The logistics of Covid vaccination

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Daniel Schludi - Unsplash

Coronavirus Vaccine

Coronavirus Vaccine Analytics & Decision Optimization

Problems

- Who should be vaccinated first
- Where to locate vaccination centers
- How many vaccines and how to get them to vaccination centers





United Nations - Unsplash

Who should be vaccinated first

Fusion Medical Animation - Unsplash



Transmission risk

The risk each person has to give the virus to someone else differs

- Some people are in regular contact with many other people due to their profession, lifestyle, etc. These are called **super spreaders**
- Other people only meet a very small and stable number of persons



Transmission risk

- Medical staff
- Politicians
- Customer-facing professionals
- Urban transportation workers
- Professors and teachers
- Artists and performers
- Workers in places of worship
- Detention centers
- Entrepreneurs / sales people



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Risk of death

The risk each person has of dying from Covid depends of their health condition

- Age (+65)
- Immunodeficiencies : diabetes, cancer, sida
- Other chronic illnesses : respiratory diseases, blood pressure, etc

Risk of death

- Older people
- Politicians
- People chronically ill
- Low-income people







Risks side by side



Transmission

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Data

Available data is usually not precise enough

- Number and frequency of contacts for each person
- Number of people with health conditions and their localization

Many decisions need to be based on imprecise estimates.





Vaccination policy

Countries create **vaccination policies** based on their appreciation of the risks involved

- Risk of death
- Risk of transmission
- Other external factors

In most countries the policy is to vaccinate elderly and medical staff first



Optimization theory

Optimization problems usually have **multiple objectives** that need to be simultaneously optimized

The search of solutions that are good enough on all objectives at the same time is named **robust optimization**. It started being studied in the 50s in economy and later moved to the field of optimization.

Location of vaccination centers

CDC- Unsplash

Vaccination center strategy

- Bring vaccines where the people that need it are
 - Hospitals, retirement homes, companies, etc.
- Bring the vaccines to places easily accessible by those that need to be vaccinated
 - Community centers, health centers, city halls, stadiums



Specificity

Specificity is the fact that all people vaccinated were high-priority (no vaccines were used in low priority people)

- In some parts of the US the vaccination of medical staff was done by appointment which has high specificity but sometimes people miss them
- Another approach is to vaccinate directly the hospital



Sensitivity

Sensitivity is the fact that all people that categorized as high priority were vaccinated (nobody was missed).



Vaccination centers

The location of vaccination centers is decided based on the geographic distribution of the high-priority population, itself approximated with the distribution of

- Income
- Seniority
- Health condition



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Seniority

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Optimization theory

The **facility location** problem was first studied in 1909 by Alfred Weber to locate warehouses. In the 60s started appearing mathematical models for facility location. Today facility location is a very active in optimization due to its many applications to logistics

How many vaccines and how to transport them

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Assortment of vaccines

There are 15 vaccines in phase III

- Various technologies and efficiencies
- 1, 2 or 3 doses at days 0, 14, 21 o 56
- Different transportation and storage requirements (cold containers, etc)
- Originating from different places in the world

Limitations in distribution

- In isolated areas it is better to send single dose vaccines
- Vaccines that require extreme cold storage shall be used in urban areas only









Vaccines distribution plan

The plan is similar to S&OP (sales & operations planning) done by many consumer good companies around the world

- A demand in each commune of the country
- Inventory is perishable
- Production plants have limited capacity
- Warehouses can be rented as well as consolidation centers
- Transportation by air, truck and sometimes river
- An assortment of products that can be partially substituted



Assortment of products to limit risk

Each "customer" location receives an **assortment of products** based on its profile (geography, type of population) in order to balance

- Incompatibility risks
 - An unknown variant appears to resists to some of the vaccines
 - A vaccine doesn't give good results on a subset of the population
- Supply risks
 - A supplier is unable to comply with the supply orders



Workforce planning



The workforce needs to be carefully planned, from nurses and doctors, to supporting positions like admin, cleaning, transportation



Mobile teams planning

The planning of mobile teams is complex for it combines the complexity of routing, resources planning and workforce planning (labor laws, rests, etc)





Optimization theory

The production and distribution planning problem (S&OP), and the detailed routing problem are typical logistic problems that companies need to solve on a regular basis. Tools to solve them have been improving from the 90s

Workforce optimization problems started getting attention in the 2000. Mobile workforce management is more recent.

