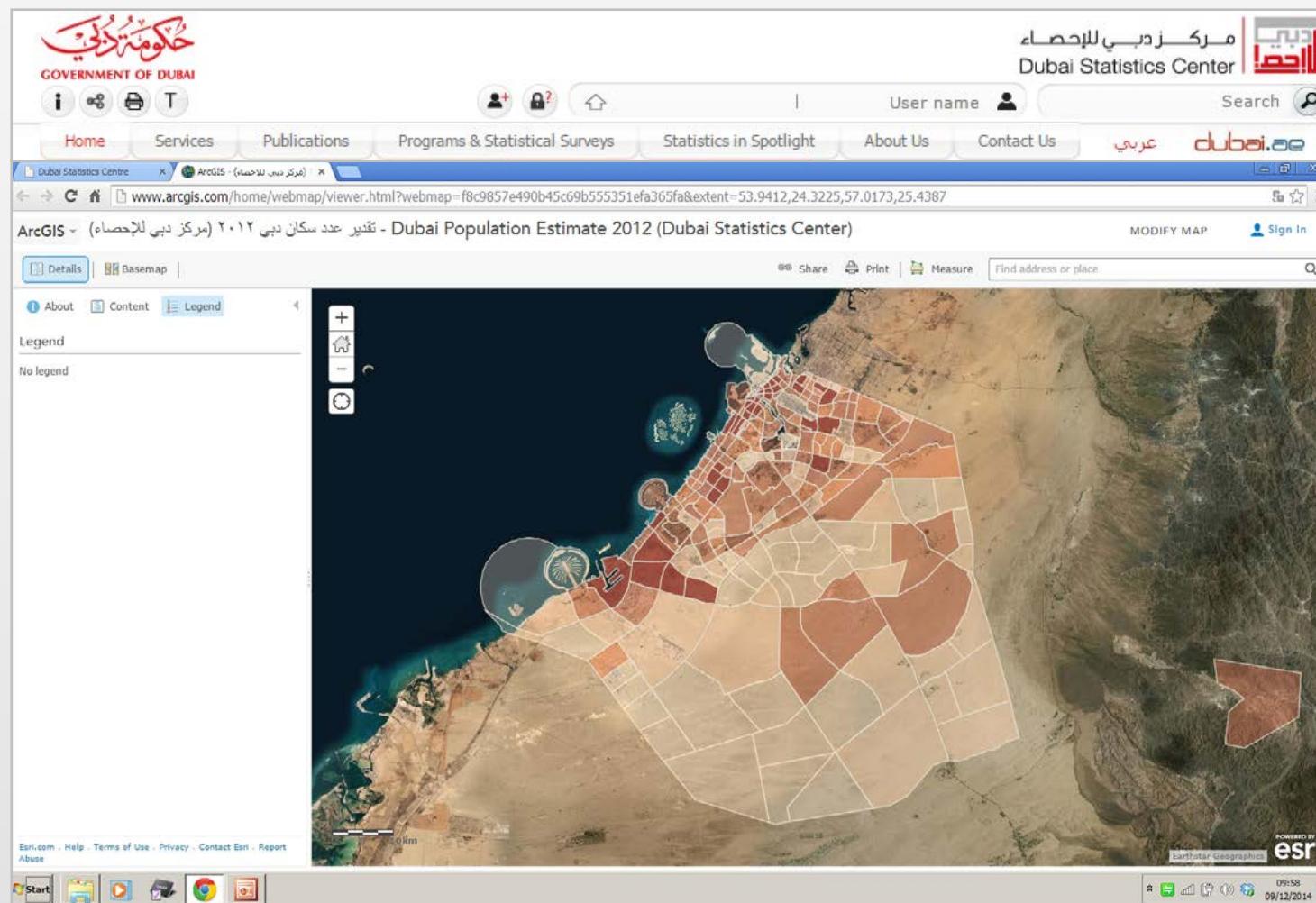




The Family of Spatial Interaction Models Again and General Urban Models

Quick and Dirty Models

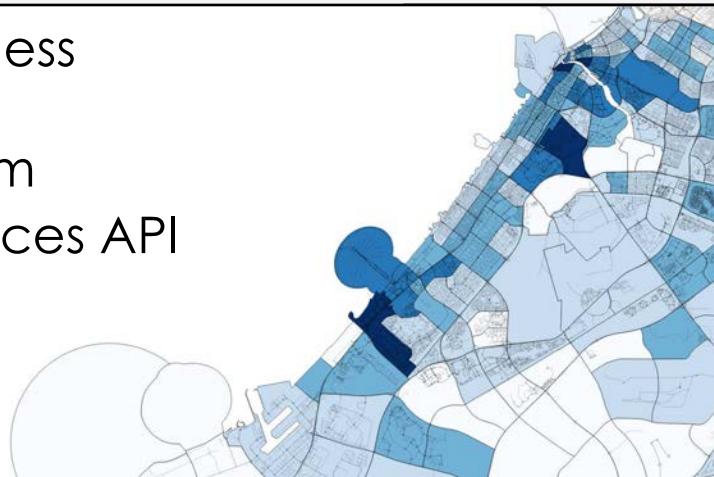
A New Retail Centre in Dubai



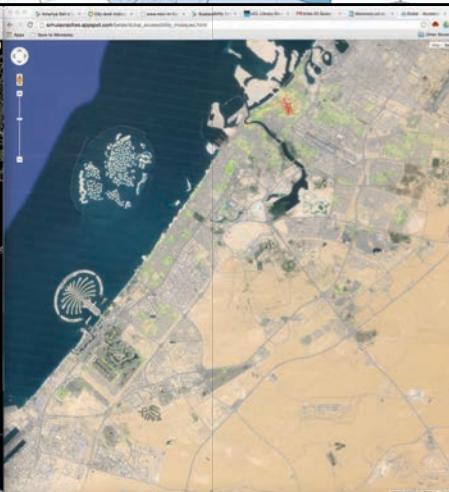
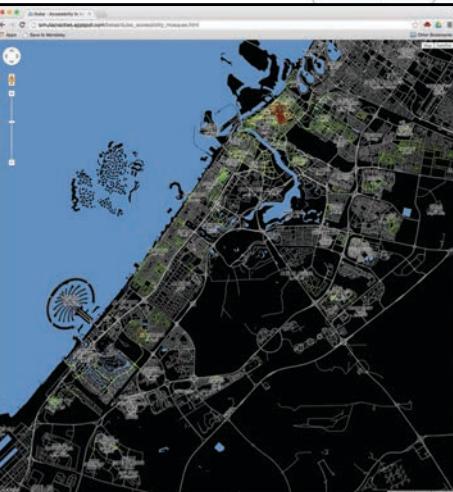
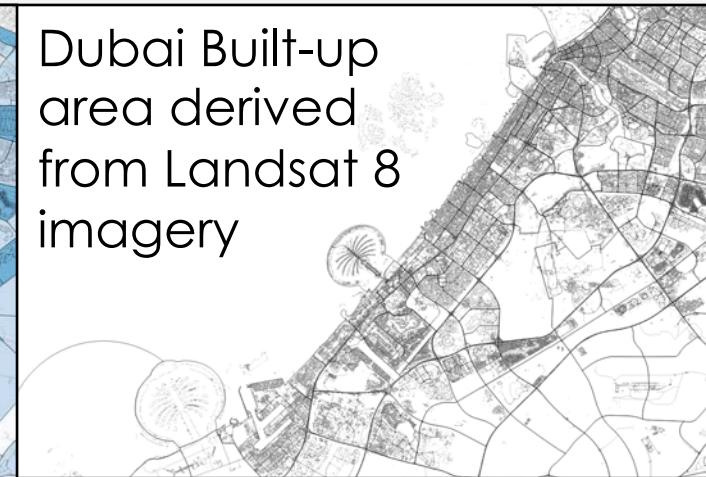
The Family of Spatial Interaction Models Again and General Urban Models

Where did we get the data – in a data poor environment?

Dubai Business Density derived from Google Places API



Dubai Built-up area derived from Landsat 8 imagery



Dubai Business Diversity Density Index





Computer



Recycle Bin



DESKTOP



Dubai-Model

CASA and the Future Cities Catapult Projects

Predicting Urban Futures for Dubai

Simulating Land Use, Population, Employment, Retailing, and Transportation

Dubai Population Estimate 2012 (Dubai Statistics Center)
تقدير عدد سكان دبي ٢٠١٢ (مركز دبي للإحصاء) - Share | Print | Measure

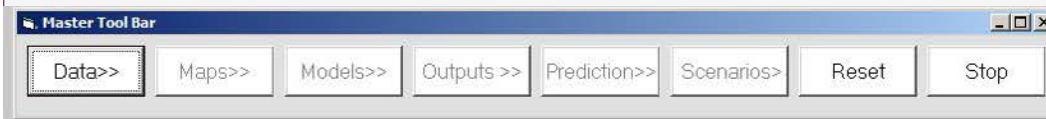
Here we simulate the impact of large changes in urban structure on the population and employment distributions in 220 communities which define the Emirate of Dubai. The population and employment which are linked together through the transportation system and flows of trips. The model we use is heavily data driven as the data mirrors how people locate and interact in the city.

This is a simple demonstration to indicate the features of such a simulation model. If we were building this model for operational use in planning Dubai, we would have many different sectors describing different types of population, distinguishing particularly between guest workers and the local population, and between retailing, construction, financial services and related industrial activities. We would also define transport by different modes.

