A Fuzzy Linear Programming Model for Optimal Allocation of Health Workers in a Medical Facility under Crisis Conditions

Krista Danielle S. Yu[1], Kathleen B. Aviso[2], Michael Angelo B. Promentilla[2], Joost R. Santos[3], and Raymond R. Tan[2]

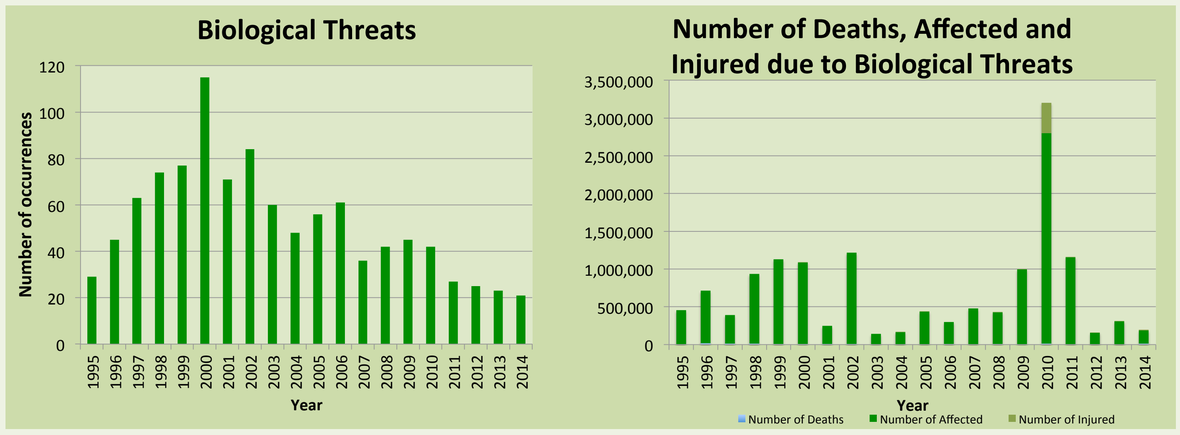
[1]School of Economics, De La Salle University, Manila, Philippines

[2]Chemical Engineering Department, De La Salle University, Manila, Philippines

[3]Engineering Management and Systems Engineering Department, The George Washington University, Washington D.C., USA

Introduction

While the occurrence of biological threats have continued to decrease over time, the number of people affected, deaths and injured have increased. With pandemic outbreaks such as AH1N1, MERS-CoV and SARS affecting lives on a global stage, medical facilities should be equipped with plans for addressing increased demand for their services.



Medical facilities follow an organizational structure where they are divided into departments, with individual functions that provide services both to internal clients (transactions between departments) and external clients (patients)

Research Question

Under a crisis situation, how should a hospital allocate its workforce to to minimize the adverse effect of drop in staff levels to the level of service delivered to external customers?

Model Specification

This study implements a fuzzy linear programming model following the input-output framework to identify the optimal allocation of workforce in a medical facility during a crisis scenario. The model develop is defined as:

$$\max \lambda$$

s.t.

$$\left(\vec{\mathrm{I}} - \vec{\mathrm{A}}\right)\vec{\mathrm{x}} = \vec{\mathrm{y}}$$

$$\vec{\mathrm{x}} \le \mathrm{f}\,\vec{x_0}$$

$$\left(\frac{y_i - y_i^L}{y_{i0} - y_i^L}\right) \ge \lambda$$

Where
- λ = index of satisfaction
- I = identity matrix
- A = technical coefficients matrix
- x = total services vector
- y = external demand vector
- f = fraction of labor available
- x_0 = initial service available
- y_i = external demand for services provided by department *i*
- y_i^L = lower limit of the fuzzy ramp of external demand for services provided by department *i*
- y_{i0} = initial level of external demand for services provided by department *i*

Case Study

This study adapts the organizational input-output table of an acute care hospital (ACH) in Correa and Parker (2005). The ACH is divided into 10 departments ranging from management, support, finance, medical, ancillary and other services. A case wherein the ACH suffers from reduced labor availability due to a pandemic outbreak is considered.

Conclusions

In a case wherein a medical facility suffers from an adverse drop in staff level, management can opt to require less people to come in for departments that are not directly involved in providing patient care to reduce their exposure. This can result to a more efficient operation during crisis conditions as interactions between number of persons is reduced.

