Gravity Model of Spatial Interaction: Concepts

- Spatial interaction models predict the amount of interaction between two places.

- In their simplest form, the models consider three factors, analagous to the formula for gravity:
  - Weight or attractiveness of the `origin`
  - Weight or attractiveness of the `destination`
  - `Distance` between the origin and destination
- A common formula for predicting this potential interaction follows the model:
  - `(origin weight * destination weight) / distance`^{2}
- In the numerator, potential for interaction increases with increased weight or attractiveness of either the source or the destination.
  - For studies of interaction between settlements, both weights are usually *population*
  - What measures of attractiveness or weight could be used for commercial retail destinations? List three.
    i)
    ii)
    iii)
  - For health care service destinations? List three.
    i)
    ii)
    iii)
- In the denominator, distance has an exponent, representing the *friction of distance* increasing exponentially with increasing distance between the source and destination.
  - Illustrate the Friction of Distance Concept:

Gravity Model of Spatial Interaction: Planning and Assumptions	• Modelling spatial interaction will require several steps. Before you start, you should consider the following questions. Please complete the questions below as if you are modelling interaction between Central Falls zones, based on population, and Central Falls parks, based on the number of sports fields. • What is the *origin (input)* layer? ◦ Which field uniquely identifies features in the origin (input) layer? This is the *origin (input) unique ID field* ◦ Which field represents the "weight" or "attractiveness" of the origin (input) layer? This will be the *origin weight field* • What is the *destination (target)* layer? ◦ Which field uniquely identifies features in the destination layer? This will be the *destination (target) unique ID field* ◦ Which field represents the "weight" or "attractiveness" of the destination layer? This will be the *destination weight field* • The origin (input) and destination (target) layers should both be *points* using the *same projected coordinate system* which can be used to calculate accurate planar distance. ◦ Convert polygon features to points using CENTROIDS for this type of analysis • The *output* from a gravity model of spatial interaction is a measure of *potential interaction* between two places. This measure has no units, but can be interpreted in relation to potential interaction between other places.

`Gravity Model of Spatial Interaction: General Procedure`

1. DISTANCE MATRIX
    i) **Input point layer**, **input unique ID field**, **Target point layer**, and **Target unique ID** field according to your answers in Spatial Interaction Model Planning above
    ii) **Output matrix type**: *Linear (N*k*3) distance matrix*
    iii) **Use only the nearest (k) target points**: default of `0` calculates distance for all origin-destination pairs. If the datasets are very large, you may need to limit this to fewer pairs by entering a number here.
    iv)

2. JOIN BY ATTRIBUTE to the `distance matrix`
    i) **Join layer**: *origin (input) layer*
    ii) **Join field**: *origin (input) unique ID field*
    iii) **Target field**: `InputID`
    iv) **Joined fields**: *origin weight field*

3. JOIN BY ATTRIBUTE to the `distance matrix`
    i) **Join layer**: *destination (target) layer*
    ii) **Join field**: *destination (target) unique ID field*
    iii) **Target field**: `TargetID`
    iv) **Joined fields**: *destination weight field*

4. FIELD CALCULATOR
    i) **Name**: `potential`
    ii) **Type**: decimal
    iii) **Expression**:
    `("origin weight" * "destination weight") / "Distance"^2`

5. FIELD CALCULATOR
    i) **Name**: `maxPoten`
    ii) **Type**: decimal
    iii) **Expression**: `maximum("potential", group_by:="InputID")`
    iv) This is an *aggregate* function for finding summary statistics with FIELD CALCULATOR. It will enter the same result for all of the features in each group, and the `group_by:=` part of the function works like the group fields in the GROUP BY tool.

