# Data Driven Optimized Budget allocation for maximizing healthcare benefits while minimizing overall expenditure

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Term Project Optimization Techniques in Engineering (CE5516)

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November 24,2023

# OVERVIEW

# Introduction

- In today's rapidly evolving healthcare landscape, optimizing the allocation of resources is paramount for ensuring the well-being of a nation's population.
- The challenge lies in distributing limited budgets across diverse healthcare domains, including the treatment of specific diseases, funding for research initiatives, and investments in infrastructure.
- The optimization process becomes crucial as countries strive to enhance the overall health outcomes of their citizens while grappling with constrained financial resources.

# Introduction (Cont...)

- The objective of this study is to formulate a robust strategy for healthcare expenditure optimization at the global level.
- This entails the identification and allocation of optimal budgets to address various diseases.
- To achieve this, a Linear Programming (LP) model will be constructed, integrating a comprehensive set of variables and constraints to simulate the complexities of the healthcare ecosystem.
- *The remedy to the cost crisis does not require medical science breakthroughs or new governmental regulation. It simply requires a new way to accurately measure costs and compare them with outcomes.*

# Motivation

- Motivation for this study lies in the imperative to develop a forward-thinking, transparent, and data-driven strategy for healthcare expenditure optimization that considers the diverse global health challenges, economic constraints, and the potential for positive, widespread impact on public health outcomes.
  1. Rising Healthcare Costs
  2. Diversity of Healthcare Needs
  3. Limited Resources and Budget Constraints
  4. Global Health Inequities
  5. Advancements in Data Analytics and Modeling Techniques
  6. Public Health Impact
  7. Adaptability to Changing Healthcare Landscapes

# Problem Formulation

- This study aims to formulate a comprehensive Linear Programming (LP) model. The primary objective is to identify and allocate optimal budgets efficiently, ensuring the effective management of resources to combat a diverse range of diseases prevalent in the global healthcare landscape.

# Study Area

| Country | Region | Income Bracket |
|---|---|---|
| USA | N.America | High |
| Japan | Asia | High |
| Germany | Europe | High |
| U.K | Europe | High |
| Brazil | S.America | Upper Middle |
| China | Asia | Upper Middle |
| Indonesia | Asia | Upper Middle |
| India | Asia | Lower Middle |
| Nigeria | Africa | Lower Middle |
| D.R. Congo | Africa | Low |

Table: Americas: 2, Europe: 2, Asia: 4, Africa: 2

# Decision variables

We assumed expenditure on each disease in million USD units as decision variables.

- Decision variable: $X_{ij}$
- Where $X_{ij}$ is in million USD terms
- $i$ represents ith country and $j$ represents jth disease, total variables $=$ 10 x 10 $=$ 100.

| Diseases | Type |
|---|---|
| Tuberculosis (TB) | infectious |
| Malaria | parasite |
| Heart diseases | Life style |
| Cancer | Complex |
| Covid-19 | Pandemic |
| Asthma | Respiratory (Air pollution) |
| Nutrional | Poverty |
| infant mortality | Backwardness |
| trauma | injury |
| Parkinson's disease | Nervous system disorder |

Fig: Diseases selected

# Decision variables (Contd...)

| Country | Tuberculosis (TB) | Malaria | Cardiovascular Disease | Cancer | Covid-19 | Asthma | Malnutrition | infant mortality | trauma | Parkinson's disease |
|---|---|---|---|---|---|---|---|---|---|---|
| USA | x11 | x12 | x13 | x14 | x15 | x16 | x17 | x18 | x19 | x110 |
| Brazil | x21 | x22 | x23 | x24 | x25 | x26 | x27 | x28 | x29 | x210 |
| Japan | x31 | x32 | x33 | x34 | x35 | x36 | x37 | x38 | x39 | x310 |
| China | x41 | x42 | x43 | x44 | x45 | x46 | x47 | x48 | x49 | x410 |
| India | x51 | x52 | x53 | x54 | x55 | x56 | x57 | x58 | x59 | x510 |
| Indonesia | x61 | x62 | x63 | x64 | x65 | x66 | x67 | x68 | x69 | x610 |
| Nigeria | x71 | x72 | x73 | x74 | x75 | x76 | x77 | x78 | x79 | x710 |
| D.R Congo | x81 | x82 | x83 | x84 | x85 | x86 | x87 | x88 | x89 | x810 |
| Germany | x91 | x92 | x93 | x94 | x95 | x96 | x97 | x98 | x99 | x910 |
| U.K | x101 | x102 | x103 | x104 | x105 | x106 | x107 | x108 | x109 | x1010 |

