
# Inception Report
# Enterprise Medical Imaging for Streamlined Radiological Diagnosis in Zambian Public Health Facilities

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**December 21, 2021**

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|  | ***Inception Report***<br>***Enterprise Medical Imaging for Streamlined Radiological Diagnosis in Zambian Public Health Facilities*** |

# Document Information

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| **Project Name** | *Enterprise Medical Imaging for Streamlined Radiological Diagnosis in Zambian Public Health Facilities* | | |
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***Inception Report***
***Enterprise Medical Imaging for Streamlined Radiological Diagnosis in Zambian Public Health Facilities***

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# List of Abbreviations

| Abbreviation | Description |
|---|---|
| AI | Artificial Intelligence |
| CRISP-DM | CRoss Industry Standard Process for Data Mining |
| CXR | Chest X-Ray |
| DICOM | Digital Imaging and Communications in Medicine |
| EHRs | Electronic Health Records |
| EI | Enterprise Imaging |
| PACS | Picture Archiving and Communication System |
| RIS | Radiology Information System |
| UNZA | The University of Zambia |
| UTHs | University Teaching Hospitals |


***Inception Report***
***Enterprise Medical Imaging for Streamlined Radiological Diagnosis in Zambian Public Health Facilities***

# 1. Executive Summary

The Republic of Zambia, like many countries world-over, is faced with a critical shortage of trained radiologists, medical experts specialised in the interpretation of medical images for radiological diagnosis of health conditions. It was reported that as of 2019, Zambia had only five (5) trained radiologists against a population of 17 million (Bwanga et al., 2019). This project is a pilot study that seeks to investigate the challenges resulting from the shortage of radiologists and to investigate the feasibility of implementation of efficient and effective medical imaging workflows using enterprise imaging techniques, in order to demonstrate the potential of enterprise imaging in addressing the grand challenges associated with medical imaging in Zambia.

## 1.1. Document Objective

The contents of this Inception report are aimed at providing a complete and concise lay-out of the project concept, its proposed proceeding and the expected outcomes to be achieved.
The key elements of this report include:

- A description of the project aim and objectives in regard to the existing problem. These are outlined in Section 2
- A detailed work plan (that conforms to a specific timeline) that indicates specific project activities and tasks to be undertaken, project stages, project monitoring and an outline of expected deliverables. These are contained in Section 3
- The methodology that will be used in order to effectively undertake the project; given in Section 4
- A detailed description of the risk management strategy, including all potential project risks and mitigation strategies - Section 5
- Resources that will be required to undertake the project - Section 6

## 1.2. Project Scope

The researchers will carry out the project as outlined in the proposal with predefined update/feedback interactions, as specified by the project funders. The specific scope of the researchers' work will include:

- **Drafting of the Inception Report (this document) detailing the work plan of the project:** This includes assigning responsibilities to the researchers, specific tasks and assignments by the researchers, and project timeline and target dates for deliverables.
- **Carrying out the research work**
    - Data collection, processing and analysis
    - Dataset collection, preprocessing and labelling
    - Machine Learning model development and evaluation
- **Compiling the final project report**

## 1.3. Project Closing

The project shall be objectively closed at the stage when the data will have been analysed and interpreted, the Machine Learning model developed during the project evaluated and the final project report accepted by the project funders.

# 2. Introduction

## 2.1. Researchers' Intentions and Goals

This project is an undertaking aimed at streamlining radiological workflows using enterprise imaging techniques that incorporate artificial intelligence in order to potentially mitigate the challenges resulting from the shortage of radiologists in Zambian public health facilities.

## 2.2. Project Goals

The main objective of the project is to investigate the feasibility of leveraging enterprise medical imaging techniques for the efficient and effective reading of medical images in public health facilities in Zambia.

# 3. Project Work Plan

## 3.1. Project Phases

This research project is segmented into three high-level phases, aligned with the key objectives of the project, as outlined in Section 4.3. Table 1 shows the project phases and associated estimated durations.

Table 1: Project Phases

| ID | Phase | Duration (Days) | Start Date | End Date |
|---|---|---|---|---|
| P-1 | Drafting Inception Report | 14 | December 13, 2021 | December 27, 2021 |
| P-2 | Project Scoping and Planning | 5 | December 27, 2021 | December 31, 2021 |
| P-3 | Situation Analysis | 190 | January 3, 2022 | July 12, 2022 |
| P-4 | Archival Records Analysis | 160 | January 3, 2022 | June 12, 2022 |
| P-5 | Machine Learning Model Implementation | 270 | February 7, 2022 | November 4, 2022 |
| P-6 | Project Decommissioning Meeting | 1 | December 12, 2022 | December 12, 2022 |
| P-7 | Project Dissemination | 1 | December 12, 2022 | December 12, 2022 |

### 3.1.1. Phase 1. Exploratory Study of Radiological Workflows

In Phase 1 of this research project, a situation analysis will be conducted in order to explore and understand current radiological workflows. The exploratory study will primarily focus on all Referral Health Facilities (Hospital Levels 1 - 3) in Zambia, although some activities will be restricted to Level 3 Hospitals in Lusaka district.

### 3.1.2. Phase 2. Archival Records Analysis

In Phase 2 of the research project, a retrospective study of archived historical medical images will be conducted in order to understand the archival practises associated with the different medical image modalities.

### 3.1.3. Phase 3. Machine Learning Model Implementation

In Phase 3 of the research project, machine learning classification models will be implemented and evaluated in order to determine their relative effectiveness and usefulness.

## 3.2. Detailed Project Working Plan

As indicated in the contract signed with the funders, the duration of this research project will be between December 13, 2021 and December 13, 2022. The detailed project timeline is outlined in Figure 4, in Appendix B.

## 3.3. Project Deliverables

The project deliverables, including specific details of the deliverables, are outlined in Table 5, in Appendix C.

## 3.4. Project Monitoring

The progress of the project will be monitored through the delivery of deliverables, and by accomplishing the predefined milestones specified by the project funders. In addition, the researchers will use effective project management practises and tools to ensure that the project is successfully executed.

Specifically, the researchers will use Trello[1] as the primary project management tool.

[1] https://trello.com

# 4. Methodology

This research will take advantage of a mixed-methods approach. A combination of quantitative and qualitative data collection techniques will be used to understand how the radiological images are interpreted in Level 1, Level 2 and Level 3 hospitals, while retrospective data collection, using quantitative content analysis, will be leveraged to determine how much radiological images data is generated. Finally, reliable machine learning frameworks will be used to implement the machine learning classification models, with quantitative approaches used to evaluate the effectiveness and usefulness of the classification model.

