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Simulating supermarket home deliveries in Cambridge: A whole system view

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SRF International Conference

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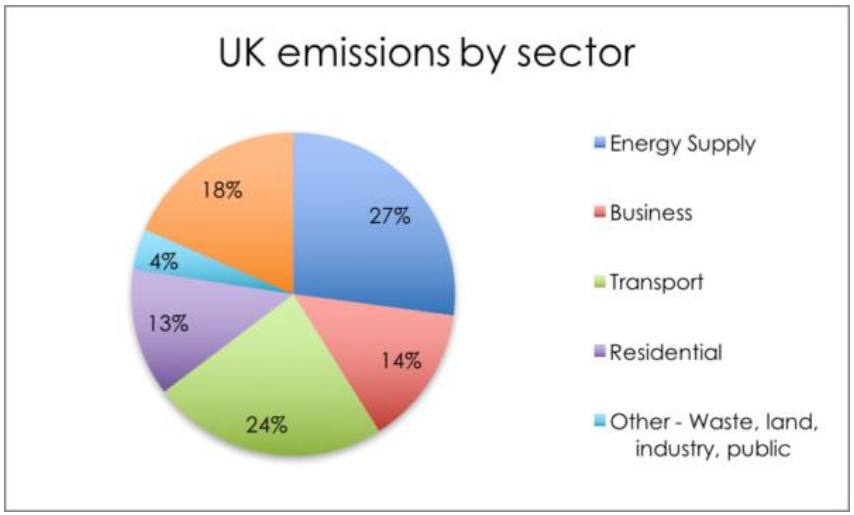
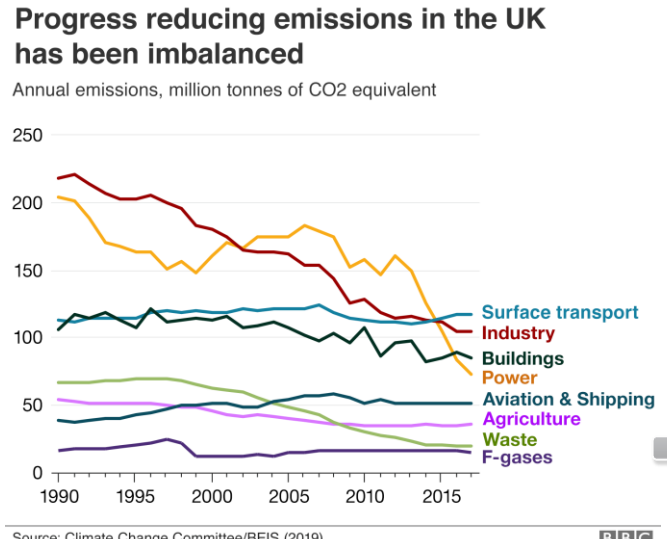
"A whole system view"

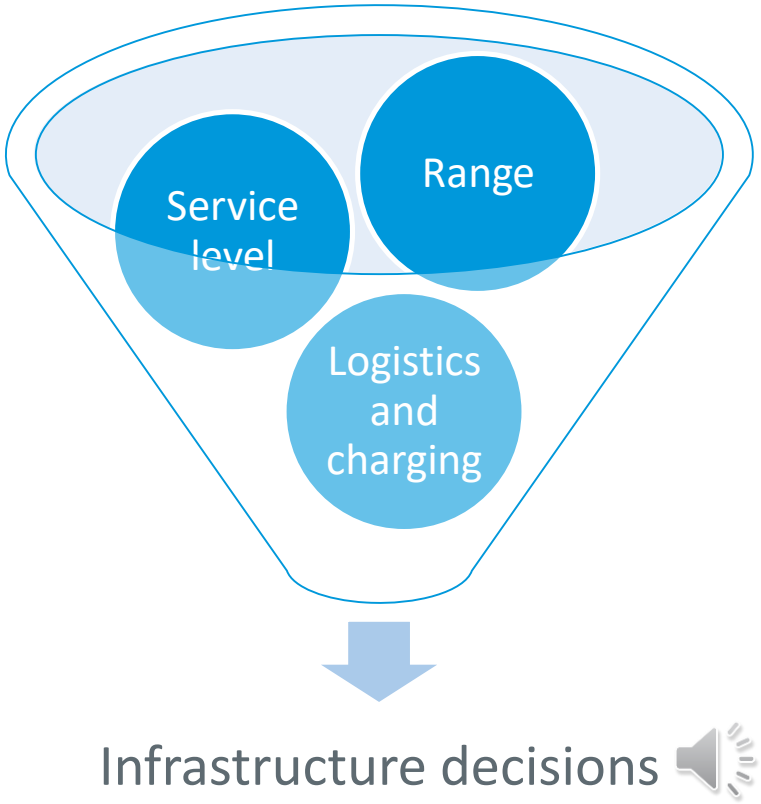
- Global climate crisis
- Transport sector emissions
- Step change in EV uptake





