Transport and Mobility Coursework

Alfred Sydney Brown

May 2020

*EMATM0021 Transport and Mobility Modelling Summer 2020 Exam-replacement coursework

Part A

Q1. Demand Modelling

(a) The four steps in the Four-step Model are:

- Trip generation: This concerns the number of trips that originate (O) and destinate (D) in different zones.
- Trip distribution: This tries to estimate the origin-destination distributions/pairings.
- Mode Choice (or Modal Split): This looks at the different possible modes of transport, e.g. cycling, public transport, cars, etc...
- Traffic Assignment: This deals with the route choices that an individual or multiple individuals have when making a journey.

Prior to performing these steps it is common to first tessellate (discretize) the space you are working with, and decide on which data to consider (e.g. UK Conses data, MSOA).

(b) There are multiple constraints that can be added to the gravity model in order to improve its prediction accuracy. Examples include adding a:

- Global constraint. (The sum total of generated trips matches the expected total number of trips.)
- Origin constraint. (One scales the coefficient to ensure that the sum of all origin flows from every zone correspond to empirical data.)
- Destination constraint. (This is the analogous to the origin constraint, but for destination flows.)

(c) The Sørensen Index is often a preferred method to measure the goodness of fit of a demand model (compared to more common methods such as Pearson's r value), because it is less sensitive to outliers, and better suited for non-homogeneous data sets.

(d) To find which city will attract the highest number of incoming trips, we compute:

$$\max\{A : T_{BA} + T_{BC}, B : T_{AB} + T_{CB}, C : T_{AC} + T_{BC}\},$$

where $T_{ik} + T_{jk} \propto \frac{T_i T_k}{d_{ik}^2} + \frac{T_j T_k}{d_{jk}^2}$, $i, j, k \in \{A, B, C\}$. Assuming my calculations are correct this yields: $\max\{A : 15000000, B : 16000000, C : 7000000\} = B : 16000000$, so city B will attract the most trips.

(e) Evaluating the impact of a working-from-home policy:

(i) At first glance, the Gravity model seems suitable. However, given that no reliable empirical commuter origin-destination data exists for the particular country being investigated, the gravity model would be a bad choice, because we cannot fit its parameters. I therefore propose to use the radiation model [1] instead, as this requires no parameters to be fitted.

Base Case:

I define the total distance travelled (D_{BC}), if no restrictions are imposed, as:

$$D_{BC} = \sum_{i,j} T_{ij} d_{ij}, \quad \forall d_{ij},$$

where $T_{ij} = T_i P_i P_j / [(P_i + s_{ij})(P_i + P_j + s_{ij})]$ is the radiation model ($P_{\{i,j\}}$ are the populations of the zones i, j and s_{ij} is the regional, surrounding population between zones i, j (as defined in [1]), d_{ij} is the distance between zones i and j, and $T_i \equiv \sum_{i \neq j} T_{ij}$. The sum, $\sum_{i,j}$ is expressed in short-hand and is used to mean the total sum of all the accumulated distances between two zones (the number of trips between two zones times the distance between the zones), for all zones - thereby encapsulating the total distance travelled.

Option 1:

For Option 1, I define the total distance travelled ($D_{Op1.}$), as:

$$D_{Op1} = \sum_{i,j} \begin{cases} T_{ij} d_{ij}, & d_{ij} \leq 25km \\ 0.8 * T_{ij} d_{ij}, & d_{ij} > 25km \end{cases}$$

since for this option only 80% of all trips with a distance further than $25km$ are allowed.

Thus, we can write the equation that evaluates the percentage decrease in total distance travelled in Option 1 compared to the base case ($\% D_{Op1,BC}$), as:

$$\% D_{Op1,BC} = \left(1 - \frac{D_{Op1}}{D_{BC}}\right) \times 100\%.$$

(ii) Option 2:

For Option 2, I define the total distance (D_{Op2}), as:

$$D_{Op2} = 0.95 * \sum_{i,j} T_{ij} d_{ij}, \quad \forall d_{ij},$$

since 5% of all journeys are replaced with home-working.