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Future Cities



The Family of Spatial Interaction Models Again and General Urban Models



Recycle Bin

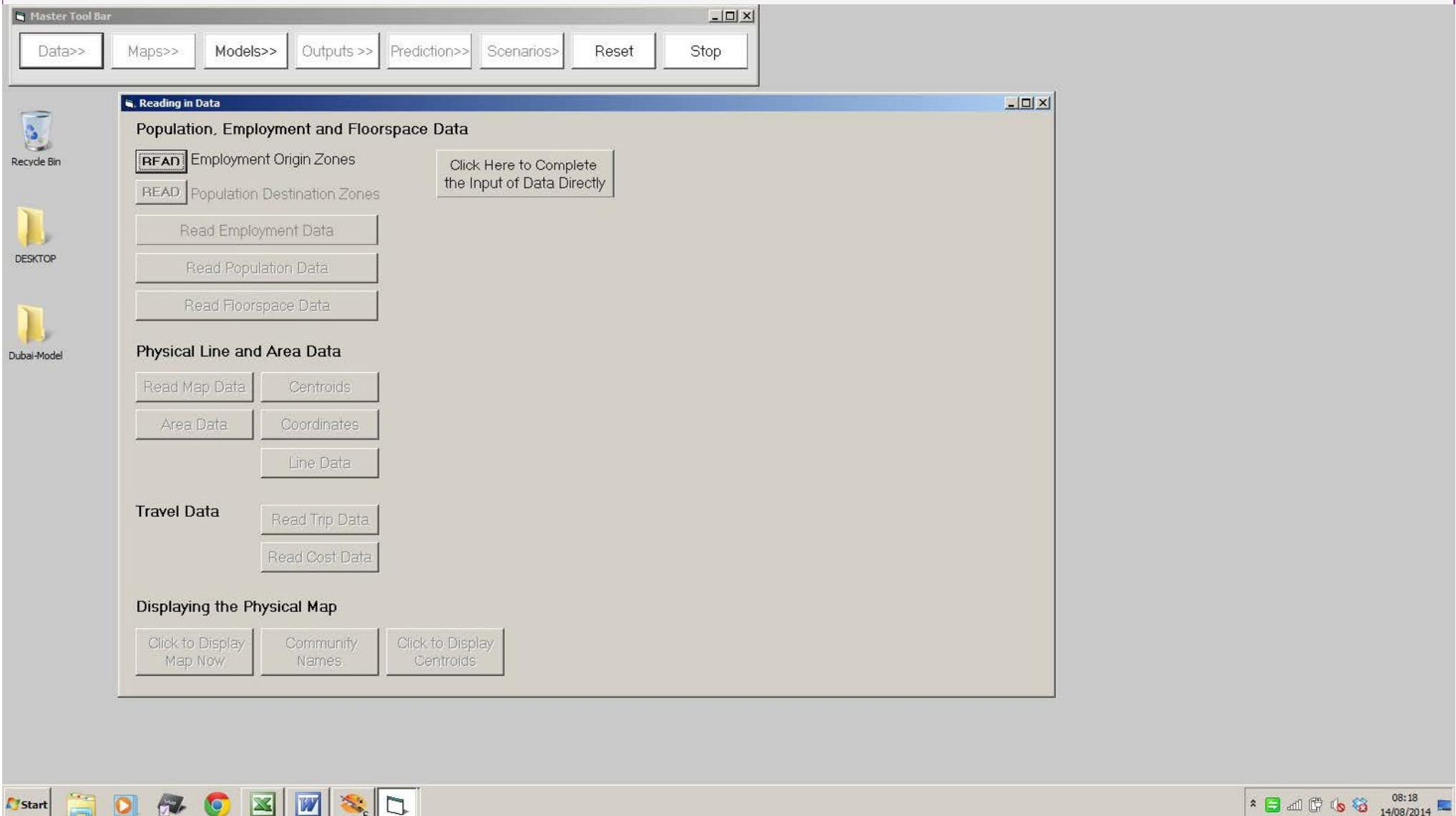


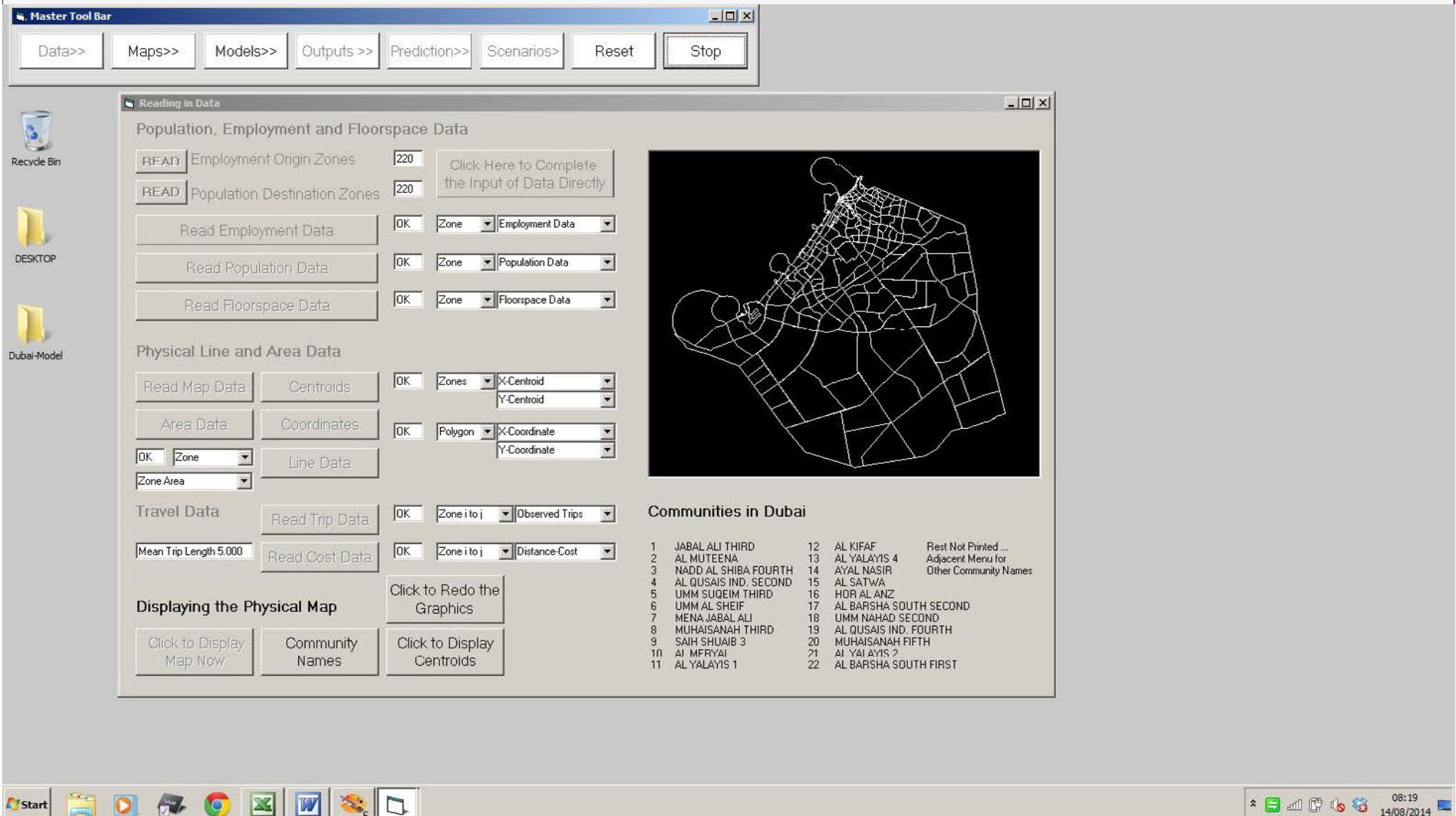
DESKTOP

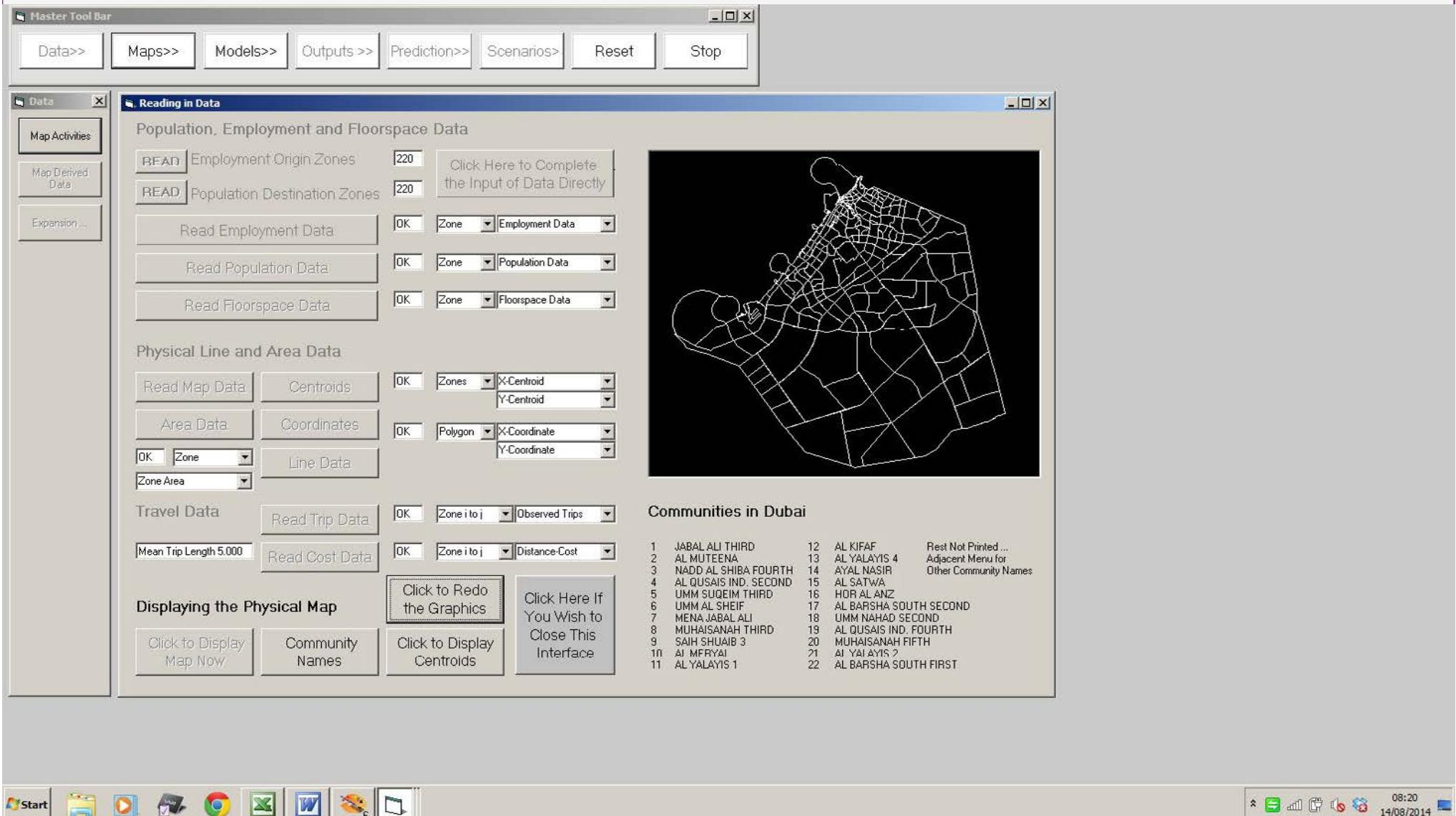


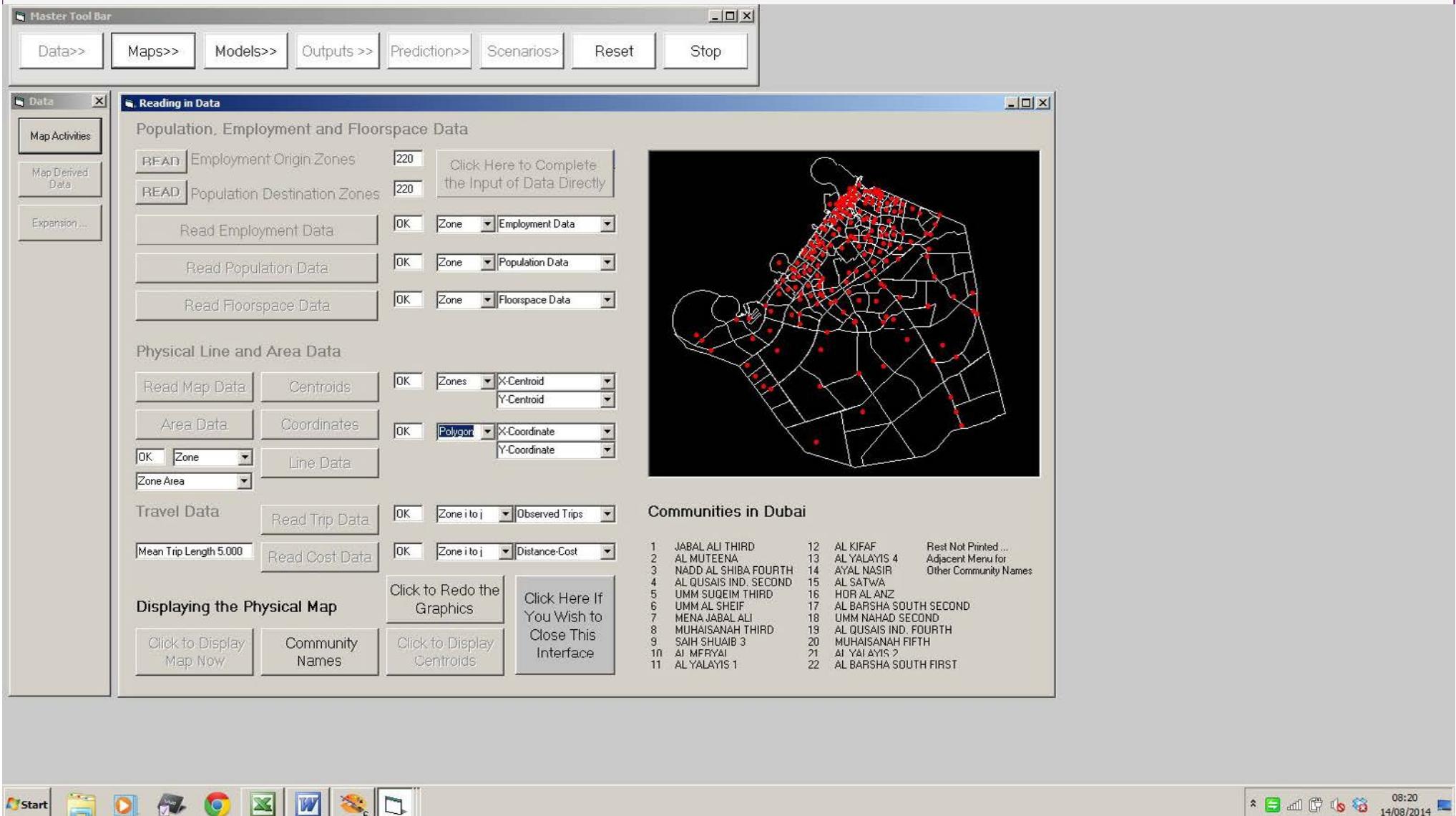
Dubai-Model











Master Tool Bar

- Data>>
- Maps>>
- Models>>
- Outputs >>
- Prediction>>
- Scenarios>>
- Reset
- Stop