Future infrastructure for EVs

- Popularity of online shopping
- Green delivery operations



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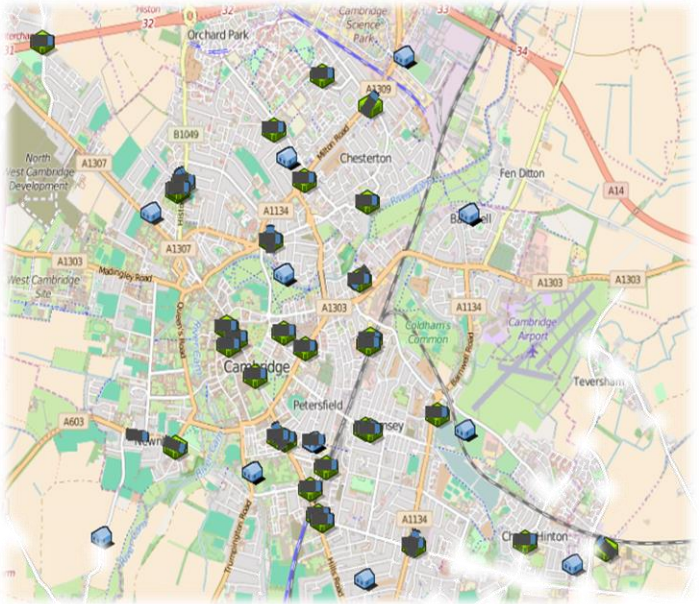
Virtual living lab

- Past no longer good predictor of future
- Huge capital costs for physical field test
- Computer modelling of decision-making agents



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ASDA Morrisons Since 1899 WAITROSE & PARTNERS

TESCO Sainsbury's

But it needs data…

- Supermarkets "can do this ourselves"…?
  - Limited by own budget
  - Costly to build dedicated infrastructure
- System-wide solutions
  - Local authority engagement
  - Strategic policy planning
- So → simulate all consumer behaviour
  - By demanding order data from ***everyone???***

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Consumer behaviour survey

Cl.	Description	Resp.
1	Willing but Struggling	256
2	Online Omnivores	284
3	Committed and Old School	288
4	Middle Ground	349
5	Fiercely Resisting and Responsible	142
6	Uncaring Pragmatists	275
7	Aspiring Techno Lovers	317
8	Intensive Urbanites	121

- Encodes:
  - Supermarket preference
  - Order frequency
  - Delivery/collection
  - Order size
  - Times of day, etc…

- Good characterisation of behaviour
- “Only” need to predict cluster distribution in area

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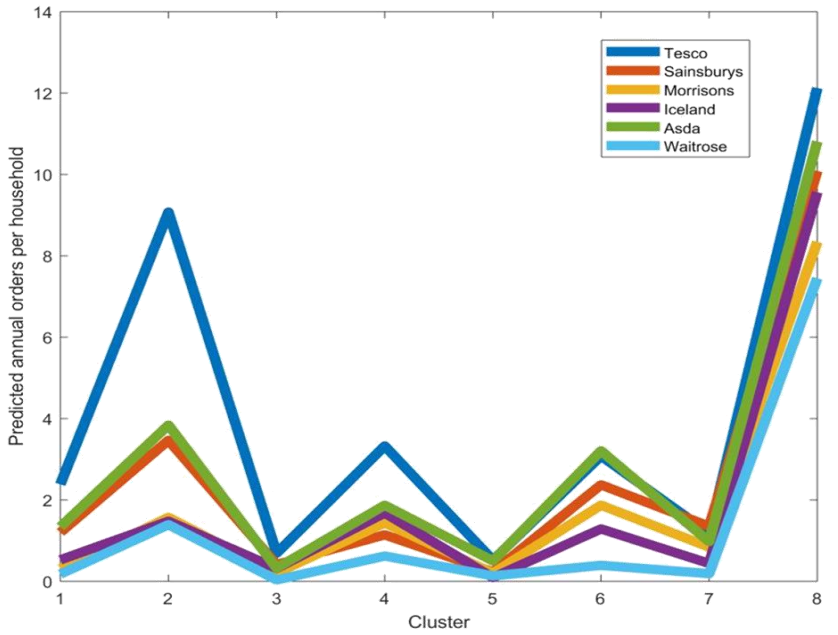