In order to find the policy (option 1, or option 2) that is most effective in reducing the impact of transport on the environment, we simply need to compute:

$$\min\{D_{Op1}, D_{Op2}\},$$

as this will find the option that results in the smaller amount of total distance travelled.

———————— END OF Q1 ————————

Q2. Assignment Modelling

(a)

(i) There exists a binary choice (choosing or not choosing) a route for all n routes. This implies 2^n combinations (patterns/problems) that need to be solved for the complementarity method. However, since the demand is always greater than zero ($d > 0$) we do not need to check the case where no route is chosen. Hence we end up with $2^n - 1$ different problems needing to be solved. Thus:

- **For n = 3, how many different patterns of used links would you need to consider?** Ans: 7
- **How many such patterns would you need to consider for general n?** Ans: $2^n - 1$

Complementarity Method for $n = 3$:

To solve for the User Equilibrium (UE) assignment using the complementarity method, we need to apply the following steps.

1. We know from the Wardrop Principle that the costs of used routes will be equal and less than or equal to the costs of the unused routes. Thus we can generate all the different problems that need to be solved:
   (a) $c_1(x_1) = c_2(x_2) = c_3(x_3)$ with $x_1 + x_2 + x_3 = d$
   (b) $x_1 = 0$, $c_1(0) \geq c_2(x_2) = c_3(x_3)$ with $x_2 + x_3 = d$
   (c) $x_2 = 0$, $c_2(0) \geq c_1(x_1) = c_3(x_3)$ with $x_1 + x_3 = d$
   (d) $x_3 = 0$, $c_3(0) \geq c_1(x_1) = c_2(x_2)$ with $x_1 + x_2 = d$
   (e) $x_1 = 0, x_2 = 0$, $c_1(0) \geq c_3(x_3), c_2(0) \geq c_3(x_3)$ with $x_3 = d$
   (f) $x_1 = 0, x_3 = 0$, $c_1(0) \geq c_2(x_2), c_3(0) \geq c_2(x_2)$ with $x_3 = d$
   (g) $x_2 = 0, x_3 = 0$, $c_2(0) \geq c_1(x_1), c_3(0) \geq c_1(x_1)$ with $x_3 = d$

   where the conditions $x_1, x_2, x_3 \geq 0$ and $c_1(x_1), c_2(x_2), c_3(x_3) \geq 0$ always hold.
2. Next we solve each of the problems for x_1, x_2, x_3 and find for which values of demand d they hold true.
3. Finally, we find the UE assignment by computing the total cost $f = c_1(x_1)x_1 + c_2(x_2)x_2 + c_3(x_3)x_3$ for each of the different conditions of demand d.

(ii) The UE assignment problem (for the Pigou-like network) can be expressed as the Beckmann optimisation problem like so: Minimise

$$\sum_{i=1}^{n} \int_0^{x_i} c_i(\tilde{x}) d\tilde{x},$$

given the constraints $x_i \geq 0$ and $\sum_{i=1}^{n} x_i = d$.

(iii) The system optimal (SO) assignment can be found by computing: Minimise

$$\sum_{i=1}^{n} x_i c_i(x_i),$$

given the constraints $x_i \geq 0$ and $\sum_{i=1}^{n} x_i = d$.

(b)

(i) Let the integers from 1 to 6 be the links as shown in the diagram. Then the possible routes in terms of the links visited are: $y_1 = [1,2,3]$, $y_2 = [1,2,6]$, $y_3 = [1,5,3]$, $y_4 = [1,5,6]$, $y_5 = [4,2,1]$, $y_6 = [4,2,6]$, $y_7 = [4,5,3]$, $y_8 = [4,5,6]$. This information can also be expressed in terms of the link-route incidence matrix:

$$\mathbf{A} = \begin{pmatrix} 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \end{pmatrix}$$

(ii) Reasons why UE computations based on route flows are usually a bad idea:

- The UE assignment problem do not usually have a unique solution in route flows.
- For larger networks (like most real-world networks) the number of possible routes is very large, so using the route flows to determine the UE assignment could be very slow to compute.