Data

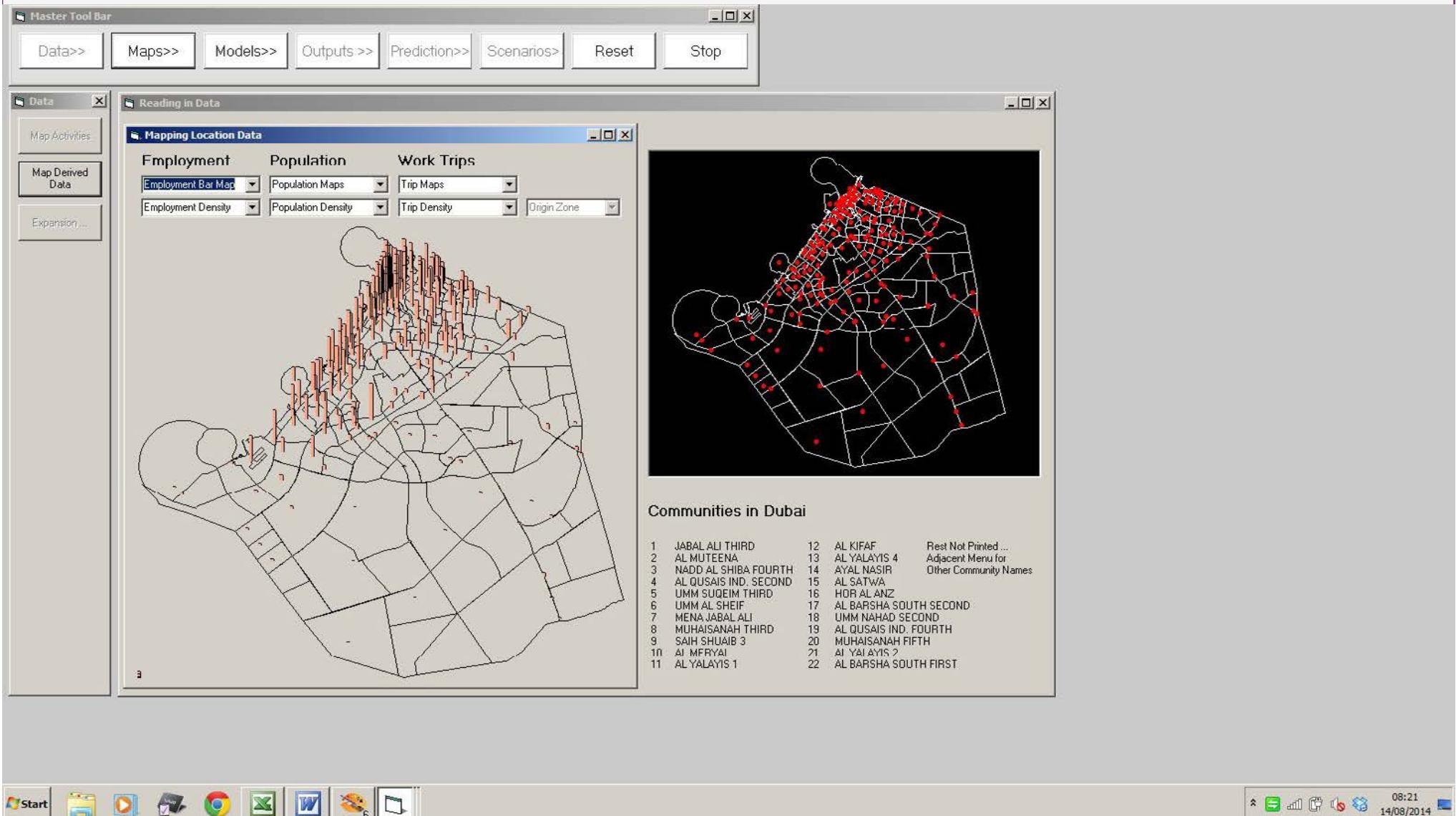
Reading in Data

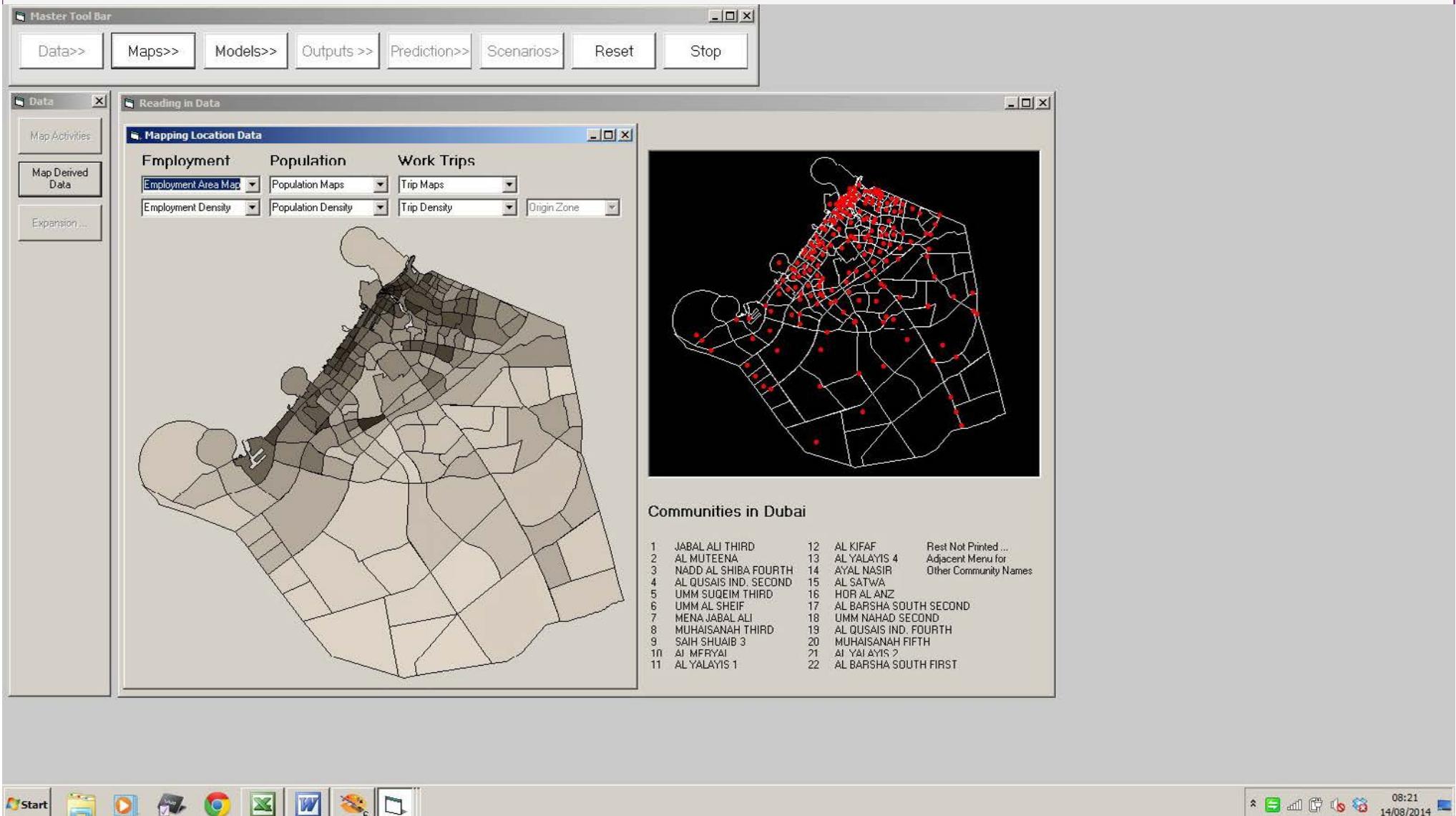
List of Community Names

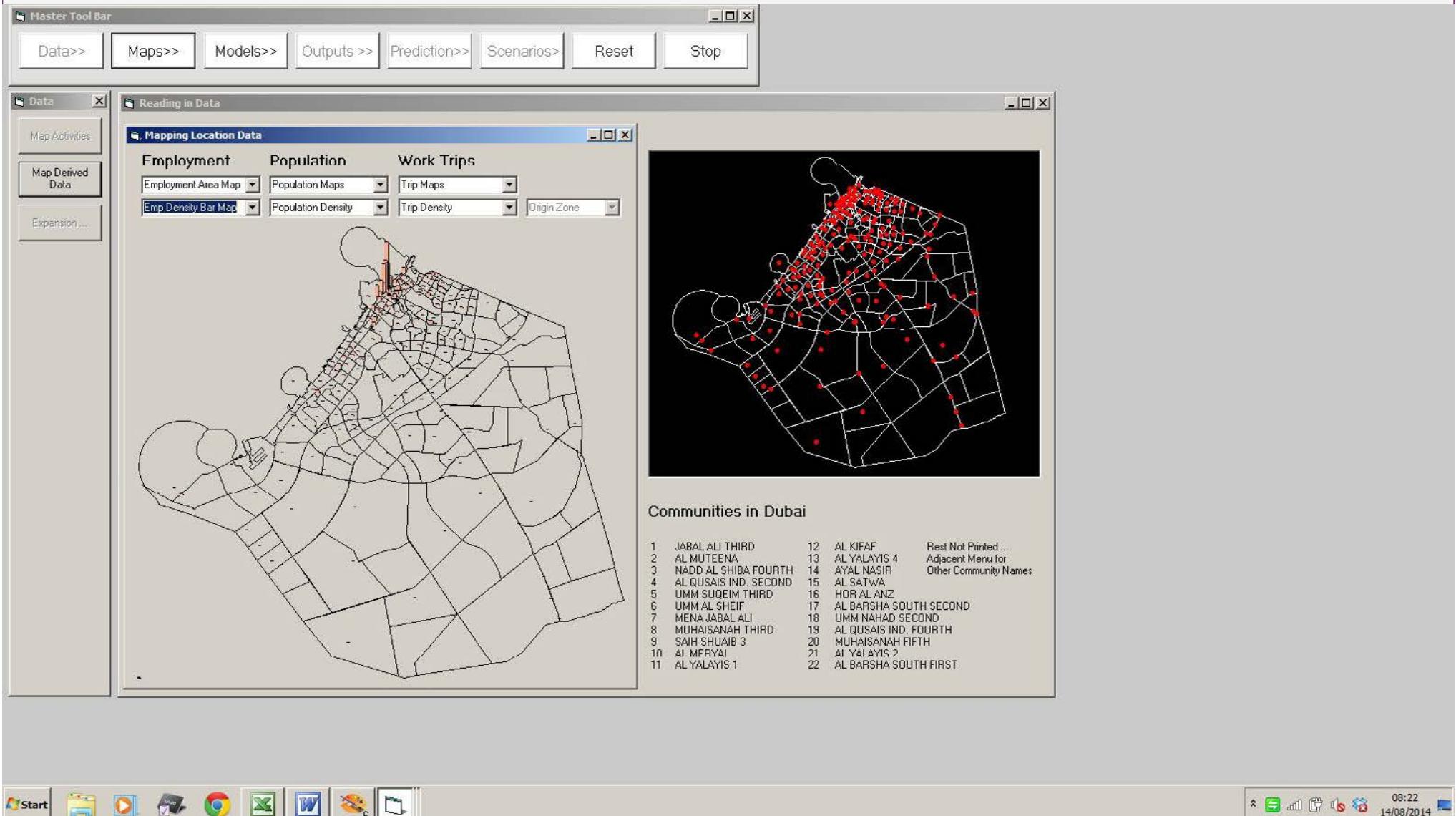
1. JARAI AL I THIRD	46. UMM HUAIR SECOND	91. AI SFI AI	136. AI QOUZ FOURTH	181. .II IMFIRASI AND ONF
2. AL MUTEENA	47. UMM NAHAD FIRST	92. AL WARQA'A FOURTH	137. AL BARSHA SOUTH THIRD	182. AL TWAR THIRD
3. NADD AL SHIBA FOURTH	48. HEFAIR	93. RAS AL KHOR IND. FIRST	138. AL KHEERAN FIRST	183. AL GARHOUDE
4. AL QUSAIS IND. SECOND	49. WARSAN THIRD	94. MARGHAM	139. NAKHLAT DEIRA	184. AL JAFILIYA
5. UMM SUQEIM THIRD	50. MUHAISANAH SECOND	95. AL TTAY	140. AL RAS	185. NAZWAH
6. UMM AL SHEIF	51. AL QUSAIS THIRD	96. AL BARAHA	141. WADI AL SAFA 5	186. AL LAYAN 2
7. MENA JABAL ALI	52. AL MURAQQABAT	97. AL YALAYIS 5	142. AL QOUZE IND.FOURTH	187. MANKHOOL
8. MUHAISANAH THIRD	53. NAIF	98. PORT SAED	143. UMM SUQEIM SECOND	188. NADD HESSA
9. SAIH SHUAIB 3	54. AL QOUZ FIRST	99. AL MIZHAR FIRST	144. AL SAFA SECOND	189. MUHAISANAH FOURTH
10. AL MERYAL	55. MARGAB	100. AL QOUZE IND.THIRD	145. NADD SHAMMA	190. AL BARSHA SECOND
11. AL YALAYIS 1	56. AL HEBIAH SECOND	101. AL MAMZAR	146. SAIH SHUA'ALAH	191. AL BARSHA SOUTH FOURTH
12. AL KIFAF	57. ABU HAIL	102. AL RAFFA	147. LE HEMAIRA	192. MUHAISNAH FIRST
13. AL YALAYIS 4	58. JUMEIRA THIRD	103. MEREEYEEEL	148. KADRA	193. AL TWAR SECOND
14. AYAL NASIR	59. MUGATRAH	104. JUMEIRA FIRST	149. AL RIOWAYAH SECOND	194. AL HEBIAH THIRD
15. AL SATWA	60. AL THANYAH FOURTH	105. CORNICHE DEIRA	150. AL THANYAH SECOND	195. UMM HURAIR FIRST
16. HOR AL ANZ	61. NADD AL SHIBA FIRST	106. AL MIZHAR SECOND	151. AL SABKHA	196. WADI AL SAFA 4
17. AL BARSHA SOUTH SECOND	62. AL BUTEEN	107. WADI AL SAFA 3	152. WADI AL SAFA 2	197. AL SAFOUH SECOND
18. UMM NAHAD SECOND	63. AL HEBIAH FIFTH	108. WADI AL SAFA 6	153. HOR AL ANZ EAST	198. AL QOUZE IND.SECOND
19. AL QUSAIS IND. FOURTH	64. AL FAGAA'	109. AL MARMOOD	154. AL KHWAINEEJ SECOND	199. AL WASL
20. MUHAISANAH FIFTH	65. GRAYTEESAH	110. WARSAN FOURTH	155. DUBAI INVESTMENT PARK FIRST	200. AL CORNICHE
21. AL YALAYIS 2	66. AL YALAYIS 3	111. DUBAI INT'L AIRPORT	156. AL QUSAIS SECOND	201. MIRDIF
22. AL BARSHA SOUTH FIRST	67. REMAH	112. AL WARQA'A SECOND	157. AL HEBIAH FOURTH	202. UMM SUQEIM FIRST
23. YARAAH	68. ME'AISEM SECOND	113. TRADE CENTER FIRST	158. WARSAN FIRST	203. GHADEER BARASHY
24. AL LESAILY	69. SAIH AL DAHAL	114. AL AWIR SECOND	159. AL QUSAIS FIRST	204. MADINAT DUBAI AL MELAHEYAH
25. AL NAHDA SECOND	70. JABAL AL INDUSTRIAL FIRST	115. AL RASHIDIYA	160. SAIH AL SALAM	205. AL MERKADH
26. LEHBAB FIRST	71. MADINAT AL MATAAR	116. RIGGAT AL BUTEEN	161. RAS AL KHOR IND. SECOND	206. AL KARAMA
27. AL HAMRIYA	72. AL THANYAH FIRST	117. RAS AL KHOR	162. SAIH SHUAIB 2	207. AL MAHA
28. AL SAFA FIRST	73. AL THANYAH FIFTH	118. AL BARSHA SOUTH FIFTH	163. UMM ESELAY	208. AL WAJEHA AL BAHRIAH
29. AL MANARA	74. CNKIALI	119. AL ITTIMIAMI	164. AL WANDAQ'A TIIND	209. SAII CIUAIID 1
30. UMM AL MO'MENEEN	75. NADD AL HAMAR	120. AL KHABASI	165. JABAL AL INDUSTRIAL SECOND	210. MARSA DUBAI
31. ALEYAS	76. AL RIOWAYAH THIRD	121. AL LAYAN 1	166. AL MURAR	211. UMM RAMOOL
32. WADU AL ALAMARDI	77. LEHBAB SECOND	122. AL WARQA'A FIRST	167. AL KHEERAN	212. ZAA'BEEL FIRST
33. AL HEBIAH FIRST	78. AL YUFRAH 2	123. AL KHEERAN SECOND	168. AL BARSHA FIRST	213. HADEQ SHEIKH MOHAMMED B-R
34. AL QUSAIS IND. FIFTH	79. AL SHINDAGHA	124. AL AWIR FIRST	169. UMM NAHAD THIRD	214. AL THANYAH THIRD
35. TRADE CENTER SECOND	80. UMM AL DAMAN	125. HESSYAN SECOND	170. NAKHLAT JABAL ALI	215. HESSYAN FIRST
36. NADD AL SHIBA SECOND	81. AL BARSHA THIRD	126. AL TWAR FIRST	171. AL RIOWAYAH FIRST	216. AL WARQA'A FIFTH
37. BURJ KHALIFA	82. OUD AL MUTEENA SECOND	127. WARSAN SECOND	172. AL WOHOOSH	217. AL NAHDA FIRST
38. AL QUSAIS IND. THIRD	83. AL SAFOUH FIRST	128. AL QOUZ THIRD	173. RAS AL KHOR IND. THIRD	218. JABAL ALI SECOND
39. AL QOUZ SECOND	84. AL YUFRAH 1	129. AL QUSAIS IND. FIRST	174. ME'AISEM FIRST	219. WADI AL SAFA 7
40. ZAA'BEEL SECOND	85. JABAL AL FIRST	130. AL HAMRIYA PORT	175. JABAL AL INDUSTRIAL THIRD	220. AL BADA'
41. AL JADAF	86. AL SOQU AL KABEER	131. AL WUHEIDA	176. NADD AL SHIBA THIRD	
42. JUMEIRA SECOND	87. AL RIGGA	132. OUD AL MUTEENA FIRST	177. WADI ALSHABAK	
43. DUBAI INVESTMENT PARK SECOND	88. UMM NAHAD FOURTH	133. AL O'SHOOSH	178. AL QOUZE IND.FIRST	
44. SAIH SHUAIB 4	89. MUSHRAIF	134. OUD METHA	179. AL HUDAIBA	
45. AL KHWAINEEJ FIRST	90. OUD AL MUTEENA THIRD	135. NAKHLAT JUMEIRA	180. AL DAGHAYA	