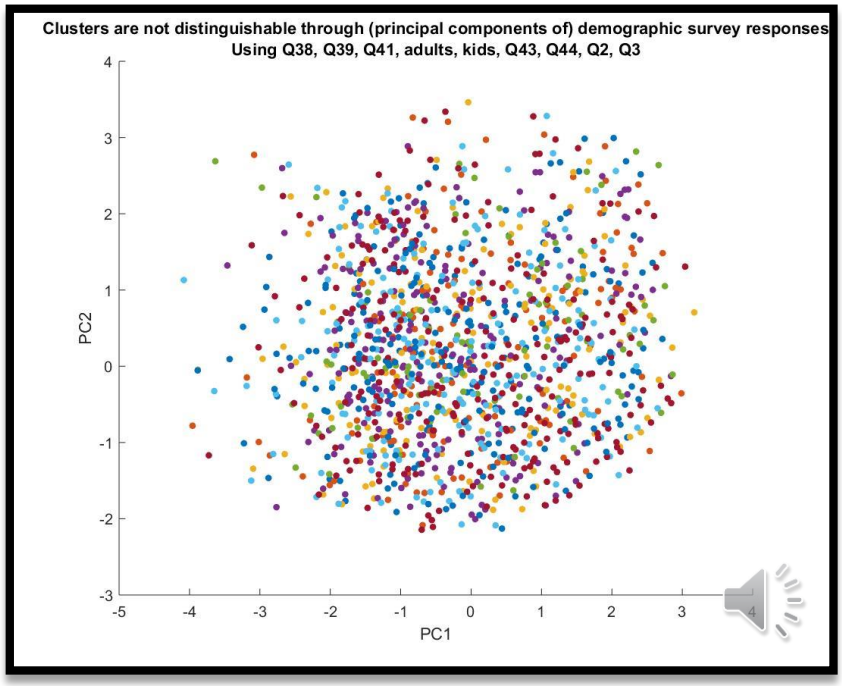

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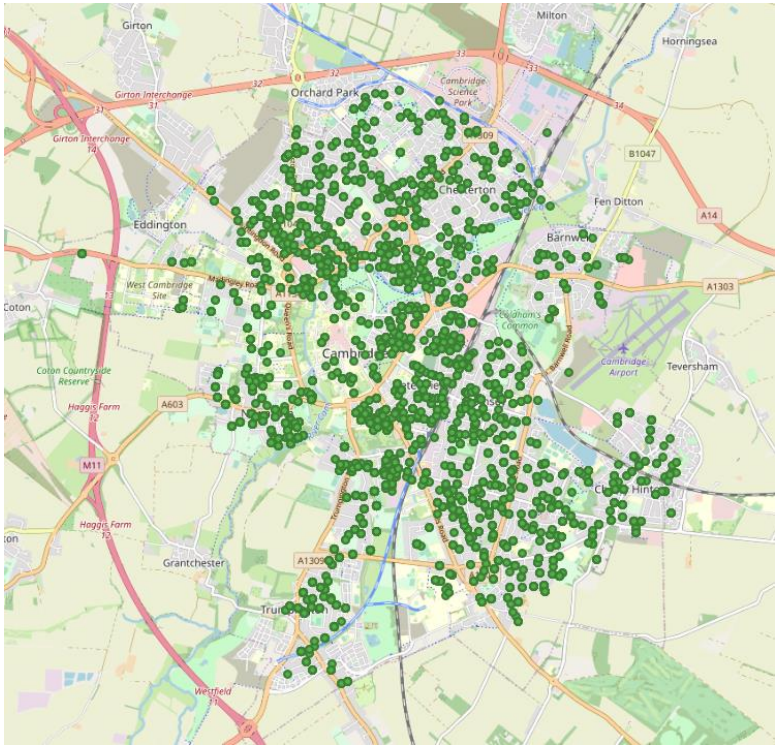
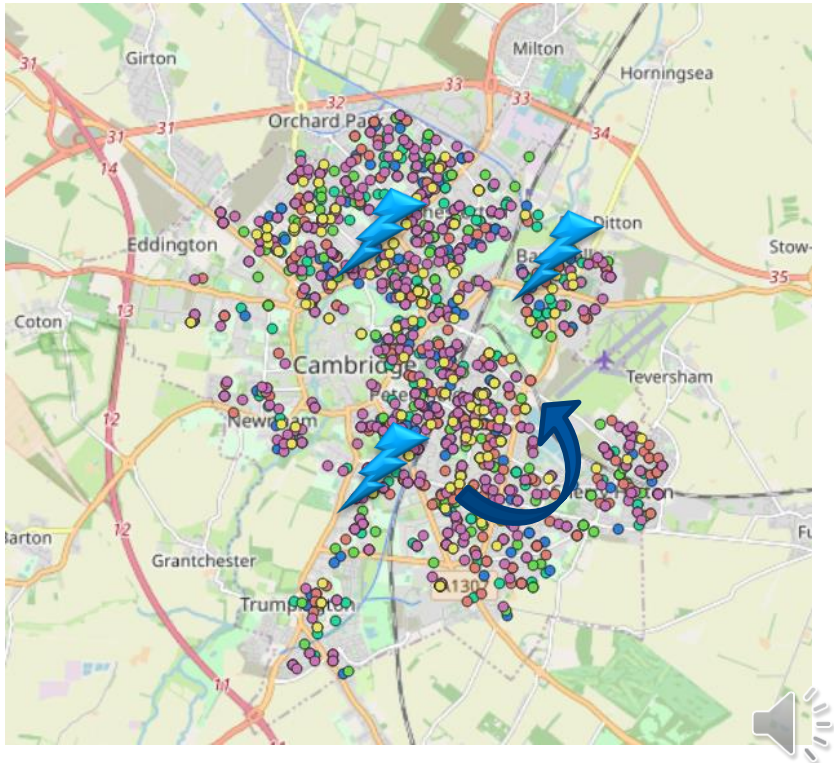
Waitrose orders in Cambridge

