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HDPSA

Milestone 1

BIN381 Group A

9/9/2025

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# Background

**Dataset Context**

This project analyses South African health datasets from the Health Data Platform South Africa (HDPSA), comprising 13 national-level datasets following DHS format covering:

* Healthcare access and mortality rates
* Child and maternal health indicators
* Nutrition and immunization data
* Disease prevention and management
* Social determinants (literacy, water, sanitation)

**CRISP-DM Methodology**

This project follows the CRISP-DM (Cross-Industry Standard Process for Data Mining) methodology, a structured approach for data science projects consisting of six phases:

1. **Business Understanding** - Define objectives and requirements.
2. **Data Understanding** - Collect, describe, and explore data.
3. **Data Preparation** - Clean and transform data for analysis.
4. **Modelling** - Apply analytical techniques.
5. **Evaluation** - Assess model performance and business value.
6. **Deployment** - Plan implementation and monitoring

CRISP-DM provides a proven framework for systematic data analysis, ensuring comprehensive coverage of all project aspects from business objectives through to deployment, making it ideal for this health data analysis project.

# Business Objectives and Success Criteria Definition

## **Business Relevance**

Understanding patterns across these interconnected health domains is crucial for:

* Government policy formulation and resource allocation
* Non-profit organizations targeting health interventions.
* International development agencies supporting health programs.
* Healthcare providers planning service delivery.
* Researchers investigating social determinants of health.

The comprehensive nature of this data collection allows for multifaceted analysis revealing relationships between healthcare access, socioeconomic factors, and health outcomes, providing actionable insights for improving population health in South Africa.

## **Business Problem and Objectives**

**Business Problem:**  
Despite numerous past interventions, vulnerable populations in South Africa still experience poor healthcare outcomes due to systematic issues like sanitation, lack of clean water and healthcare access. Stakeholders require reliable, data-driven insights to understand the relationships between living conditions, healthcare access, and healthcare risks.

**Business Objectives:**

* Provide actionable insights that stakeholders can use to target interventions more effectively.
* Discover the key factors that are currently contributing to poor health outcomes, for example clean water, sanitation, literacy etc.
* Develop interactive dashboards and reports that make complex data easy to understand.
* Identify high-risk regions and communities based on demographic and health indicators.

## **Stakeholders and Their Requirements**

|  |  |  |
| --- | --- | --- |
| Stakeholder | Requirements | Example KPI |
| Government (Department of Health) | Identify provinces with the high health risks and resource gaps. | Reduction in child mortality rates (%). |
| NGOs/NPOs | Prioritize regions for campaigns (HIV prevention, sanitation, immunization) | Increase in immunization coverage (%). |
| Healthcare Providers and Clinics | Understand the population needs and healthcare access issues. | Clinic to population ratio. |
| Researchers/Academics | Access to structured datasets and insights for policy studies. | Number of published findings. |

**Success Criteria**

**Analytical Success:**

* Build models (classification, clustering, association rules) that achieve acceptable performance (for example, prediction accuracy > 70%).
* Identify meaningful clusters with similar healthcare challenges.
* Extract meaningful rules (for example, low literacy + no sanitation = high ARI risk).

**Business Success:**

* Insights led to practical recommendations for healthcare and community interventions.
* Dashboards highlight priority areas for intervention (geographic or demographic).
* Stakeholders confirm results are useful for guiding decision-making.

# Inventory of Resources Assessment

## **Data Resources**

**Primary Datasets**

13 HDPSA (Health Data Platform South Africa) datasets in DHS (Demographic and Health Surveys) format:

* access-to-health-care\_national\_zaf.csv
* anthropometry\_national\_zaf.csv
* child-mortality-rates\_national\_zaf.csv
* covid-19-prevention\_national\_zaf.csv
* dhs-quickstats\_national\_zaf.csv
* hiv-behavior\_national\_zaf.csv
* immunization\_national\_zaf.csv
* iycf\_national\_zaf.csv
* literacy\_national\_zaf.csv
* maternal-mortality\_national\_zaf.csv
* symptoms-of-acute-respiratory-infection-ari\_national\_zaf.csv
* toilet-facilities\_national\_zaf.csv
* water\_national\_zaf.csv

**Data Processing Pipeline**

* **01\_Raw/**: Original datasets
* **02\_Cleaned/**: Processed data with empty records removed
* **03\_Processed/**: Feature engineered data
* **04\_Scaled/**: Scaled and encoded data ready for analysis

**Documentation**

* **Data\_Dictionary.md**: Field definitions and structure
* **Data\_Pipeline.md**: Processing methodology

**Technical Tools**

**Analysis Software**

* **R**: Statistical analysis and data processing
* **R Markdown**: Reproducible reporting and documentation
* **Power BI**: Interactive dashboards and visualizations
* **Web Technologies**: Interactive components for stakeholder review

**Development Environment**

* Integrated development environment for R and Python
* Version control and collaboration tools
* Data visualization libraries and packages

# Risks, Assumptions and Constraints

## **Risks**

A primary risk that we could face is having missing or incomplete data within our dataset. This compromises the accuracy and integrity of the data analysed. Such gaps can lead to a skewed and inaccurate understanding of South African healthcare. This issue extends not only from simple data gaps, such as rural population or specific age brackets.

Relying on national-level data may overshadow regional results, which could lead to misconceptions, causing generalized insights that fail to address specific situations faced by each province and/or community.

Finally, time limitations for modelling and cleaning data could force teams assigned to the project to take shortcuts and cut corners. This leads to sub-par model selections and fills the dataset with errors ranging from insignificant to major, reducing the reliability of the recorded datasets.

## **Assumptions**

There are two fundamental assumptions made for this project. Firstly, all datasets provided will be accurate and a true representation of the population. This assumes that the Demographic and Health Surveys (DHS) are accurate and provide a proper representation of the nation's varied demographic and health environment. It further assumes that sampling (collection, cleaning, storage, etc.) will be bias-free.

Secondly, we assume that stakeholders will use the data collected as actionable insights to enhance healthcare policies. This is a critical component of the project's impact since it assumes organizational buy-in and a commitment to convert data-driven conclusions into concrete policy changes.

