Risk Modelling in Hazardous Material Transport

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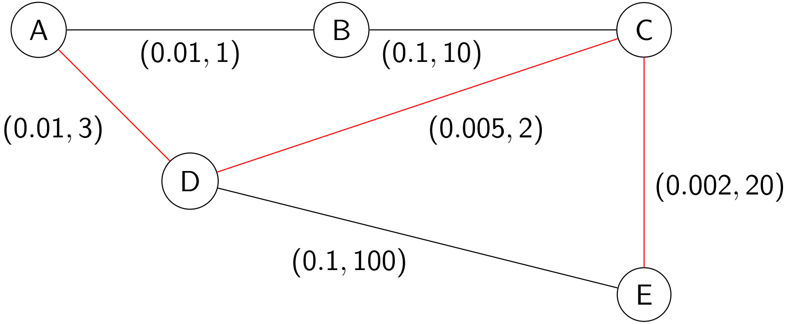
Motivation

Traditional Risk

- In order to model risk we use a wide variety of models; the most common being Traditional Risk:

$$TR = \sum_{i=1}^{n} p_i c_i$$



Modelling Consequence

- The consequence vector is calculated through the use of population density in an area around the network.
- Three Models exist for examining consequence:
  - Simple Circular
  - US DoT (Rectangular)
  - Semi-Circular Risk

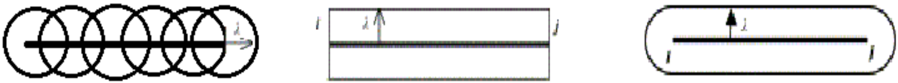


Figure: Left to Right: Circular, DoT, Semi-Circular

Double Counting

The consequence models are not exact and can double count regions:

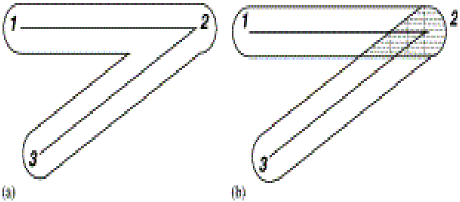
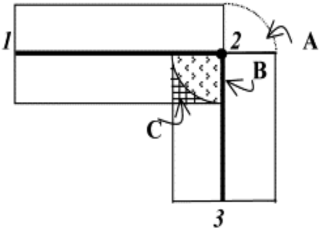


Figure: Double Counting in Semi-Circular Risk (Above)
Over counting of node areas in Rectangular Risk (Below)



Error

- It is possible to reduce the double counting, with the semi-circular model being exactly reduced:

$$\rho(i)\left[\frac{r^2}{\tan\left(\frac{\alpha}{2}\right)} - \frac{(180-\alpha)r^2\pi}{360} + r^2\pi\right]$$

  where $\rho(i)$ is the population density, r is the radius and α the joining angle.

- This formula, however, can be reduced to an approximation that assumes that, in a large network, the average angular change is 90°:

$$r^2 - \frac{\pi r^2}{4}$$

Modelling an Example Network

- We can model four routes between Lancaster and Preston using half-mile intervals, as seen below:

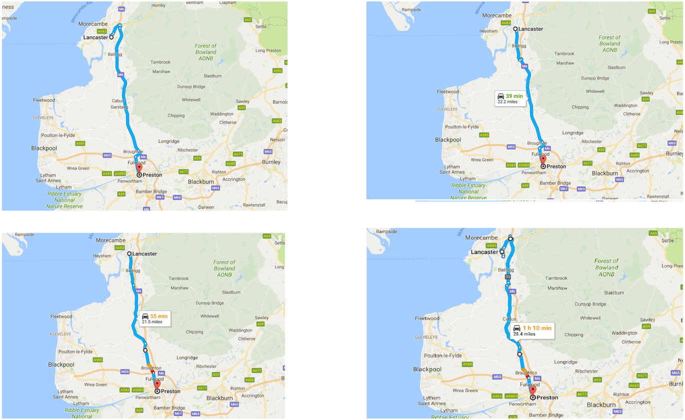


Figure: Clockwise: Route 1, Route 2, Route 4, Route 3

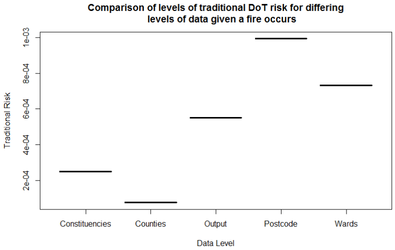
Methodology

Accident Probability

Figures for accident probability on each type of UK road can be obtained from the UK DfT