Look like this:



We need this:



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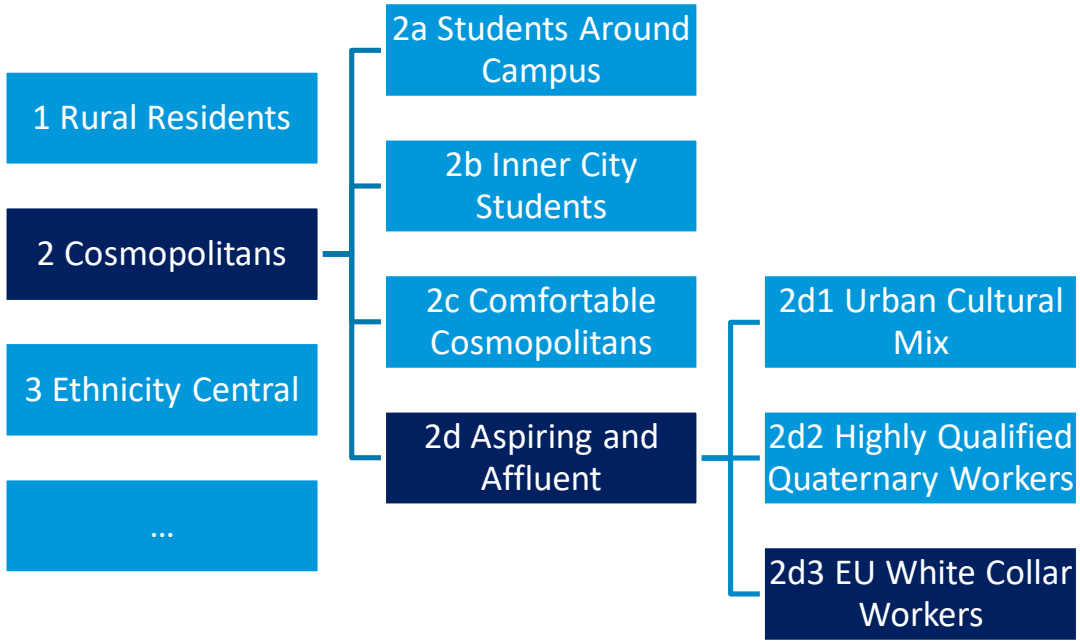
Office for National Statistics

ONS small area classifications

- 232296 output areas (OAs)
- Hierarchical:
  - OAC1: 8 classes (1, 2, 3…)
  - OAC2: 26 classes (1a, 1b, …)
  - OAC3: 76 classes (1a1, 1a2, …)



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Office for National Statistics