## **Constraints**

Since there is no provision for primary data collection, the project’s reliance on the provided datasets represents its biggest limitation. As a result, any research questions not covered by the 13 available datasets cannot be addressed, as the analysis is tightly constrained by existing information. The team is therefore unable to confirm findings using fresh data, making the integrity of the HDPSA datasets crucial to the project’s overall conclusions.

Additionally, most of the datasets are cross-sectional, which makes it difficult to examine patterns or the long-term effects of health-related factors over time. This limitation significantly reduces the possibility of conducting longitudinal research.

# Data Mining Goals and Success Criteria

## **Data-Mining Goals**

1. **Predictive Modelling of Health Risks:**  
   Develop classification models to predict high-risk populations and regions based on socioeconomic and healthcare access variables, aiming for prediction accuracy above 70%.
2. **Clustering of Communities by Health Challenges:**  
   Identify meaningful clusters of communities with similar healthcare access issues and health outcomes to enable targeted interventions.
3. **Association Rule Mining for Key Risk Factors:**  
   Extract actionable association rules that reveal combinations of factors (e.g., low literacy and poor sanitation) strongly linked to adverse health outcomes.
4. **Geospatial Analysis for Priority Area Identification:**  
   Analyse geographic patterns to pinpoint provinces and districts with the greatest healthcare resource gaps and health risks.
5. **Interactive Dashboard Development:**  
   Create user-friendly dashboards that visualize complex data and model results, facilitating stakeholder understanding and decision-making.
6. **Data Structuring and Integration for Research Use:**  
   Prepare and structure datasets to support researchers and policymakers in conducting further studies on social determinants of health.

## **Data-Mining Success Criteria**

1. **Model Performance Benchmarks:**  
   Classification models must achieve a minimum prediction accuracy of 70% or higher on validation datasets to be considered successful.
2. **Meaningful Pattern Discovery:**  
   Clustering and association rule mining should identify interpretable and actionable patterns, such as clusters of communities with similar health risks and rules linking key factors (e.g., sanitation, literacy) to health outcomes, validated by domain experts.
3. **Stakeholder Validation and Usefulness:**  
   Insights and visualizations must be confirmed by stakeholders (government, NGOs, healthcare providers) as relevant and useful for guiding targeted health interventions and resource allocation.
4. **Deployment and Accessibility:**  
   Interactive dashboards and reports must be successfully deployed and accessible to all key stakeholders, enabling real-time decision-making and ongoing monitoring of health indicators.

# Detailed Descriptions of HDPSA Datasets

This document profiles 12 aggregated datasets compiled for the HDPSA project. Each dataset summarises key indicators from nationally representative surveys conducted in South Africa. The profiling includes variable definitions, data types, ranges, distributions, structural characteristics, and methodological notes.

## **1. Access to Health Care (national, ZAF)**

Focus: Accessibility of primary healthcare services, including facility distance, travel time, barriers to access, and antenatal/postnatal coverage.

* Variables: Distance to facility (categorical, <30 mins, 30–59 mins, ≥1 hour); medical aid coverage (binary, yes/no); ANC visits (numeric, 0–10).
* Data types: Categorical, binary, and numeric.
* Value ranges: Proportions 0–100%.
* Distributions: Typically, right skewed for distance/time, normalized percentages for service coverage.
* Structure: Aggregated proportions, stratified by sex, age, and urban/rural.

## **2. Anthropometry (national, ZAF)**

Focus: Nutritional status of children under five years.

* Variables: Stunting (height-for-age z-score < −2), wasting (weight-for-height z-score < −2), underweight (weight-for-age z-score < −2), overweight.
* Data types: Numeric (z-scores) and categorical (prevalence categories).
* Value ranges: Z-scores typically between −6 and +6; prevalence reported as %.
* Distributions: Bell-shaped for z-scores, prevalence clustered around WHO thresholds.
* Structure: National proportions disaggregated by age group and sex.

## **3. Child Mortality Rates (national, ZAF)**

Focus: Neonatal, infant, and under-five mortality.

* Variables: Neonatal mortality (deaths <28 days), infant mortality (<1 year), under-five mortality (<5 years).
* Data types: Numeric (per 1,000 live births).
* Value ranges: Typically, 10–60 per 1,000.
* Distributions: Declining trend over years; higher in rural/poorer quintiles.
* Structure: Time-series rates derived from retrospective birth histories.

## **4. COVID-19 Prevention (national, ZAF)**

Focus: Behavioural and preventive practices during COVID-19.

* Variables: Mask usage (binary), handwashing frequency (ordinal), vaccination awareness (binary).
* Data types: Binary, categorical.
* Value ranges: 0–100% prevalence.
* Distributions: Skewed towards high uptake of basic preventive measures.
* Structure: Cross-sectional, age/sex disaggregation.

## **5. HIV Behaviour (national, ZAF)**

Focus: Risk behaviours and HIV-related knowledge.

* Variables: Condom use at last sex (binary), multiple partners (numeric), HIV testing history (binary), knowledge of PMTCT (binary).
* Data types: Binary, numeric.
* Value ranges: Binary (0/1), proportions 0–100%.
* Distributions: Urban/rural differences; higher condom use among youth.
* Structure: Individual-level survey items aggregated nationally.

## **6. Immunisation (national, ZAF)**

Focus: Child vaccination coverage.

* Variables: BCG, DPT, Polio, Measles, PCV, Rotavirus, fully immunised (binary/coverage %).
* Data types: Binary and percentage.
* Value ranges: 0–100%.
* Distributions: Skewed towards high coverage for BCG, lower for measles.
* Structure: Aggregated for children 12–23 months.

## **7. Infant and Young Child Feeding (IYCF) (national, ZAF)**

Focus: Breastfeeding and complementary feeding.

* Variables: Early initiation, exclusive breastfeeding (0–5 months), minimum dietary diversity (6–23 months).
* Data types: Binary, categorical.
* Value ranges: 0–100% prevalence.
* Distributions: Exclusive breastfeeding low, dietary diversity uneven across wealth quintiles.
* Structure: Aggregated by child age bands.

## **8. Literacy (national, ZAF)**

Focus: Household literacy and education proxies.

* Variables: Adult literacy (binary: can read a sentence), education attainment (categorical levels).
* Data types: Binary, categorical.
* Value ranges: 0–100%.
* Distributions: Urban–rural disparities; female literacy lower in certain regions.
* Structure: Aggregated national proportions.

