WORLD TUBERCULOSIS 2023

Correlation and prediction of Tuberculosis incidences and severity level according to health, socio-economic and environmental factors

Timo Lischke
Ironhack Data Analyst Bootcamp
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WHO TUBERCULOSIS REPORT 2024

Tuberculosis (TB) = contagious lung infection caused by
Mycobacterium tuberculosis (MTB) bacteria.
TB was the world´s leading infectious disease killer in 2023.
Worldwide 1.25 million people died due to TB in 2023.
Worldwide 10.8 million people fell ill with TB in 2023.
TB incidence rates per country over time reported.
Still no effective prevention (vaccine) available.
Bacillus Calmette-Guérin (BCG) subopt. vaccine statistics reported.
Only suboptimal treatment options available.
https://www.who.int/teams/global-tuberculosis-programme/data

DATA ACQUISITION & ENRICHMENT

Investigate correlation of TB incidences / severity level with:

- further disease-related information (treat.res. & BCG vac. rate)
- other health indicators (HIV, smoking rates)
- socio-economic (population density, multidim. poverty index)
- environmental (air pollution) circumstances

-> data obtained mostly via web scraping

DATA CLEANING AND WRANGLING

Preprocessing of data for modelling:

- all column names conclusive & lower case
- some columns dropped
- all values numerical
- still many null values, replaced with NaN
- no duplicated values
- country iso2 and iso3 codes introduced

-> Extensive cleaning needed before table merging

EXPLORATORY DATA ANALYSIS

Top 5 countries per world region displayed according to:

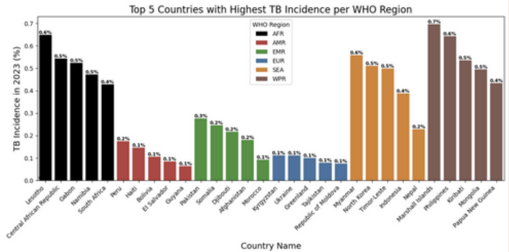
- TB incidences
- treatment resistance
- BCG vaccination rate
- population density
- poverty index
- smoking rates
- air pollution
- TB severity

Three-letter code of the 6 WHO regions:

- **AFR** → African Region
- **AMR** → Region of the Americas
- **EMR** → Eastern Mediterranean Region
- **EUR** → European Region
- **SEA** → South-East Asia Region
- **WPR** → Western Pacific Region