Fig: All decision variables summarized

# Objective

- To maximize budget allocation efficiency for healthcare
- To minimize overall expenditure to help countries with constraints
- To reduce bias in budget allocation
- To develop a transparent mechanism for budget allocation
- To develop a LP model which can be applied easily in similar budget distribution at national level or state level

# Constraints

- Country level constraints
  1. $\sum_{i \leq 10} \sum_{j \leq 10} X_{ij} = \lambda_i$
  2. A country $i$ will have its own health budget $\lambda_i$
  3. Develop countries can overspend by 10% of their budget
  4. Developing countries can overspend by 2% of their budget (international donors)
- Disease level constraints
  1. $\sum_{j \leq 10} \sum_{i \leq 10} X_{ji} = \lambda_j$
  2. There are existing guidelines by WHO global expenditure required for a disease $\lambda_j$ to eradicate it by 2030 (Malaria, TB etc)
  3. For other diseases we used total death caused by that disease to total deaths by all 10 diseases and then fixed its budget $\lambda_j$ using that fraction.

# Analysis

- If we look closely we can see that the LP now resembles Transportation problem.
- All we need is cost matrix
- For cost matrix we used deaths per million from each disease in each country $p_{ij}$
- Then cost (marginal cost) would be $t_{ij} = \frac{C}{p_{ij}}$. Where C is a constant
- We choose the value of C as 1,00,000 as it was reducing the rounding error when converting to integer.

# Analysis (Cont...)

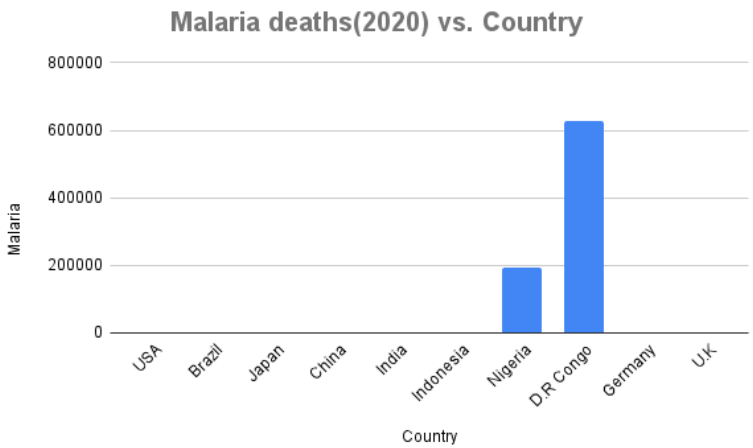
| Cost Matrix | Tuberculosis (TB) | Malaria | Cardiovascular Disease | Cancer | Covid-19 | Asthma | Malnutrition | infant mortality | trauma | Parkinson's disease |
|---|---|---|---|---|---|---|---|---|---|---|
| USA | 55548 | 3332876 | 75 | 73 | 94 | 11903 | 11110 | 20005 | 734 | 2198 |
| Brazil | 2796 | 371230 | 161 | 87 | 111 | 9174 | 3623 | 8 | 459 | 5208 |
| Japan | 6782 | 1000000000 | 119 | 88 | 3,616 | 27806 | 24391 | 50 | 2,395 | 4292 |
| China | 4413 | 14121750 | 136 | 71 | 29,488 | 7752 | 12820 | 20 | 540 | 2532 |
| India | 295 | 1523842 | 114 | 120 | 951 | 541 | 14286 | 4 | 683 | 2188 |
| Indonesia | 250 | 23832 | 113 | 89 | 1,234 | 746 | 874 | 5 | 720 | 2083 |
| Nigeria | 146 | 113 | 305 | 102 | 16,954 | 934 | 4237 | 1 | 614 | 1786 |
| D.R Congo | 188 | 15 | 355 | 97 | 16,226 | 482 | 840 | 2 | 361 | 2703 |
| Germany | 75071 | 1000000000 | 54 | 71 | 179 | 21726 | 66730 | 33 | 2,527 | 2353 |
| U.K | 33486 | 2232380 | 73 | 66 | 71 | 11627 | 111619 | 25 | 3,306 | 2321 |