## **9. Maternal Mortality (national, ZAF)**

Focus: Maternal health outcomes.

* Variables: Maternal mortality ratio (numeric, per 100,000 live births), skilled birth attendance (binary), facility delivery (binary).
* Data types: Numeric, binary.
* Value ranges: Ratios typically 100–500.
* Distributions: Higher ratios in rural provinces.
* Structure: Modelled estimates with survey indicators.

## **10. Symptoms of Acute Respiratory Infection (ARI) (national, ZAF)**

Focus: Prevalence of ARI symptoms among under-fives.

* Variables: Cough, rapid breathing, care-seeking for ARI.
* Data types: Binary, categorical.
* Value ranges: Prevalence typically 5–20%.
* Distributions: Higher among poorer households.
* Structure: Two-week recall aggregated nationally.

## **11. Toilet Facilities (national, ZAF)**

Focus: Sanitation access.

* Variables: Toilet type (improved/unimproved), shared facility (binary).
* Data types: Categorical, binary.
* Value ranges: 0–100% proportions.
* Distributions: Skewed by urban–rural divide.
* Structure: Aggregated at national level.

## **12. Water (national, ZAF)**

Focus: Drinking water access.

* Variables: Source type (improved/unimproved), on-premises availability, time to fetch.
* Data types: Categorical, binary.
* Value ranges: 0–100% prevalence.
* Distributions: Improved sources dominant in urban areas, longer collection times in rural.
* Structure: Aggregated proportions nationally.

# Data Sources and Methodology

All datasets are based on the South Africa Demographic and Health Survey (SADHS) 2016 and related national health surveys. The SADHS employed a two-stage stratified cluster sampling design: in the first stage, 750 enumeration areas (EAs) were selected from the national sampling frame, stratified by province and urban/rural status. In the second stage, households were systematically sampled within EAs. A total of 11,083 households were selected, with interviews conducted for 8,514 women (15–49 years) and 3,618 men (15–59 years) (Statistics South Africa et al., 2017).

Indicators such as anthropometry and immunisation were collected through biomarker measurements and vaccination card/recall, while literacy and access to services were captured via household and individual questionnaires. Mortality estimates were derived from retrospective birth histories.

# Data Understanding

## Load All Datasets

base <- "../../Data/01\_Raw"  
# Optional: set to TRUE to write CSV exports alongside this HTML  
write\_exports <- FALSE  
# Optional: print full duplicate rows if count <= this threshold (to avoid huge output)  
dup\_print\_threshold <- 200L  
  
# Debug: check working directory and if base path exists  
cat("Working directory:", getwd(), "\n")

## Working directory: C:/Users/edcul/OneDrive/Documents/Work/Modules/Year 3/BIN381/data-analysis-dashboard/02\_Project/Milestone\_1/BIN381\_M1\_R

cat("Base path exists:", dir.exists(base), "\n")

## Base path exists: TRUE

cat("Base path contents:", length(list.files(base)), "files\n")

## Base path contents: 13 files

# Detect files  
files\_csv <- list.files(base, pattern = "\\.(csv)$", ignore.case = TRUE, full.names = TRUE)  
files\_xlsx <- list.files(base, pattern = "\\.(xlsx)$", ignore.case = TRUE, full.names = TRUE)  
  
# Read helpers  
read\_csv\_clean <- function(path){  
 # Read first line as headers, skip the comment line  
 headers <- readr::read\_lines(path, n\_max = 1)  
 readr::read\_csv(path, show\_col\_types = FALSE, skip = 2, col\_names = strsplit(headers, ",")[[1]]) |> janitor::clean\_names()  
}  
read\_xlsx\_all <- function(path){  
 sh <- readxl::excel\_sheets(path)  
 setNames(  
 purrr::map(sh, ~ readxl::read\_excel(path, sheet = .x) |> janitor::clean\_names() |> as\_tibble() ),  
 paste0(tools::file\_path\_sans\_ext(basename(path)), "\_\_", sh)  
 )  
}  
  
# Load data  
dfs\_csv <- purrr::map(files\_csv, read\_csv\_clean); names(dfs\_csv) <- tools::file\_path\_sans\_ext(basename(files\_csv))  
dfs\_xlsx <- purrr::map(files\_xlsx, read\_xlsx\_all); dfs\_xlsx <- if(length(dfs\_xlsx)) purrr::list\_flatten(dfs\_xlsx) else list()  
dfs <- c(dfs\_csv, dfs\_xlsx)  
  
# Ensure unique names  
if(length(dfs)){  
 names(dfs) <- make.unique(names(dfs), sep = "\_")  
}  
  
# Inventory  
inventory <- tibble(  
 dataset = names(dfs),  
 rows = purrr::map\_int(dfs, nrow),  
 cols = purrr::map\_int(dfs, ncol)  
) |> arrange(dataset)  
  
if(nrow(inventory) == 0){  
 stop("No datasets found. Place this .Rmd in the folder with your CSV/XLSX files and Knit again.")  
}  
  
gt::gt(inventory)

| dataset | rows | cols |
| --- | --- | --- |
| access-to-health-care\_national\_zaf | 275 | 29 |
| anthropometry\_national\_zaf | 37 | 29 |
| child-mortality-rates\_national\_zaf | 40 | 29 |
| covid-19-prevention\_national\_zaf | 34 | 29 |
| dhs-quickstats\_national\_zaf | 52 | 29 |
| hiv-behavior\_national\_zaf | 118 | 29 |
| immunization\_national\_zaf | 116 | 29 |
| iycf\_national\_zaf | 22 | 29 |
| literacy\_national\_zaf | 20 | 29 |
| maternal-mortality\_national\_zaf | 21 | 29 |
| symptoms-of-acute-respiratory-infection-ari\_national\_zaf | 26 | 29 |
| toilet-facilities\_national\_zaf | 46 | 29 |
| water\_national\_zaf | 100 | 29 |