6. EXTRACT BY EXPRESSION
    i) **Input layer**: `Distance Matrix`
    ii) **Expression**: `"potential" = "maxPoten"`

- Gravity Model of Spatial Interaction: Workflow

Gravity Model of Spatial Interaction: Solution

- Finding the distance matrix between ZoneCentroids (sources, with *InputID* = Zone) and ParkEntrances (destinations, with *TargetID* = ParkName)

	NE	NW	SE	SW
Blackstone				
FC				
Jenks				
Macomber				
Spintex				

- The more convenient output for GIS analysis will spread this information out into a *linear* table with one source and one target per row:

InputID	TargetID	Distance	Pop	Fields	Potential	MaxPoten
NE	Blackstone	1274.987	4800	1	0.003	0.046
NE	FC	1274.755	4800	4	0.012	0.046
NE	Jenks	790.5694	4800	1	0.008	0.046
NE	Macomber	559.017	4800	3	0.046	0.046
NE	Spintex	353.5534	4800	1	0.038	0.046
NW	Blackstone	417.3982	5300	1	0.03	
NW	FC	346.723	5300	4	0.176	
NW	Jenks	997.6056	5300	1	0.005	
NW	Macomber	1293.75	5300	3	0.009	
NW	Spintex	1251.657	5300	1	0.003	
SE	Blackstone	1768.276	4400	1	0.001	
SE	FC	1457.738	4400	4	0.008	
SE	Jenks	353.5534	4400	1	0.035	
SE	Macomber	559.017	4400	3	0.042	
SE	Spintex	1274.755	4400	1	0.003	
SW	Blackstone		4600	1		
SW	FC		4600	4		
SW	Jenks		4600	1		
SW	Macomber		4600	3		
SW	Spintex		4600	1		

Interpreting and Applying Spatial Interaction Models	• "Potential" is a unit-less measure, so it's best interpreted *in relation to* other potential interactions in the model. • Models can be calibrated with known data in order to use the measure of potential as a more meaningful estimate. Some examples may include: ◦ number of patients likely to visit a health facility ◦ number of customers likely to shop at a retail destination ◦ volume of mail, phone calls, or air travel • Parameters of the model can be modified or calibrated by: ◦ Converting the units of distance or time ◦ Adjust the exponent on distance ◦ Apply coefficients or exponents to either the origin or destination weights • Sometimes more attractive distant sites often capture activity away from closer, but less attractive sites. ◦ In reality, interaction is "fuzzy": rather than *all* people from a given region using the *maximum* potential site, *most* people from the region will use the maximum potential sites, while other people will also still use alternative sites. • More sophistocated service delivery models use a two-step process: ◦ First, they assess measure of availability/congestion at the point of service based on a ratio of customers/patients and service providers in a single region ◦ Second, they use a spatial interaction model to predict ineractions between regions, using availability/congestion as the weight for the points of service. • In health geography, sometimes the friction of distance is more complex than we have modelled here. For example, the friction of distance is not always monotonic: it may increase at some distances and decrease at others. (see figure 11.1, pg 415 of *Health Care and Promotion* Meade and Emch 2010) • Outputs of spatial interaction models can be analyzed in numerous ways, including: ◦ Create service regions by grouping the origin regions by their most likely destination ◦ Find the percentage market share a specific destination commands for each origin region ◦ Find the regions with the most competition or the most unmet services
Dartmouth Atlas of Health Care Hospital Service Areas	• What if you had access to actual customer or patient behavior and could associate populations with the facility they most often interact with based o this behavior? • Researchers at Dartmouth University used a database of all visits to hospitals reimbursed by the federally-funded Medicare and Medicaid health care programs. Researchers delineated Hospital Service Areas using the frequency of patient visits to hospitals and the zip codes for patients' home addresses and the hopstials they went to. They assigned each zip code to the hopsital service area people most frequently used. • At a higehr level of the health care hierarchy, they also determined hopsital referral regions providing tertiary care to a region of smaller hospitals. • At a lower level of the health care hierarchy, the atlas provides primary care service areas. • The hospital service areas were featured in recent data-driven journalism describing the capacity of hospital systems in relation to the population of demographics vulnerable to COVID-19.