## 4.1. Conceptual Framework

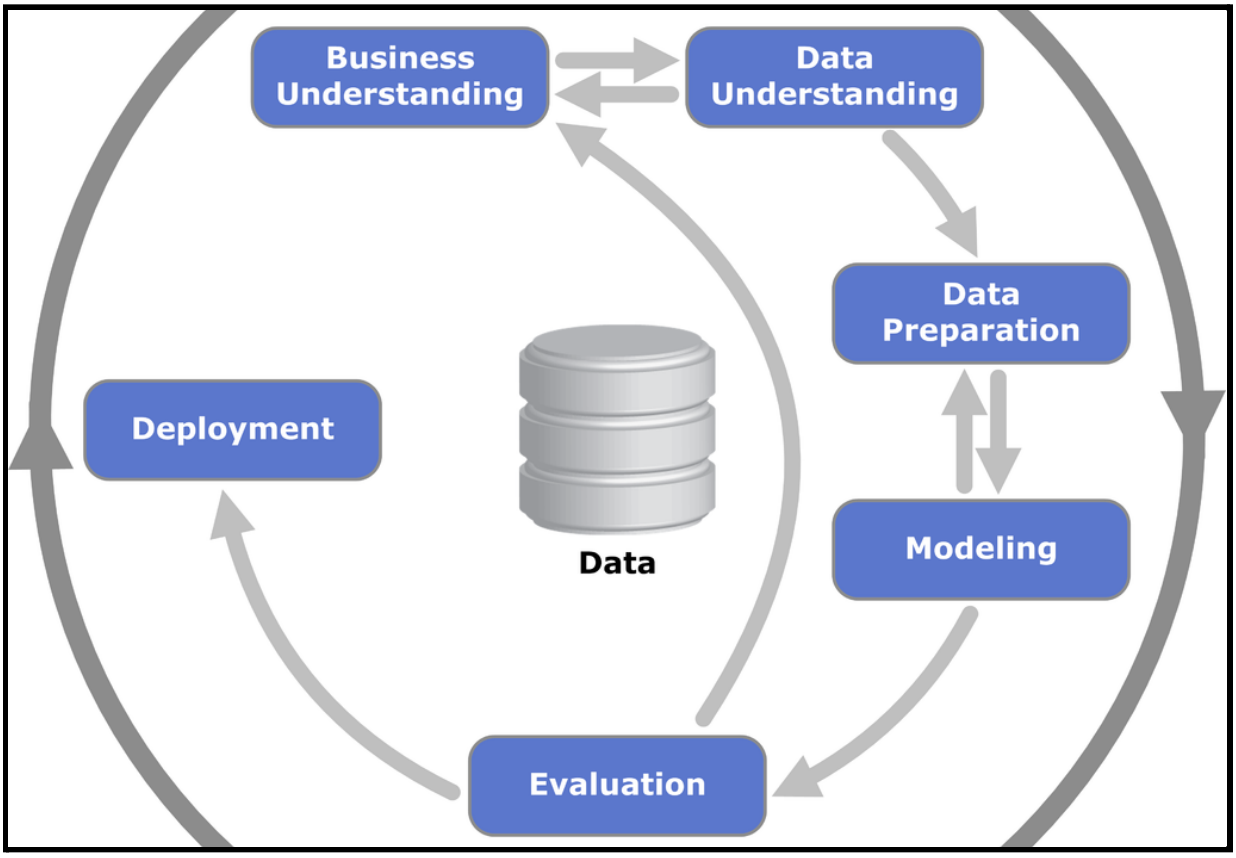


Figure 1: Core Phases of the CRISP-DM Model

The CRoss Industry Standard Process for Data Mining (CRISP-DM) model (Wirth & Hipp, 2000), shown in Figure 1, will be used to guide this research. Specifically, the six (6) phases of the model will be used as follows:

- Business Understanding—In order to understand current radiological workflows, interactions with key stakeholders—Radiologists, trainee Radiologists, Radiographers, Medical doctors and Clinical officers—will be undertaken, as outlined in Section 4.3.1.
- Data Understanding—Archival records analyses of historical reports and medical images will be performed, as outlined in Section 4.3.2.
- Data Preparation—Dataset
- Modelling—Classification models will be implemented for the classification of medical image modalities, as outlined in Section 4.3.3.
- Evaluation—The effectiveness and usefulness of the machine learning models will be systematically evaluated, as outlined in Section 4.3.3.
- Deployment—As part of the process of evaluating the usefulness of the model, an end user interface will be implemented and interfaced with the offline model.

## 4.2. Study Setting

This research will be carried out in the Republic of Zambia at all Level 1, Level 2 and Level 3 health facilities that offer at least one of any of the radiological imaging modalities.

Zambia has a recorded 2815 health facilities, out of which 151 are classified as Level 1, Level 2 or Level 3 Hospitals (*MFL*, n.d.). Table 2 shows the number of health facilities in Zambia, by facility type, while Figure 2 shows the distribution of Level 1, Level 2 and Level 3 health facilities in Zambia. While this research will be carried out in all Hospital - Level facilities, some activities will be restricted to facilities in Lusaka Province, as shown in Figure 3, in Appendix A; and facilities in Lusaka District, as shown in Figure 4, in Appendix B.

The study will specifically focus on Hospital - Level facilities as they are the facilities equipped with radiological machines. That being said, the researchers understand that there are isolated lower ranking  government-owned, private/missionary- or military-owned facilities that may have radiology services, mainly ultrasound modalities. These shall not be included in this study.

Table 1: Health Facilities in the Republic of Zambia

| | GRZ | Military | NGO | Police | Private | Total |
|---|---|---|---|---|---|---|
| Border Health Post | 3 | 0 | 0 | 0 | 0 | 3 |
| Community Health Post | 1003 | 12 | 17 | 8 | 13 | 1053 |
| Hospital - Level 1 | 72 | 4 | 30 | 0 | 9 | 115 |
| Hospital - Level 2 | 13 | 1 | 3 | 0 | 5 | 22 |
| Hospital - Level 3 | 12 | 1 | 0 | 0 | 1 | 14 |
| Hospital Affiliated Health Centre | 12 | 0 | 0 | 0 | 0 | 12 |
| Rural Health Centre | 1021 | 17 | 50 | 1 | 15 | 1104 |
| Unclassified | 43 | 5 | 10 | 3 | 58 | 119 |
| Urban Health Centre | 273 | 14 | 14 | 12 | 47 | 360 |
| Zonal Health Centre | 11 | 0 | 2 | 0 | 0 | 13 |
| Total | 2463 | 54 | 126 | 24 | 148 | 2815 |

The health facilities for inclusion in the study will be identified through records obtained at the Radiation Protection Authority (RPA) of Zambia, a licencing body that maintains national registers and inventory records of radiology equipment.