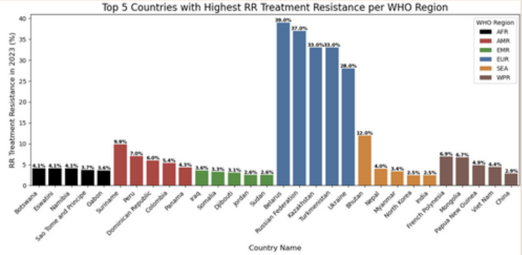
EDA: TB INCIDENCES

African & Asian countries have highest TB incidences



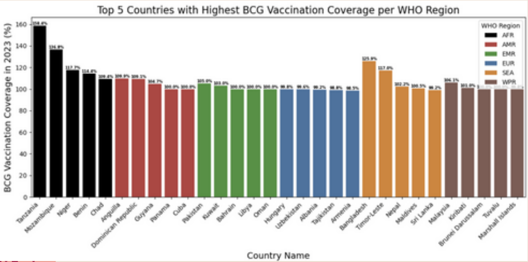
EDA: TREATMENT RESISTANCE

Resistance to rifampicin treatment highest in post-Soviet states



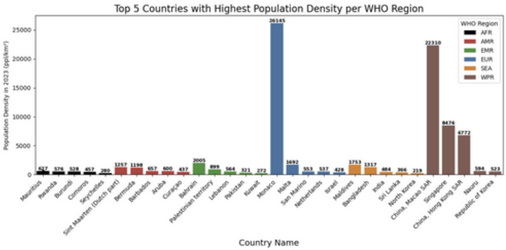
EDA: BCG VACCINATION COVERAGE

BCG vaccination rates generally high & highest in developing countries



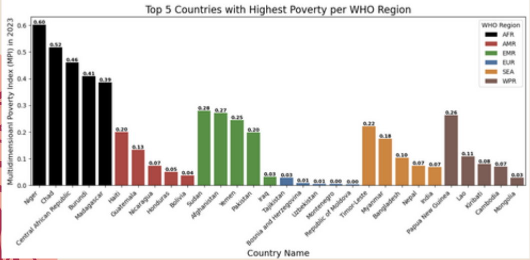
EDA: POPULATION DENSITY

Population density highest in city states



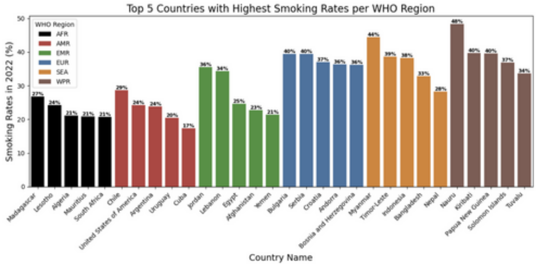
EDA: MULTIDIMENSIONAL POVERTY INDEX

Central Africa, Central America, & South/South East Asia have highest poverty



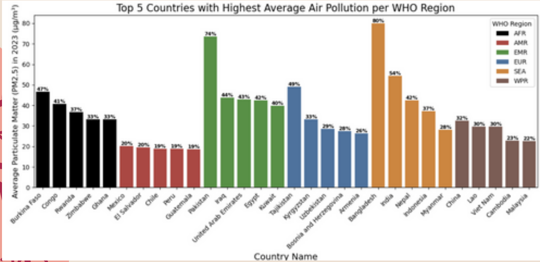
EDA: SMOKING RATE

Pacific, South East Asian, Eastern European & Arab countries have highest smoking rates



EDA: AIR POLLUTION

South Asian, Arab & Central African countries have highest air pollution

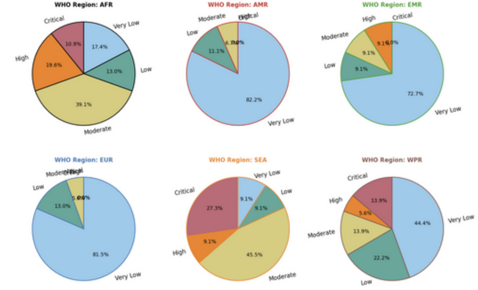


TB INCIDENCES -> TB SEVERITY LEVEL

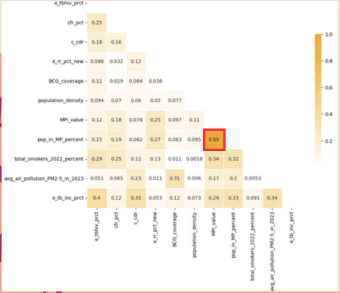
TB severity level defined as target

Based on SD intervals:
0.1% (Mean),
0.244% (Mean + 1 SD),
0.388% (Mean + 2 SD)

Levels of TB severity:
Very Low ⩽0.05%
Low ⩽ 0.1%
Moderate ⩽ 0.244%
High ⩽ 0.388%
Critical > 0.388%



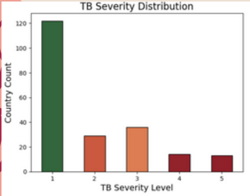
FEATURE ENGINEERING AND SELECTION



Correlation of features with TB incidence:
3 features from TB burden data set,
7 enriched features -> drop % pop in pov
-> 9 features for model

DATA PREPARATION FOR PREDICTION MODELLING

total 214 countries: train & test split = 171 (80%) & 43 (20%)
normalization: Min/Max scaling, tuning: hyperparameters
balancing: impute NaN -> SMOTE, class weighting




```
RangeIndex: 214 entries, 0 to 213
Data columns (total 9 columns):
 #   Column                             Non-Null Count
---  ------                             --------------
 0   e_tbhiv_prct                       214 non-null
 1   cfr_pct                            196 non-null
 2   c_cdr                              192 non-null
 3   e_rr_pct_new                       214 non-null
 4   BCG_coverage                       156 non-null
 5   population_density                 214 non-null
 6   MPI_value                          109 non-null
 7   total_smokers_2022_percent         164 non-null
 8   avg_air_pollution_PM2-5_in_2023    131 non-null
dtypes: float64(9)
```

PREDICTION OF TB SEVERITY USING ML MODELS

Implement **supervised ML models** to predict TB severity levels

Ensemble prediction model testing:

- HistGradientBoostingClassifier
- RandomForestClassifier (DecTree + RandPatch)

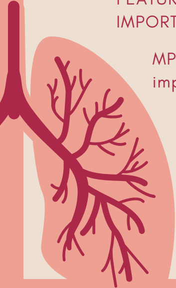
Model optimization:

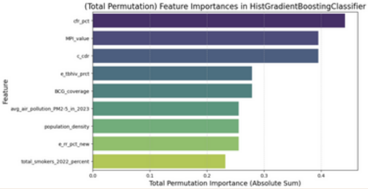
- hyperparameter tuning for HGBC model
- impute missing NaN using KNN
- target parameter balancing using SMOTE or Class Weight balancing on RFC model

