Lecture / Ponencia XX

Fighting the Ebola Virus – an Exercise in Risk Analysis & Decision Making

J. Houston [1] and M. Acharyya [2]

[1] *Glasgow Caledonian University, Department of Law, Accounting, Economics & Risk, Glasgow, Scotland, G4 0BA (j.houston@gcu.ac.uk) & corresponding author.*

[2] *Glasgow Caledonian University, London Campus, 40 Fashion Street, Spitalfields, London, England, E1 6PX (Madhusudan.Acharyya@gcu.ac.uk)*

Abstract

Ebola is a deadly epidemic and has already cost the lives of at least 10,000 people in West Africa. A vaccine has yet to be discovered and the focus remains on containing the spread of the virus. Although its spread has come under control in recent months, the actions of international agencies has been criticized. In this study, we present a choice-problem, associated with the handling of Ebola by Health Policymakers. We combine actual demographic data with realistic cost data for a limited range of interventions intended to slow transmission of the disease, into a quantitative model. The model facilitates trials of many combinations of interventions, in an effort to minimise the further spread of Ebola. The model can be used both as a teaching tool, as well as a prototype decision-making tool for the agencies involved in fighting such outbreaks, with limited budgets.

1. Introduction

The Ebola virus was first identified in the Sudan in 1976, and has re-manifested itself 16 other times between then and 2012, causing 1,579 deaths and a 67% fatality rate (WHO, 2014). In 2014, the World Health Organization (WHO) declared the epidemic to be a “public health emergency of international concern” (WHO Ebola Response Team, 2014). Ebola is categorised as high-risk epidemic and the current outbreak is believed to have led to the deaths of at least 10,000 people by February 2015, mainly in Guinea, Liberia and Sierra Leone (Centers for Disease Control and Prevention, 2015; WHO, 2015; UN 2015a and 2015b). The UN has initiated a five point strategy, under the title "Global Ebola Response" (UN, 2015a, op.cit.): (1) stop the outbreak from spreading further; (2) treat the infected; (3) ensure essential services; (4) preserve stability; and; (5) prevent further outbreaks. The International Federation of Red Cross and Red Crescent Societies and UNICEF have also joined with the WHO to lead the implementation of the lines of actions associated with this five point strategy. However, these agencies' abilities to act are constrained by tight budgets. The UN estimates that the total effort from October 2014 to June 2015 will cost $2.27billion, of which only $1.4billion has been either spent, or pledged. Post-outbreak reconstruction will increase the likely total cost to over $4billion (UN, 2015b, op.cit.). The problem is exacerbated by the remoteness of the affected regions and quality of the infrastructure, that combine to affect adversely, the strategic and operational decisions facing the Agencies. Notwithstanding this, they have to justify the costs and benefits of their actions associated with the handling of this epidemic. This paper demonstrates the complexity associated with analysing risk and decision making. This is achieved by designing and presenting a risk model that exhibits an example of constrained choice that the policymakers face.

2. The Risk Model

In this context, we refer to *risk* as the risk of the virus continuing to spread both within each region, and into other, previously unaffected regions. We score the risk of Ebola being transmitted to other victims in the regions of five West African countries: Guinea, Sierra Leone, Liberia, Mali and the Ivory Coast, according to pre-selected risk-attracting attributes. Some of these pertain to the whole country (e.g. GDP, Public Expenditures, Literacy/Death Rates and number of Ebola Treatments Centres (ETCs)). Others pertain to the region itself (location to Capital City, population densities), according to data availability. Each component yields a score, emanating from its own risk table and the 'value' possessed by the region at that point in time. The relative importance of each component is expressed through the absolute values of the scores. For example, Table 1 summarises the scores awarded for location to the nation's capital city. The sum of these attribute scores gives a total risk score, which is then mapped to a specific qualitative risk class. For illustrative purposes, it is assumed that each region will exhibit one of *four* levels of risk, as indicated in Table 2.

This gives the 'opening' risk position for each region. It is assumed that the Agencies have at their disposal, *three* risk-reducing interventions that can be offered to each region, within the confines of the available budget.

Table 1 Ebola Risk : Location to Capital City Risk component

Location	Risk Score
Adjacent	10
Close	50
Distant	100

Table 2 Ebola Problem : Qualitative Risk Classes

Risk Category	Threshold Risk Score
1. Moderately Serious	0
2. Serious	400
3. Very Serious	750
4. Extremely Serious	900

From previous experience, these are believed to reduce risk *scores* with the possibility that their implementation may be able to move a region into a lower risk *class*. These are: (1) New ETCs, each staffed with care workers and equipment, including a laboratory; (2) Burial and Sanitization teams to safely dispose of victims' remains and to disinfect their living spaces; (3) Public Education Programmes (PEPs), to educate citizens in how to detect the early signs of Ebola and take precautions to reduce the risk of acquiring, or transmitting it. In this model, a region can be offered an ETC, whose effectiveness is determined by the number already there (Table 3).

Table 3 Impact on the Risk Score of the construction of another ETC

# ETCs already in the Region	% reduction	# ETCs already in the Region	% reduction
0	25%	4	2%
1	10%	5	1%
2	8%	6	0.5%
3	5%		

A Burial and Sanitization Team's effectiveness is determined by the physical territory (in km^2) it has to cover. This territory is a function of the region's overall size and the number of teams to be deployed there. Accordingly, the model calculates the average territory implied as it considers the number of teams to deploy, and thence the region's component score, according to Table 4.

