GOAL PROGRAMMING FOR OPTIMUM ALLOCATION OF RESOURCES IN EMERGENCY MEDICAL SYSTEM

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1 ABSTRACT-

This paper was focused on robust emergency medical service system design. The robustness follows the idea, which aims to make the system resistant to various randomly occurring detrimental events, which may negatively affect system performance and quality of the service provided. The main focus was on the set of detrimental scenarios, which allows forming an additional constraint to the model for each element of the scenario set. In this paper, three approaches were introduced and experimentally compared. It can be observed that the computational time demands depend on the model structure. If we replace a min-sum objective by a min-max optimization criterion, then the model gets more complicated so it requires a longer computation time.. Besides that, quality of obtained results is very satisfactory. The future research in this field could be aimed at other approximate techniques, which will enable to reach shorter computational time with acceptable solution accuracy. Another future research goal could be focused on mastering the presented problem with a larger set of detrimental scenarios.

2 INTRODUCTION-

Health systems are complex. For one, they are made up of multiple inter-acting components. Indeed, according to the World Health Organization (WHO), a health system consists of all 'organizations, people and actions whose primary intent is to promote, restore or maintain health'. They are also usually defined as country-level entities, rendering them large, encompassing both rural and urban areas, public and private systems as well as formal/allopathic and informal/traditional systems of health provision.

Health systems perform multiple functions in society – they do not merely deliver healthcare services and other interventions aimed at maintaining or improving health. They play a role in protecting households from the financial impacts of both illness and the costs of healthcare. It is important to note that health systems also perform an economic function in society (Reference SachsSachs, 2001). For example, there is some evidence that the health of a population can influence economic productivity, while for many health workers and businesses, the health system is an economic sector that provides employment, wages and business opportunities. Health systems are also social and cultural institutions that play a function in helping establish 'a wider set of societal norms and values' (Reference GilsonGilson, 2003).

Health systems are open systems that exist in a dynamic relationship with their wider context. Indeed, they are diffuse systems with poorly defined and often porous boundaries and are thus adaptive and continuously evolving in response to multiple factors. For this reason, the social, political and economic context of any health system has to be considered when assessing its structure and performance.

Finally, health systems are sites of competition and contestation between actors with different needs and wants. There is contestation over how health priorities are set, how health systems are financed and how resources are allocated within the system. There are often ideologically and politically contrasting visions of what role a health system should play in society and what role the state and the market should play within health systems.

These different aspects of the complexity of health systems are rarely addressed simultaneously and in an inter-disciplinary manner. The truth is that health systems can only be comprehensively studied and understood through multiple disciplinary lenses, including those of history, economics, medicine, epidemiology, politics, law, ethics, anthropology and sociology.

This book presents a comprehensive and critical analysis of health systems within the context of local politics, history and socio-economic development. In the following sub-sections, we unpack some of the different dimensions of health systems complexity. First, we look at the different societal functions performed by the health system. We then investigate how health systems are also sites of contestation between different ideas and values as well as different interest groups. We then examine a variety of approaches to constructing health systems frameworks and typologies and how these can be used to describe and understand the functioning and performance of health systems. The next section discusses the open and contextual nature of health systems and the relationship between the health system and a variety of external factors, including shifts in international health policy-making. The chapter concludes with a brief discussion of systems thinking, which is discussed in greater detail.

The Different Societal Functions of a Health System

For most, the obvious function of a health system is to deliver a variety of services and interventions. These services may be 'personal' services (delivered to individuals or families) or 'non-personal' services (typically public health interventions targeted at entire populations or the environment in which people live). Clearly, this is a primary function of health systems, and most evaluations of health systems performance are based on how well these personal and non-personal services are delivered in terms of their effectiveness, accessibility, fairness, efficiency and affordability.

However, health systems are more than just a vehicle for delivering health services. For example, health systems can help define and shape the identity of countries. For many post-colonial countries, health systems development is an important ingredient in nation-building, with the construction of health facilities and the extension of healthcare to rural populations viewed as indicators of progress and modernisation that are sources of national pride. Similarly, the health systems of the United Kingdom, Germany and Canada are often viewed emblematically as a national characteristic.