Model Framework

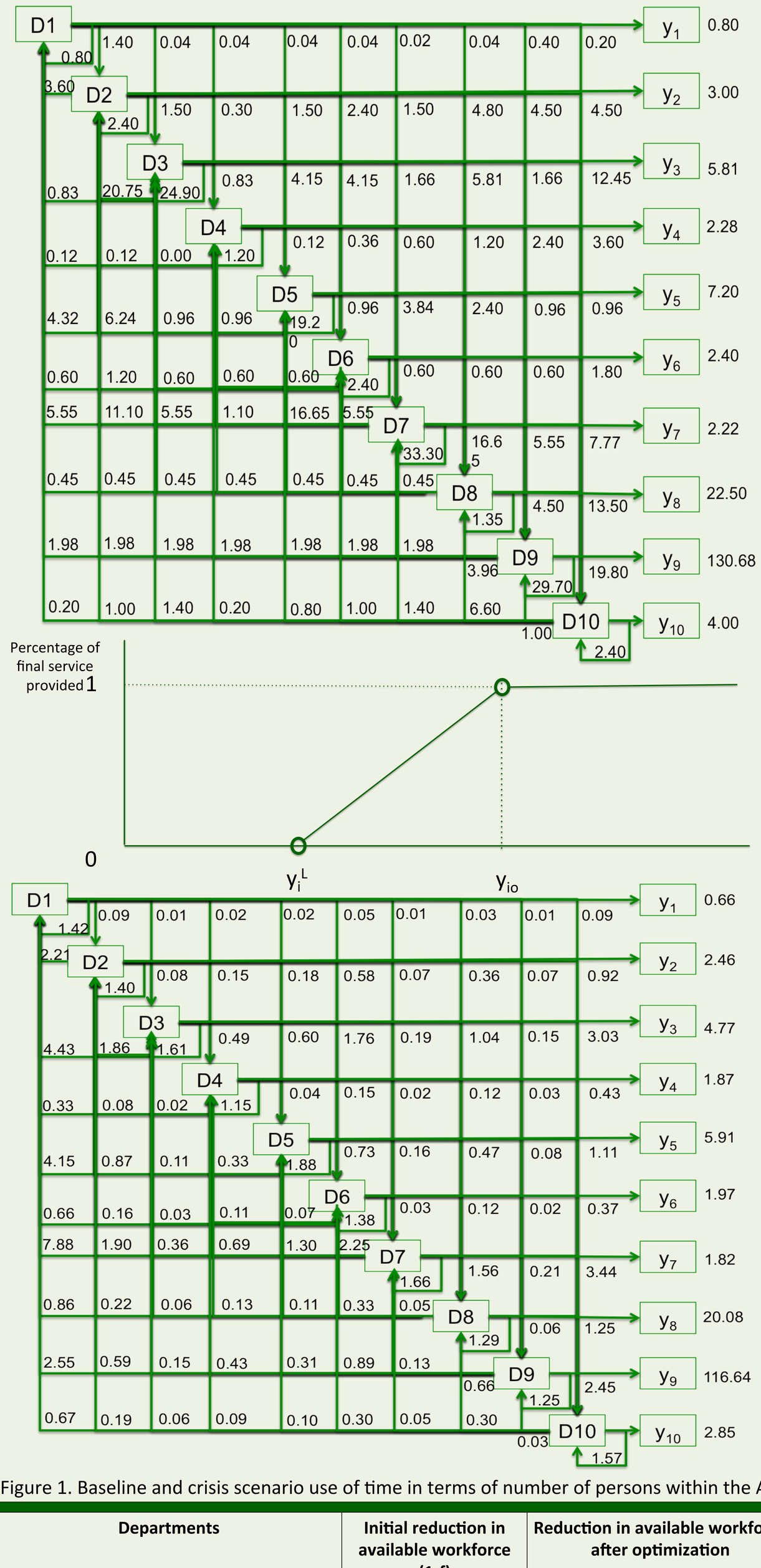


Figure 1. Baseline and crisis scenario use of time in terms of number of persons within the ACH

	Departments	Initial reduction in available workforce (1-f)	Reduction in available workforce after optimization
D1	High-Level Management	10%	17.90%
D2	Middle-level Management	10%	17.90%
D3	General Administration	10%	17.90%
D4	Support Administration	10%	17.90%
D5	Finance Administration	10%	17.90%
D6	Human Services	10%	17.90%
D7	Information Services	10%	17.90%
D8	Medical Staff	12%	10.74%
D9	Nursing Staff	12%	10.74%
D10	Ancillary Staff	10%	28.64%
λ-value = 0.2840			

References

Correa, H. and Parker, B.R. (2005). An application of organizational input-output analysis to hospital management. Socio-Economic Planning Sciences 39 pp. 307-333.

Guha-Sapir, D., Below, R., and Hoyois, P.H. (2015). Biological Threats. EM-DAT: International Disaster Database. Université Catholique de Louvain, Brussels, Belgium.

Santos, J.R., Yu, K.D.S., Herrera, L.C., Pagsuyoin, S.A.T. and Tan, R.R. (2014) State of the Art in Risk Analysis of Workforce Criticality Influencing Disaster Preparedness for Interdependent Systems. Risk Analysis 34(6) pp.1056-1068.

Acknowledgements

The authors would like to thank the De La Salle University Office of the Vice Chancellor for Research and Innovation and the Society of Risk Analysis for providing support for this study.