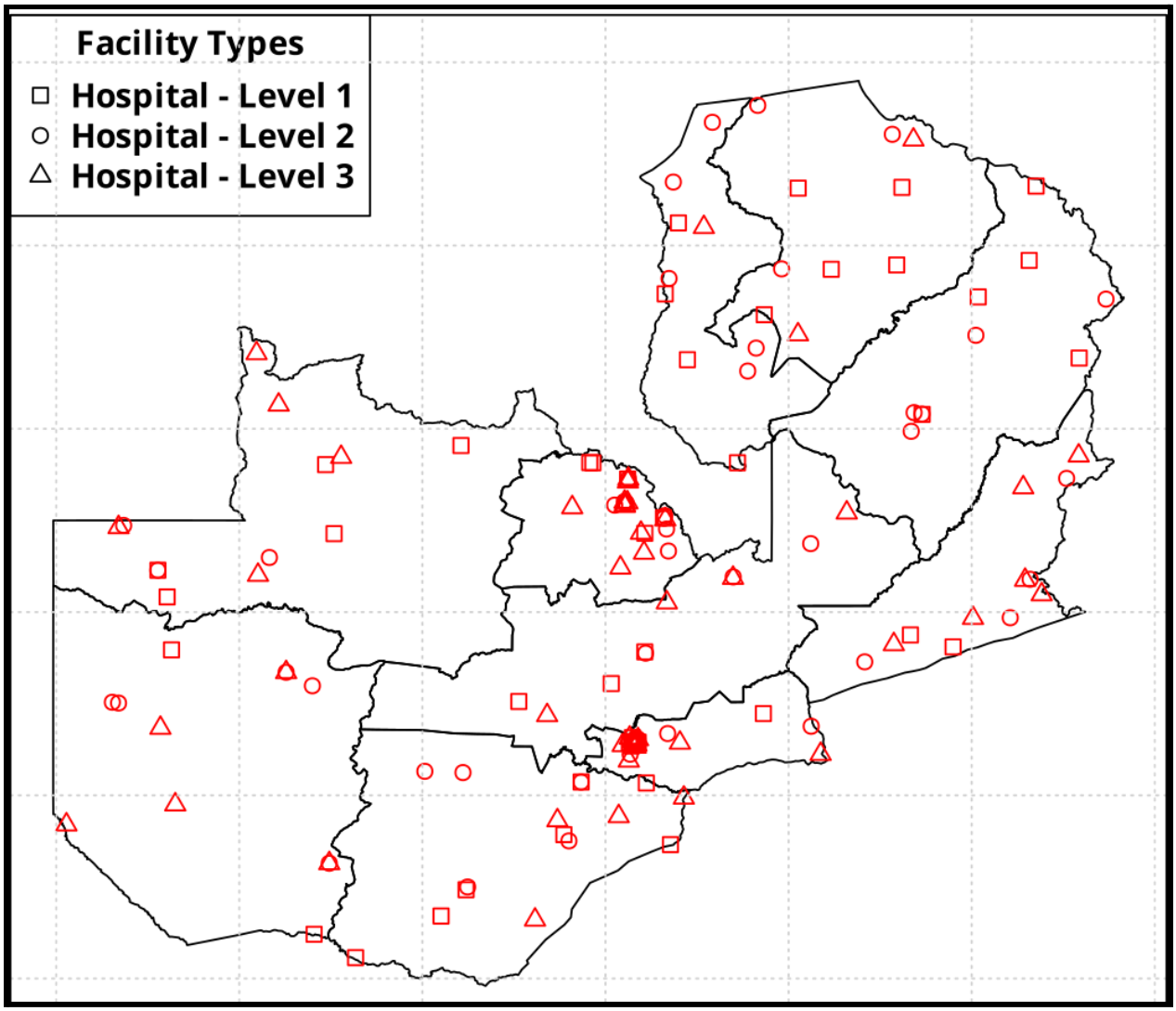


Figure 2: Distribution of Level 1, 2 and 3 Hospitals in Zambia

## 4.3. Experimental Design

### 4.3.1. Objective 1. Current Medical Imaging Workflows

The target population, approximated at 510, shall include qualified Radiologists, trainee Radiologists, Radiographers (including Radiography Technologists and Sonographers), Medical

doctors and Clinical officers. From the estimated 510 target population, a sample size of 220 is calculated. Telephone interviews, online profession-specific questionnaires, semi-structured interviews, data record sheets and on-site procedure observation checklists will be used to collect data.

Arrangements will be made via telephone and email communication for participants to take the online questionnaires. Semi-structured interviews will be held with randomly selected participants at a government, private/mission and military Level 1, 2 and 3 facilities. Additionally, observatory procedures will be held at randomly selected government, private/mission and military Level 1, 2 and 3 facilities by actively following through the process from image acquisition to the dispatch of reports. Important observed procedures will be recorded on the procedure observation checklist. This will be done in order to objectively collect data on image interpretation practises by medical practitioners.

### 4.3.2. Objective 2. Empirical Analysis of Archived Imaging Modalities

Retrospective records reviews will be conducted on the annual returns for the number of examinations performed in each modality from 2011 to 2020 at all the Level 1 - 3 facilities in Lusaka District. The collected data will then be analyzed for data volume size and various trends of interest.

### 4.3.3. Objective 3. Interpretation of Medical Images Using Machine Learning

Supervised Machine Learning binary classification models will be implemented using the scikit-learn Python library (Pedregosa et al., 2011) and TensorFlow software Machine Learning library (*TensorFlow*, n.d.).

The effectiveness of the binary classification models will be evaluated by measuring the accuracy, precision and recall of standard Machine Learning estimators. In addition, the effectiveness of feature combinations was assessed in order to determine the appropriate feature combinations to be used during final implementation of the models. Application Programming Interface (API) endpoints were implemented, using the Python Flask Web framework (*Welcome to Flask — Flask Documentation (2.0.x)*, n.d.), for the classification models to facilitate the integration of the models with third-party tools and services.

Expert radiologists and radiographers will be recruited to aid in the creation of labelled datasets for use duration experimentation. In order to evaluate the usefulness of the classification models, the System Usability Scale (SUS) (Brooke, 1996) instrument will be used, enabling the measurement of the relative usefulness and usability of the model.

## 4.4. Data Analysis

Basic data analyses of quantitative data will be done using Spreadsheet applications like Microsoft Excel[2], LibreOffice Calc[3] and OpenRefine[4], while statistical analyses will be conducted using the SPSS statistical package[5] and the R programming language[6]. Qualitative data from interview sessions will be analysed using Nvivo[7].

## 4.5. Ethical Consideration

This research will involve collection of annotated medical images as data, and as such, appropriate clearance and authority will be sought from the UNZA Biomedical Research Ethics Committee (UNZABREC) and the National Health Research Authority (NHRA) before the commencement of the research. It is further anticipated that the requirement for patient consent to the use of their medical images in the form of chest x-ray will be waived by the ethical clearance bodies as the data will be retrospective and amenable to anonymisation.

The researchers pledge to ensure that images and all data used shall be de-identified and treated with utmost confidentiality.

## 4.6. Limitations

There are three major limitations that have the potential to affect that generalisation of results from this project:

[2] https://www.microsoft.com/en-us/microsoft-365/excel
[3] https://www.libreoffice.org/discover/calc
[4] https://openrefine.org
[5] https://www.ibm.com/analytics/spss-statistics-software
[6] https://www.r-project.org
[7] https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software

- The sample size of participants for Study 1—Radiological Workflows—might not be sufficient to generalise the results. In addition, there are potentially unique challenges in the different hospitals in Zambia
- The machine learning model that will be implemented is associated with one diagnosis, making it difficult to generalise its performance against other diagnoses
- The period to time—ten years—for analysing historical medical images might not be sufficient to derive reliable patterns

# 5. Risk Management

The major potential risks identified, including their mitigation, monitoring and contingency plans are outlined in Table 5, in Appendix D.

# 6. Resources

The research project team will comprise of the individuals listed in Table 2. The specific roles and responsibilities for the project team members are presented in the RACI matrix shown in Table 3.