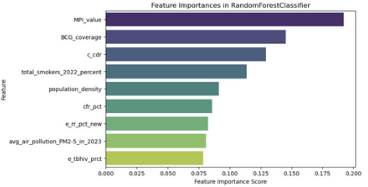
EVALUATION

FEATURE IMPORTANCE

MPI highest importance







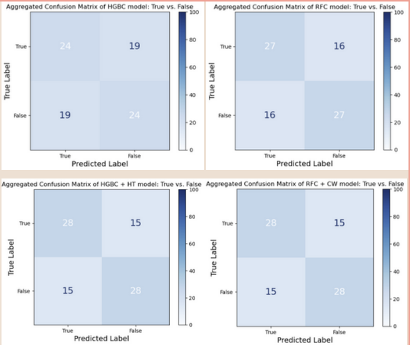
EVALUATE PREDICTION MODEL´S PERFORMANCE

model	precision	recall	F1-score	accuracy
HistGradBoost	0.59	0.56	0.54	0.56
Random Forest	0.48	0.63	0.54	0.63
RFC + CW	0.47	0.65	0.54	0.65
RFC + SMOTE	0.58	0.49	0.47	0.49
RFC(CW)+SMOTE	0.38	0.40	0.38	0.40
HGBC_HT	0.47	0.65	0.54	0.65

EVALUATION

CONFUSION MATRICES

HGBC improved after HT
RFC improved with CW



PREDICTION OF TB SEVERITY USING ML MODELS

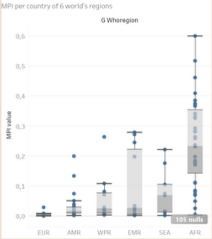
Implement **unsupervised ML models** to predict TB severity levels

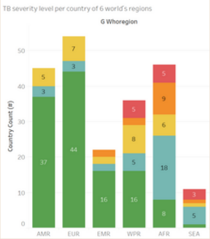
Clustering prediction model testing:

- no train/test split, use whole data for clustering
- impute missing NaN using KNN, Min/Max norm.
- KMeans clustering (not useful)
  - Adjusted Rand Index (ARI): -0.0361 (similarity)
  - Normalized Mutual Information (NMI): 0.0378 (dep.)
- create dendrogram to determine cluster no.
- Hierarchical clustering (not useful either)
  - Adjusted Rand Index (ARI): 0.1552 (similarity)
  - Normalized Mutual Information (NMI): 0.1043 (dep.)

TABLEAU VISUALIZATIONS

Cloropleth world maps of TB incidence, BCG vaccination coverage & MPI.
Stacked bar chart of TB severity level, box-whiskers of MPI in 6 world regions.





poverty levels (based on MPI):
No Poverty <= 0.10
Mild Poverty <= 0.20
Moderate Poverty <= 0.35
Severe Poverty <= 0.50
Extreme Poverty > 0.50

https://public.tableau.com/app/profile/timo.lischke/viz/TB_severity_level_Timo/TB_severity

KEY FINDINGS AND INSIGHTS

Key Findings:

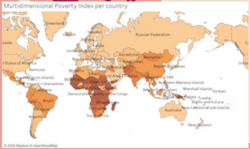
- TB remains to be a severe global health problem
- TB severity: EUR = AMR < EMR < WPR < SEA = AFR
- MPI is feature showing highest correlation with TB severity
- AVG MPI: EUR < AMR < WPR < EMR < SEA < AFR

Insights:

- selected features do not correlate strongly with target
- ML prediction models work poorly
- RFC + CW and HGBC + HT work best

REAL WORLD APPLICATION AND IMPACT

Application:
Aiming to predict TB severity for future years (not accomplished yet) in order to take preventive measures



Impact:

- Need to reduce poverty
- Need to develop an effective vaccine
- Need to develop new treatment options

CHALLENGES AND LEARNINGS

Challenges:

- define & find meaningful data for enrichment
- frequent null values / incomplete data
- low number of rows, i.e. countries
- inconsistant annotation / naming of data

Learnings:

- take good care when selecting data
- biological/medical data are often incomplete

FUTURE WORK & IMPROVEMENTS

Improve data set:

- fill in / impute missing values for 2023
- include data of years before 2023
- find other data for enrichment with higher correlation to target (gender, age, malnutrition, diabetes, alcoholism, urbanization rate, health care access & quality index, ...)

Improve supervised ML models:

- run time corrleated predictions

Improve unsupervised clustering models:

- Perform PCA before running unsupervised clustering models to reduce noise and redundant features.
- Experiment with different values of K for Kmeans (e.g., using the Elbow Method or Silhouette Score).
- Consider other clustering algorithms like DBSCAN.

THANK YOU !

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(based on WHO Tuberculosis report 2024)

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