(iii) From the conservation of flow through the nodes we get: $-x_1 + -x_4 = -d$, $x_1 + x_4 - x_2 - x_5 = 0$, $x_2 + x_5 - x_3 - x_6 = 0$, $x_3 + x_6 = d$ (using x_i to indicate the route flows). We can then re-write this in terms of matrices, as the matrix equation $\mathbf{Bx} = \mathbf{s}$, to find the constraints needed for the Beckmann method:

$$\underbrace{\begin{pmatrix} -1 & 0 & 0 & -1 & 0 & 0 \\ 1 & -1 & 0 & 1 & -1 & 0 \\ 0 & 1 & -1 & 0 & 1 & -1 \\ 0 & 0 & 1 & 0 & 0 & 1 \end{pmatrix}}_{\mathbf{B}} \underbrace{\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{pmatrix}}_{\mathbf{x}} = \underbrace{\begin{pmatrix} -d \\ 0 \\ 0 \\ d \end{pmatrix}}_{\mathbf{s}}.$$

Naturally, we also require the constraint $\mathbf{x} \geq 0$.

END OF Q2

Q3. Micro-simulation

(a) The free speed v^0_α is the speed of a pedestrian in the desired direction $\vec{e}_\alpha(t)$ if their path is undisturbed. If the path of the pedestrian is disturbed then there is a deviation of the actual velocity $\vec{v}_\alpha(t)$ from the desired velocity $\vec{v}^0_\alpha(t) := v^0_\alpha \vec{e}_\alpha(t)$ due to necessary deceleration processes or avoidance processes, which leads to a tendency to approach the desired velocity again within a certain amount of time - this is the relaxation time [2].

(b) The three different phases in pedestrian crowd flow are:

- Laminar flow
- Stop-and-go flow
- Turbulent flow

(c) Cellular automata models are discrete in space and time, and car-following models are continuous in space and time.

(d)

(i) The flow speed was defined as $v(\rho) = 1 - \rho/\rho_{max}$ [m/s] This implies that the flow $\Phi := v\rho = \rho - \rho^2/\rho_{max}$ [P/ms]. Differentiating this w.r.t to density we get $\frac{\partial \Phi}{\partial \rho} = 1 - 2\rho/\rho_{max}$. Setting this to zero, we find that at max possible flow $\rho = \rho_{max}/2$. Plugging this into the equation for Φ we find that the max flow $\Phi_{max} = 2$. The units of flow are *people per ms*, and we know the max door width is $1.5m$, and given that the max evacuation time is 5 [min] which is equivalent to $5 \times 60 = 300$ [sec], we find that the maximum number of people is $P = 2 \times 1.5 \times 300 = 900$. Given that the maximum capacity is 750 which is less than 900, in theory, an evacuation of the concert venue on-board the ship within 5 minutes should be possible.

(ii) The social force model (without the ship rolling) can be expressed as:

$$\frac{d\vec{v}_\alpha(t)}{dt} = \vec{f}_\alpha(t) + \vec{\xi}_\alpha(t),$$

$$\vec{f}_\alpha(t) = \frac{1}{\tau_\alpha}(v^0_\alpha \vec{e}_\alpha - \vec{v}_\alpha) + \sum_{\beta(\neq\alpha)} \vec{f}_{\alpha\beta}(t) + \sum_i \vec{f}_{\alpha i}(t).$$

where τ_α is the relaxation time, $v_\alpha^0 \overrightarrow{e}_\alpha$ is the desired velocity, $\overrightarrow{v}_\alpha$ is the actual velocity, $\sum_{\beta(\neq\alpha)} \overrightarrow{f}_{\alpha\beta}(t)$ are the forces from other pedestrians, and $\sum_i \overrightarrow{f}_{\alpha i}(t)$ are the forces from obstacles.

In order to compensate for the rolling of the boat, we need to add another term to $\overrightarrow{f}_\alpha(t)$. I will start with a very simplistic approach and then move on to a more complicated one.