Table 2: Human Resources

| Member | Role | Responsibilities |
|---|---|---|
| Dr. Lighton Phiri (L.P) | Principal Investigator | Responsible for all key activities of the project |
| Dr. Ernest Obbie Zulu (E.O.Z) | Co-Principal Investigator | Responsible for all key activities of the project |
| Research Assistant 1 (RA 1) | Research Assistant | Records reviews of archived imaging modalities and collection of chest x-ray images |
| Research Assistant 2 (RA 2) | Research Assistant | Implementation and Deployment of Machine Learning Model |

Table 3: Project RACI Matrix

| | | | L.P | E.O.Z | RA 1 | RA 2 |
|---|---|---|---|---|---|---|
| **Task/Deliverable** | | Status | | | | |
| P-1. Drafting Inception Report | | DONE | R | R | I | I |
| D 1.1 | Inception Report | DONE | R | R | I | I |
| P-2. Project Scoping and Planning | | | R | R | I | I |
| | UNZABREC Ethical Clearance Approval | WIP | I | R | I | I |
| | NHRA Ethical Clearance Approval | WIP | I | R | I | I |
| P-3. Situation Analysis | | PENDING | C | R | I | I |
| D 2.1 | Experiment 1. Radiological Workflows | PENDING | C | R | I | I |
| D 2.2 | Radiological Workflows Publication | PENDING | R | R | I | I |
| P-4. Archival Records Analysis | | PENDING | C | R | I | I |
| D 2.2 | Experiment 2. Archival Records Analysis | PENDING | C | R | I | R |
| | Archival Records Analysis Publication | PENDING | R | R | I | I |
| P-5. Machine Learning Model Implementation | | PENDING | R | R | R | I |
| D 3.1 | Labelled Dataset for Chest X-Rays | PENDING | R | R | I | I |
| D 4.1 | Chest X-Rays Model | PENDING | R | R | R | I |
| D 2.3 | Experiment 3. Machine Learning Model: Effectiveness | PENDING | R | R | R | I |
| D 2.4 | Experiment 4. Machine Learning Model: Usefulness | PENDING | R | R | I | I |
| P-6. Project Decommissioning | | | R | R | I | I |

| | | | | | | |
|---|---|---|---|---|---|---|
| D 6.1 | Mid-Term Progress Report | PENDING | R | R | I | I |
| D 6.2 | Final Research Report | PENDING | R | R | I | I |
| | | | | | | |

| | | |
|---|---|---|
| **R** | **Responsible** | **Assigned to complete the task or deliverable.** |
| **A** | **Accountable** | **Has final decision-making authority and accountability for completion. Only 1 per task.** |
| **C** | **Consulted** | **An advisor, stakeholder or subject matter expert who is consulted before a decision or action is taken.** |
| **I** | **Informed** | **Must be informed after a decision or action is taken.** |

# 7. References

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# 8. Appendix A: Level 1, 2 and 3 Health Facilities in Lusaka Province