## Dataset-Level Summary

dataset\_summary <- purrr::imap\_dfr(dfs, function(df, nm){  
 n\_rows <- nrow(df); n\_cols <- ncol(df)  
 dup\_rows <- sum(duplicated(df))  
 total\_cells <- n\_rows \* n\_cols  
 miss\_cells <- sum(is.na(df))  
 miss\_pct <- if (total\_cells > 0) round(100 \* miss\_cells / total\_cells, 2) else 0  
 num\_cols <- df |> dplyr::select(where(is.numeric)) |> ncol()  
 tibble(  
 dataset = nm,  
 rows = n\_rows,  
 cols = n\_cols,  
 duplicate\_rows = dup\_rows,  
 missing\_cells = miss\_cells,  
 missing\_pct = miss\_pct,  
 numeric\_cols = num\_cols,  
 categorical\_cols = n\_cols - num\_cols  
 )  
}) |> arrange(dataset)  
  
gt::gt(dataset\_summary)

| dataset | rows | cols | duplicate\_rows | missing\_cells | missing\_pct | numeric\_cols | categorical\_cols |
| --- | --- | --- | --- | --- | --- | --- | --- |
| access-to-health-care\_national\_zaf | 275 | 29 | 0 | 1181 | 14.81 | 13 | 16 |
| anthropometry\_national\_zaf | 37 | 29 | 0 | 193 | 17.99 | 13 | 16 |
| child-mortality-rates\_national\_zaf | 40 | 29 | 0 | 192 | 16.55 | 15 | 14 |
| covid-19-prevention\_national\_zaf | 34 | 29 | 0 | 174 | 17.65 | 13 | 16 |
| dhs-quickstats\_national\_zaf | 52 | 29 | 0 | 249 | 16.51 | 15 | 14 |
| hiv-behavior\_national\_zaf | 118 | 29 | 0 | 667 | 19.49 | 13 | 16 |
| immunization\_national\_zaf | 116 | 29 | 0 | 536 | 15.93 | 13 | 16 |
| iycf\_national\_zaf | 22 | 29 | 0 | 114 | 17.87 | 13 | 16 |
| literacy\_national\_zaf | 20 | 29 | 0 | 104 | 17.93 | 13 | 16 |
| maternal-mortality\_national\_zaf | 21 | 29 | 0 | 133 | 21.84 | 15 | 14 |
| symptoms-of-acute-respiratory-infection-ari\_national\_zaf | 26 | 29 | 0 | 120 | 15.92 | 13 | 16 |
| toilet-facilities\_national\_zaf | 46 | 29 | 0 | 238 | 17.84 | 13 | 16 |
| water\_national\_zaf | 100 | 29 | 0 | 508 | 17.52 | 13 | 16 |

## Data Quality Assessment

## Missing Values (Per Column, All Datasets)

# Get all unique column names across datasets  
all\_columns <- unique(unlist(lapply(dfs, names)))  
  
# Create 2D table: rows = datasets, columns = fields, values = missing counts  
missingness\_2d <- purrr::imap\_dfr(dfs, function(df, nm){  
 total\_rows <- nrow(df)  
   
 # Create row for this dataset with all possible columns  
 row\_data <- tibble(dataset = nm)  
 for(col in all\_columns) {  
 if(col %in% names(df)) {  
 missing\_count <- sum(is.na(df[[col]]))  
 # If all entries are missing, the field effectively doesn't exist  
 if(missing\_count == total\_rows) {  
 row\_data[[col]] <- "N/A"  
 } else {  
 row\_data[[col]] <- as.character(missing\_count)  
 }  
 } else {  
 # Column doesn't exist in this dataset  
 row\_data[[col]] <- "N/A"  
 }  
 }  
 row\_data  
})  
  
# Display the 2D table with heatmap background colors  
numeric\_cols <- names(missingness\_2d)[-1] # exclude 'dataset' column  
  
# Create numeric version for gt color scaling  
missingdata <- missingness\_2d  
for(col in numeric\_cols) {  
 missingdata[[col]] <- ifelse(missingness\_2d[[col]] == "N/A", NA, as.numeric(missingness\_2d[[col]]))  
}  
  
# Get the actual range of values for proper scaling  
all\_values <- unlist(missingdata[numeric\_cols])  
all\_values <- all\_values[!is.na(all\_values)]  
max\_val <- if(length(all\_values) > 0) max(all\_values) else 1  
# Display a simplified missing values table that fits on A4  
print("Creating missing values table...")

## [1] "Creating missing values table..."

gt::gt(missingdata) |>  
 gt::tab\_header(title = "Missing Values (Count) - 2D View") |>  
 gt::data\_color(  
 columns = all\_of(numeric\_cols),  
 palette = c("white", "darkred"),  
 domain = c(0, max\_val),  
 na\_color = "lightgray"  
 ) |>  
 gt::fmt\_missing(columns = all\_of(numeric\_cols), missing\_text = "N/A") |>  
 gt::tab\_options(  
 table.font.size = px(8),  
 column\_labels.font.size = px(8),  
 data\_row.padding = px(2)  
 )

Table : Missing Values (Count) - 2D View

| dataset | iso3 | data\_id | indicator | value | precision | dhs\_country\_code | country\_name | survey\_year | survey\_id | indicator\_id | indicator\_order | indicator\_type | characteristic\_id | characteristic\_order | characteristic\_category | characteristic\_label | by\_variable\_id | by\_variable\_label | is\_total | is\_preferred | sdrid | region\_id | survey\_year\_label | survey\_type | denominator\_weighted | denominator\_unweighted | ci\_low | ci\_high | level\_rank |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| access-to-health-care\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | N/A | 0 | 0 | 34 | 34 | N/A | N/A | N/A |
| anthropometry\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | N/A | 0 | 0 | 0 | N/A | 0 | 0 | 4 | 4 | N/A | N/A | N/A |
| child-mortality-rates\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | N/A | 0 | 0 | 36 | 36 | 10 | 10 | N/A |
| covid-19-prevention\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | N/A | 0 | 0 | 0 | N/A | 0 | 0 | 2 | 2 | N/A | N/A | N/A |
| dhs-quickstats\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 0 | 0 | 0 | N/A | 0 | 0 | 18 | 18 | 38 | 38 | N/A |
| hiv-behavior\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | N/A | 0 | 0 | 0 | N/A | 0 | 0 | 39 | 38 | N/A | N/A | N/A |
| immunization\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 56 | 0 | 0 | 0 | N/A | 0 | 0 | 8 | 8 | N/A | N/A | N/A |
| iycf\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | N/A | 0 | 0 | 0 | N/A | 0 | 0 | 2 | 2 | N/A | N/A | N/A |
| literacy\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | N/A | 0 | 0 | 0 | N/A | 0 | 0 | 2 | 2 | N/A | N/A | N/A |
| maternal-mortality\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | N/A | 0 | 0 | 0 | N/A | 0 | 0 | 19 | 15 | 18 | 18 | N/A |
| symptoms-of-acute-respiratory-infection-ari\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | N/A | 0 | 0 | 8 | 8 | N/A | N/A | N/A |
| toilet-facilities\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | N/A | 0 | 0 | 0 | N/A | 0 | 0 | 4 | 4 | N/A | N/A | N/A |
| water\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | N/A | 0 | 0 | 0 | N/A | 0 | 0 | 4 | 4 | N/A | N/A | N/A |