Perhaps more importantly, health systems play an essential social function in both shaping and reflecting relations amongst groups of people in a society. For example, national health systems reflect the depth and breadth of the social contract between governments and citizens by determining the scope of health-related rights and entitlements afforded to the citizens or residents. They also shape and reflect the relationship between the different socio-economic segments of society by either reinforcing or mitigating the relationship between social inequalities and health inequalities. The degree to which healthcare is affordable, accessible and responsive is also a critical determinant of social mobility.

Furthermore, much research and evidence have demonstrated how health systems play a significant role in defining the lived experience of being poor, socially disadvantaged or infirm. For example, studies from multiple countries have described how sub-standard and abusive treatment from healthcare providers are viewed as core defining features of what it is to be poor (WHO & World Bank, 2002). Similarly, the chronic anxiety and fear produced by the lack of protection from the costs of illness, injury and disability are a feature of relative poverty in the USA, even for working families. The International Labour Organization (ILO) defines social health protection as the provision of organised measures to mitigate the distress caused by the reduction of productivity, stoppage or reduction of earnings, or the cost of necessary treatment that can result from ill health (ILO, 2008).

3 DATA OF THE PROBLEM

WHO has projected the rise in the burden of various diseases causing death in SEAR in 2015 and 2030 (Table 1).This projection shows a significant decrease in mortality from communicable. maternal, perinatal and nutritional causes from 25.2% to 16.1%. However, there is a projected rise in deaths due to non-communicable diseases (NCD) from 63.5% in 2015 to 72.5% in 2030, which is a cause for concern.

Table 1: Projections of mortality by cause for 2015 and 2030

Deaths (thousands) by cause projected to 2015 and 2030 in SEAR						
Year			2015		2030	
Population (thousands)			1920761		2205146	
GHE 2012 cause category			Deaths	% Total	Deaths	% Total
	All Causes		14851	100	18595	100
I.	Communicable, maternal, perinatal and nutritional conditions		3748	25.2	2998	16.1
II.	Non-communicable diseases		9428	63.5	13472	72.5
	A.	Cardiovascular diseases	4159	28.0	5872	31.6
	B.	Respiratory diseases	1712	11.5	2561	13.8
	C.	Malignant neoplasms	1412	9.5	2310	12.4
	D.	Diabetes mellitus	434	2.9	690	3.7

III.	**Injuries**	1676	11.3	2125	**11.4**
(Based on the GHE 2012 estimates of causes of death for 2011, the regional projectionsof mortality by cause for years 2015 and 2030 were carried out in 2012.[4]					

Injuries came at 6th in the list of common causes of death and are responsible for 11.3% of all deaths in SEAR (Table 1). Road injuries are the commonest cause of death in SEAR increasing from 24.7% to 28.9% from 2015 to 2030, respectively.[4] With 90% of deaths occurring in LMICs which only account for 54% of the world s vehicles, these deaths and injuries are unevenly distributed[5] Figure 2 illustrates country-specific road traffic fatality rates. Amongst people 15 to 29 years of age, road traffic injuries are the leading cause of death, and cost governments approximately 5% of GDP in LMICs. Other notable areas of injuries are falls (18.5%) and self-harm (19.4%) leading to deaths in SEAR (Table 2)

Table 2: Table 2: Percentage contribution of disease categories to total deaths byage groups for all of India, 2016

Year			2016
Population (thousands)			**1324200**
GHE 2012 cause category			**Total (%)**
	All Causes		**100**
I.	**Communicable, maternal, perinatal and nutritional conditions**		**27.5**
II.	**Non-communicable diseases**		**61.8**
	A.	Cardiovascular diseases	**28.1**
	B.	Respiratory diseases	**10.9**
	C.	Malignant neoplasms	**8.3**
	D.	Diabetes mellitus	**6.5**
III.	**Injuries**		**10.7**
Data are % (95% uncertainty interval).			

