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An introduction to Spatial Interaction Modelling

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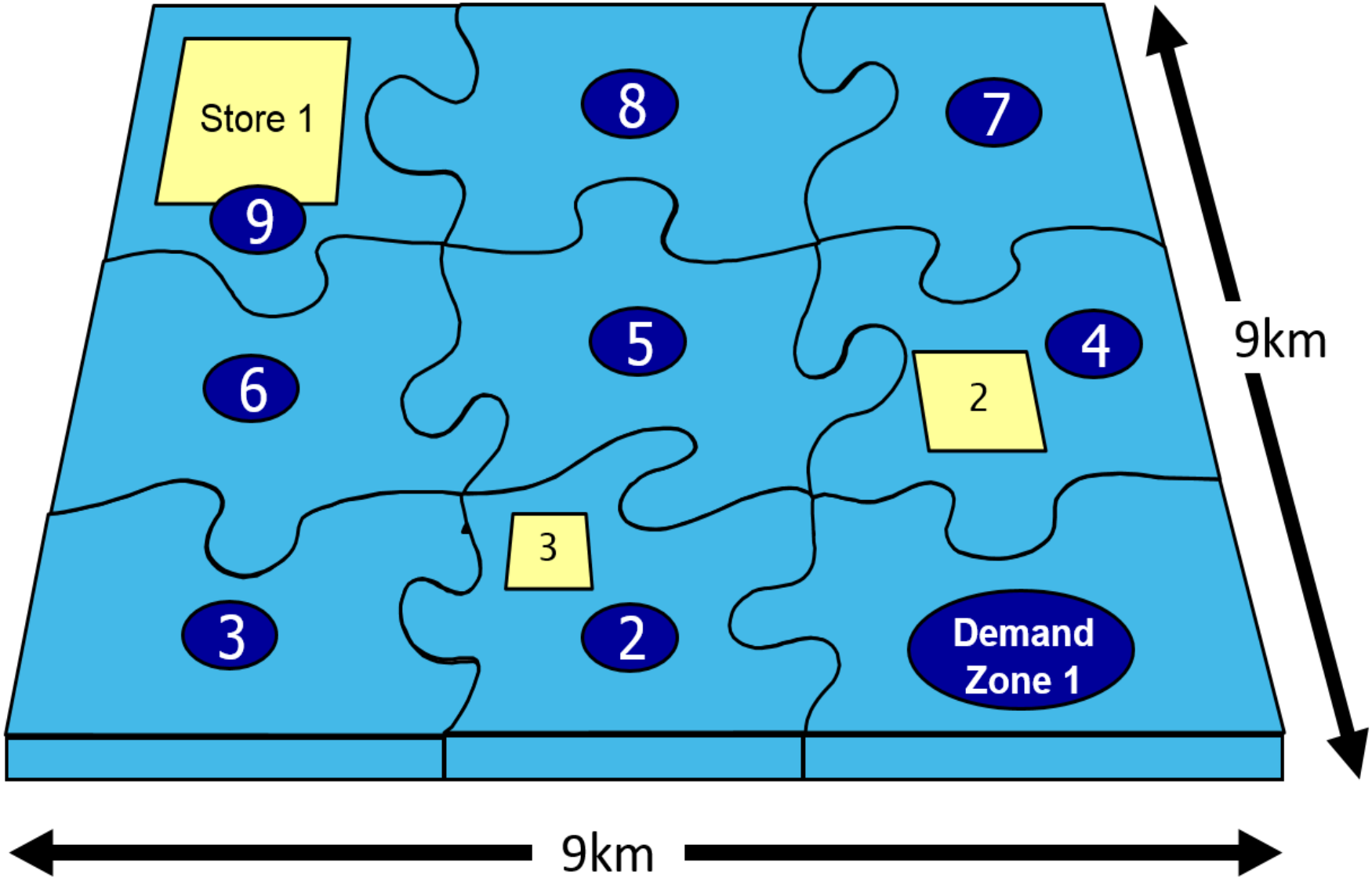

Store 1
8
7
9
5
4
6
2
3
3
2
Demand Zone 1
9km
9km

- Demand
- Accessibility
- Attractiveness
- Competition (intervening opportunities)

Spatial Interaction

- Important concept in Geography
- Flows:
  - Of people (migration, commuting etc.)
  - Of money (expenditure, goods etc.)
- Interaction between origin and destination

Origins and destinations

- **Origins** are generally zonal (e.g. countries, regions, local authorities, neighbourhoods).
  - We'll typically have multiple origins within a SIM:

    i_1 i_2 i_3 etc.