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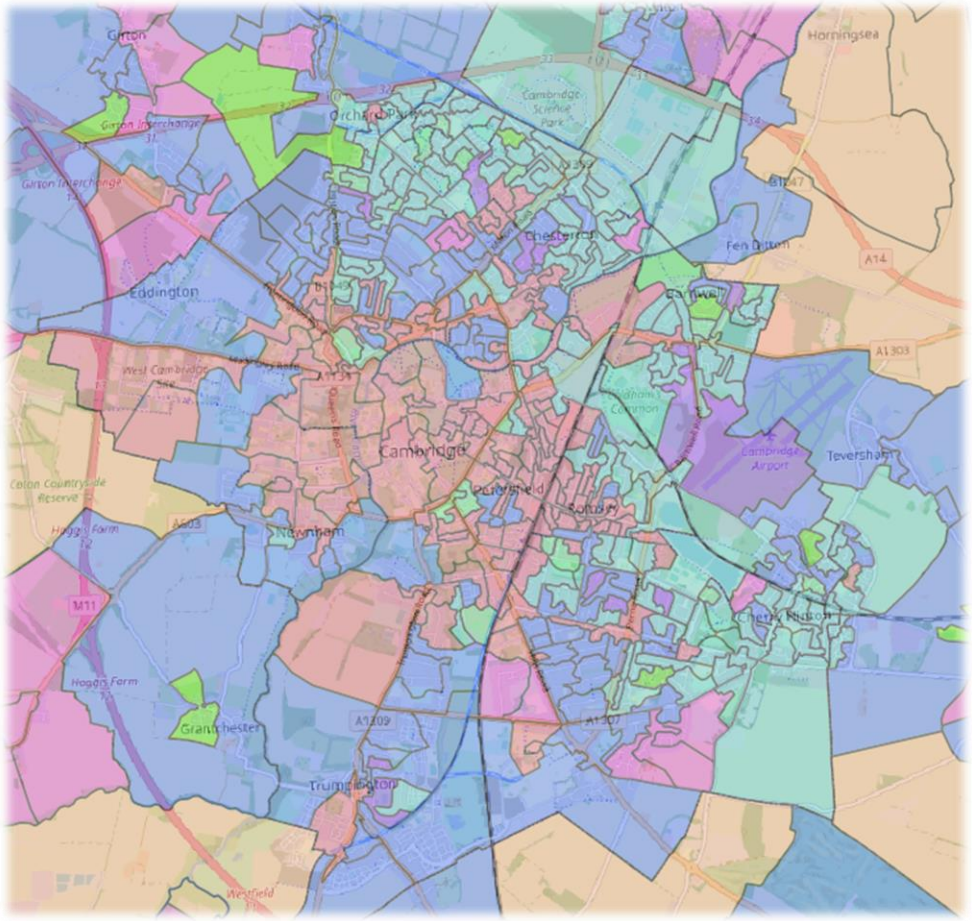

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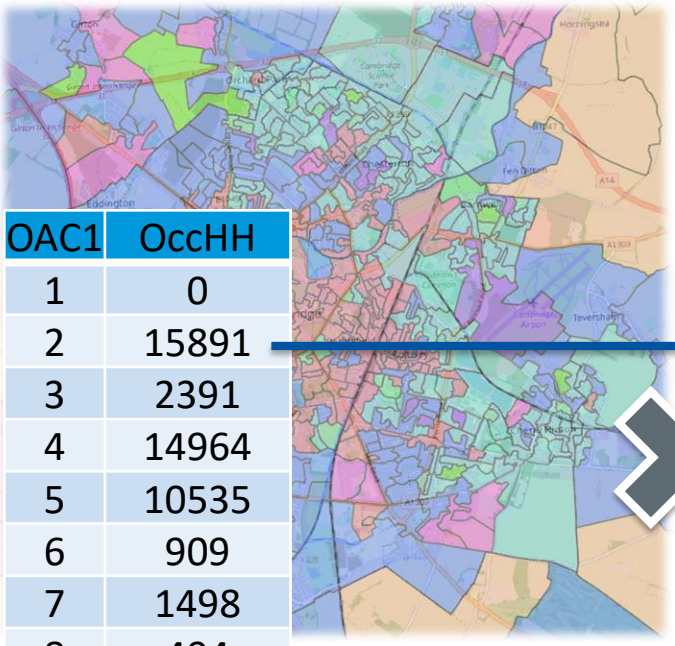
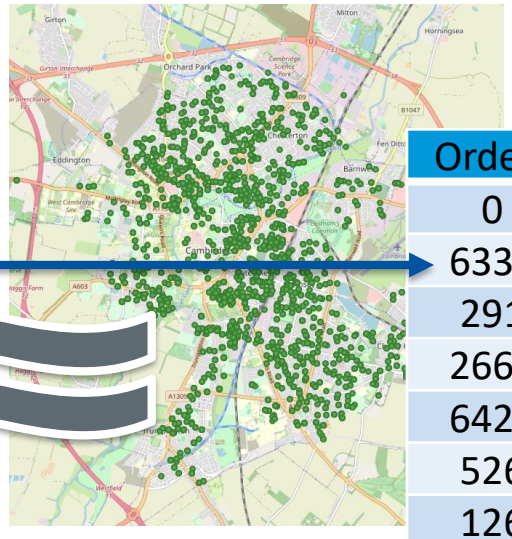
Waitrose orders in Cambridge