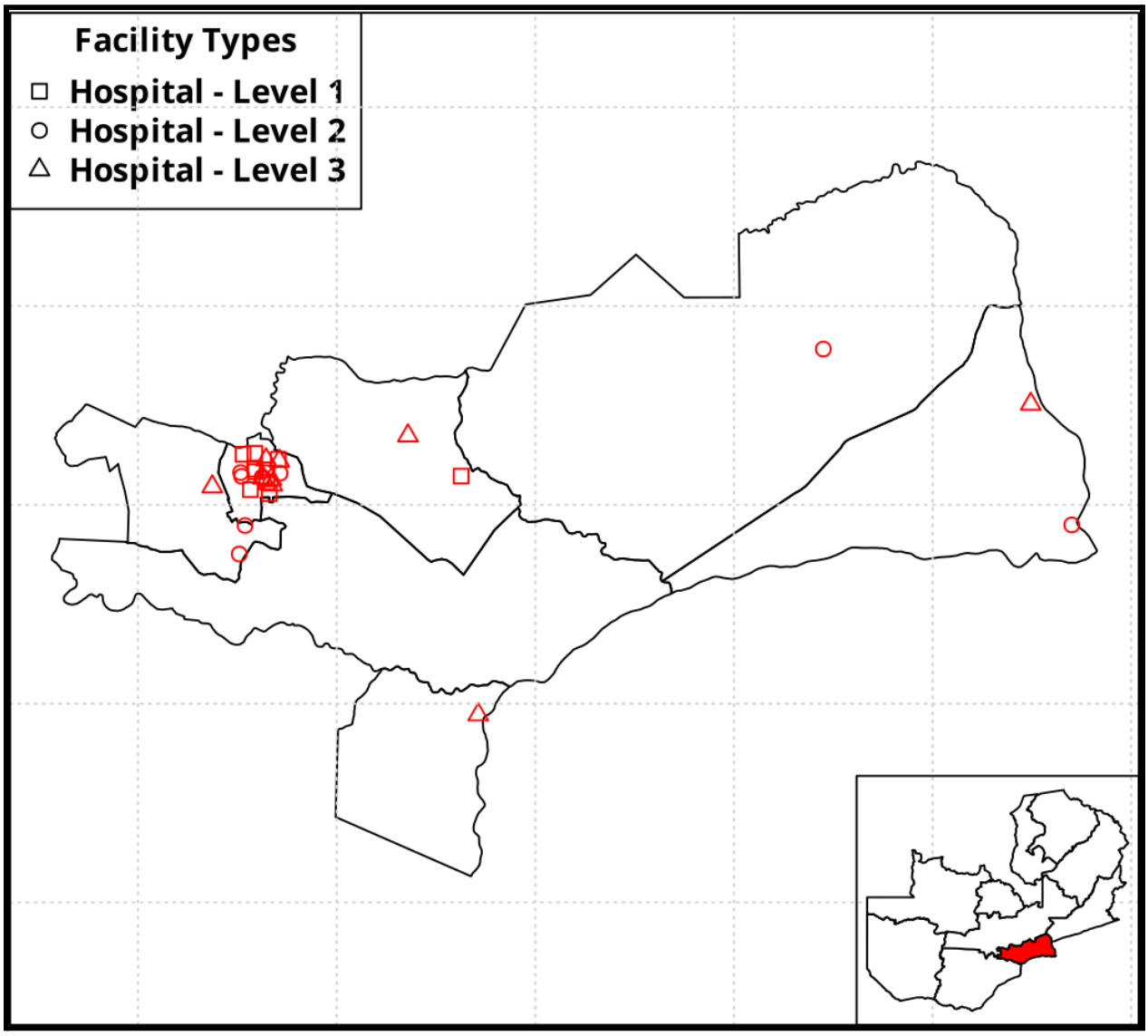


Figure 3: Distribution of Level 1, 2 and 3 Health Facilities in Lusaka Province

# 9. Appendix B: Level 1, 2 and 3 Health Facilities in Lusaka District

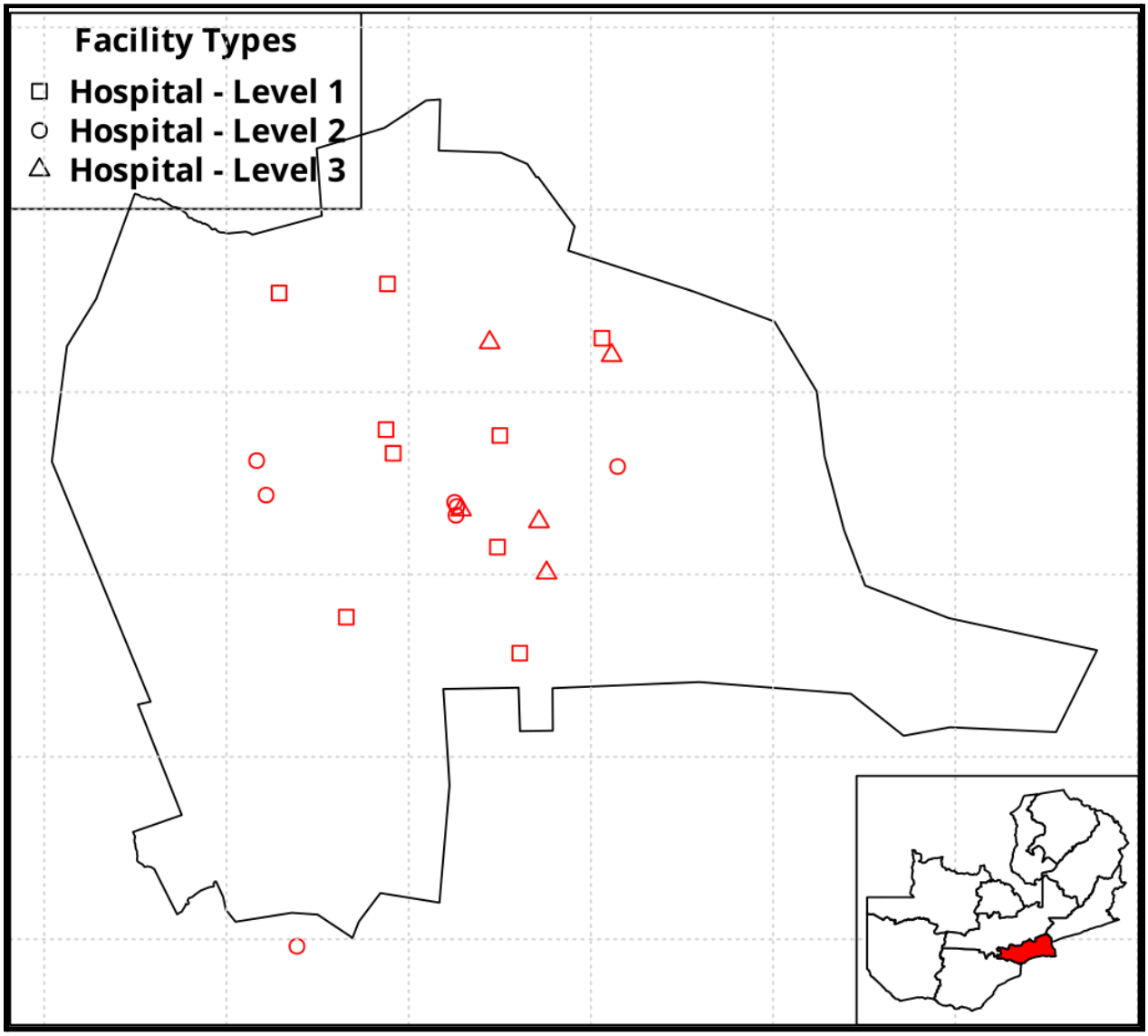


Figure 4: Distribution of Level 1, 2 and 3 Health Facilities in Lusaka District

# 10. Appendix C: Level 1, 2 and 3 Health Facilities in Zambia

Table 4: Level 1, 2 and 3 Health Facilities in Zambia

| Facility Name | Facility Type | Ownership | Status | District | Province |
|---|---|---|---|---|---|
| Liteta District Hospital | Hospital - Level 1 | GRZ | Operational | Chisamba | Central |
| Chitambo District Hospital | Hospital - Level 1 | GRZ | Operational | Chitambo | Central |
| Itezhi-Tezhi District Hospital | Hospital - Level 1 | GRZ | Operational | Itezhi-Tezhi | Central |
| Kabwe General Hospital | Hospital - Level 2 | GRZ | Operational | Kabwe | Central |
| Kabwe Mine Hospital | Hospital - Level 2 | GRZ | Operational | Kabwe | Central |
| Kohima Camp Hospital | Hospital - Level 1 | Military | Operational | Kabwe | Central |
| Kapiri-Mposhi District Hospital | Hospital - Level 1 | GRZ | Operational | Kapiri-Mposhi | Central |
| Mkushi District Hospital | Hospital - Level 1 | GRZ | Operational | Mkushi | Central |
| Tusekelemo Rural Health Centre | Hospital - Level 1 | Private | Operational | Mkushi | Central |
| Mumbwa District Hospital | Hospital - Level 1 | GRZ | Operational | Mumbwa | Central |
| Nangoma Mission Hospital | Hospital - Level 1 | NGO | Operational | Mumbwa | Central |
| Serenje District Hospital | Hospital - Level 1 | GRZ | Operational | Serenje | Central |
| Chililabombwe District Hospital | Hospital - Level 1 | GRZ | Operational | Chililabombwe | Copperbelt |
| Konkola Mine Private Hospital | Hospital - Level 2 | Private | Operational | Chililabombwe | Copperbelt |
| Kalulushi General Hospital | Hospital - Level 2 | GRZ | Operational | Kalulushi | Copperbelt |
| CBU Urban Health Centre | Hospital - Level 2 | GRZ | Operational | Kitwe | Copperbelt |

| | | | | | |
|---|---|---|---|---|---|
| Kitwe Teaching Hospital | Hospital - Level 3 | GRZ | Operational | Kitwe | Copperbelt |
| Kitwe Teaching Hospital Affiliated Health Centre | Hospital - Level 3 | GRZ | Operational | Kitwe | Copperbelt |
| Progress Medical Centre | Hospital - Level 1 | Private | Operational | Kitwe | Copperbelt |
| Sinozam Friendship Hospital | Hospital - Level 1 | Private | Operational | Kitwe | Copperbelt |
| Tinna Medical Centre | Hospital - Level 1 | Private | Operational | Kitwe | Copperbelt |
| Wusakile Mine Hospital | Hospital - Level 1 | Private | Operational | Kitwe | Copperbelt |
| Roan Antelope Hospital Affiliated Health Centre | Hospital - Level 2 | GRZ | Operational | Luanshya | Copperbelt |
| Thomson District Hospital | Hospital - Level 1 | GRZ | Operational | Luanshya | Copperbelt |
| Lufwanyama District Hospital | Hospital - Level 1 | GRZ | Operational | Lufwanyama | Copperbelt |
| Masaiti District Hospital | Hospital - Level 1 | GRZ | Operational | Masaiti | Copperbelt |
| Mpongwe Mission Hospital | Hospital - Level 1 | NGO | Operational | Mpongwe | Copperbelt |
| St. Theresa's Mission Hospital | Hospital - Level 1 | NGO | Operational | Mpongwe | Copperbelt |
| Kamuchanga District Hospital | Hospital - Level 1 | GRZ | Operational | Mufulira | Copperbelt |
| Malcolm Watson Hospital | Hospital - Level 3 | Private | Operational | Mufulira | Copperbelt |
| Malcolm Watson Hospital Affiliated Health Centre | Hospital - Level 1 | Private | Operational | Mufulira | Copperbelt |
| Ronald Ross General Hospital Affiliated Health Centre | Hospital - Level 2 | GRZ | Operational | Mufulira | Copperbelt |
| Arthur Davidson Hospital | Hospital - Level 3 | GRZ | Operational | Ndola | Copperbelt |
| Commando Unit Urban Health Centre (Ndola) | Hospital - Level 1 | Military | Operational | Ndola | Copperbelt |
| Hilltop Hospital | Hospital - Level 1 | Private | Operational | Ndola | Copperbelt |
| Ndola Teaching Hospital | Hospital - Level 3 | GRZ | Operational | Ndola | Copperbelt |
| Northern Command Military Hospital | Hospital - Level 3 | Military | Operational | Ndola | Copperbelt |