Table 4 Impact on the Risk Score of the Burial and Sanitisation Team density

Area (km^2) per team	% reduction in score	Area (km^2) per team	% reduction in score
10-99	25%	10000-99999	3%
100-999	15%	100000-plus	0%
1000-9999	8%		

The Agencies responsible for Public Health have to decide on whether to offer any form of public health awareness programme in each region. If they do decide to, then there are two levels of programme available: 'Low' and 'High', with different per-capita costs and effectiveness in reducing the region's total risk score. 'Low' reduces the region's score by 15%, 'High' by 25%. Of course, these Interventions are not costless, and the budget available to the Agencies is, perforce, limited. Different costs were assumed for each country, to take into account the different terrains, labour markets, etc in each one. The absolute costs of the ETCs dwarf all the other interventions, though it should be borne in mind that they are either *per-team* or *per-capita* costs. Nevertheless, the per-dollar effectiveness of each Intervention is designed, deliberately, to be very different in order to provoke a debate to the extent to which 'expensive' interventions can be ignored as part of the solution. We use Palisade's Risk Optimizer program and Excel, to trial and cost, combinations of ETCs, Burial-Sanitization Teams and PEPs in each region. A budget of $4billion was assumed, being broadly in line with the UN's current estimate as to the total cost of fighting Ebola. However, this is deliberately less than the total cost of giving each region an additional ETC, a large number of Teams and High-level PEPs, otherwise, there would be no decision problem. When trialling each combination of interventions, the model computes the new risk score and corresponding risk class for each region. If the percentage reduction is sufficient, a region will be moved into a lower Risk Class (Table 2). The objective is to maximise the total number of changes across all 64 regions, subject to not exceeding the $4billion budget. In order to reduce the search for the optimal solution, it was assumed that a region can: (1) receive, at most, one new ETC; (2) receive a maximum of 50 Burial & Sanitization teams, regardless of its physical area and/or population; (3) be considered for either a Low- or High-level PEP.

3. Results

The model was then run for 18 hours, on a Dell Optiplex 7020 PC, in which time it performed 13.21 million combinations of interventions. [1]

[1] The spreadsheet showing the detailed computation and simulation are available from the Corresponding Author, upon request.

The best combination found in the time allowed results in a total of 76 Risk-class reductions, affecting 55 of the 64 regions. Of those 55, two regions were moved down by three risk classes (the maximum possible); 17 by two and 36 by one. The average cost of each risk class improvement is $54.5 million, though with a large standard deviation ($67.7m). Table 5 summarises the number and costs of ETCs, Burial and Sanitization Teams and PEPs to be deployed into the regions.

Table 5 Summary Results: all areas

Interventions	#	Cost ($m)	People reached (m)	Spend per person	% of total
ETCs to be built	23	$3,679	18.679	$196.96	96.6%
Burial & Sanitization teams	2,189	$1.58	48.444	$0.03	0.0%
PEP	24 (High) 27 (Low)	$129.59	36.337	$3.57	3.4%
Total Spent $3,810.17m		Total Unspent $189.83m			

Table 6 summarises the distribution of regions into the four risk classes before and after the Interventions. Remembering that the assumed costs were not actually ‘real’, but ‘realistic’, we can see that the expensive ETCs account for almost all the $3.8billion spent. The apparent cost per person reached by the 23 ETCs is also considerably greater than both the Burial Teams and PEPs. This may cast some doubt on the wisdom of devoting so much of the budget on the ETCs, a point that is used to provoke debate amongst the students. Is it acceptable to spend so much money on high-profile interventions, such as ETCs when lower-cost solutions, might be more ‘dollar-effective’?

Table 6 Risk Categories before- and after Interventions

Risk Categories	Before	After
Moderately Serious	0	25
Serious	32	28
Very Serious	2	11
Extremely Serious	30	0

In assessing how good the Optimizer is in finding the optimal solution, we note that even after 18 hours run-time, $190million remains unspent. We might consider purchasing another ETC in Guinea, Mali or Sierra Leone, or thousands more Burial-Follow-up teams, and/or upgraded PEPs. Any seven of the nine regions left in their original classes (all ‘Serious’ in this case), could be moved down to the ‘Moderately Serious’ category if an extra ETC were committed. However, these are all in countries where an ETC costs more than the unspent budget. Manually adjusting the Burial Teams and PEPs does, of course, use up some of the unspent budget, though it was not possible to obtain any additional risk class changes. However, the Optimizer does suggest committing over $9million on five of the nine 'no-change' regions. This money could be added back into the unspent portion and the resulting $199million used to try and find further improvements. It may be that the Optimizer just had not got around to doing that when the time permitted to find a solution, had elapsed.

4. Conclusion

It is claimed that the probabilities of spreading Ebola across other parts of the world and the size of the associated impact are totally unknown and unpredictable. Moreover, no effective cure has yet been discovered to treat the Ebola infected patients successfully. Consequently, the mitigation of risks associated with spreading Ebola is the only way to manage this emerging risk. In this paper, we have offered a practical approach to the choice problem associated with the handling of the Ebola virus by health policy makers. This practical exercise of mitigating the risk of spreading Ebola may contribute to the policy development and implications' issues both a public and private levels (e.g. Health Insurers). In addition, the exercise can be used in teaching resource-constrained optimisation approaches to Risk Students.

References

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