The higher proportion of the total DALY burden relative to their proportion of the population was observed in the age groups of younger than 5 years and 45 years or older. The age group of younger than 5 years group constituted 8.5% of the population and had 17.6% of the DALYs. The highest proportion of DALYs were in children younger than 5 years (83·4%) attributed to Communicable, maternal, perinatal and nutritional conditions%), and the lowest was in the 50 54 years age group (14·7%).The proportion of DALYs due to Non-communicable diseases was highest at 78·8% in the 65 69 years group and exceeded 50% in the 30 34 years group. The proportion of total DALYs due to injuries was highest in the age groups from 15 years to 39 years(range 18·3 28·1%).

4 GOAL PROGRAMMING MODEL

Decision models are simply a means to an end. A decision model represents, to some degree, an existing problem. Analysis of the model then should yield results that indicate optimal or preferred courses of action to be taken in the solution of the actual problem. It seems intuitively obvious that, the "better" the model, the more likely it is that the results from such a model will determine the proper actions to be taken. One objective of this thesis is to furnish the ability to build a decision model that is, in general, hopefully better than those that have traditionally been taught. This is because the models with in this thesis will both acknowledge and deal with the fact that, in most real world problems, multiple conflicting objectives will exist. Unfortunately, with only a few exceptions, most works in the area of decision analysis (or mathematical programming optimization, etc.,) consider only models having a "single" objective. In fact, in most instances, the very existence of multiple objectives is completely ignored.

The multiple objective approaches, on the other hand, attempts to include all pertinent objectives. Such an approach recognizes that no all objectives can (or should) be optimized. However, one may establish aspired levels of achievement or goals for each of these objectives. Goal programming is then used to establish a solution that comes as "close as possible" to the satisfaction of all of these goals. Thus, while traditional approaches stress the optimization of single objectives, goal programming stresses the satisfaction of multiple objectives and one should recognize the significant differences between these two approaches.

Another, related, aspects of goal programming that is different from the traditional approach lies in the treatment of the so-called system "constraints". Such constraints are used to determine the design boundaries of a system and, with traditional methods, a solution must satisfy each and every constraint in order for it to be considered "feasible". Those employing goal programming, however, realize that is highly unlikely that all of these "constraints" are truly absolute. Consequently, for the no absolute "constraint", goal programming attempts to minimize the deviation from a pre specified level rather than to satisfy this level absolutely.

Although goal programming (GP) is itself a development of the 1950s, it has only been since the mid 1970's that GP has finally received truly substantial and wide spread attention. Much of the reason for such interest is due to GP's demonstrated ability to serve as an efficient and effective tool for the modeling, solution, and analysis of mathematical models that involve multiple and conflicting goals and objectives – the types of models that involve that most naturally represent real-world problems. Yet another reason for the interest in GP is a result of a growing recognition that conventional (i.e., single objective) mathematical programming methods (e.g., linear programming) do not always provide reasonable answers, not do they typically lead to a true understanding of and insight in to actual problem.

$$\min \sum P_i \left(w_i^- d_i^- + w_i^+ d_i^+\right)$$

i = 1

$$\text{s.t. } c^1 x + d_1^- - d_1^+ = t_1$$

$$c^k x + d_k^- - d_k^+ = t_k$$

$$x \in S$$

$$x,\ d_k^-,\ d_k^+ \geq 0$$

in which S is the feasible region, P_i is the priority of the i'th goal, $c^i x$ is the i th goal criterion function, and the i th are the target values of the k goal criteria. The d_i^- and d_i^+ are deviational variables, which measure achievements below and above goal. The w_i^- and w_i^+ are relative importance weights attached to the underachievement and overachievement deviational variables.