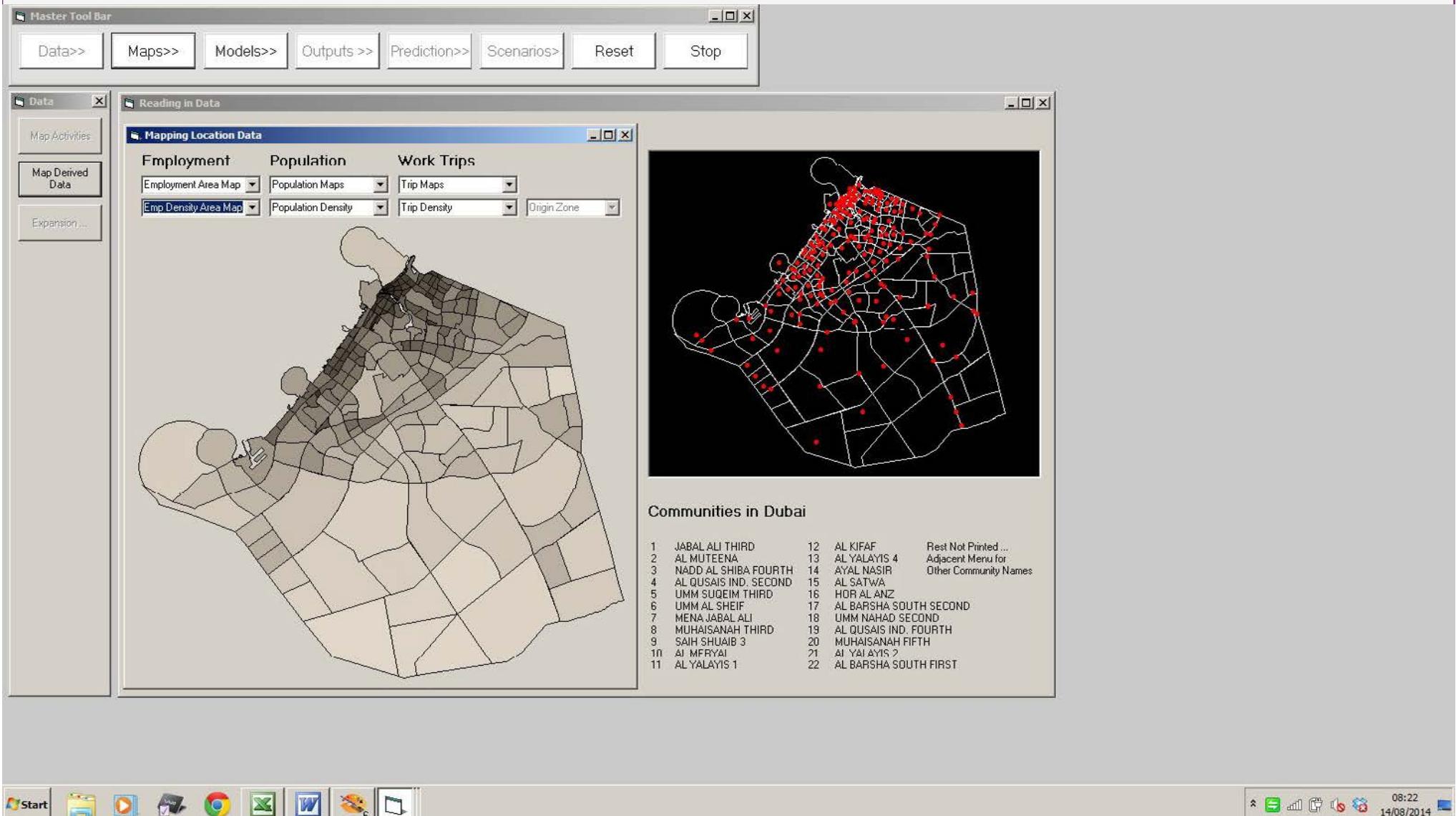
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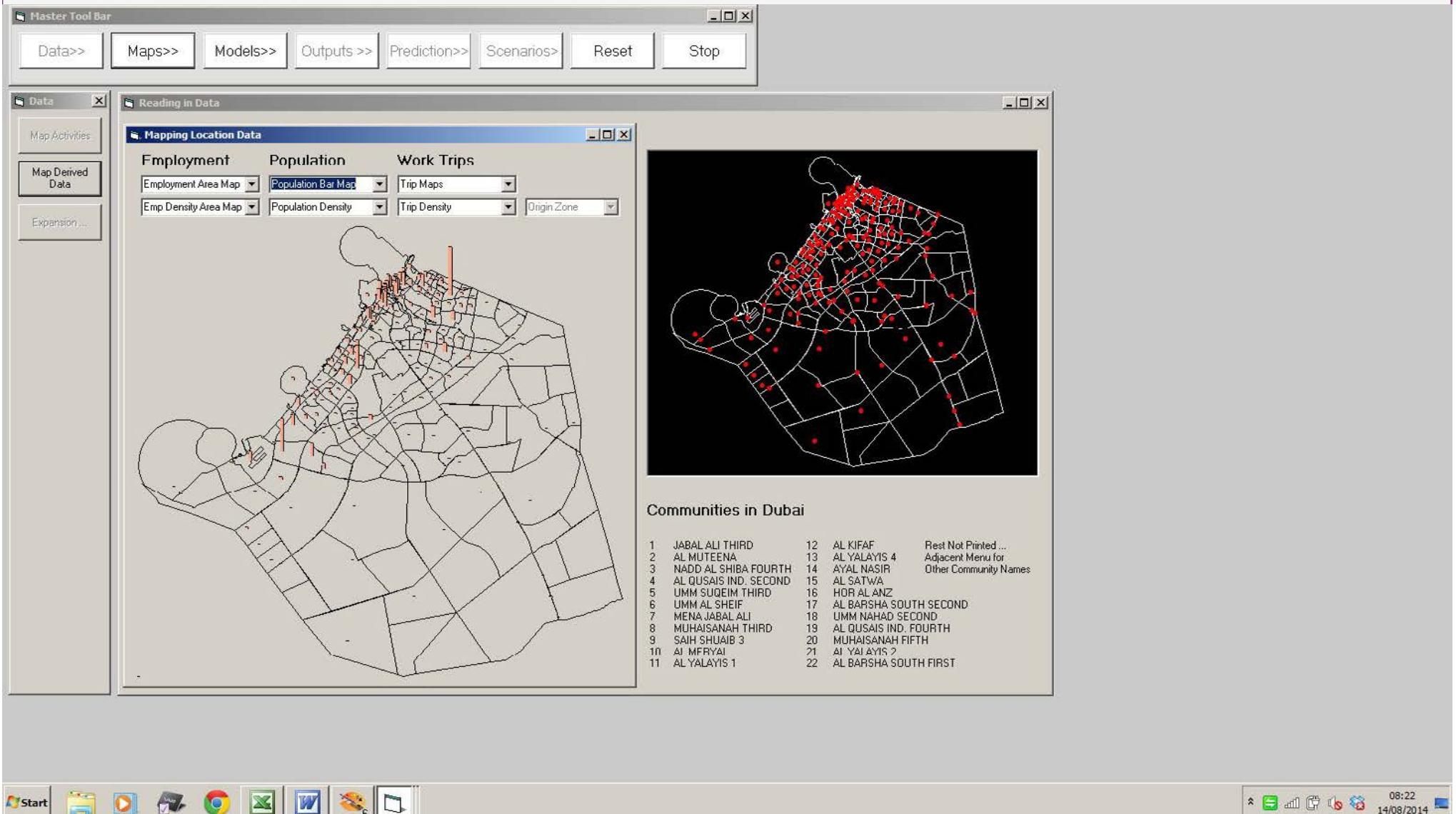
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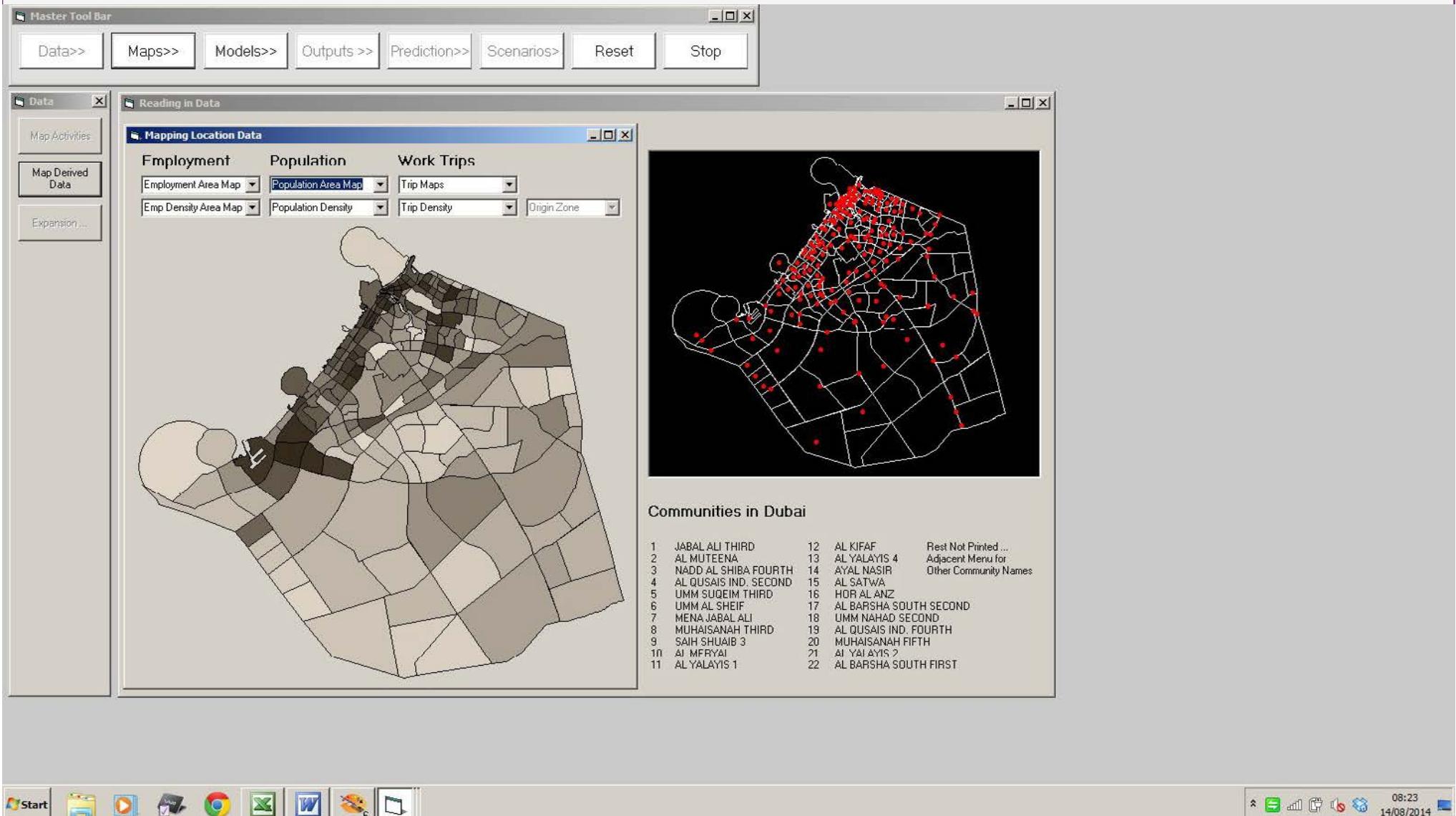