- **Destinations** could be zonal (e.g. countries, regions, local authorities, neighbourhoods) or points (e.g. the location of specific services or facilities such as retail stores, schools, hospitals).
  - We'll typically have multiple destinations within a SIM:

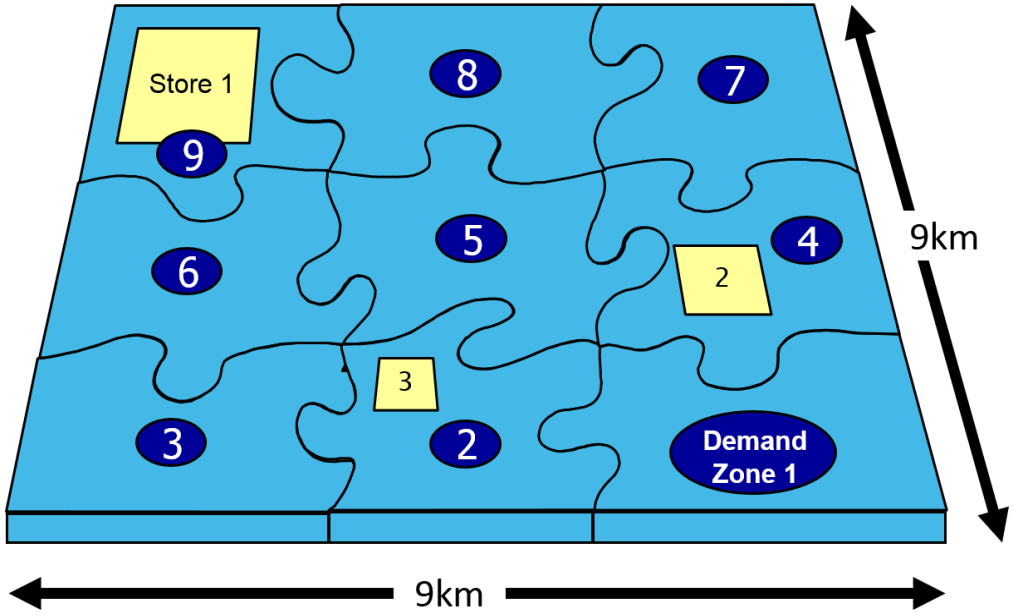
    j_1 j_2 j_3 etc.

- We use SIMs to model the interactions (flows) between origins and destinations

i_1 to j_1
i_1 to j_2
i_1 to j_3
i_2 to j_1
etc.