The angle θ, by which the ship rotates around its center of mass, has a period of 10 seconds. We can thus write θ as $\theta = A_w sin((2\pi/10)t)$, where A_w is a constant that is dependent on the power of the wind. Now, the boat exerts a normal force on each passenger which is countered by the force $m_\alpha g sin(\theta)$. If we assume frictional forces to be negligible (for now) and the center of mass of the boat to be on the same plane as the passengers, then the resultant force on each passenger will be $\overrightarrow{F}_\alpha = m\overrightarrow{g} sin(\theta)$ (note that the sign will depend on how one defines in which direction θ is positive, and in which it is negative). To find the resultant velocity on each passenger, we need $\overrightarrow{v}_\alpha^{roll} = \int \frac{\overrightarrow{F}_\alpha}{m} dt = \int \overrightarrow{g} sin(A_w sin(0.2\pi t))dt$ - which could be approximated by solving this with a series expansion.

If we do include frictional forces (say f_f) and the center of mass is not on the same plane as the people (note, we are considering 'people' as point-masses) then this problem becomes like the inverted pendulum problem. In this case:

$$\overrightarrow{F}_\alpha = \overrightarrow{f}_f - m\frac{\overrightarrow{g}}{l_\alpha} sin(\theta).$$

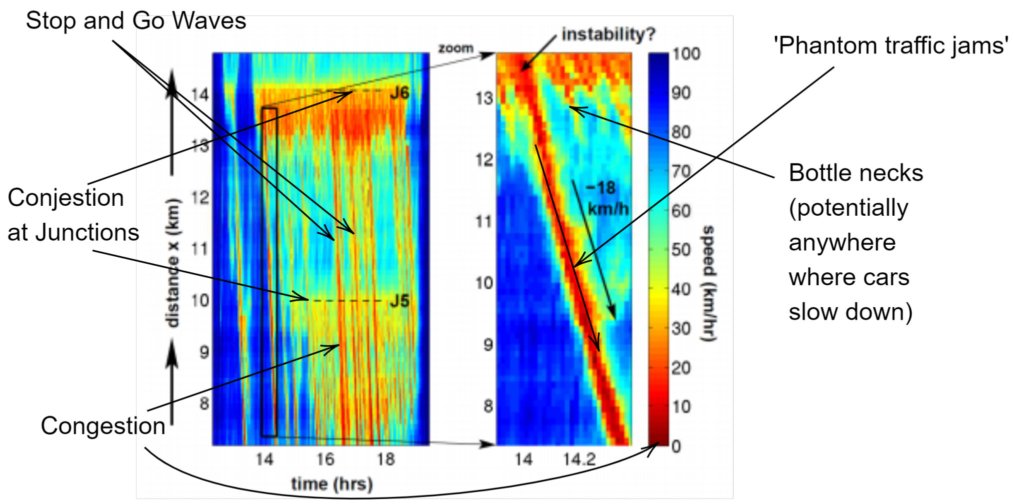
As an aside, we could also compute the factor A_w by computing $I_b\ddot{\theta} = P_w/v_w$ to find another equation for θ, where P_w is the power of the wind ($P_w = 1/2\rho_w A v_w^3$, where A is the area of side of the boat, ρ is the wind density, and v_w is the wind velocity), and I_b is the moment of inertia of the boat, and then compare the two equations for θ to find A_w as a function of wind velocity.

Q4. Macro-modelling

(a) There are various sensing systems that are used to monitor the speed and/or the flow of traffic in a highway:

- Inductance loops: An insulated, electrically conducting loop is installed in the pavement. When a vehicle passes over the loop or is stopped within the loop, some of the vehicle's ferrous body material increases the loop's inductance, which is detected and translated into vehicle speed [3].
- Average speed cameras: These are based on automatic number plate recognition (ANPR) technology. They count passing vehicles and their speed by re-identifying number plates over a section of road.
- Other monitoring methods include Bluetooth / WiFi, GPS Floating vehicle data, CCTV and dash-cams.