## Duplicates (Row-Level)

# Count duplicates per dataset (across all columns)  
dup\_summary <- purrr::imap\_dfr(dfs, function(df, nm){  
 tibble(dataset = nm, duplicate\_rows = sum(duplicated(df)))  
}) |> arrange(desc(duplicate\_rows))  
  
# Create 2D table: datasets as rows, duplicate\_rows as column  
dup\_2d <- dup\_summary |>  
 select(dataset, duplicate\_rows)  
  
# Apply heatmap styling to duplicates table  
max\_dup\_val <- max(dup\_2d$duplicate\_rows, na.rm = TRUE)  
  
gt::gt(dup\_2d) |>  
 gt::tab\_header(title = "Duplicate Rows Count - 2D View") |>  
 gt::data\_color(  
 columns = duplicate\_rows,  
 palette = c("white", "darkred"),  
 domain = c(0, max\_dup\_val),  
 na\_color = "lightgray"  
 )

Table : Duplicate Rows Count - 2D View

| dataset | duplicate\_rows |
| --- | --- |
| access-to-health-care\_national\_zaf | 0 |
| anthropometry\_national\_zaf | 0 |
| child-mortality-rates\_national\_zaf | 0 |
| covid-19-prevention\_national\_zaf | 0 |
| dhs-quickstats\_national\_zaf | 0 |
| hiv-behavior\_national\_zaf | 0 |
| immunization\_national\_zaf | 0 |
| iycf\_national\_zaf | 0 |
| literacy\_national\_zaf | 0 |
| maternal-mortality\_national\_zaf | 0 |
| symptoms-of-acute-respiratory-infection-ari\_national\_zaf | 0 |
| toilet-facilities\_national\_zaf | 0 |
| water\_national\_zaf | 0 |

## Outliers (Numeric Columns, |z| > 3)

outlier\_counts <- function(df){  
 nums <- df |> dplyr::select(where(is.numeric))  
 if(ncol(nums) == 0) return(tibble(column=character(), outliers\_abs\_z\_gt\_3=integer()))  
 purrr::map\_dfr(names(nums), function(col){  
 v <- nums[[col]]  
 v <- v[!is.na(v)]  
 if(length(v) < 5 || sd(v) == 0) return(tibble(column = col, outliers\_abs\_z\_gt\_3 = 0L))  
 z <- (v - mean(v)) / sd(v)  
 tibble(column = col, outliers\_abs\_z\_gt\_3 = as.integer(sum(abs(z) > 3)))  
 }) |> arrange(desc(outliers\_abs\_z\_gt\_3))  
}  
  
outliers\_by\_dataset <- purrr::imap(dfs, function(df, nm){  
 oc <- outlier\_counts(df) |> mutate(dataset = nm, .before = 1)  
 oc  
})  
outliers\_all <- bind\_rows(outliers\_by\_dataset)  
  
if(nrow(outliers\_all) > 0){  
 # Get all unique numeric column names across datasets  
 all\_numeric\_columns <- unique(outliers\_all$column)  
   
 # Create 2D table: rows = datasets, columns = numeric fields, values = outlier counts  
 outliers\_2d <- outliers\_all |>  
 pivot\_wider(names\_from = column, values\_from = outliers\_abs\_z\_gt\_3, values\_fill = 0)  
   
 # Apply heatmap styling to outliers table  
 outlier\_cols <- names(outliers\_2d)[-1] # exclude 'dataset' column  
 max\_outlier\_val <- max(unlist(outliers\_2d[outlier\_cols]), na.rm = TRUE)  
   
 gt::gt(outliers\_2d) |>  
 gt::tab\_header(title = "Outlier Counts (|z|>3) - 2D View") |>  
 gt::data\_color(  
 columns = all\_of(outlier\_cols),  
 palette = c("white", "darkred"),  
 domain = c(0, max\_outlier\_val),  
 na\_color = "lightgray"  
 )  
   
} else {  
 cat("No numeric columns suitable for outlier analysis were found.")  
}

Table : Outlier Counts (|z|>3) - 2D View

| dataset | by\_variable\_id | value | data\_id | precision | survey\_year | indicator\_order | characteristic\_id | characteristic\_order | is\_total | is\_preferred | survey\_year\_label | denominator\_weighted | denominator\_unweighted | ci\_low | ci\_high |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| access-to-health-care\_national\_zaf | 13 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| anthropometry\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| child-mortality-rates\_national\_zaf | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| covid-19-prevention\_national\_zaf | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| dhs-quickstats\_national\_zaf | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| hiv-behavior\_national\_zaf | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| immunization\_national\_zaf | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| iycf\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| literacy\_national\_zaf | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| maternal-mortality\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| symptoms-of-acute-respiratory-infection-ari\_national\_zaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| toilet-facilities\_national\_zaf | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| water\_national\_zaf | 0 | 4 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## Consolidated Data Quality Issues Log