Fig: Cost Matrix

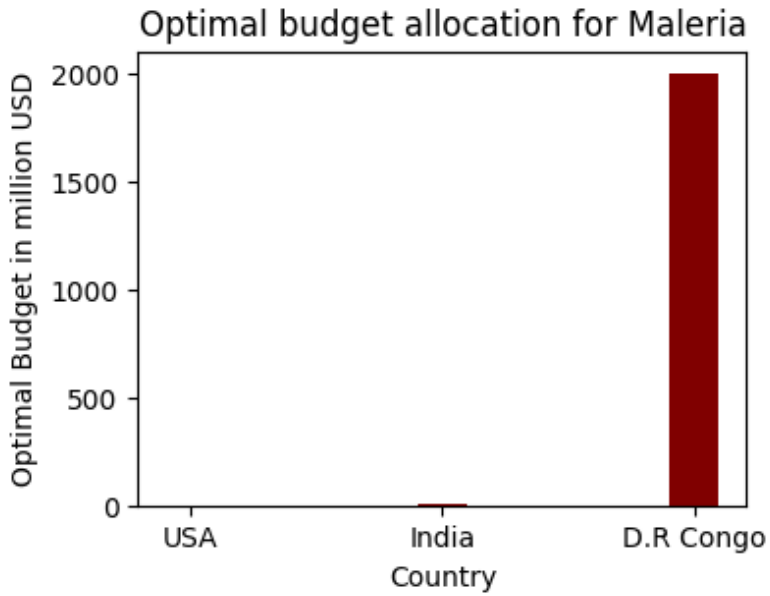
- Objective function: $\min \sum_{i \leq 10} \sum_{j \leq 10} t_{ij} * X_{ij}$
- Subject to:
  1. $\sum_{i \leq 10} \sum_{j \leq 10} X_{ij} = \lambda_i$
  2. $\sum_{j \leq 10} \sum_{i \leq 10} X_{ji} \leq \lambda_j$
  3. $X_{ij} \geq 0 \forall i \leq 10 \& j \leq 10$
- We used python to solve above formulated LP as Lingo has rate limit

# Interpretation

- On solving we get optimum healthcare expenditure globally = $ 9 trillion. for Other results check Juypter notebook. Analysing 3 diseases across three countries High (US), Middle(India), Low(DRC):