(b) I'm really sorry, but I don't own a scanner (and my camera phone is not very good), so I haven't been able to create a sketch. Instead I have taken the Spatiotemporal figure on page 8 (Macroscopic lecture 1), and added annotations of additional features. Hope that's okay!



(c) $\bar{v}_S = \frac{1}{\rho}\sum_{i=1}^{n}\rho_i v_i$

(d) $\bar{v}_T = \frac{\sum_{i=1}^n \rho_i v_i^2}{\sum_{i=1}^n \rho_i v_i}$

(e) In class i, there are $n_i = \rho_i v_i T$ vehicles given a time interval of length T. Likewise, for class j there are $n_j = \rho_j v_j T$ vehicles given a time interval of length T. The number of passing events is observed relative to the two classes. A density of ρ_j vehicles observe n_i vehicles passing and a density of ρ_i vehicles observe n_j vehicles being passed. Thus the total number of passing events, per unit length, is

$$\sum_{i=1}^{n} \sum_{j:v_i>v_j}^{n} \rho_j v_i \rho_i \ T - \rho_i v_j \rho_j T = \sum_{i=1}^{n} \sum_{j:v_i>v_j}^{n} (v_i - v_j)\rho_i \rho_j T$$

and the total number of passing events, per unit length, per unit time, is given by:

$$\sum_{i=1}^{n} \sum_{j:v_i>v_j}^{n} (v_i - v_j)\rho_i \rho_j.$$

Part B

Introduction

Covid-19, for a while, brought most transportation systems to a stand still in the UK. Only 'key workers' were allowed to travel from A to B in order to fulfill their essential work, while the rest of the population was asked to stay in their homes. This nationwide lock-down, which started on the 23rd of March 2020, is still on going as I write this report, but restrictions are gradually being lifted as the so-called R_0 reproduction number is falling. With the relaxation of restrictions, citizens of the UK will be (and are already) using a variety of transport systems in order to visit loved ones, see friends, go to and from work, do their grocery shopping and exercise, amongst other things. Some forms of transport, however, pose a risk of increasing the R_0 number again, because they require groups of people to stay in close proximity (e.g. London Tube, Buses) for periods of time. We need therefore to transform the current transport methods in place, to mitigate this risk. In this report, I re-think some of the standard forms of travel in order to keep the reproduction number to a minimum, while ensuring that the population can thrive. I strongly believe that the answer lies not in creating an entirely new system (although some radical alternatives will be presented), but rather re-adjusting the current systems in place to ensure that a second-wave of Coronavirus, or another entirely new pandemic, can be mitigated in the future.

Relevant Background Information

According to the Transport Statistics for Great Britain 2018/19 [4]:

- On average, less than 20% of adults cycled at least once a week in 2018. There were a total of 99 cycling related deaths, while there were a total of 456 pedestrian deaths in 2018 (however, it is not clear if these deaths involved being hit by cars or not). In the same year there were 777 car deaths, and 354 motorcycle deaths.
- In 2018/19, £32.5bn of public expenditure was spent on transport. 55% of this expenditure went towards railways, 31% towards roads, 8% towards public transport and 6% towards other forms of travel.
- On a typical day 68% of people travelled by car to and from work, 10% took a train, 10% walked, and 7% took a bus, and 7% used a different form of transport.

According to the Office for National Statistics UK [5]:

- The leading cause of death for both men and woman for all ages between the years 2001 to 2018 were ischaemic heart diseases. Ischaemic heart diseases, are often caused by being overweight, smoking, and not exercising enough. According to the UK heart foundation, one can reduce ones risk of developing heart and circulatory disease by as much as 35% by being more active.

- The most-common pre-existing health conditions linked to Covid-19 deaths are dementia and alzheimer disease (old age), influenza and pneumonia and ischaemic heart diseases. According to the Intensive Care National Audit & Research Center [6, 7], 73% of patients in critical units are overweight, 31.5% of which are obese and 7% morbidly obese. According to [8, 7], in the UK, those who were obese (a body mass index (BMI) greater than 30) had a 33% greater risk of dying than those who were not obese.