| | | | | | |
|---|---|---|---|---|---|
| St. Dominics (Kavu) Mission Hospital | Hospital - Level 1 | GRZ | Operational | Ndola | Copperbelt |
| Chadiza District Hospital | Hospital - Level 1 | GRZ | Operational | Chadiza | Eastern |
| Chipata District Hospital | Hospital - Level 1 | GRZ | Operational | Chipata | Eastern |
| Chipata Central Hospital | Hospital - Level 3 | GRZ | Operational | Chipata | Eastern |
| Gondar Camp Barracks 4ZR | Hospital - Level 2 | Military | Operational | Chipata | Eastern |
| Mwami Mission Hospital | Hospital - Level 1 | NGO | Operational | Chipata | Eastern |
| St. Francis General Hospital | Hospital - Level 2 | GRZ | Operational | Katete | Eastern |
| Lumezi Mission Hospital | Hospital - Level 1 | NGO | Operational | Lumezi | Eastern |
| Lundazi District Hospital | Hospital - Level 1 | GRZ | Operational | Lundazi | Eastern |
| Nyimba District Hospital | Hospital - Level 1 | GRZ | Operational | Nyimba | Eastern |
| Minga Mission Hospital | Hospital - Level 1 | NGO | Operational | Petauke | Eastern |
| Petauke District Hospital | Hospital - Level 1 | GRZ | Operational | Petauke | Eastern |
| Nyanje Mission Hospital | Hospital - Level 1 | NGO | Operational | Sinda | Eastern |
| Chienge District Hospital | Hospital - Level 1 | GRZ | Operational | Chienge | Luapula |
| Lubwe Mission Hospital | Hospital - Level 1 | NGO | Operational | Chifunabuli | Luapula |
| St. Margaret’s (Kasaba) Mission Hospital | Hospital - Level 1 | NGO | Operational | Chifunabuli | Luapula |
| Kawambwa District Hospital | Hospital - Level 1 | GRZ | Operational | Kawambwa | Luapula |
| Mansa General Hospital | Hospital - Level 1 | GRZ | Operational | Mansa | Luapula |
| Milenge District Hospital | Hospital - Level 1 | GRZ | Operational | Milenge | Luapula |
| Mbereshi Mission Hospital | Hospital - Level 1 | NGO | Operational | Mwansabombwe | Luapula |
| Mambilima Mission Hospital | Hospital - Level 1 | GRZ | Operational | Mwense | Luapula |
| Mwense District Hospital | Hospital - Level 1 | GRZ | Operational | Mwense | Luapula |

| | | | | | |
|---|---|---|---|---|---|
| St. Paul's Mission General Hospital | Hospital - Level 1 | NGO | Operational | Nchelenge | Luapula |
| Samfya District Hospital | Hospital - Level 1 | GRZ | Operational | Samfya | Luapula |
| Chilanga Hospice | Hospital - Level 2 | NGO | Operational | Chilanga | Lusaka |
| Human Service Trust Hospice | Hospital - Level 1 | NGO | Operational | Chilanga | Lusaka |
| Zambia Helpers Society Hospital | Hospital - Level 1 | NGO | Operational | Chilanga | Lusaka |
| Mtendere Mission Hospital | Hospital - Level 1 | NGO | Operational | Chirundu | Lusaka |
| Chongwe District Hospital | Hospital - Level 1 | GRZ | Operational | Chongwe | Lusaka |
| Kafue District Hospital | Hospital - Level 1 | GRZ | Operational | Kafue | Lusaka |
| Katondwe Mission Hospital | Hospital - Level 1 | NGO | Operational | Luangwa | Lusaka |
| Luangwa District Hospital | Hospital - Level 1 | GRZ | Operational | Luangwa | Lusaka |
| Arakan Camp Hospital | Hospital - Level 1 | Military | Operational | Lusaka | Lusaka |
| Cancer Diseases Hospital | Hospital - Level 3 | GRZ | Operational | Lusaka | Lusaka |
| Chainama Hills Hospital | Hospital - Level 3 | GRZ | Operational | Lusaka | Lusaka |
| Chawama First Level Hospital | Hospital - Level 1 | GRZ | Operational | Lusaka | Lusaka |
| Chilenje First Level Hospital | Hospital - Level 1 | GRZ | Operational | Lusaka | Lusaka |
| Chipata First Level Hospital | Hospital - Level 1 | GRZ | Operational | Lusaka | Lusaka |
| Chisomo Hospital | Hospital - Level 1 | Private | Operational | Lusaka | Lusaka |
| Fairview Hospital | Hospital - Level 2 | Private | Operational | Lusaka | Lusaka |
| Kanyama First Level Hospital | Hospital - Level 1 | GRZ | Operational | Lusaka | Lusaka |
| Levy Mwanawasa Teaching Hospital | Hospital - Level 3 | GRZ | Operational | Lusaka | Lusaka |
| Maina Soko Military Hospital | Hospital - Level 3 | GRZ | Operational | Lusaka | Lusaka |
| Matero First Level Hospital | Hospital - Level 1 | GRZ | Operational | Lusaka | Lusaka |

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|---|---|---|---|---|---|
| Pearl of Health Hospital | Hospital - Level 2 | Private | Operational | Lusaka | Lusaka |
| UTH-Women and NewBorn Hospital | Hospital - Level 3 | GRZ | Operational | Lusaka | Lusaka |
| UTH Adult Hospital | Hospital - Level 3 | GRZ | Operational | Lusaka | Lusaka |
| UTH Children's Hospital | Hospital - Level 3 | GRZ | Operational | Lusaka | Lusaka |
| UTH Eye Hospital | Hospital - Level 3 | GRZ | Operational | Lusaka | Lusaka |
| Victoria Hospital | Hospital - Level 2 | Private | Operational | Lusaka | Lusaka |
| ZAF Headquarters Hospital | Hospital - Level 1 | Military | Operational | Lusaka | Lusaka |
| | Hospital - Level 2 | Private | Operational | Lusaka | Lusaka |
| Mpanshya (St. Luke) Mission Hospital | Hospital - Level 1 | NGO | Operational | Rufunsa | Lusaka |
| Chama District Hospital | Hospital - Level 1 | GRZ | Operational | Chama | Muchinga |
| Chinsali General Hospital | Hospital - Level 2 | GRZ | Operational | Chinsali | Muchinga |
| Isoka District Hospital | Hospital - Level 1 | GRZ | Operational | Isoka | Muchinga |
| Muyombe Rural Health Centre | Hospital - Level 1 | GRZ | Operational | Mafinga | Muchinga |
| Chilonga Mission General Hospital | Hospital - Level 2 | NGO | Operational | Mpika | Muchinga |
| Michael Chilufya Sata Hospital | Hospital - Level 1 | GRZ | Operational | Mpika | Muchinga |
| Mpika Urban Health Centre | Hospital - Level 1 | GRZ | Operational | Mpika | Muchinga |
| Nakonde District Hospital | Hospital - Level 1 | GRZ | Operational | Nakonde | Muchinga |
| Mulanga Rural Health Centre | Hospital - Level 1 | NGO | Operational | Shiwangandu | Muchinga |
| Chavuma District Hospital | Hospital - Level 1 | GRZ | Operational | Chavuma | North-Western |
| Chavuma Mission Hospital | Hospital - Level 1 | NGO | Operational | Chavuma | North-Western |
| Kalene Mission Hospital | Hospital - Level 1 | NGO | Operational | Ikelenge | North-Western |
| Kabompo District Hospital | Hospital - Level 1 | GRZ | Operational | Kabompo | North-Western |