- **Idea**: find "best fit" cluster proportions that match order data most closely



OAC1	OccHH
1	0
2	15891
3	2391
4	14964
5	10535
6	909
7	1498
8	494



Orders
0
6332
291
2666
6426
526
126
35

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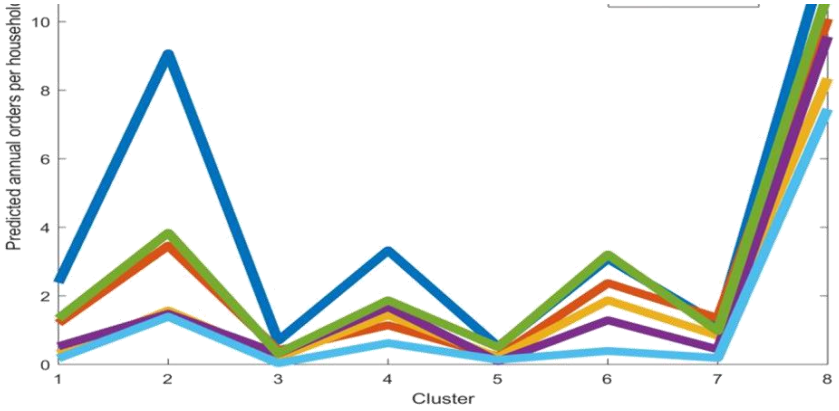
Interpreting survey responses



- Q15: “How often do you buy any type of groceries online from the following retailers?”
- Q18a: "Please tell us how frequently you use [home delivery] when you purchase groceries online."

Likert scale	Frequency	Interpreted annual orders
1	Never	0
2	Less than once a month	4
3	2-3 times a month	20
4	Around once a week	52
5	More than once a week	80
6	Every day	250

Resp	Supermarket
2	Asda
3	Iceland
4	Morrison’s
6	Sainsburys
7	Tesco
8	Waitrose

Simultaneous equations

- Taking OAC2 as an example:
- Let $M_{21}, M_{22}, \ldots, M_{28}$ be the eight cluster proportions that an OAC2 area comprises
- Let $R_1, R_2, \ldots, R_8$ be the predicted annual orders from each cluster from the survey
- Then:
  - $M_{21} + M_{22} + \cdots + M_{28} = 1$
  - $M_{2j} \in [0,1]$
  - $R_1 M_{21} + R_2 M_{22} + \cdots + R_8 M_{28} \approx O_2$
- Orders **normalised** over all areas so total order numbers agree

Observed in order data

M	C1	C2	C3	C4	C5	C6	C7	C8	O
OAC1	.25	.01	.01	.23	.23	.02	.03	.22	11
OAC2	.03	.21	.21	.05	.05	.20	.19	.06	13
OAC3	.07	.18	.18	.08	.08	.17	.16	.09	25
OAC4	.15	.10	.10	.14	.14	.12	.12	.13	62
OAC5	.12	.13	.13	.11	.11	.15	.15	.10	91
OAC6	.16	.09	.08	.17	.17	.07	.07	.18	4
OAC7	.19	.06	.05	.20	.20	.04	.04	.22	36
OAC8	.03	.22	.23	.02	.02	.24	.24	.00	172
R	0.2	0.8	3.5	0.01	1.2	2.6	0.3	6.1	