# Build a tidy issues log: one row per issue instance  
issues\_missing <- missingness\_all |>  
 filter(missing\_count > 0 & missing\_pct < 100) |> # Exclude 100% missing (field doesn't exist)  
 transmute(dataset, issue\_type = "missing", column, detail = paste0(missing\_pct, "% (", missing\_count, " cells)"))  
  
issues\_dup <- dup\_summary |>  
 filter(duplicate\_rows > 0) |>  
 transmute(dataset, issue\_type = "duplicates", column = NA\_character\_, detail = paste0(duplicate\_rows, " duplicate rows"))  
  
issues\_outliers <- outliers\_all |>  
 filter(outliers\_abs\_z\_gt\_3 > 0) |>  
 transmute(dataset, issue\_type = "outliers", column, detail = paste0(outliers\_abs\_z\_gt\_3, " outliers (|z|>3)"))  
  
issues\_log <- bind\_rows(issues\_missing, issues\_dup, issues\_outliers) |>  
 arrange(dataset, issue\_type, desc(detail))  
  
gt::gt(issues\_log)

| dataset | issue\_type | column | detail |
| --- | --- | --- | --- |
| access-to-health-care\_national\_zaf | missing | by\_variable\_label | 4.73% (13 cells) |
| access-to-health-care\_national\_zaf | missing | denominator\_unweighted | 12.36% (34 cells) |
| access-to-health-care\_national\_zaf | missing | denominator\_weighted | 12.36% (34 cells) |
| access-to-health-care\_national\_zaf | outliers | value | 8 outliers (|z|>3) |
| access-to-health-care\_national\_zaf | outliers | by\_variable\_id | 13 outliers (|z|>3) |
| anthropometry\_national\_zaf | missing | denominator\_unweighted | 10.81% (4 cells) |
| anthropometry\_national\_zaf | missing | denominator\_weighted | 10.81% (4 cells) |
| child-mortality-rates\_national\_zaf | missing | denominator\_unweighted | 90% (36 cells) |
| child-mortality-rates\_national\_zaf | missing | denominator\_weighted | 90% (36 cells) |
| child-mortality-rates\_national\_zaf | missing | by\_variable\_label | 50% (20 cells) |
| child-mortality-rates\_national\_zaf | missing | ci\_high | 25% (10 cells) |
| child-mortality-rates\_national\_zaf | missing | ci\_low | 25% (10 cells) |
| child-mortality-rates\_national\_zaf | outliers | value | 2 outliers (|z|>3) |
| covid-19-prevention\_national\_zaf | missing | denominator\_unweighted | 5.88% (2 cells) |
| covid-19-prevention\_national\_zaf | missing | denominator\_weighted | 5.88% (2 cells) |
| covid-19-prevention\_national\_zaf | outliers | precision | 1 outliers (|z|>3) |
| dhs-quickstats\_national\_zaf | missing | ci\_high | 73.08% (38 cells) |
| dhs-quickstats\_national\_zaf | missing | ci\_low | 73.08% (38 cells) |
| dhs-quickstats\_national\_zaf | missing | by\_variable\_label | 63.46% (33 cells) |
| dhs-quickstats\_national\_zaf | missing | denominator\_unweighted | 34.62% (18 cells) |
| dhs-quickstats\_national\_zaf | missing | denominator\_weighted | 34.62% (18 cells) |
| dhs-quickstats\_national\_zaf | outliers | value | 2 outliers (|z|>3) |
| dhs-quickstats\_national\_zaf | outliers | by\_variable\_id | 1 outliers (|z|>3) |
| hiv-behavior\_national\_zaf | missing | denominator\_weighted | 33.05% (39 cells) |
| hiv-behavior\_national\_zaf | missing | denominator\_unweighted | 32.2% (38 cells) |
| hiv-behavior\_national\_zaf | outliers | value | 4 outliers (|z|>3) |
| immunization\_national\_zaf | missing | denominator\_unweighted | 6.9% (8 cells) |
| immunization\_national\_zaf | missing | denominator\_weighted | 6.9% (8 cells) |
| immunization\_national\_zaf | missing | by\_variable\_label | 48.28% (56 cells) |
| immunization\_national\_zaf | outliers | value | 2 outliers (|z|>3) |
| iycf\_national\_zaf | missing | denominator\_unweighted | 9.09% (2 cells) |
| iycf\_national\_zaf | missing | denominator\_weighted | 9.09% (2 cells) |
| literacy\_national\_zaf | missing | denominator\_unweighted | 10% (2 cells) |
| literacy\_national\_zaf | missing | denominator\_weighted | 10% (2 cells) |
| literacy\_national\_zaf | outliers | value | 1 outliers (|z|>3) |
| maternal-mortality\_national\_zaf | missing | denominator\_weighted | 90.48% (19 cells) |
| maternal-mortality\_national\_zaf | missing | ci\_high | 85.71% (18 cells) |
| maternal-mortality\_national\_zaf | missing | ci\_low | 85.71% (18 cells) |
| maternal-mortality\_national\_zaf | missing | denominator\_unweighted | 71.43% (15 cells) |
| symptoms-of-acute-respiratory-infection-ari\_national\_zaf | missing | denominator\_unweighted | 30.77% (8 cells) |
| symptoms-of-acute-respiratory-infection-ari\_national\_zaf | missing | denominator\_weighted | 30.77% (8 cells) |
| toilet-facilities\_national\_zaf | missing | denominator\_unweighted | 8.7% (4 cells) |
| toilet-facilities\_national\_zaf | missing | denominator\_weighted | 8.7% (4 cells) |
| toilet-facilities\_national\_zaf | outliers | value | 2 outliers (|z|>3) |
| water\_national\_zaf | missing | denominator\_unweighted | 4% (4 cells) |
| water\_national\_zaf | missing | denominator\_weighted | 4% (4 cells) |
| water\_national\_zaf | outliers | precision | 8 outliers (|z|>3) |
| water\_national\_zaf | outliers | value | 4 outliers (|z|>3) |

# Preliminary Visualizations

## Highest Variance Numeric Columns Summary

# Get highest variance column and its variance for each dataset  
variance\_summary <- purrr::imap\_dfr(dfs, function(df, nm){  
 nums <- df |> dplyr::select(where(is.numeric))  
 if(ncol(nums) == 0) return(tibble(dataset = nm, highest\_var\_column = "N/A", variance = "N/A"))  
   
 var\_tbl <- summarize(nums, across(everything(), function(y) var(y, na.rm = TRUE)))  
 var\_results <- var\_tbl |> pivot\_longer(everything(), names\_to="col", values\_to="v") |>  
 arrange(desc(v)) |> slice(1)  
   
 tibble(  
 dataset = nm,  
 highest\_var\_column = var\_results$col,  
 variance = as.character(round(var\_results$v, 2))  
 )  
})  
  