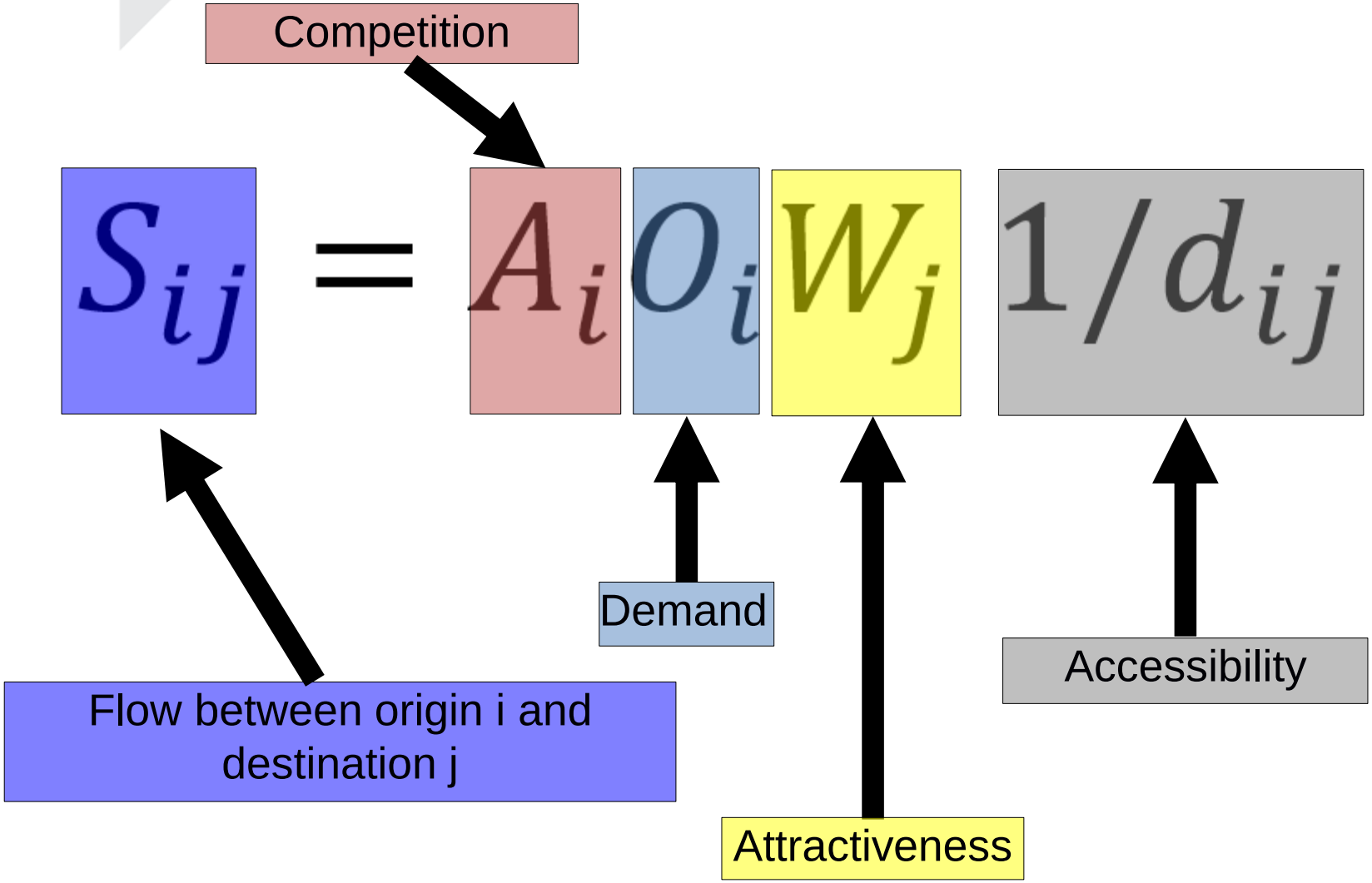
$$S_{ij}$$

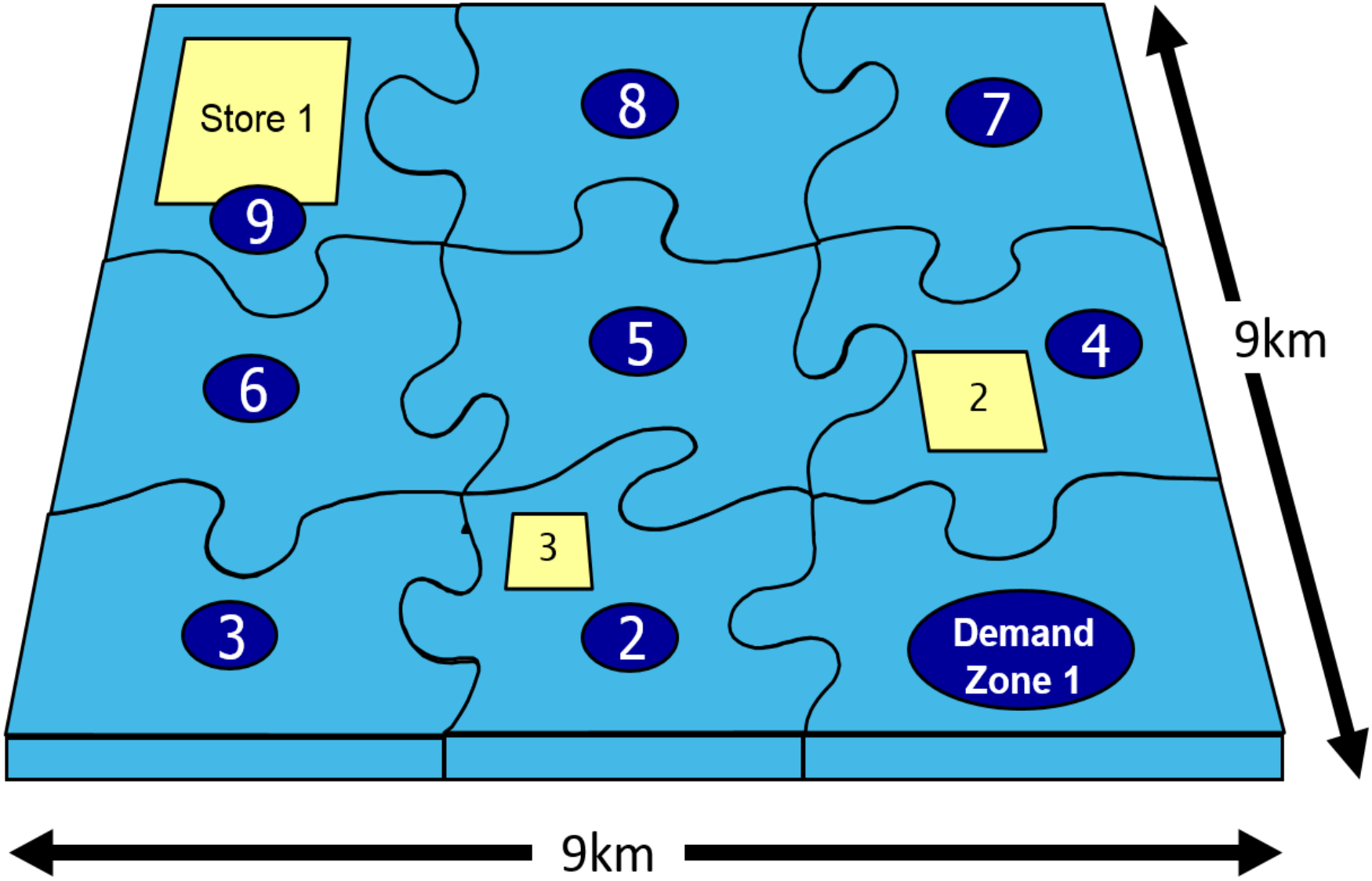
	j_1	j_2	j_3
i_1	$i_1 j_1$	$i_1 j_2$	
I_2			
I_3			
I_4			
I_5			
I_6			
I_7			
I_8			
i_9			