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|---|---|---|---|---|---|
| Loloma Mission Hospital | Hospital - Level 1 | NGO | Operational | Manyinga | North-Western |
| Mufumbwe District Hospital | Hospital - Level 1 | GRZ | Operational | Mufumbwe | North-Western |
| Luwi Mission Hospital | Hospital - Level 1 | NGO | Operational | Mwinilunga | North-Western |
| Mwinilunga District Hospital | Hospital - Level 1 | GRZ | Operational | Mwinilunga | North-Western |
| Hill Top Private Hospital | Hospital - Level 1 | Private | Operational | Solwezi | North-Western |
| Solwezi General Hospital | Hospital - Level 2 | GRZ | Operational | Solwezi | North-Western |
| Chitokoloki Hospital Affiliated Health Centre | Hospital - Level 1 | NGO | Operational | Zambezi | North-Western |
| Zambezi District Hospital | Hospital - Level 1 | GRZ | Operational | Zambezi | North-Western |
| Zambezi District Hospital Affiliated Health Centre | Hospital - Level 1 | GRZ | Operational | Zambezi | North-Western |
| Chilubi Mainland District Hospital | Hospital - Level 1 | GRZ | Operational | Chilubi | Northern |
| Kaputa District Hospital | Hospital - Level 1 | GRZ | Operational | Kaputa | Northern |
| Kasama General Hospital | Hospital - Level 2 | GRZ | Operational | Kasama | Northern |
| Lubushi Mission Hospital | Hospital - Level 1 | GRZ | Operational | Kasama | Northern |
| Luwingu District Hospital | Hospital - Level 1 | GRZ | Operational | Luwingu | Northern |
| Mbala General Hospital | Hospital - Level 2 | GRZ | Operational | Mbala | Northern |
| Mporokoso District Hospital | Hospital - Level 1 | GRZ | Operational | Mporokoso | Northern |
| Mpulungu District Hospital | Hospital - Level 1 | GRZ | Operational | Mpulungu | Northern |
| Senga Hill Rural Health Centre | Hospital - Level 1 | GRZ | Operational | SengaHill | Northern |
| Chikankata Referral Hospital | Hospital - Level 1 | NGO | Operational | Chikankata | Southern |
| Kafue Gorge Hospital | Hospital - Level 1 | GRZ | Operational | Chikankata | Southern |
| Gwembe District Hospital | Hospital - Level 1 | GRZ | Operational | Gwembe | Southern |
| New Gwembe District Hospital | Hospital - Level 1 | GRZ | Operational | Gwembe | Southern |

| | | | | | |
|---|---|---|---|---|---|
| Kalomo District Hospital | Hospital - Level 1 | GRZ | Operational | Kalomo | Southern |
| NewKalomo District Hospital | Hospital - Level 1 | GRZ | Operational | Kalomo | Southern |
| Kazungula District Hospital | Hospital - Level 1 | GRZ | Operational | Kazungula | Southern |
| New Kazungula District Hospital | Hospital - Level 1 | GRZ | Operational | Kazungula | Southern |
| Mazabuka General Hospital | Hospital - Level 1 | GRZ | Operational | Mazabuka | Southern |
| Mazabuka General Hospital Affiliated Health Centre | Hospital - Level 1 | GRZ | Operational | Mazabuka | Southern |
| Chikuni Mission Hospital | Hospital - Level 1 | NGO | Operational | Monze | Southern |
| Monze Mission Hospital | Hospital - Level 2 | NGO | Operational | Monze | Southern |
| Namwala District Hospital | Hospital - Level 1 | GRZ | Operational | Namwala | Southern |
| New Namwala District Hospital | Hospital - Level 1 | GRZ | Operational | Namwala | Southern |
| Siavonga District Hospital | Hospital - Level 1 | GRZ | Operational | Siavonga | Southern |
| Maamba General Hospital | Hospital - Level 1 | GRZ | Operational | Sinazongwe | Southern |
| Zimba Mission Hospital | Hospital - Level 1 | NGO | Operational | Zimba | Southern |
| Kalabo District Hospital | Hospital - Level 1 | GRZ | Operational | Kalabo | Western |
| Yuka Mission Hospital | Hospital - Level 1 | NGO | Operational | Kalabo | Western |
| Kaoma District Hospital | Hospital - Level 1 | GRZ | Operational | Kaoma | Western |
| Mangango Mission Hospital (St. Joseph) | Hospital - Level 1 | NGO | Operational | Kaoma | Western |
| Mangango Mission Hospital Affiliated Health Centre (St. Joseph) | Hospital - Level 1 | NGO | Operational | Kaoma | Western |
| Lukulu District Hospital | Hospital - Level 1 | GRZ | Operational | Lukulu | Western |
| Lewanika Referral Hospital | Hospital - Level 2 | GRZ | Operational | Mongu | Western |

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|---|---|---|---|---|---|
| Mulobezi District Hospital | Hospital - Level 1 | GRZ | Operational | Mulobezi | Western |
| Sichili Mission Hospital | Hospital - Level 1 | NGO | Operational | Mulobezi | Western |
| Mwandi Mission Hospital | Hospital - Level 1 | NGO | Operational | Mwandi | Western |
| Senanga General Hospital | Hospital - Level 1 | GRZ | Operational | Senanga | Western |
| Yeta District Hospital | Hospital - Level 1 | GRZ | Operational | Sesheke | Western |
| Shangombo District Hospital | Hospital - Level 1 | GRZ | Operational | Shangombo | Western |

# 11. Appendix D: Project Timeline—Gantt Chart

| | WBS | Name | Duration | Start | Finish |
|---|---|---|---|---|---|
| 1 | 1 | **Project Inception** | **11 days** | **12/13/21 8:00 AM** | **12/27/21 5:00 PM** |
| 2 | 1.1 | Contract Signing | 0 days | 12/13/21 8:00 AM | 12/13/21 8:00 AM |
| 3 | 1.2 | Drafting Inception Report | 11 days | 12/13/21 8:00 AM | 12/27/21 5:00 PM |
| 4 | 1.3 | Inception Report | 0 days | 12/27/21 5:00 PM | 12/27/21 5:00 PM |
| 5 | 2 | **Project Scoping and Planning** | **5 days** | **1/3/22 8:00 AM** | **1/7/22 5:00 PM** |
| 6 | 2.1 | Kickoff Meeting | 0 days | 1/3/22 8:00 AM | 1/3/22 8:00 AM |
| 7 | 2.2 | UNZABREC Ethical Clearance | 5 days | 1/3/22 8:00 AM | 1/7/22 5:00 PM |
| 8 | 2.3 | NHRA Ethical Clearance | 5 days | 1/3/22 8:00 AM | 1/7/22 5:00 PM |
| 9 | 3 | **Study 1. Radiological Workflows** | **180 days** | **1/3/22 8:00 AM** | **9/9/22 5:00 PM** |
| 10 | 3.1 | Experiment Planning and Design | 30 days | 1/3/22 8:00 AM | 2/11/22 5:00 PM |
| 11 | 3.2 | Experiment Execution | 120 days | 2/14/22 8:00 AM | 7/29/22 5:00 PM |
| 12 | 3.3 | Data Analysis | 30 days | 8/1/22 8:00 AM | 9/9/22 5:00 PM |
| 13 | 3.4 | Scholarly Publiction Drafting | 130 days | 2/7/22 8:00 AM | 8/5/22 5:00 PM |
| 14 | 3.5 | Scholarly Publication Submission | 0 days | 8/5/22 5:00 PM | 8/5/22 5:00 PM |
| 15 | 4 | **Study 2. Archival Records Analysis** | **135 days** | **1/3/22 8:00 AM** | **7/8/22 5:00 PM** |
| 16 | 4.1 | Data Preprocessing and Organisation | 115 days | 1/3/22 8:00 AM | 6/10/22 5:00 PM |
| 17 | 4.2 | Scholarly Publication Drafting | 45 days | 5/9/22 8:00 AM | 7/8/22 5:00 PM |
| 18 | 4.3 | Scholarly Publication Submission | 0 days | 7/8/22 5:00 PM | 7/8/22 5:00 PM |
| 19 | 5 | **Study 3. Machine Learning Model Implementation** | **220 days** | **2/7/22 8:00 AM** | **12/9/22 5:00 PM** |
| 20 | 5.1 | Data Collection and Preprocessing | 90 days | 2/7/22 8:00 AM | 6/10/22 5:00 PM |
| 21 | 5.2 | Data Labeling | 90 days | 6/13/22 8:00 AM | 10/14/22 5:00 PM |
| 22 | 5.3 | Labeled Dataset | 0 days | 10/14/22 5:00 PM | 10/14/22 5:00 PM |
| 23 | 5.4 | Model Implementation | 95 days | 6/13/22 8:00 AM | 10/21/22 5:00 PM |
| 24 | 5.5 | Model Evaluation: Effectiveness | 5 days | 10/24/22 8:00 AM | 10/28/22 5:00 PM |
| 25 | 5.6 | Model Deployment | 10 days | 10/31/22 8:00 AM | 11/11/22 5:00 PM |
| 26 | 5.7 | Model Evaluation: Usefulness | 15 days | 11/14/22 8:00 AM | 12/2/22 5:00 PM |
| 27 | 5.8 | Scholarly Publication Drafting | 130 days | 6/13/22 8:00 AM | 12/9/22 5:00 PM |
| 28 | 5.9 | Scholarly Publication Submission | 0 days | 12/9/22 5:00 PM | 12/9/22 5:00 PM |
| 29 | 6 | **Project Decomissioning** | **0 days** | **12/12/22 8:00 AM** | **12/12/22 8:00 AM** |
| 30 | 6.1 | Project Decomissioning Meeting | 0 days | 12/12/22 8:00 AM | 12/12/22 8:00 AM |