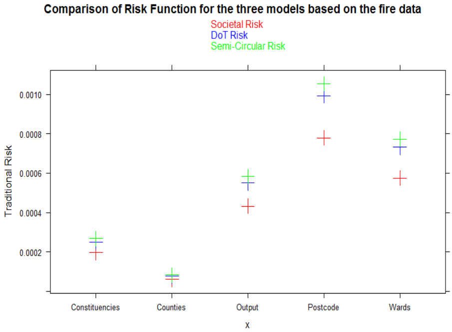
Consequence Values

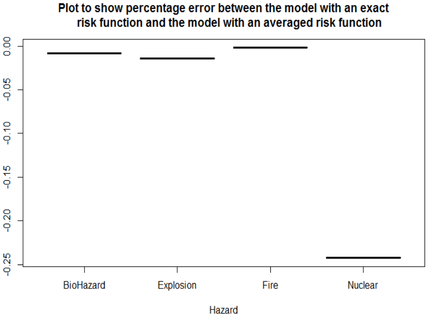
- In order to model consequence we model population density
- Comparing different levels we see, using t-tests, the maximum detail needed to be significantly different is ward density.



Comparing Consequence Methods

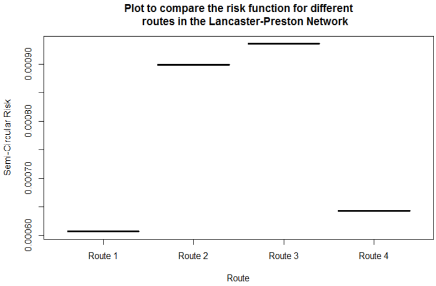
- The highest, and so best, risk representation is given by semi-circular risk.
- As such we propose to use Semi-Circular Risk with averaged error and ward population density for our future modelling work.





Comparing Risk in the Network

- Route 1 has the lowest risk value:



- One method to find the optimal route across a network would be Djikstra's algorithm.
- Policy Iteration can also be considered - see Poster for details.

Questioning Assumptions

- Assumes that all road types have different accident probabilities
- Assumes all accidents will be equally severe, and that all cause damage
- Assumes injuring people is the only form of consequence

Do Different Road Types Have a Different Accident Frequency?

- We can use ANOVA to test the difference in the datasets:

$$H_0 : \mu_{\text{Motorway}} = \mu_{\text{Rural}} = \mu_{\text{Urban}} \quad H_1 : \mu_{\text{Motorway}} \neq \mu_{\text{Rural}} \neq \mu_{\text{Urban}}$$

- Pairwise t-testing suggests Rural and Urban are similar but that they are significantly different from motorways.

Do Accidents Always Cause Damage?

- There is the assumption in the model that accidents lead to damages, however is it the case that more frequent accidents cause an increase?