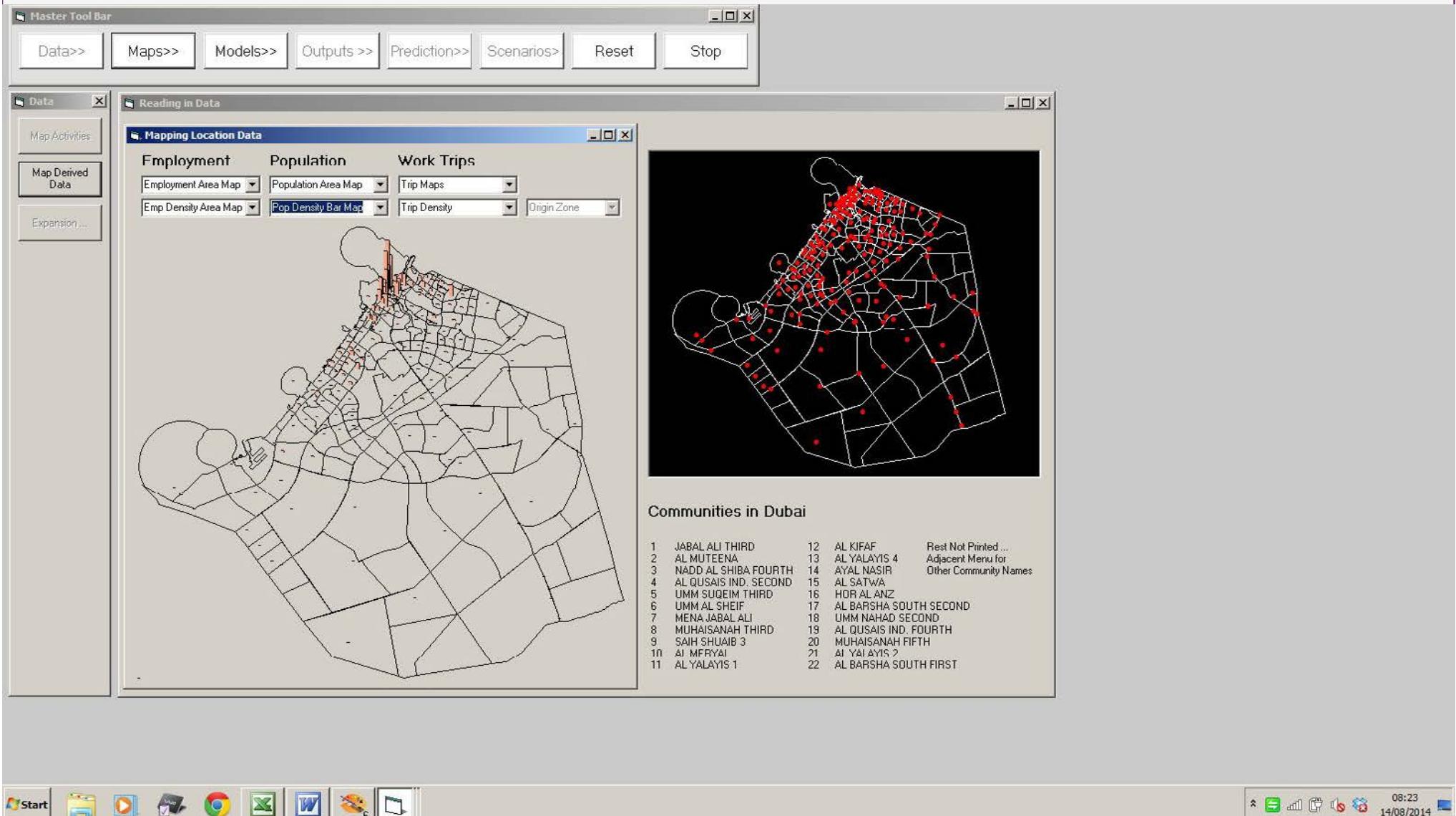


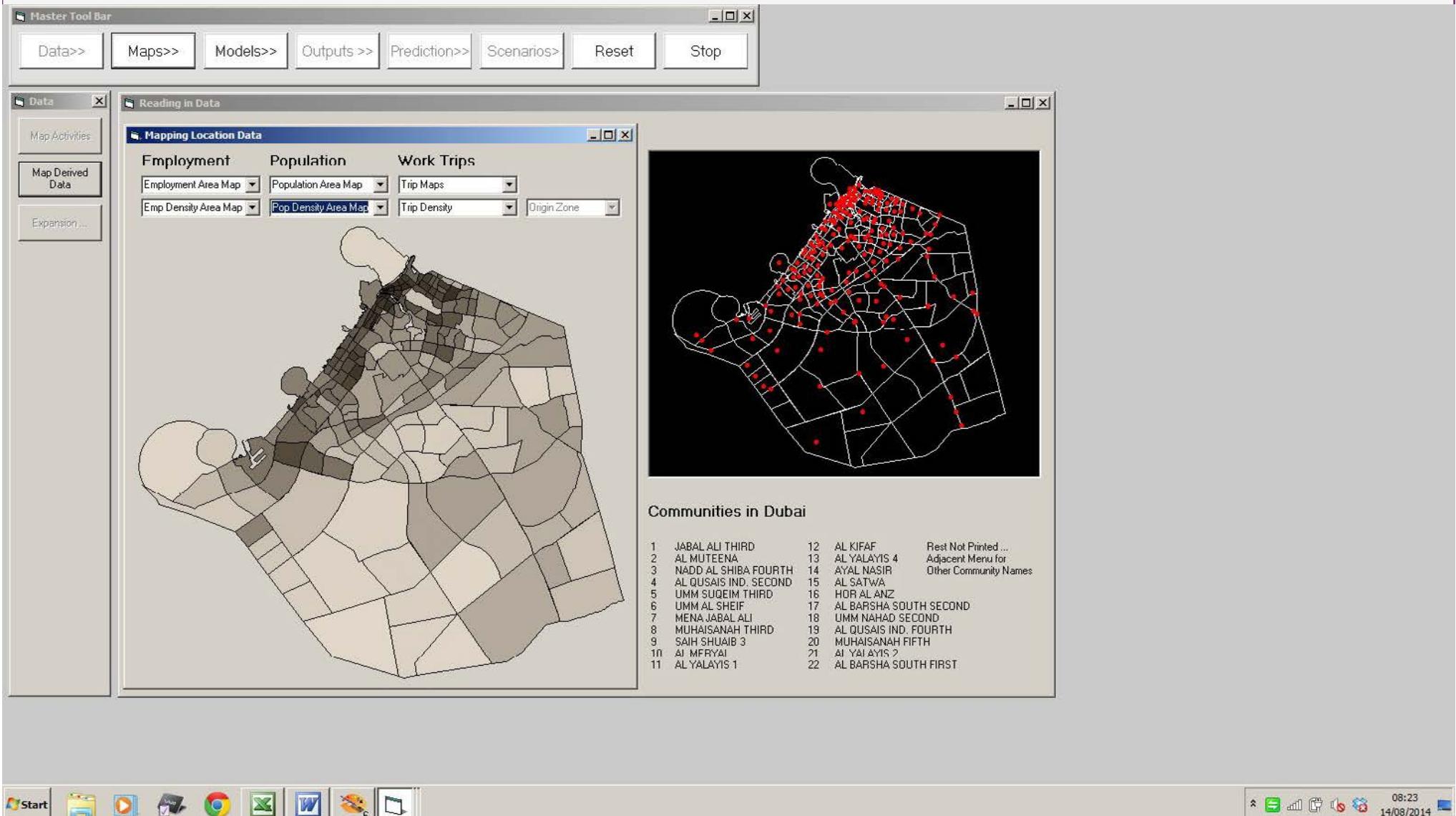




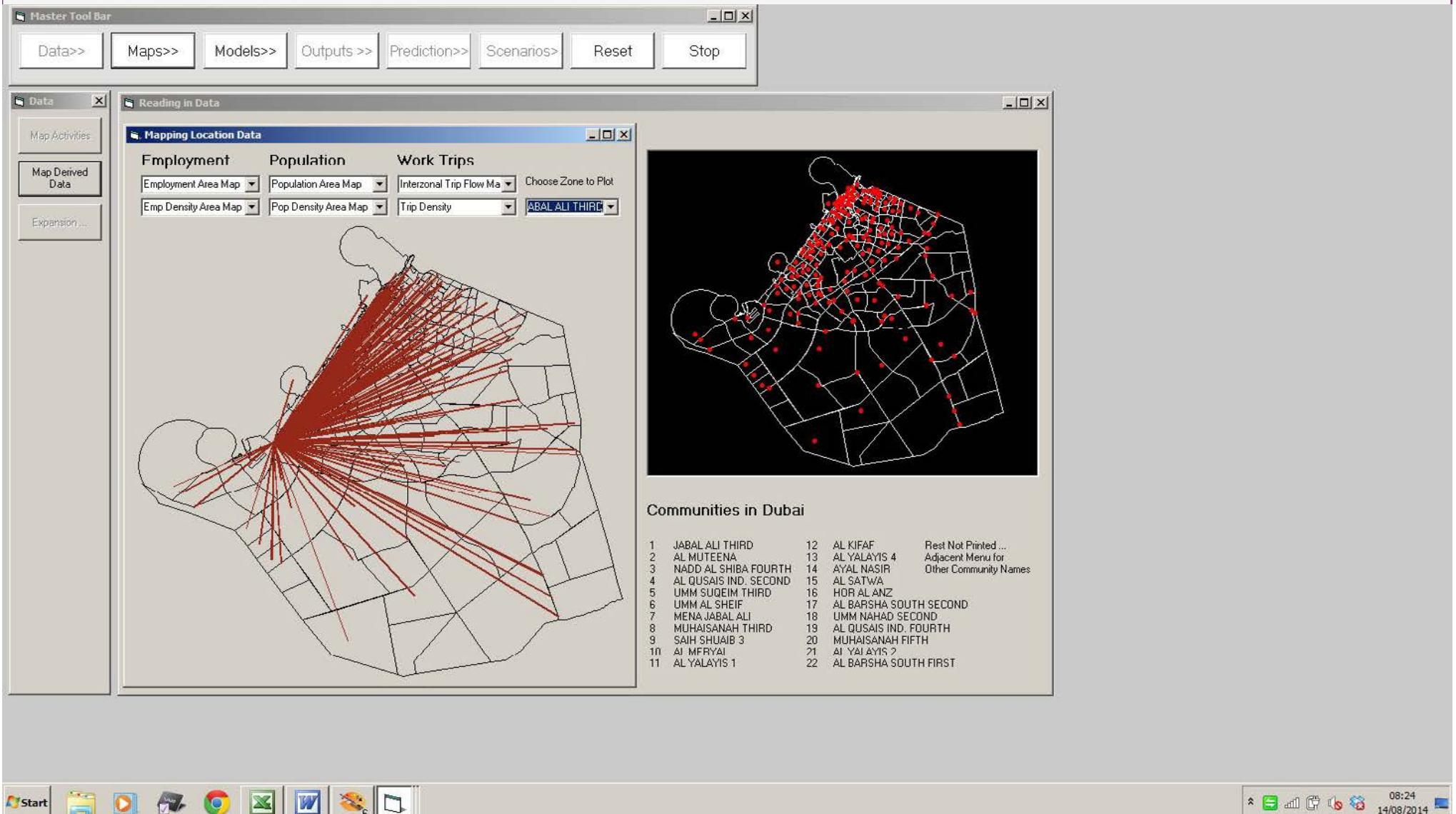


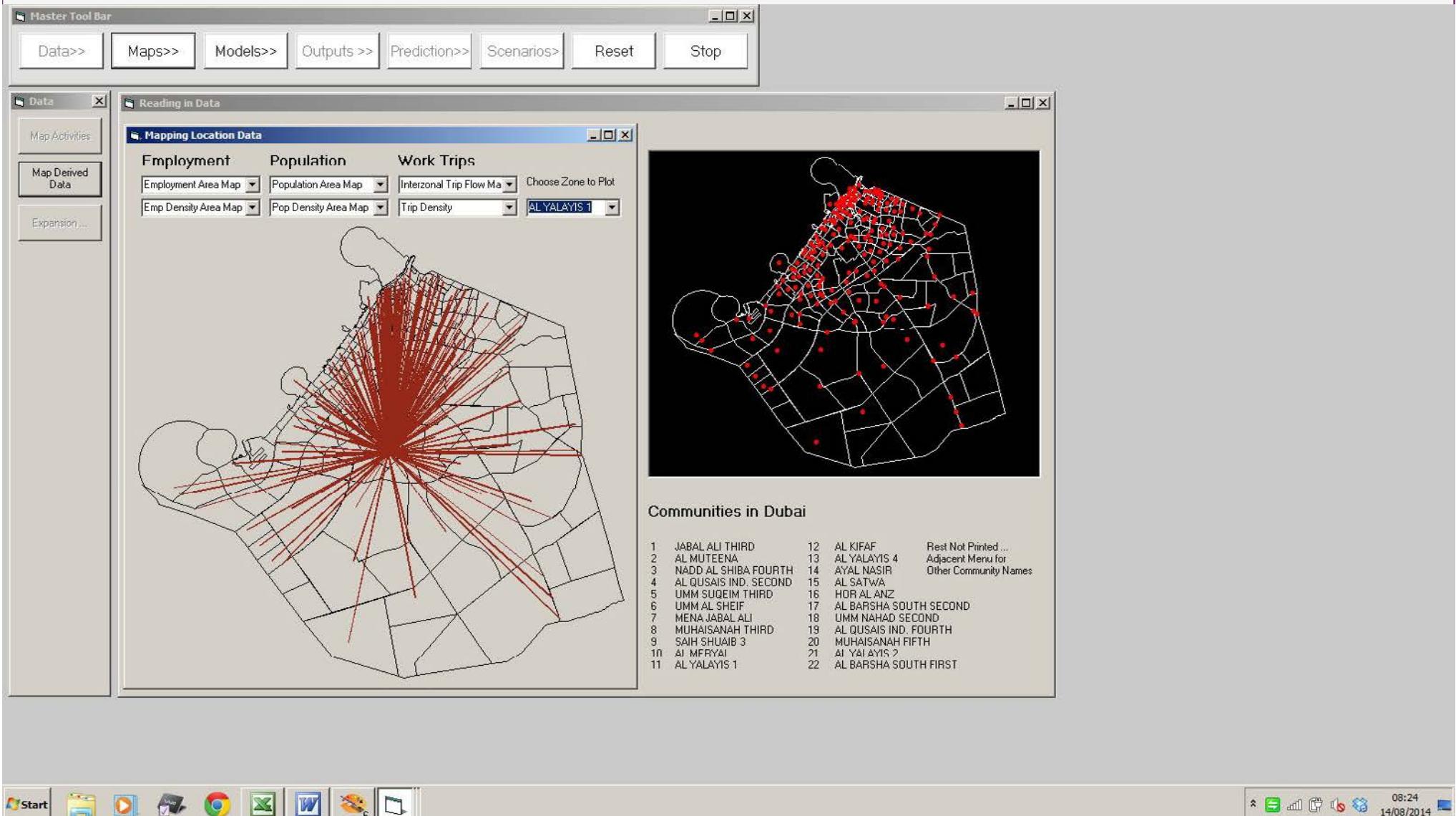


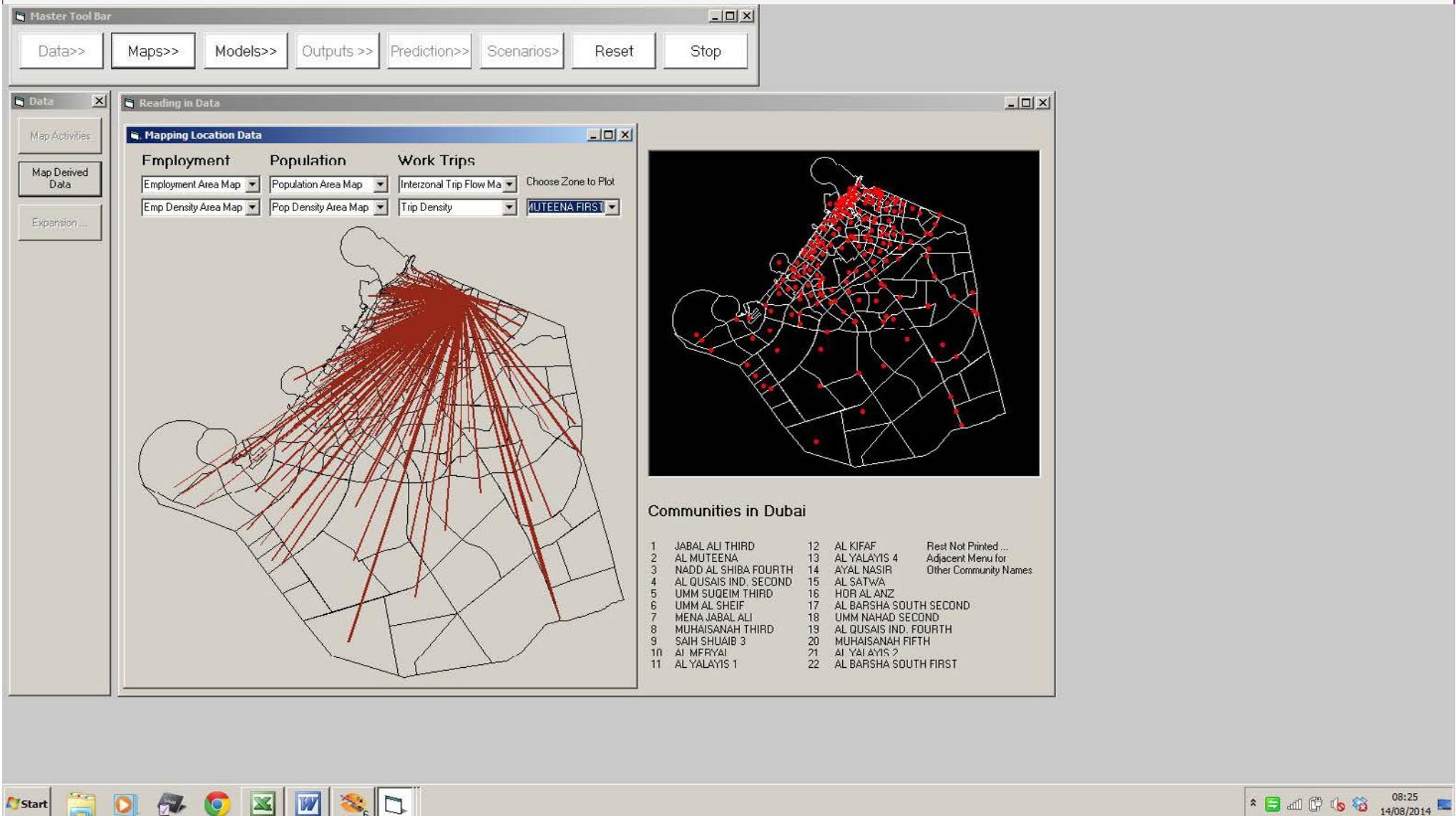