The flow between i_1 and j_1 is proportional to

- The demand available in origin zone i_1
- The attractiveness of destination j_1
- The accessibility of destination j_1 to [consumers] in origin zone i_1
- Intervening opportunities – the relative accessibility and attractiveness of destination j_1 to [consumers] in origin zone i_1 versus all other destinations (j_2, j_3, etc.) [Competition]


Competition
$S_{ij} = A_i O_i W_j 1/d_{ij}$
Demand
Attractiveness
Accessibility
Flow between origin i and destination j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Demand Zone 1
9km
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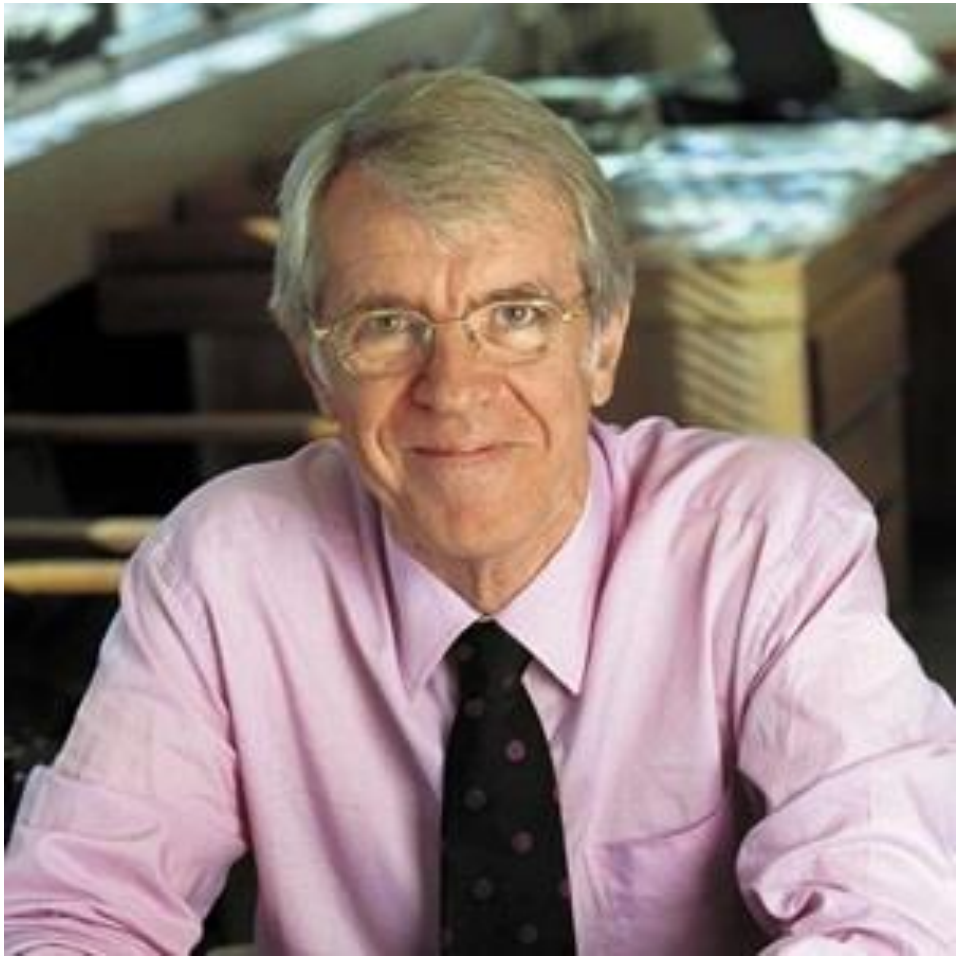
In more complex terms …