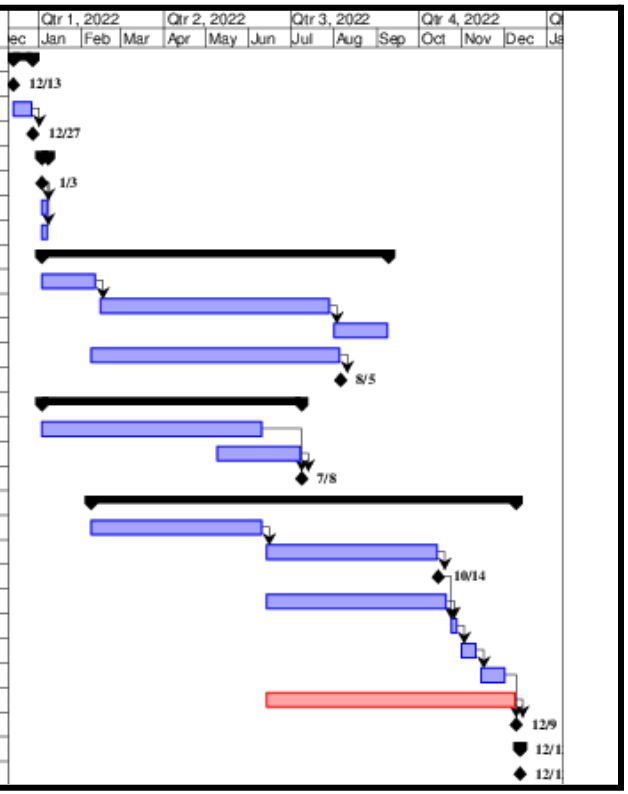


Figure 5: Project Timeline

# 12. Appendix E: Project Deliverables

Table 4: Project Deliverables

| | |
|---|---|
| **Deliverable D 1 — Inception Report Detailing the Work Plan of the Project** | |
| D 1.1 Inception Report | • Report outlining the key areas to be addressed during the consultancy, including a detailed work plan |
| **Deliverable D 2 — Experimental Results** | |
| D 2.1 Experiment 1. Radiological Workflows | • Experimental results for experiment conducted to understand current Radiological workflows |
| D 2.2 Experiment 2. Archival Records Analysis | • Experimental results for experiment conducted to analyse historical archival records of Medical Imaging modalities |
| D 2.3 Experiment 3. Machine Learning Model: Effectiveness | • Experimental results for experiment conducted to evaluate the precision, recall and accuracy of the Machine Learning classification model |
| D 2.4 Experiment 4. Machine Learning Model: Usefulness | • Experimental results for experiment conducted to evaluate the potential usefulness of the Machine Learning classification model |
| **Deliverable D 3 — Datasets** | |
| D 3.1 Labelled Dataset for Chest X-Rays | • Labelled dataset for Chest X-Rays |

| | |
|---|---|
| **Deliverable D 4 — Machine Learning Classification Model** | |
| D 4.1 Chest X-Rays | • Machine Learning classification model for classifying Check X-Rays |
| **Deliverable D 5 — Scholarly Publications** | |
| D 5.1 Radiological Workflows Public | • Publication detailing radiological workflows in public health facilities in Zambia |
| D 5.3 Semi-Automatic Classification Using Machine Learning | • Publication outlining offline Machine Learning model for classification of medical imaging modalities |
| **Deliverable D 6 — Research Reports Detailing Activities Conducted** | |
| D 6.1 Mid-Term Progress Report | • Mid-term progress report outlining progress made during execution of the project |
| D 6.2 Final Research Report | • Report outlining project activities and evaluation of project goals and objectives |

# 13. Appendix F: Risk Management

Table 5: Risk Management Strategy

| # | Risk | Consequence | Class | *P* | Impact | Mitigation | Monitoring | Management |
|---|---|---|---|---|---|---|---|---|
| 1 | Delayed Project Schedule | Leads to cost overrun and time overrun hence increasing the duration of the project development. | Project Management | Low | High | • Ensure project goals are set realistically.<br>• Periodic monitoring of project progress | • Regular project update meetings | • Assign additional resources if required |
| 2 | Covid 19 and other national emergencies | Project delayed and final product not delivered on time | Project Management | High | High | • Project team to create a crisis management plan that will mitigate the impact on the project schedule | • Project team to closely monitor the national covid 19 management efforts by GRZ | • Envoke of the Crisis Management plan |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | Delayed ethical clearance approval | Project delayed since research cannot proceed without prior ethical clearance approval | Technical | Low | High | • Ethical clearance approval application to be prioritised and regular follow-ups to be performed | • Regular project update meetings | • Assign dedicated individuals to follow-up on approvals |
| 4 | Non-availability of human experts to create labelled dataset(s) | Implementation of Machine Learning classification model affected and project delayed | Technical | Medium | High | • Identify appropriate experts and train them early during project execution | • Routinely assess progress made during labeling process | • Utilise crowdsourcing platform for labeling exercise to track individual experts |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 | Non-availability of study participants | Project delayed since subsequent phases of the project will potentially be dependent on input from participants | Technical | Low | Medium | • Interactions with study participants will be scheduled in advance<br>• Due to the large number of study participants, appropriate data collection techniques will be employed | • Follow-ups with potential study participants to confirm participation | • Use reliable scheduling tool, e.g. Google Calendar, for appointments |