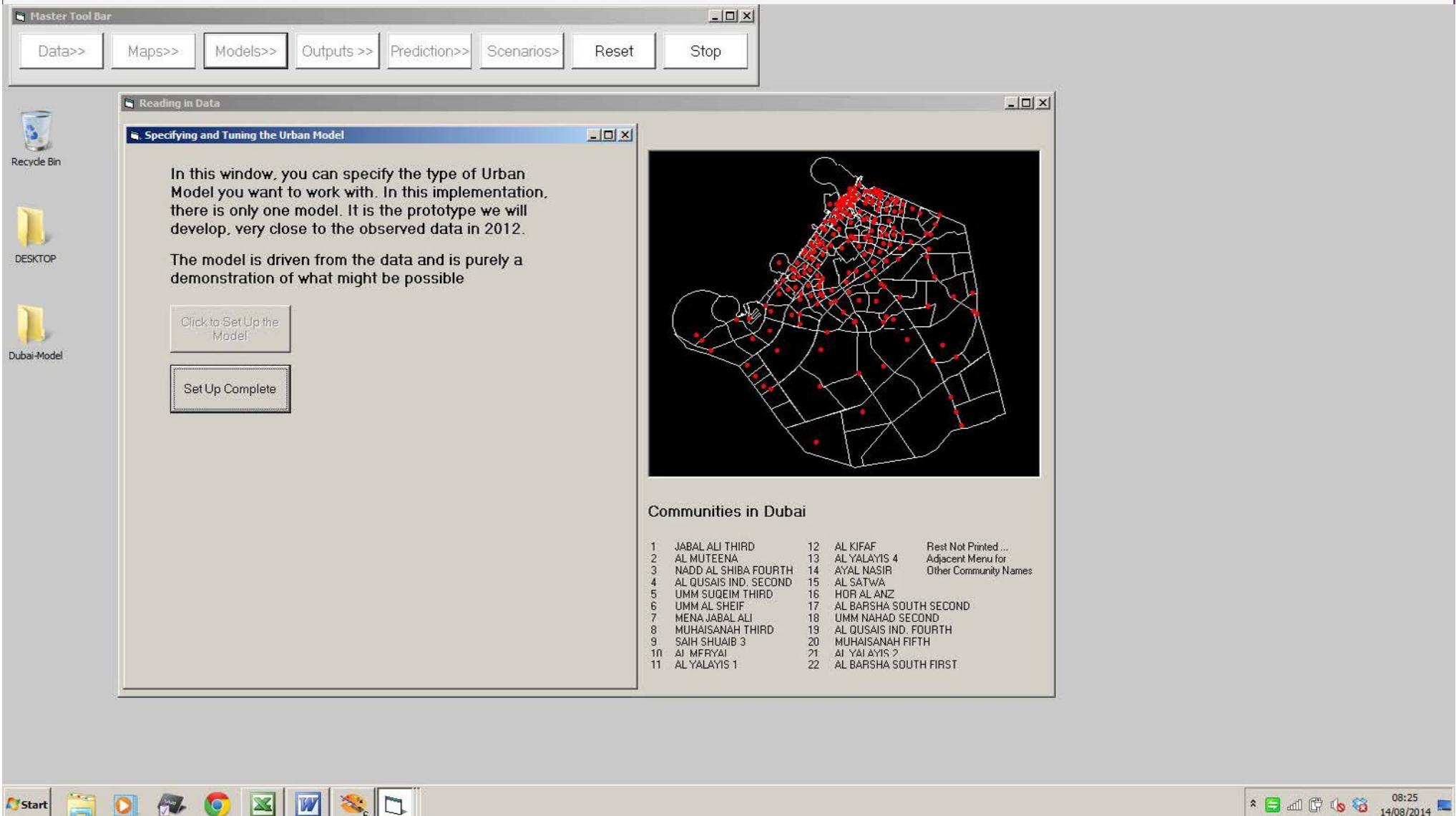


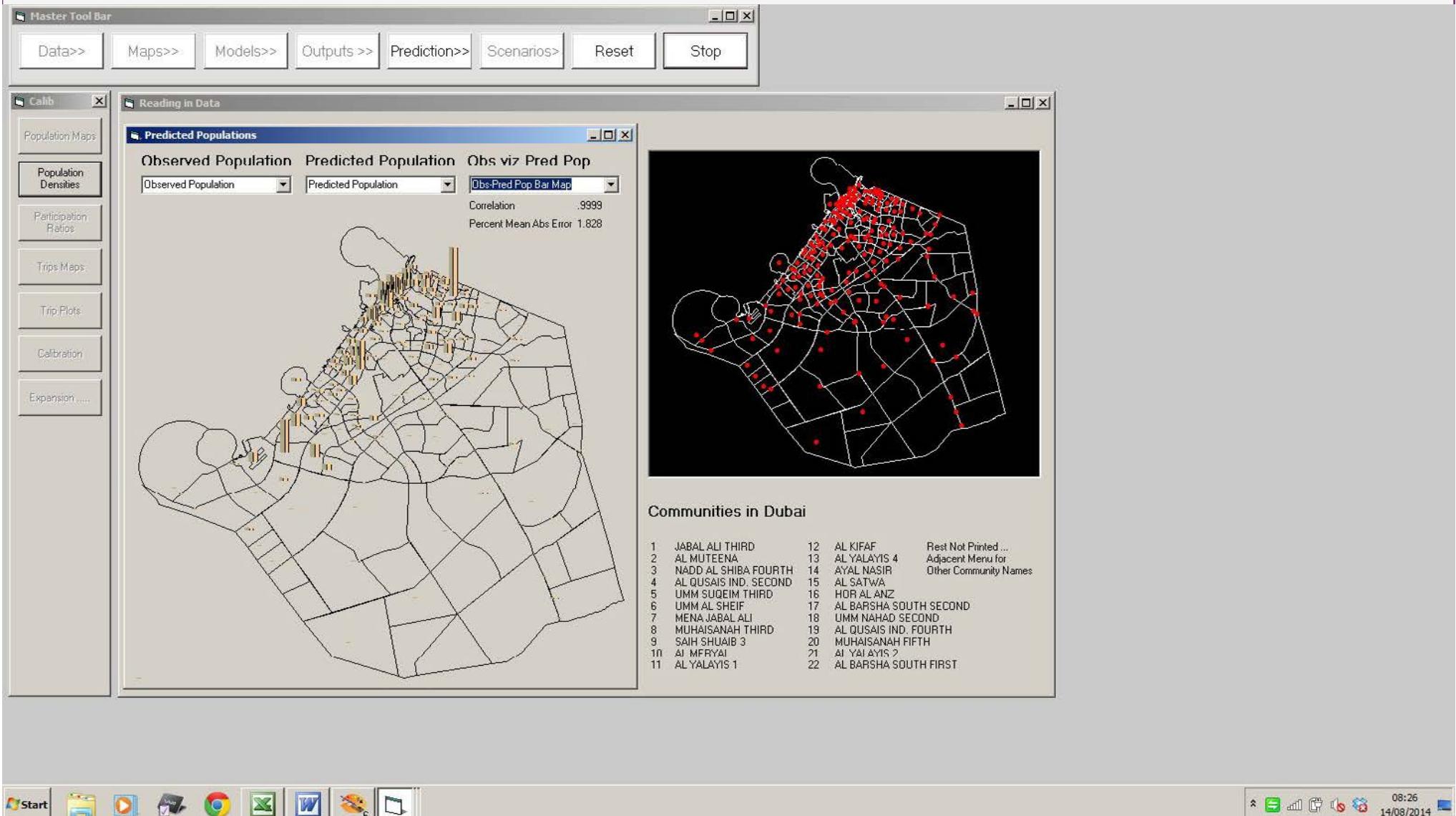
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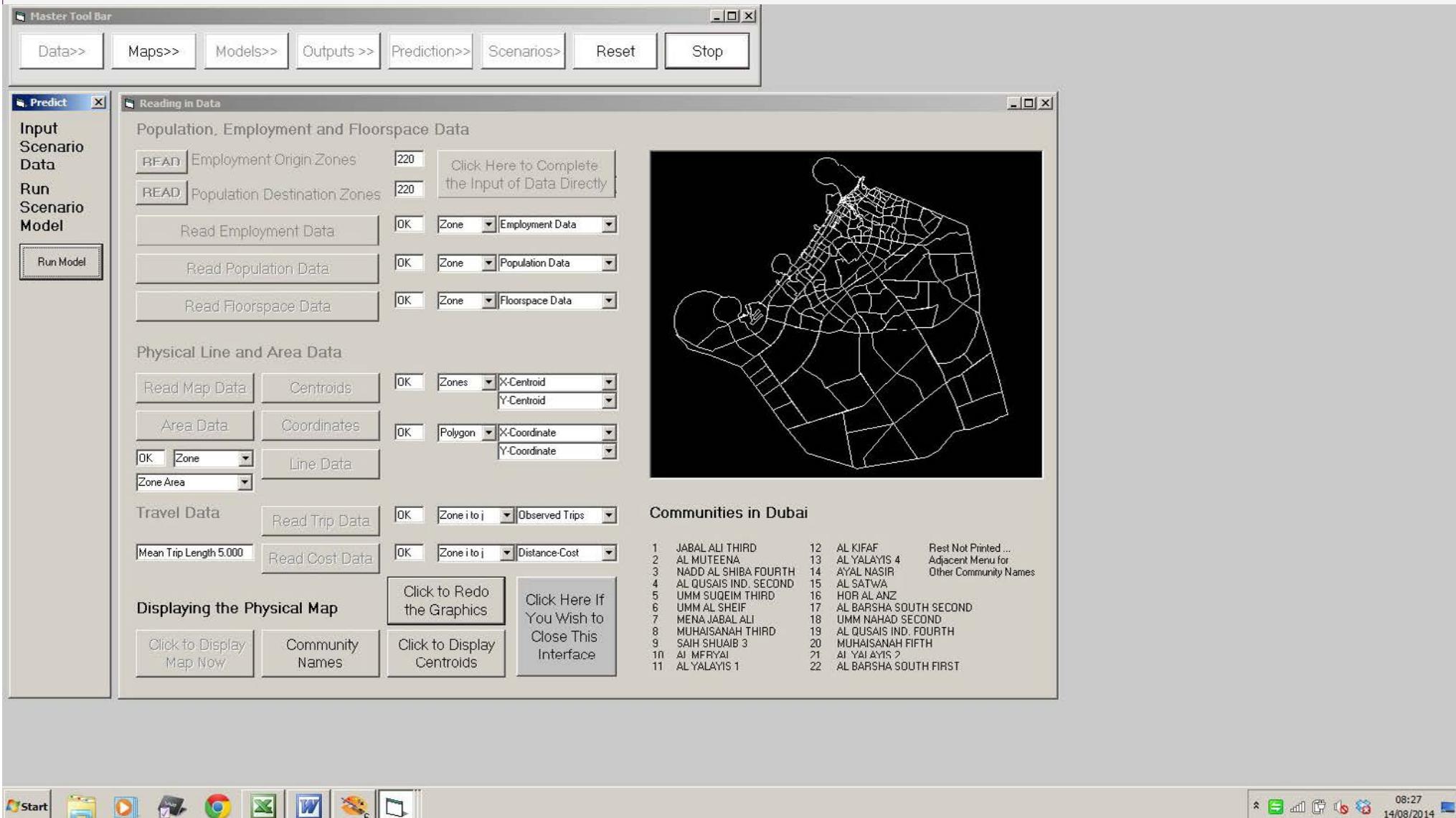