Estimated from survey

Annual orders from OAC2

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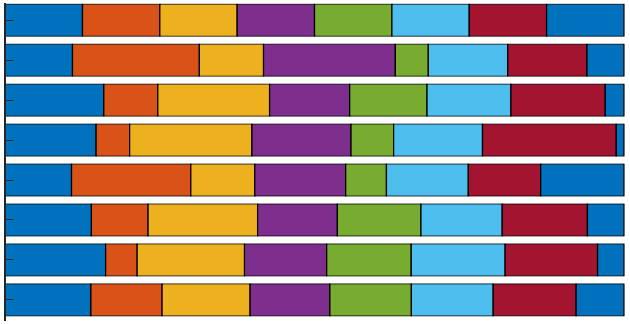
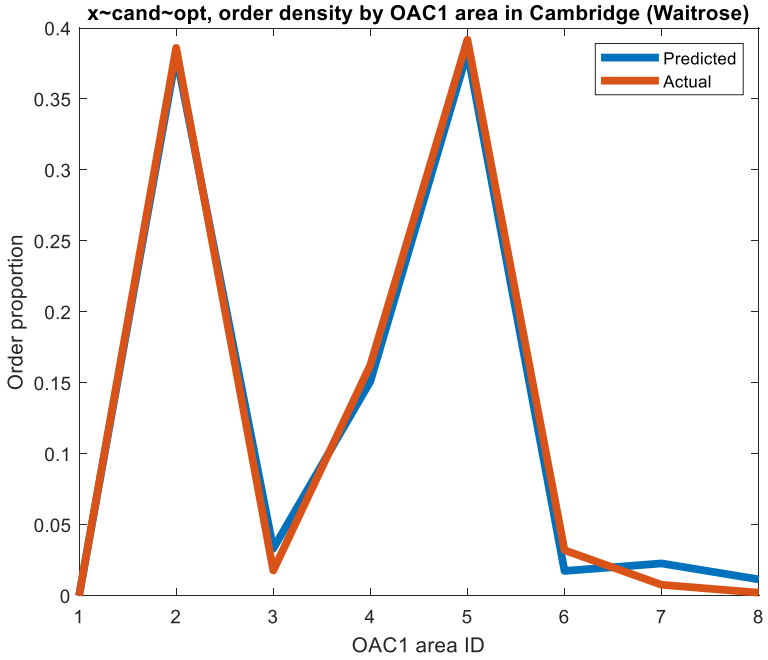
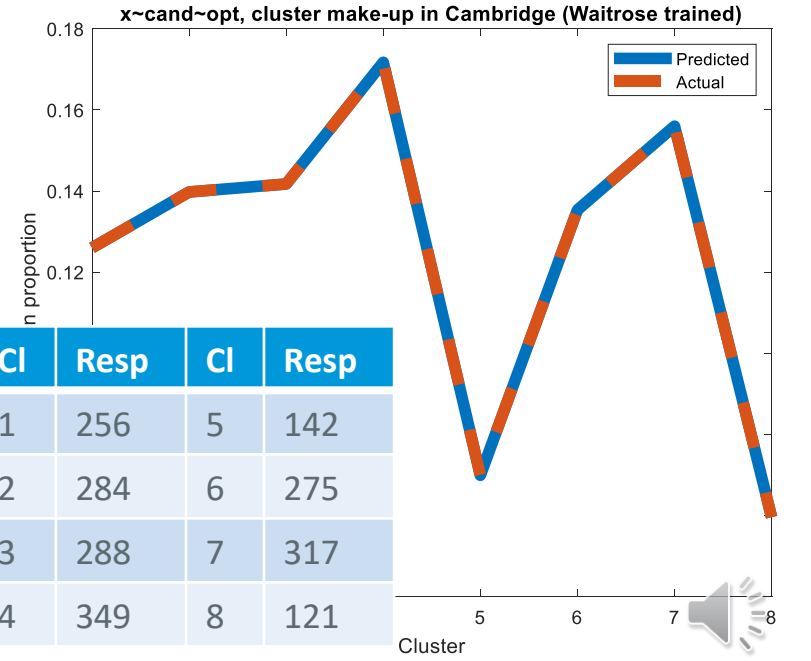


Optimisation results

- Minimise discrepancy between predicted and observed orders
- Extra condition added to encourage overall cluster proportions to be similar to those predicted by the survey
- Coded in MATLAB using `fmincon`
- Good agreement with actual order densities (Waitrose) and relative cluster populations in Cambridge
- Now trained for Waitrose, can be used in an order generator for all other supermarkets