# Apply heatmap styling to variance values  
variance\_for\_gt <- variance\_summary  
variance\_for\_gt$variance\_numeric <- ifelse(variance\_summary$variance == "N/A", NA, as.numeric(variance\_summary$variance))  
  
max\_var <- max(variance\_for\_gt$variance\_numeric, na.rm = TRUE)  
  
gt::gt(variance\_for\_gt |> select(-variance\_numeric)) |>  
 gt::tab\_header(title = "Highest Variance Numeric Columns by Dataset") |>  
 gt::data\_color(  
 columns = variance,  
 palette = c("white", "darkblue"),  
 domain = c(0, max\_var),  
 na\_color = "lightgray"  
 )

Table : Highest Variance Numeric Columns by Dataset

| dataset | highest\_var\_column | variance |
| --- | --- | --- |
| access-to-health-care\_national\_zaf | indicator\_order | 25022211281567.1 |
| anthropometry\_national\_zaf | indicator\_order | 22901215200981.2 |
| child-mortality-rates\_national\_zaf | data\_id | 97344762672.13 |
| covid-19-prevention\_national\_zaf | indicator\_order | 16089366442421.4 |
| dhs-quickstats\_national\_zaf | indicator\_order | 3738559151946484 |
| hiv-behavior\_national\_zaf | data\_id | 49066328853.83 |
| immunization\_national\_zaf | data\_id | 61479147528.61 |
| iycf\_national\_zaf | data\_id | 49203252603.6 |
| literacy\_national\_zaf | data\_id | 4569355769.73 |
| maternal-mortality\_national\_zaf | data\_id | 91243653644.16 |
| symptoms-of-acute-respiratory-infection-ari\_national\_zaf | data\_id | 45078540239.26 |
| toilet-facilities\_national\_zaf | data\_id | 108611672796.4 |
| water\_national\_zaf | data\_id | 49926220181.53 |

## 

## Most Frequent Categories Summary

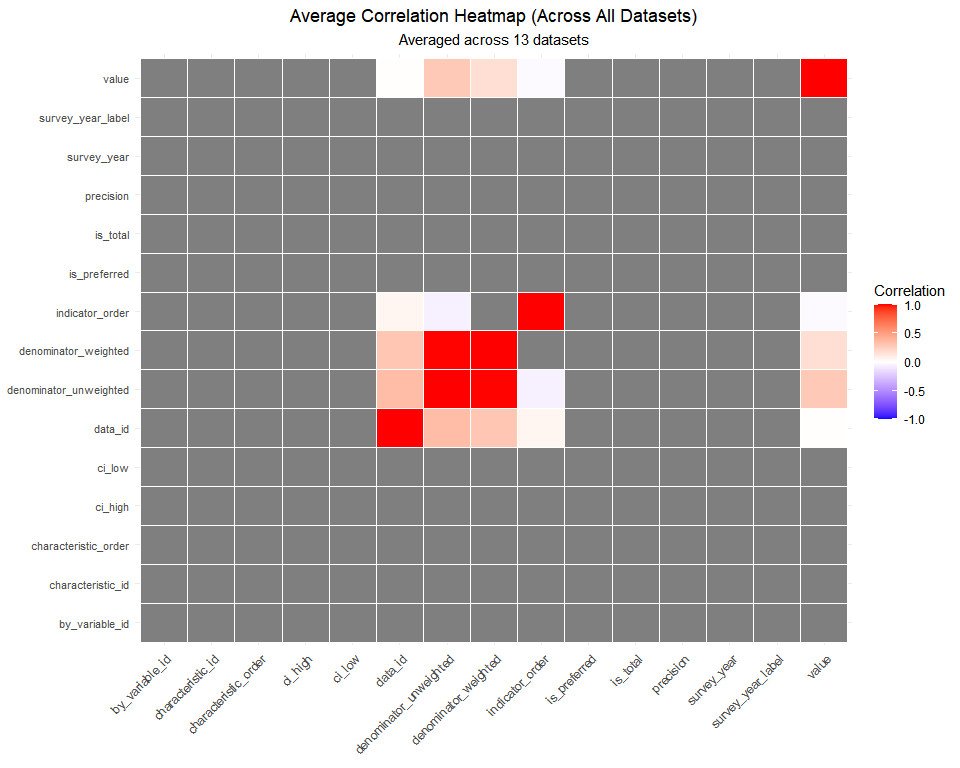
# Get most frequent category from first categorical column for each dataset  
category\_summary <- purrr::imap\_dfr(dfs, function(df, nm){  
 cats <- df |> dplyr::select(where(negate(is.numeric)))  
 if(ncol(cats) == 0) return(tibble(dataset = nm, categorical\_column = "N/A", most\_frequent\_value = "N/A", frequency = "N/A"))  
   
 col1 <- names(cats)[1]  
 top\_category <- df |> mutate(across(all\_of(col1), as.character)) |>  
 count(.data[[col1]], sort = TRUE) |> slice\_head(n = 1)  
   
 tibble(  
 dataset = nm,  
 categorical\_column = col1,  
 most\_frequent\_value = top\_category[[col1]][1],  
 frequency = as.character(top\_category$n[1])  
 )  
})  
  
# Apply heatmap styling to frequency values  
category\_for\_gt <- category\_summary  
category\_for\_gt$frequency\_numeric <- ifelse(category\_summary$frequency == "N/A", NA, as.numeric(category\_summary$frequency))  
  
max\_freq <- max(category\_for\_gt$frequency\_numeric, na.rm = TRUE)  
  
gt::gt(category\_for\_gt |> select(-frequency\_numeric)) |>  
 gt::tab\_header(title = "Most Frequent Categories by Dataset") |>  
 gt::data\_color(  
 columns = frequency,  
 palette = c("white", "darkgreen"),  
 domain = c(0, max\_freq),  
 na\_color = "lightgray"  
 )