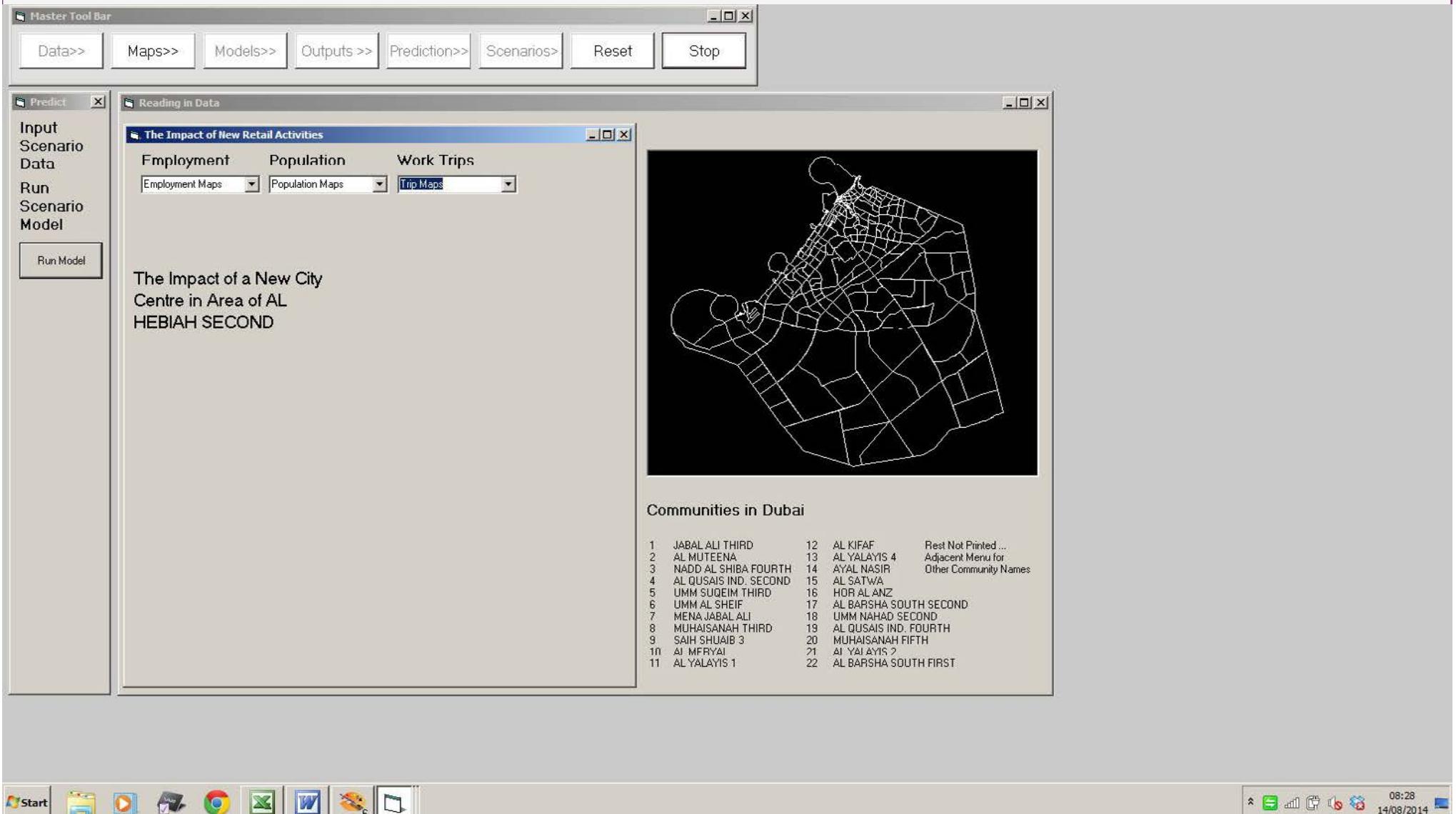


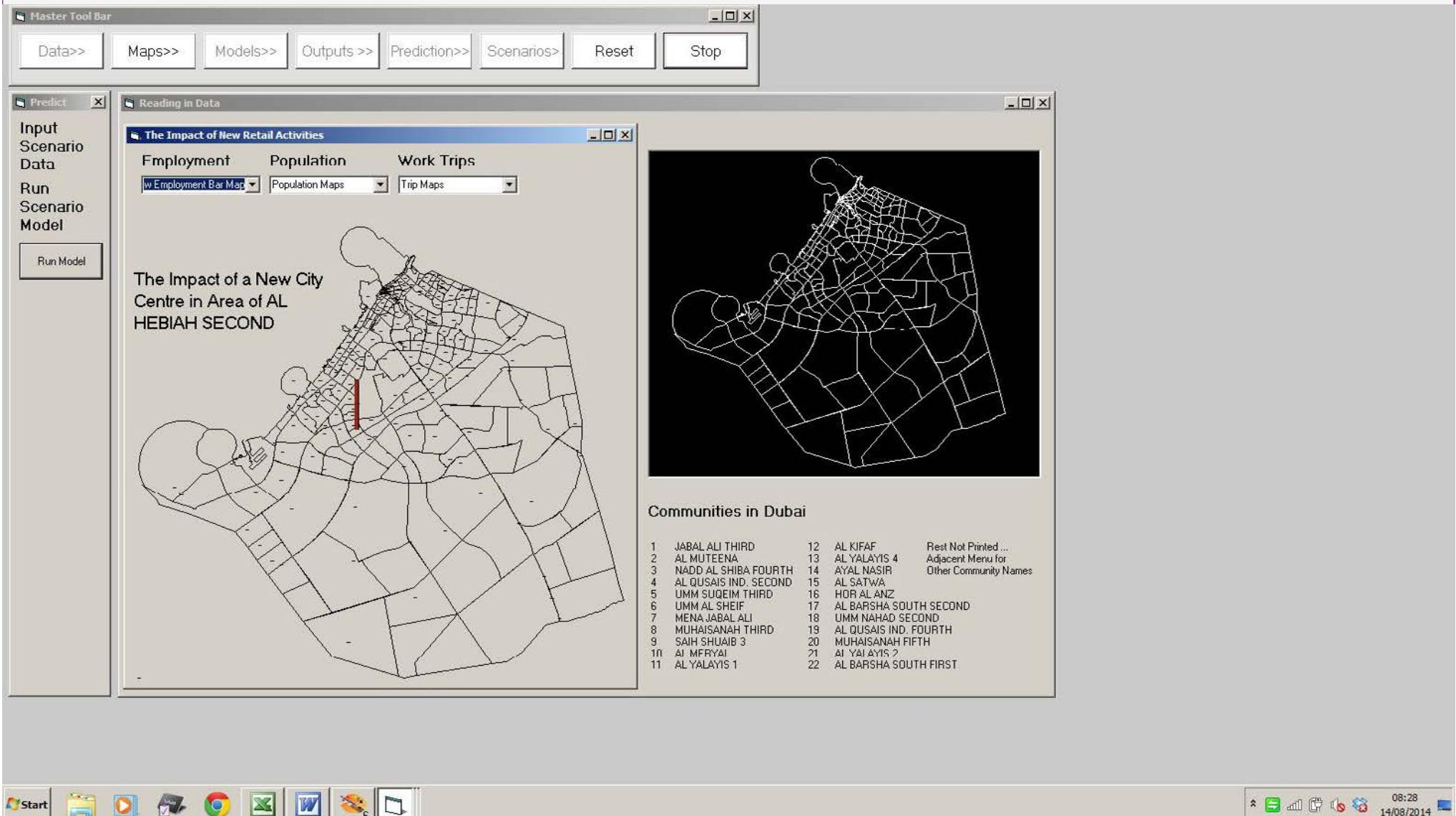


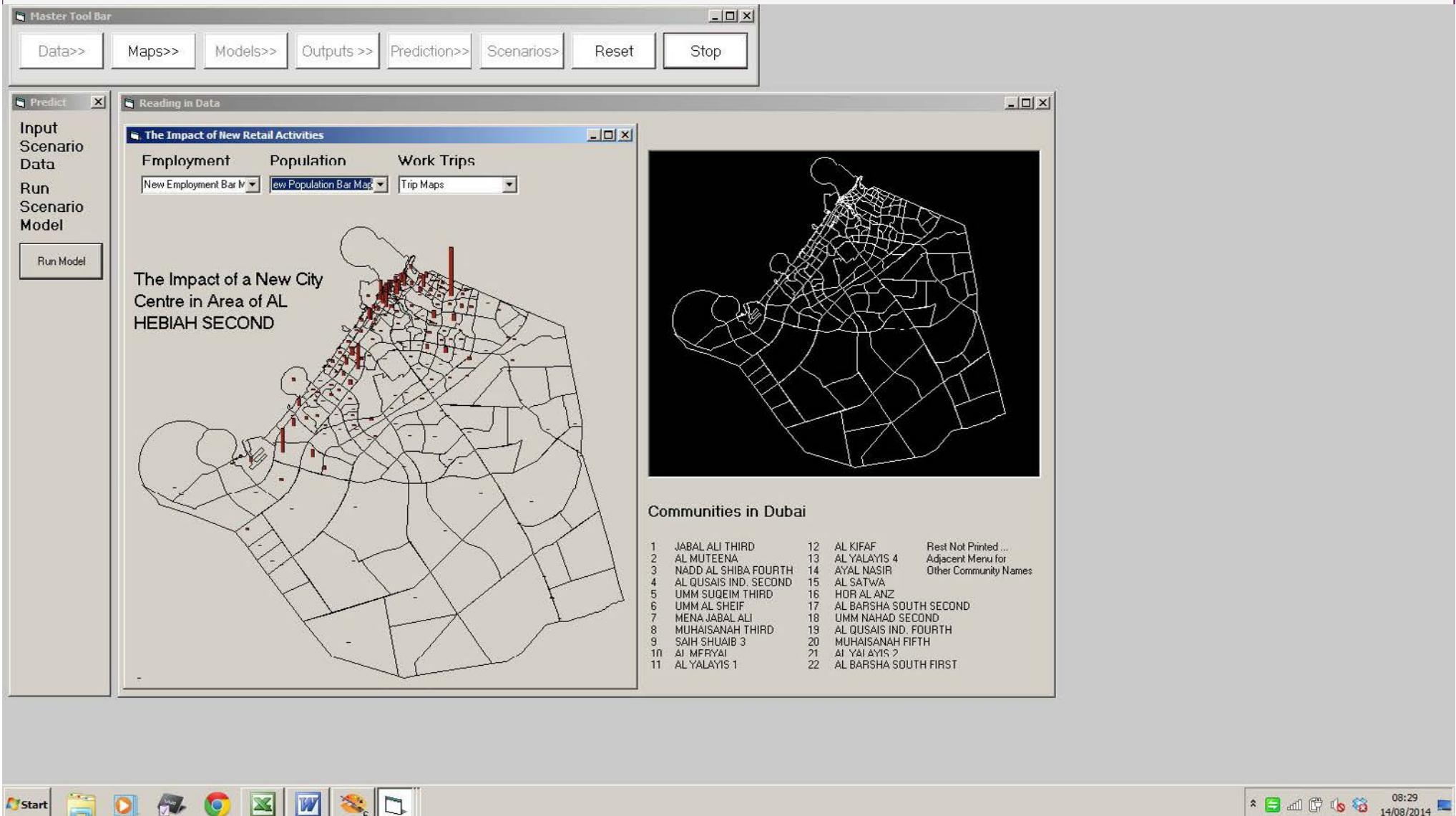


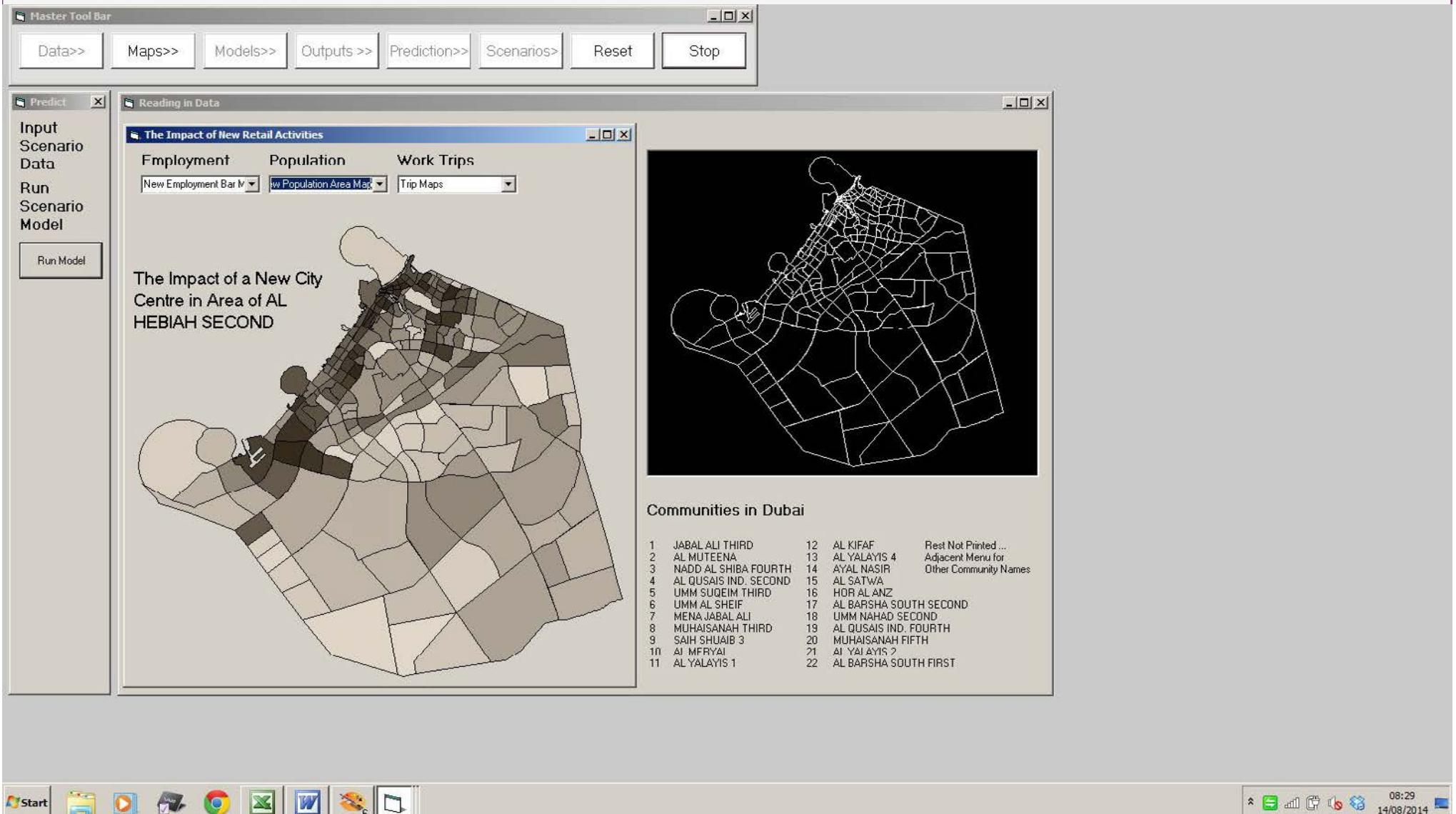


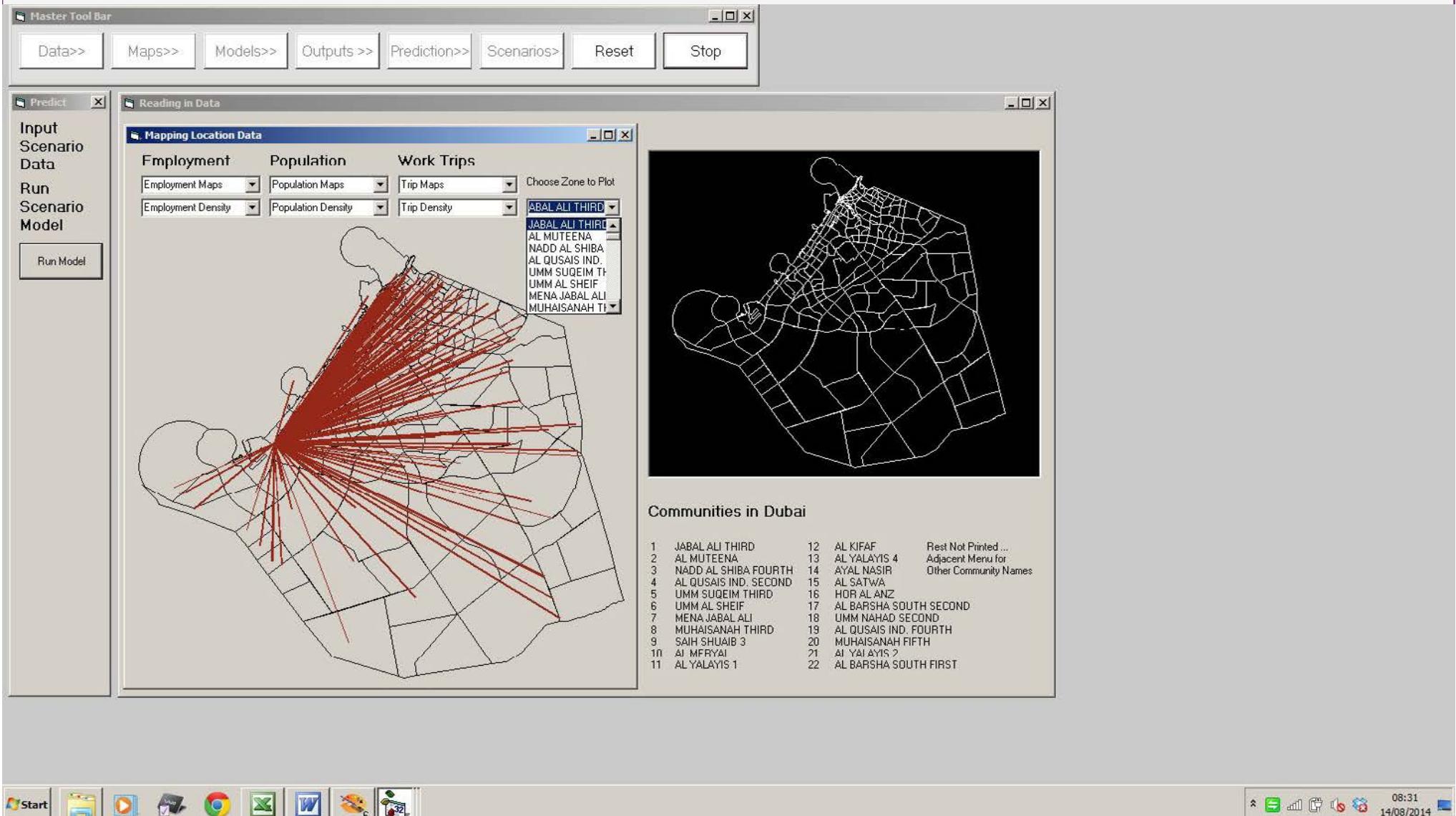


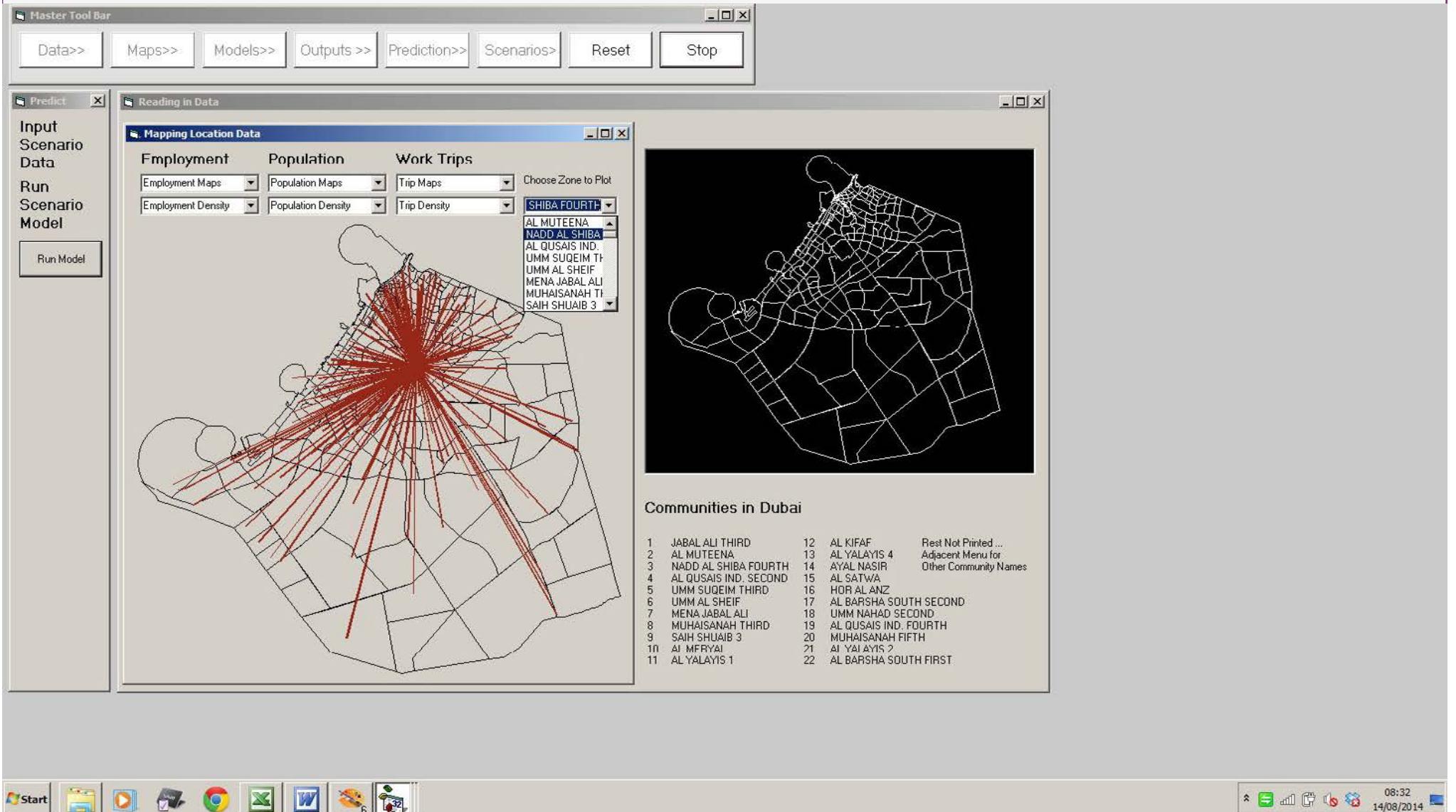


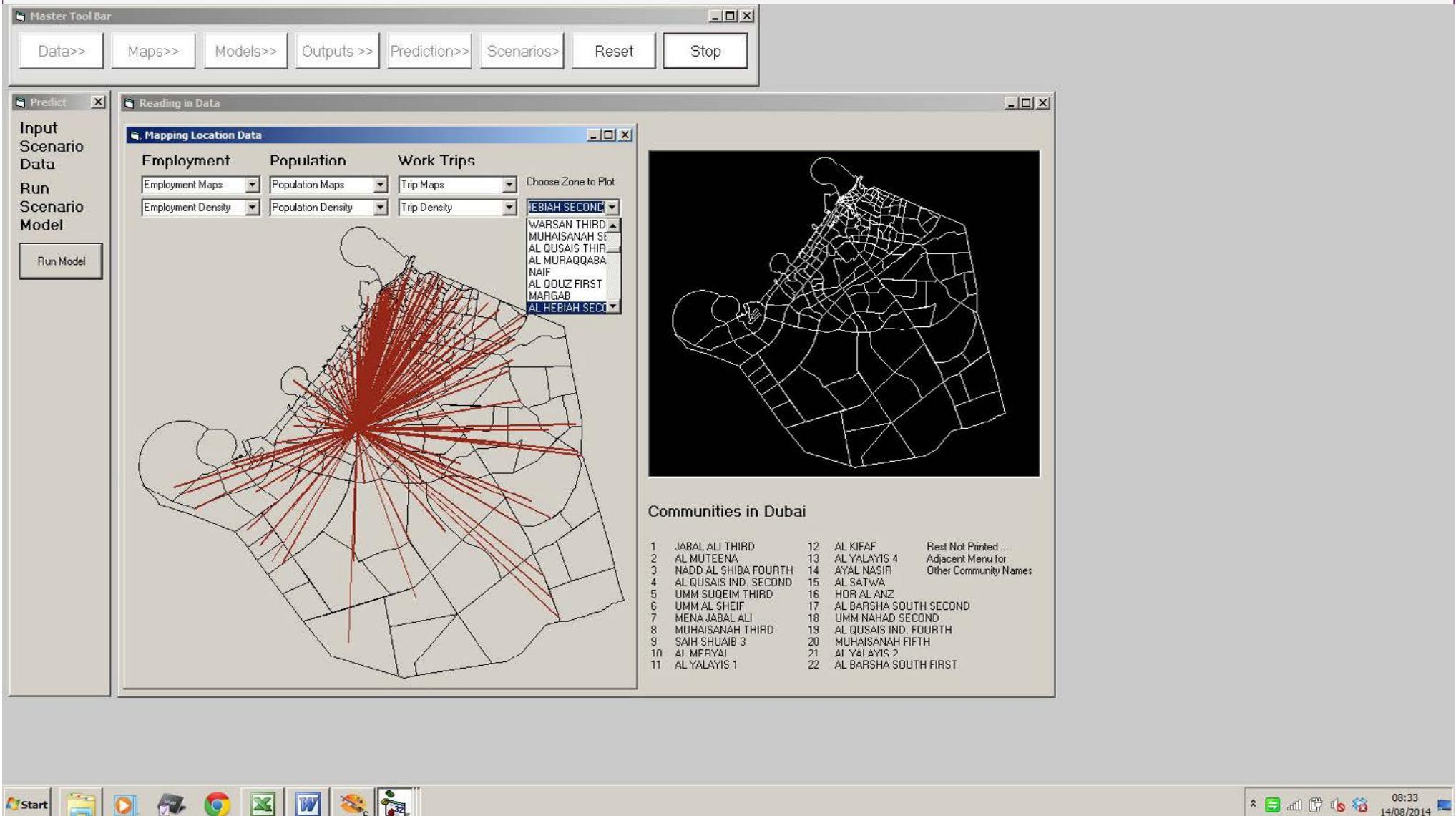












I am bound to have run out of time and we need some questions – which Elsa will act as host for – and anything you want to know about the ipynb programs, please ask the TAS and also post on Slack. Someone will pick them up

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Monday, 22nd January 2024