It seems obvious from these statistics that our focus on creating safe transport systems, to prevent the further spread of the corona-virus also needs to focus on the general health of the citizens - the healthier we are, the less vulnerable we are to viruses. We need to have systems in place that encourage exercise, and reduce the chance of harmful particulates from getting into our lungs,[1] while also mitigating the possibility of viral spread. With this in mind, this report presents a myriad of different ideas that private companies and/or the UK government could implement. For some ideas, a brief description on how the idea could be mathematically modelled, to evaluate its effectiveness, is given. Rather than stick to one, detailed approach, I have opted for multiple smaller ideas - but have therefore had to sacrifice some of the details.

Technical Innovation

Polka Dots for Social Distancing

The idea is to achieve social distancing by giving commuters who are waiting for public transport exact, socially distant places to stand/wait in order to minimise the spread of the virus. Using cheap, slip-resistant 'floor graphics' in the form of polka dots, commuters will be able to easily tell if they are standing too close to someone else. In the case of families or smaller groups, the polka dots can be grouped into hexagonal shapes, making it easier for them to travel as well.

Modelling Ideas

- Simulate pedestrians using such a polka dot system to evaluate flow effectiveness while maintaining social distance. One could do this by adjusting the Social Force Model to include attracting pods.

[1] According to a 2018 Public Health England report, the total cost to the NHS and social care of air pollution is estimated to be up to £5.56 billion for PM2.5 and NO2 combined [9]

- Do a real-world test: Set up the polka dots in one of the London Underground tube stations. Use computer vision blob detection methods on CCTV camera footage to explore effectiveness (model pedestrians as blobs using Computer Vision and compare overlap with polka dot blobs). Once a weeks worth of data has been collected, evaluate effectiveness of this idea, and if it seems to work, add it to more train stations.

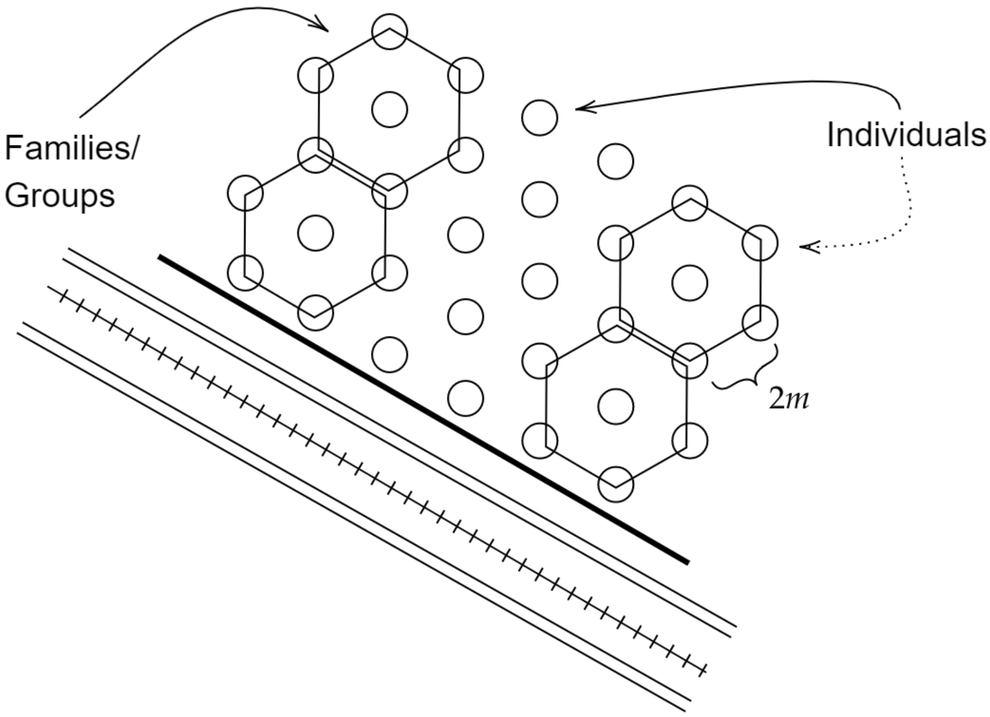


Figure 1: An example of how polka dots can be used to create effective social distancing. The dotted line indicates that individuals can also use the polka dots allocated to families/groups if none are present.