Table : Most Frequent Categories by Dataset

| dataset | categorical\_column | most\_frequent\_value | frequency |
| --- | --- | --- | --- |
| access-to-health-care\_national\_zaf | iso3 | ZAF | 275 |
| anthropometry\_national\_zaf | iso3 | ZAF | 37 |
| child-mortality-rates\_national\_zaf | iso3 | ZAF | 40 |
| covid-19-prevention\_national\_zaf | iso3 | ZAF | 34 |
| dhs-quickstats\_national\_zaf | iso3 | ZAF | 52 |
| hiv-behavior\_national\_zaf | iso3 | ZAF | 118 |
| immunization\_national\_zaf | iso3 | ZAF | 116 |
| iycf\_national\_zaf | iso3 | ZAF | 22 |
| literacy\_national\_zaf | iso3 | ZAF | 20 |
| maternal-mortality\_national\_zaf | iso3 | ZAF | 21 |
| symptoms-of-acute-respiratory-infection-ari\_national\_zaf | iso3 | ZAF | 26 |
| toilet-facilities\_national\_zaf | iso3 | ZAF | 46 |
| water\_national\_zaf | iso3 | ZAF | 100 |

# Average Correlation Heatmap (Across All Datasets)

# Get all unique numeric column names across datasets  
all\_numeric\_columns <- unique(unlist(lapply(dfs, function(df) names(df |> dplyr::select(where(is.numeric))))))  
  
if(length(all\_numeric\_columns) >= 2) {  
 # Calculate correlation matrices for each dataset and average them  
 correlation\_matrices <- purrr::map(dfs, function(df){  
 nums <- df |> dplyr::select(where(is.numeric))  
 if(ncol(nums) < 2) return(NULL)  
   
 # Ensure we have all columns (fill missing with NA)  
 for(col in all\_numeric\_columns) {  
 if(!col %in% names(nums)) {  
 nums[[col]] <- NA  
 }  
 }  
   
 # Reorder columns to match all\_numeric\_columns  
 nums <- nums |> select(all\_of(all\_numeric\_columns))  
   
 # Calculate correlation matrix  
 cor(nums, use = "pairwise.complete.obs")  
 })  
   
 # Remove NULL matrices (datasets with < 2 numeric columns)  
 correlation\_matrices <- correlation\_matrices[!sapply(correlation\_matrices, is.null)]  
   
 if(length(correlation\_matrices) > 0) {  
 # Average the correlation matrices  
 avg\_corr\_matrix <- Reduce("+", correlation\_matrices) / length(correlation\_matrices)  
   
 # Convert to tidy format for ggplot  
 tidy\_corr <- as\_tibble(avg\_corr\_matrix, rownames = "row") |>  
 pivot\_longer(-row, names\_to = "col", values\_to = "corr")  
   
 # Create heatmap  
 ggplot(tidy\_corr, aes(x = row, y = col, fill = corr)) +  
 geom\_tile(color = "white", size = 0.5) +  
 scale\_fill\_gradient2(low = "blue", mid = "white", high = "red",   
 midpoint = 0, limits = c(-1, 1), name = "Correlation") +  
 labs(title = "Average Correlation Heatmap (Across All Datasets)",  
 subtitle = paste("Averaged across", length(correlation\_matrices), "datasets"),  
 x = NULL, y = NULL) +  
 theme\_minimal() +  
 theme(axis.text.x = element\_text(angle = 45, hjust = 1, vjust = 1),  
 axis.text.y = element\_text(size = 8),  
 plot.title = element\_text(hjust = 0.5),  
 plot.subtitle = element\_text(hjust = 0.5))  
 } else {  
 cat("No datasets have sufficient numeric columns for correlation analysis.")  
 }  
} else {  
 cat("Insufficient numeric columns across all datasets for correlation analysis.")  
}



# Appendix. Session Info

sessionInfo()

## R version 4.5.1 (2025-06-13 ucrt)  
## Platform: x86\_64-w64-mingw32/x64  
## Running under: Windows 11 x64 (build 26100)  
##   
## Matrix products: default  
## LAPACK version 3.12.1  
##   
## locale:  
## [1] LC\_COLLATE=English\_United Kingdom.utf8   
## [2] LC\_CTYPE=English\_United Kingdom.utf8   
## [3] LC\_MONETARY=English\_United Kingdom.utf8  
## [4] LC\_NUMERIC=C   
## [5] LC\_TIME=English\_United Kingdom.utf8   
##   
## time zone: Africa/Johannesburg  
## tzcode source: internal  
##   
## attached base packages:  
## [1] stats graphics grDevices utils datasets methods base   
##   
## other attached packages:  
## [1] gt\_1.0.0 janitor\_2.2.1 readxl\_1.4.5 lubridate\_1.9.4  
## [5] forcats\_1.0.0 stringr\_1.5.1 dplyr\_1.1.4 purrr\_1.1.0   
## [9] readr\_2.1.5 tidyr\_1.3.1 tibble\_3.3.0 ggplot2\_3.5.2   
## [13] tidyverse\_2.0.0  
##   
## loaded via a namespace (and not attached):  
## [1] bit\_4.6.0 gtable\_0.3.6 crayon\_1.5.3 compiler\_4.5.1   
## [5] tidyselect\_1.2.1 xml2\_1.4.0 parallel\_4.5.1 snakecase\_0.11.1   
## [9] scales\_1.4.0 yaml\_2.3.10 fastmap\_1.2.0 R6\_2.6.1   
## [13] labeling\_0.4.3 generics\_0.1.4 knitr\_1.50 pillar\_1.11.0   
## [17] RColorBrewer\_1.1-3 tzdb\_0.5.0 rlang\_1.1.6 stringi\_1.8.7   
## [21] xfun\_0.52 bit64\_4.6.0-1 timechange\_0.3.0 cli\_3.6.5   
## [25] withr\_3.0.2 magrittr\_2.0.3 digest\_0.6.37 grid\_4.5.1   
## [29] vroom\_1.6.5 rstudioapi\_0.17.1 hms\_1.1.3 lifecycle\_1.0.4   
## [33] vctrs\_0.6.5 evaluate\_1.0.5 glue\_1.8.0 cellranger\_1.1.0   
## [37] farver\_2.1.2 rmarkdown\_2.29 tools\_4.5.1 pkgconfig\_2.0.3   
## [41] htmltools\_0.5.8.1

# References

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