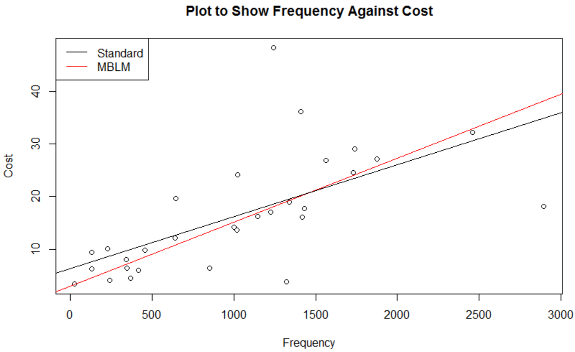
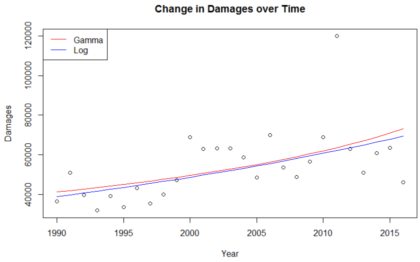
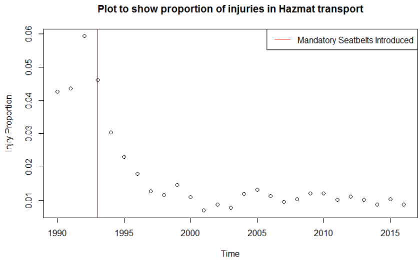


Figure: MBLM is a Median Based Linear Model

Is Population Density an effective statistic?

- We see damages increase over time but the proportion of injuries fall.
- This can be linked to the tightening of safety regulations.

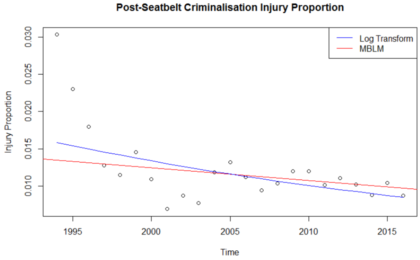


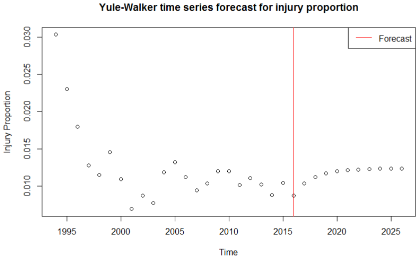


- At any rate it seems that the risk posed by accidents to human life can be reduced.
- This goes against using population density to model c_i.

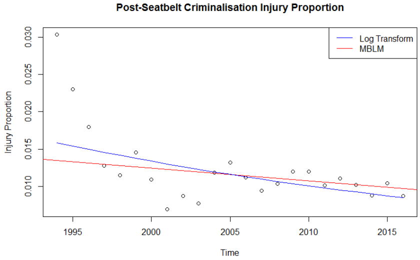
Forecasting Accident and Injury Probability

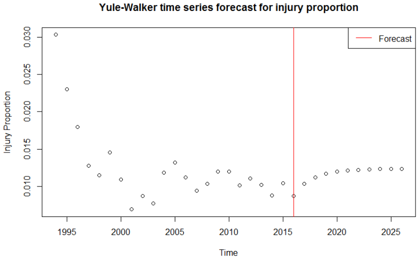
- Using the data we can attempt to quantify what is meant by a 'severe' accident.
- Namely this is one that leads to injury, or a fatality.





Forecasting Accident and Injury Probability





- Both summary statistics and these models all predict values of around 0.01.

Conclusion

- Different road types do need modelling, however the type of road alone is not enough
- The severity of accidents varies
- It may also be helpful to consider the financial cost as well as human cost for the consequence value

Further Work

- Further explore methods to predict accident and injury probability in a network
- Create a model that represents the location of the accident, perhaps using a Poisson Process
- Investigate the relationship between the weather, time of year and other climate factors on accident probability.
- Explore how these factors could be worked into a new risk model

References

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2. B.Y. Kara, E. Erkut, V. Verter, (2008) Accurate calculation of hazardous materials transport risks, Operations Research Letters 31(4):285 – 292
3. Faraway, J. (2005). Linear models with R (Texts in statistical science ; v. 63). Boca Raton, Fla.: Chapman & Hall/CRC.
4. Chatfield, C. (2004). The analysis of time series : An introduction (6th ed., Texts in statistical science). Boca Raton, Fla.: Chapman & Hall/CRC

Thanks For Listening!

Any Questions?

Figure: Perhaps our model needs to include height..?