Geofencing technology and Oyster-tracking for Public Transport

Geofences are virtual fences that define a set of GPS locations. Lots of restaurants use this technology to get reviews on their food. If you have ever received a notification from google asking whether you enjoyed your 'stay' at a certain place - that's geofencing technology. This technology (or some form of oyster-card tracking for London) could be used on buses and trains to store information on when and for how much time an anonymous individual spent on a bus/train or in a station. If an individual becomes ill, this technology could be used to notify people who shared the buses/train compartments, and they could then isolate for a certain amount of time. Given that the R_0 number is currently quite low, the chance of such an event occurring is hopefully also quite low, but if it does occur then perhaps 50 to 2000 people could end up isolating - which may be a nuisance for those people having to isolate, but if it can prevent another outbreak from happening, I'm sure millions of people would be grateful.[2]

Modelling Ideas

- This is perhaps not really something to model using transport science, but network science instead. One could adapt the SIS model to include extracting people in contact with someone who is contagious in the model and then observe the spread of the disease.

Bio-degradable adhesive disinfectant

A very simple idea: an adhesive disinfectant that can be stuck onto train door buttons, stop buttons on buses, on handle bars, etc... The technology would consist of a sticky face on one side and a porous material on the other. In the middle a disinfecting gel is placed, which then seeps through the porous material when someone presses on it. When someone is not pressing on the adhesive disinfectant, the pores are closed so the disinfectant gel cannot evaporate. This technology would help mitigate the spread of the disease through indirect contact.

Government Policies

Wearing masks for all public travel and when in doors

The government should make face-masks compulsory for all public travel and indoor-public places, like shops. According to [10], based on Cambridge and Greenwhich research, only by wearing face-masks can we prevent another pandemic, while living in less strict lock-down measures. Germany is doing this, and so far it seems to be working well.

Cycling initiative: Car Permits

Cycling is one of healthiest, most environmentally friendly forms of transport, and it is also considered one of the safer means of travelling during the Coronavirus-crisis, because it is outdoors [11]. In order to encourage cycling, the government should introduce a permit-system for people who would otherwise travel by car. If a citizen's work-place is within a 5 km radius of home, they need to cycle, walk or use public transport. If it is beyond the 5km radius, or for other specific reasons (disabilities, certain medical conditions, etc...) then they may get a permit to drive their car or be driven. Driver's can be stopped at anytime by police to check their permit. If the journey to work is hilly or the person is above a certain age group, they are entitled to a subsidised electric bicycle.

[2] I am currently developing an App that uses this technology with other engineers I got into contact with in the European Hackathon. If you would like to learn more about the technology click here and to see our website click here

Anyone who wishes to buy a new car must go through a series of bureaucratic processes, and an educational course on harmful pollutants, before they are allowed to make a purchase.[3]

The 5 Day Week

I propose that the government turns the 7 day week (5 working-days, 2 off-days) into a 5 day week (3 days working, 2 days off). In this system, a company could, for example, have two separate groups of workers, that work on alternating two-day periods, with a day in the middle for meetings/exchanging information if needed - this means the company could be running 24/5 if need-be. A company could then employ twice the number of people, thereby decreasing unemployment, pay lower wages, and rush hour will only contain half the people, thereby also reducing the spread of the virus. To reduce rush hour further, a staggered starting work-hour could also be implemented by the government.