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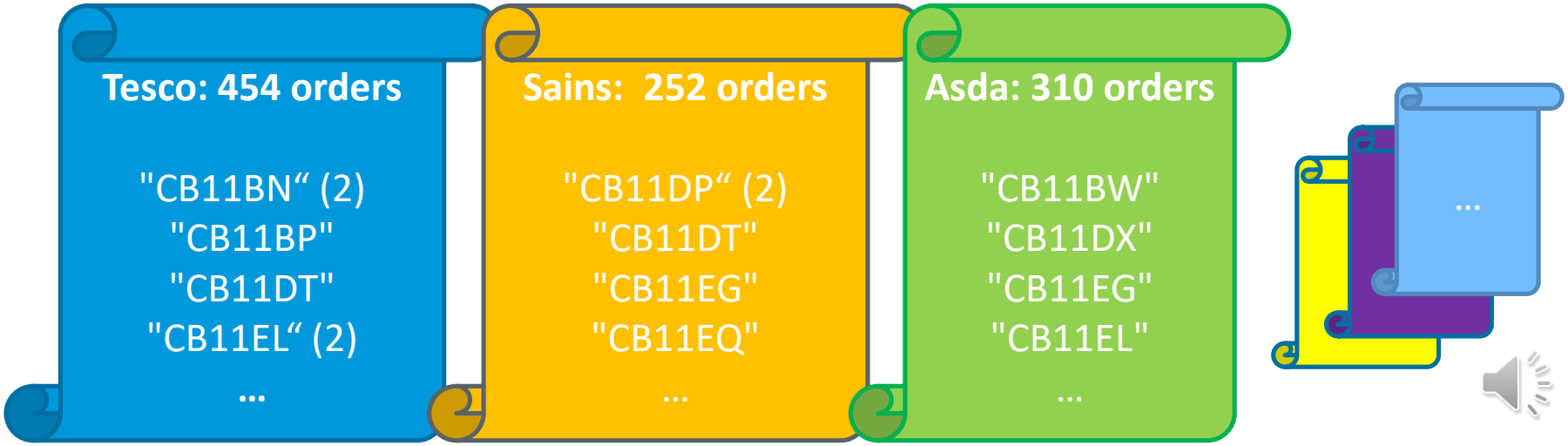
What do the results look like?

- Daily orders output from a Poisson process
- Uses 2011 census data to weight by occupied households for each postcode



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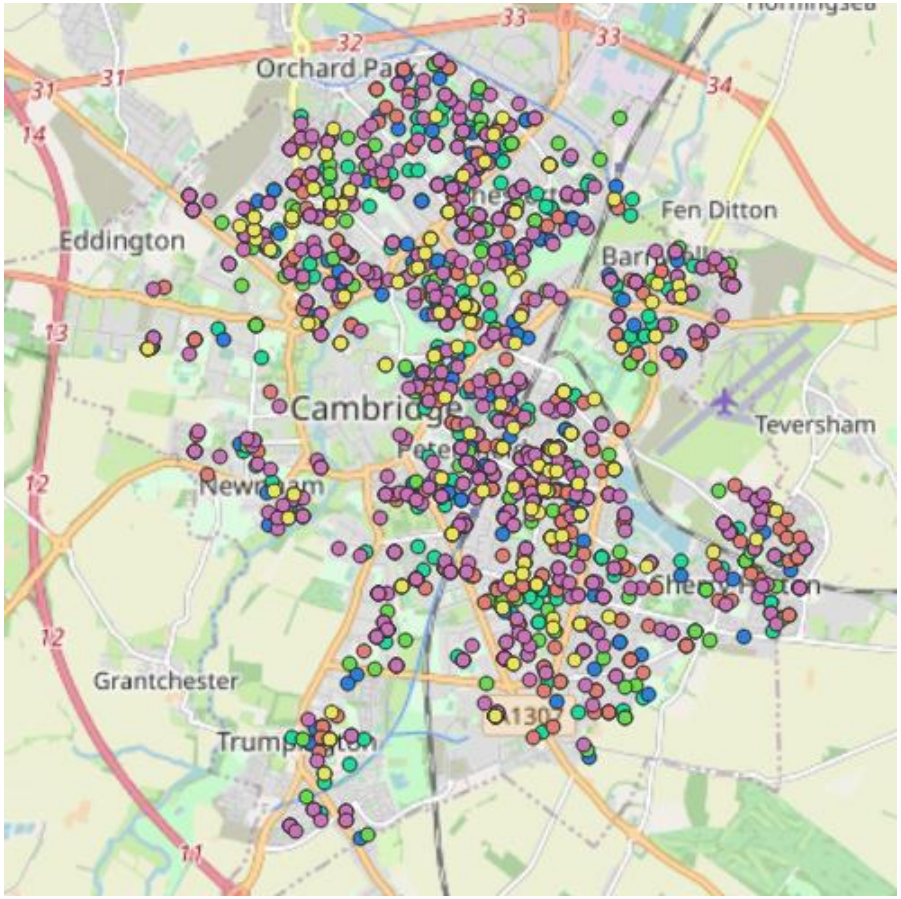
CodePoint co-ordinates

Geo-location of postcodes turns daily postcode orders into whole-system map

Not considered yet: time of day, number of crates, …

(…but adding these is straightforward now cluster definitions are set)



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Thank you

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