$$Min\ Z = P_1\delta_{Y_1}^- + P_2(\delta_{Y_2}^- + \delta_{Y_2}^+) + P_3(\delta_{Y_3}^- + \delta_{Y_3}^+)$$

$$+ P_4(\delta_{R_4}^- + \delta_{R_5}^-) + P_5(\delta_{X_1}^- + \delta_{R_1}^- + \delta_{R_2}^- + \delta_{R_3}^- + \delta_{R_5}^- + \delta_{R_6}^-)$$

Subject to:

Output constraints:

$$Y_1' + \delta_{Y_1}^- = 2 \ i.e$$

$$0.06X_1' - 0.05R_1' + 0.004R_2' - 0.67R_3' +$$

$$0.24R_4' - 0.13R_5' + 0.19R_6' - 0.18R_7' + \delta_{Y_1}^- = 2.334$$

$$Y_2' + \delta_{Y_2}^- - \delta_{Y_2}^+ = 35 \ i.e$$

$$0.05X_1' - 0.02R_1' + 0.002R_2' + 1.67R_3' + 0.21R_4'$$

$$+ 0.06R_5' + 0.02R_6' - 0.69R_7' + \delta_{Y_2}^- - \delta_{Y_2}^+ = 0.6085$$

$$Y_3' + \delta_{Y_3}^- - \delta_{Y_3}^+ = 5000 \ i.e$$

$$24.37X_1' + 9.997R_1' + 8.48R_2' - 268.68R_3' + 120.92R'$$

$${}_4 + 67.89R_6' - 27.89R_6' - 138.46R_7' + \delta_{Y_3}^- - \delta_{Y_3}^+ = 726.139$$

Input constraint

$$X_1' + \delta^-_{X_1'} = 20$$

Process constraints

$$R_1' + \delta^-_{R_1'} = 35; \quad R_2' + \delta^-_{R_2'} = 33;$$

$$R_3' + \delta^-_{R_3'} = 2.4; \quad R_4' + \delta^-_{R_4'} = 12.5;$$

$$R_6' + \delta^-_{R_6'} = 12; \quad R_7' + \delta^-_{R_7'} = 6.2;$$

With: $X_1' \geq 0; \; R_t' \geq 0, \quad t = 1,2,..,$

Were $F_i(\delta_i)$: satisfaction function asso deviations δ_i , α_{id} : indifference thresh dissatisfaction threshold; α_{iv} :veto threshold.

The GP model with satisfaction functio by sadoket al [2] can be formulated as follow

$$Maximize\, Z = \sum_{i=1}^{r} (w^+_{Y_i} F^+_{Y_i}(\delta^+_{Y_i}) + w^-_{Y_i} F^-_{Y_i}($$

$$\sum_{j=1}^{l} (w^+_{X_j} F^+_{X_j}(\delta^+_{X_j}) + w^-_{X_j} F^-_{X_j}(\delta^-_{X_j}))$$

$$+ \sum_{t=1}^{k} (w^+_{R_t} F^+_{R_t}(\delta^+_{R_t}) + w^-_{R_t} F^-_{R_t}(\delta^-_{R_t}))$$

subject to :

$$Y_i + \delta^-_{Y_i} - \delta^+_{Y_i} = g_{Y_i} \quad (for\; i = 1,2,....,r)$$

$$X_j + \delta^-_{X_j} - \delta^+_{X_j} = g_{X_j} \quad (for\; j = 1,2,....,l$$

$$R_t + \delta^-_{R_t} - \delta^+_{R_t} = g_{R_t} \quad (for\; t = 1,2,....,k$$

$$with\; \delta^-_{Y_i}\; and\; \delta^+_{Y_i} \leq \alpha_{iv}$$

$$\delta^-_{X_j}\; and\; \delta^+_{R_t} \leq \alpha_{iv}$$

$$\delta^-_{R_t}\; and\; \delta^+_{R_t} \leq \alpha_{iv}$$

$$\delta^-_{Y_i}, \delta^+_{Y_i}, \delta^-_{X_j}, \delta^+_{X_j}, \delta^-_{R_t}, \delta^+_{R_t}, Y_i, X_j\; and\; R_t \geq 0$$

Where w_i express the relative importance of the objectives.