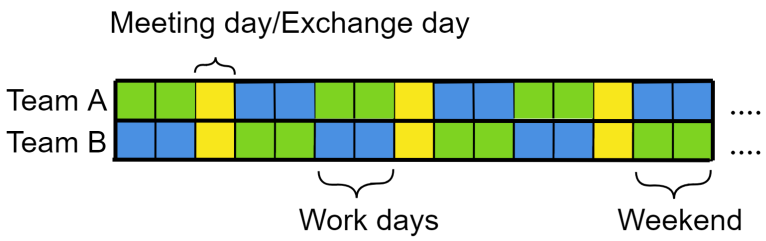


Figure 2: Example of how a 5 day week could be used by a company, so that it can remain open for all days of the week.

New and Modified Infrastructure

The government should continue to build more cycle routes, making it safer to travel by bike. They should stop the building of car parks, and make it very expensive and difficult to find parking spaces. Bicycle racks should be built on existing parking spots - especially in cities. While the corona-virus is still present, typically busy streets (like Oxford street, London) and most business-sectors, should have all their roads closed to vehicles (unless it's an emergency), so that people can walk on the streets and spread out and thereby reduce the likelihood of spreading the virus (like in New York). Office buildings that end up being empty, because a businesses transitions to being entirely online and working from home, should be turned into social housing.

[3]They should also have to watch a film on the cost ineffectiveness of owning a car and have a discussion on whether Uber or other car sharing options might not be better for them.

Conclusion

The corona-crisis is an opportunity to change the way in which we think about transport. We need to move away from polluting vehicles, and the need to own personal cars. We need to move towards making the transport system completely sustainable, non-detrimental to our health, safe and enjoyable.

References

[1] Filippo Simini, Marta C González, Amos Maritan, and Albert-László Barabási. A universal model for mobility and migration patterns. *Nature*, 484, 2012. doi: 10.1038/nature10856.

[2] Dirk Helbing and Péter Molnár. arXiv:cond-mat/9805244v1 [cond-mat.stat-mech] 20 May 1998. Technical report, 1998.

[3] Induction loop - Wikipedia. URL `https://en.wikipedia.org/wiki/Induction_loop`.

[4] Department for Transport. Transport Statistics Great Britain: 2019. Technical report, 2019. URL `www.gov.uk/dft`.

[5] Leading causes of death, UK - Office for National Statistics. URL `https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/causesofdeath/datasets/leadingcausesofdeathuk`.

[6] ICNARC – Reports. URL `https://www.icnarc.org/Our-Audit/Audits/Cmp/Reports`.

[7] Radwan Kassir. Risk of COVID-19 for patients with obesity, 6 2020. ISSN 1467789X.

[8] Annemarie B Docherty, Ewen M Harrison, Christopher A Green, Hayley E Hardwick, Riinu Pius, Lisa Norman, Karl A Holden, Jonathan M Read, Frank Dondelinger, Gail Carson, Laura Merson, James Lee, Daniel Plotkin, Louise Sigfrid, Sophie Halpin, Clare Jackson, Carrol Gamble, Peter W Horby, Jonathan S Nguyen-Van-Tam, Jake Dunning, Peter JM Openshaw, J Kenneth Baillie, and Malcolm Gracie Semple. Features of 16,749 hospitalised UK patients with COVID-19 using the ISARIC WHO Clinical Characterisation Protocol. *medRxiv*, page 2020.04.23.20076042, 4 2020. doi: 10.1101/2020.04.23.20076042. URL `https://www.medrxiv.org/content/10.1101/2020.04.23.20076042v1`.

[9] Air pollution and premature death: Life expectancy impacts described in Bristol study — Envirotec. URL `https://envirotecmagazine.com/2019/11/18/air-pollution-and-premature-death-life-expectancy-impacts-described-in-bristol-study/`.

[10] New face mask research says they prevent second, third coronavirus waves — Fortune. URL `https://fortune.com/2020/06/11/coronavirus-second-wave-face-masks/`.

[11] Coronavirus pandemic gives cyclists more road in Berlin — Germany— News and in-depth reporting from Berlin and beyond — DW — 18.04.2020. URL `https://www.dw.com/en/coronavirus-pandemic-gives-cyclists-more-road-in-berlin/a-53176110`.