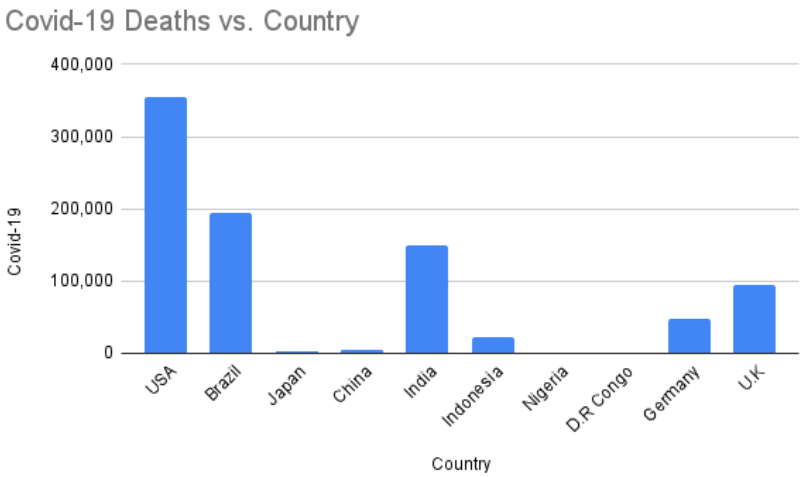

(a) Death caused by Malaria each country in 2020



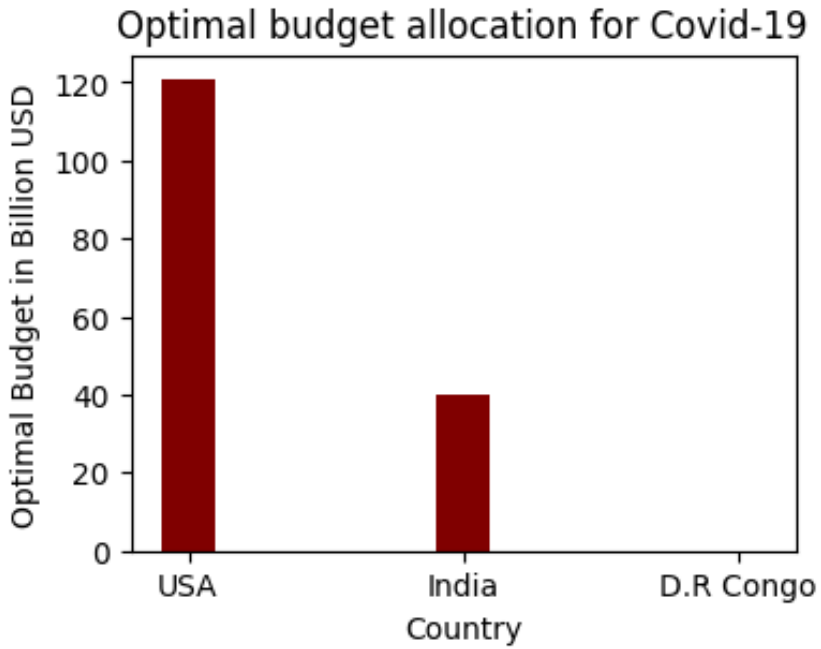

(b) Optimized Budget as per our LP

Fig: Malaria and DRC

# Interpretation (contd...)



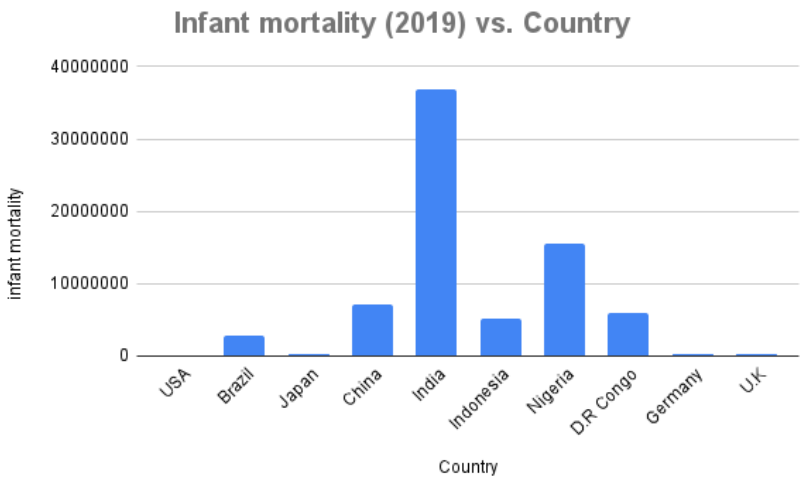

(a) Death caused by Covid-19 each country in 2020



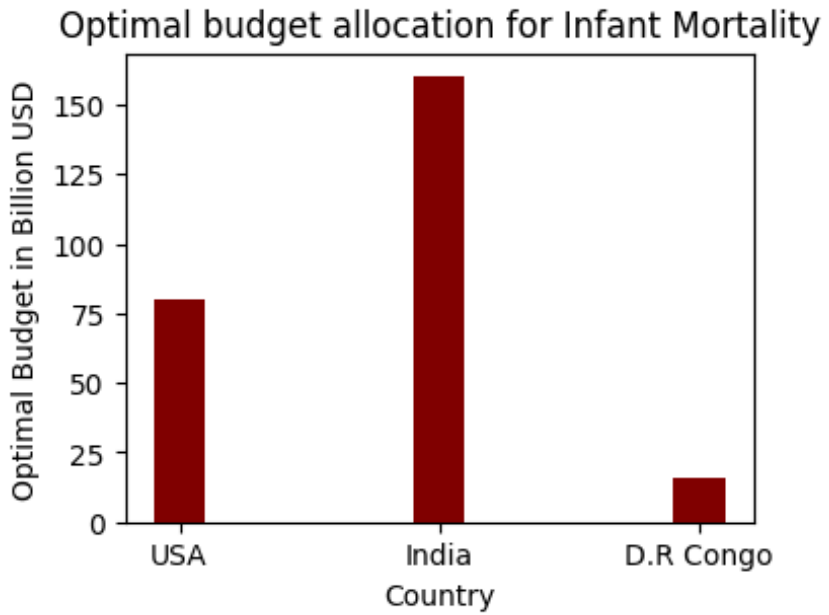

(b) Optimized Budget as per our LP

Fig: Covid-19 and USA

# Interpretation (contd...)




(a) Infant deaths each country in 2019




(b) Optimized Budget as per our LP

Fig: Infant Mortality and India

# Conclusions

- This allocation promises to not only address the immediate health challenges faced by nations but also lay the groundwork for a resilient and responsive healthcare system capable of adapting to future needs.
- Through the meticulous identification of crucial variables and the establishment of constraints, a comprehensive understanding of the nation's health landscape was achieved.
- The linear program, constructed with precision and powered by software despite the challenges posed by rate limits, will be a guiding light for decision-makers.

# References


- https://www.who.int/teams/global-tuberculosis-programme/tb-reports/global-tuberculosis-report-2022/tb-disease-burden/2-2-tb-mortality
- World Malaria report 2022 (WHO)
- WHO state of global health report 2020
- US CDC
- Detailed references in final paper.

“ Healthy citizens are the greatest asset any country can have. ”
*–Winston Churchill*

*Thank You*