Despite the good results obtained by Sadok et al but that the formulation in problem of a QCS designing the use of GP with satisfaction function proposed by Martel and Aouni [8] we will get to the formulation of non- linear programming (LP), to be converted to the LP this is what makes the model's contains a many constraints, as it would be very difficu lt to be applied in the firms that produce some products which contain many inputs and process variables.

5 RESULT AND ANALYSIS

The solution will be obtained by using LINDO package interpretated as follows:

Table 3: Summary of available Beds in Hospitals: Emergency Department Beds andInpatient Beds

District Hospitals	n	Emergency beds in Hospital	Total Inpatient bedsin Hospital	% of Emergency Beds out of all Beds at ED
		Median [IQR] Min-Max	Median [IQR] Min-Max	

More than 300 Beds	15	14 [13] 2-183	400 [205] 200-626	**3%**
Less than 300 Beds	19	6 [7] 1-22	120 [176] 47-380	**5%**

The majority of hospitals did not have system for triage in their emergency department. Only one hospital (Government Hospital, Tenali) had triage system out of all 34 hospitals; two hospitals (District Hospital, Neyyattinkara and District Hospital, Peroorkada) follow triage partially, they have red and yellow beds but did not have green beds.

References

1. Advancing effective communication, cultural competence, and patient- and family-centered care: a roadmap for hospitals. Oakbrook Terrace, IL: The Joint Commission; 2010.
2. Agarana MC. Optimization of banks loan portfolio management using goal programming technique, International journal of research in Applied, Natural, Social sciences. 2014; 2(8):43-52.
3. Aiken LH, Sloane DM, Bruyneel L, Van den Heede K, Griffiths P, Busse R, et al. Nurse staffing and education and hospital mortality in nine European countries: a retrospective observational study. Lancet 2014;383:1824–30.
4. Aiken LH, Xue Y, Clarke SP, Sloane DM. Supplemental nurse staffing in hospitals and quality of care. J Nurs Adm 2007;37:335–42.
5. Alexander M, Grumbach K, Remy L, et al. Congestive heart failure hospitalizations and survival in California: patterns according to race/ethnicity. *Am Heart J* 1999 May;137(5):919-27.
6. Alois Geyer et al.: Scenario tree generation and multi-asset financial Optimization problem, Operations Research Letters, 2013, 41, 494-498.
7. American Community Survey data accessed through American Factfinder. Suitland, MD: U.S. Census Bureau; 2009.

8. Antunes, C., H. and Henriques, C. O. 2016 Multi-objective optimization and multi-criteria analysis models and methods for problems in the energy sector. *Multiple criteria decision analysis*, Springer, 1071-1169.

9. Arthur JL and Ravindran A [1981]: A multiple objective nurse scheduling model. IIE Transactions, 13, 55-60.

10. Asadoorian J, Locker D [2006]: The impact of quality assurance programming: a comparison of two Canadian dental hygienist programs. Journal of Dental Education, 70(9), 965-971.

11. Ash M, Brandt S. Disparities in asthma hospitalization in Massachusetts. *Am J Public Health* 2006 Feb;96(2):358-62.

12. Australian Nursing Federation. Why Investing in Nursing Makes Sense. Issues Paper. Melbourne, VIC: Australian Nursing Federation; 2009.

13. Avella, P., Sassano, A., Vasil'ev, I., 2007. Computational study of large scale p-median problems. In *Mathematical Programming*, Vol. 109, No 1, pp. 89-114.

14. Bagust, A., M. Place and J.W. Posnett, 1999. Dynamics of bed use in accommodating emergency admissions: stochastic simulation model. BmJ., 319(7203): 155-8.

15. Bailey, N. T. (1952). A study of queues and appointment systems in hospital out-patient departments, with special reference to waiting-times. *Journal of the Royal Statistical Society: Series B (Methodological)*, *14*(2), 185-199.