- SIMs are statistical models that we can use to represent origin-destination flows
- Capture the mathematical relationship which accounts for the observed interactions (flows)
- Use that relationship to:
  - estimate missing data
  - model and forecast flows under various scenarios (e.g. for planning purposes)

Early SIMs (Gravity Models)

- Captured flows or interactions based on Newtonian analogies
- Lacked robust theoretical justification in a human context
- Reilly's (1929) 'law of retail gravitation' – applied the gravity concept to trade area analysis and competition between cities. Probability of a consumer shopping at a particular 'centre' – bigger centres will attract consumers from a farther distance and have a larger trade area.



https://royalsociety.org/people/alan-wilson-12528/

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Entropy Maximising Models

- Early 1970s, Sir Alan Wilson demonstrated a more robust way to derive and justify gravity models using entropy maximisation (statistical mechanics).
- First applied to transport planning models.
- Provided a better theoretical justification.
- Introduced term ‘Spatial Interaction Model’
- Realised potential role as a location model.
- Wide ranging applications in geography, planning, transportation, social science and the commercial sector

The Wilson family (of SIMs)

- ‘Family of Spatial Interaction Models’ – four variants of the same model based on the scenario being modelled.
- Driven by known information which could constrain the values that interaction could take

Attraction

Production

	j_1	j_2	j_3	
i_1				
i_2				
i_3				
i_4				
i_5				
i_6				
i_7				
i_8				
i_9				

Production-Attraction Constrained

- Also known as doubly constrained
- ‘Origin’ and ‘Destination’ totals are known

Attraction

Production

	j_1	j_2	j_3	
i_1		82,000		£150,000
i_2		28,000		£50,000
i_3	20,000	34,000	16,000	£70,000
i_4		64,000		£120,000
i_5		12,000		£65,000
i_6		20,000		£55,000
i_7		14,000		£220,000
i_8		28,000		£80,000
i_9		18,000		£110,000
	£500,000	£300,000	£200,000	

Unconstrained

- Neither ‘Origin’ and ‘Destination’ totals are known

Attraction

Production

	j_1	j_2	j_3	
i_1				
i_2				
i_3				
i_4				
i_5				
i_6				
i_7				
i_8				
i_9				

Attraction Constrained

- Destination totals are known

Attraction

Production

	j_1	j_2	j_3	
i_1		82,000		
i_2		28,000		
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i_4		64,000		
i_5		12,000		
i_6		20,000		
i_7		14,000		
i_8		28,000		
i_9		18,000		
	£500,000	£300,000	£200,000	

Production Constrained

- Origin totals are known

Attraction

Production

	j_1	j_2	j_3	
i_1				£150,000
i_2				£50,000
i_3	20,000	34,000	16,000	£70,000
i_4				£120,000
i_5				£65,000
i_6				£55,000
i_7				£220,000
i_8				£80,000
i_9				£110,000

SIMs

- Can appear complicated at first!
- Straightforward once the basics make sense.
- For a easy to digest overview, try:
- **Birkin M. and Clarke G.P. 1991. Spatial interaction in geography. *Geography Review,* 4(5), pp.16-21.**
- The SIM is one of Geography/Social Science's most successful applications in the commercial world - and not just in retail.

Further Reading

- Birkin, M., Clarke, G. P. and Clarke, M. 2010. Refining and operationalising entropy-maximising models for business applications *Geographical Analysis,* **42**(4), pp.422-445.
- Newing, A., Clarke, G. P. and Clarke, M. 2014. Developing and applying a disaggregated retail location model with extended retail demand estimations. *Geographical Analysis,* **47**(3), pp.219-239
- Roy, J. R. and Thill, J.-C. 2004. Spatial interaction modelling. *Papers in Regional Science,* **83**(1), pp.339-361.
- Wilson, A. G. 1971. A family of spatial interaction models, and associated developments. *Environment and Planning* **3**, pp.1-32.
- Wilson, A. G. 2010. Entropy in urban and regional modelling: retrospect and prospect. *Geographical Analysis,* **42**(4), pp.364-394.

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