

# TABLE OF CONTENTS

|                                                                                |      |
|--------------------------------------------------------------------------------|------|
| TABLE OF CONTENTS.....                                                         | i    |
| LIST OF FIGURES .....                                                          | iv   |
| LIST OF TABLES.....                                                            | v    |
| SELF DECLARATION AGAINST PLAGIARISM.....                                       | vi   |
| APPROVAL PAGE .....                                                            | vii  |
| ACKNOWLEDGMENTS .....                                                          | viii |
| PREFACE .....                                                                  | ix   |
| ABSTRACT.....                                                                  | x    |
| CHAPTER I INTRODUCTION.....                                                    | 1    |
| 1.1. Background.....                                                           | 1    |
| 1.2. Statement of the Problem .....                                            | 7    |
| 1.3. Objective.....                                                            | 8    |
| 1.4. Scope of Work .....                                                       | 9    |
| 1.5. Hypothesis .....                                                          | 9    |
| 1.6. Research Methodology .....                                                | 10   |
| 1.7. Research Plan .....                                                       | 11   |
| CHAPTER 2 LITERATURE REVIEW .....                                              | 13   |
| 2.1. Fundamentals of Wireless and Hybrid FSO/RF Communication .....            | 13   |
| 2.2. Free Space Optical (FSO) Communication Theory.....                        | 14   |
| 2.2.1. Transmission Principle.....                                             | 15   |
| 2.2.2. System Components and Parameters .....                                  | 15   |
| 2.2.3. Link Losses and Atmospheric Effects.....                                | 17   |
| 2.2.4. Total Link Budget .....                                                 | 19   |
| 2.2.5. Noise and Bit Error Rate (BER).....                                     | 20   |
| 2.2.6. Coherent receivers and the Role of DSP in FSO Systems .....             | 21   |
| 2.3. Microwave Communication Theory.....                                       | 22   |
| 2.3.1. Link Budget Analysis and Effective Isotropic Radiated Power (EIRP)..... | 23   |
| 2.3.2. Path Loss Models .....                                                  | 24   |
| 2.3.3. Atmospheric Attenuation .....                                           | 25   |
| 2.3.4. Receiver Parameters.....                                                | 25   |
| 2.3.5. Bit Error Rate (BER).....                                               | 26   |
| 2.4. Damping and Loss Models in Wireless Systems.....                          | 26   |
| 2.4.1. BER Thresholds for Switching Decisions.....                             | 27   |

|                                        |                                                                    |    |
|----------------------------------------|--------------------------------------------------------------------|----|
| 2.5.                                   | Regulations and Safety Standards .....                             | 28 |
| 2.5.1.                                 | Optical Safety Compliance in Free Space Optics (FSO) Systems ..... | 28 |
| 2.6.                                   | Theoretical Basis for Economic Feasibility Analysis.....           | 30 |
| 2.6.1.                                 | Cost Benefit Analysis.....                                         | 31 |
| 2.6.2.                                 | Revenue Modelling .....                                            | 31 |
| 2.6.3.                                 | Capital and Operational Expenditures (CAPEX & OPEX) .....          | 32 |
| 2.6.4.                                 | Net Present Value (NPV) .....                                      | 32 |
| 2.6.5.                                 | Internal Rate of Return (IRR).....                                 | 33 |
| 2.6.6.                                 | Payback Period (PP).....                                           | 34 |
| 2.6.7.                                 | What-If Scenario Analysis .....                                    | 35 |
| CHAPTER III RESEARCH METHODOLOGY ..... |                                                                    | 37 |
| 3.1.                                   | Research Design .....                                              | 37 |
| 3.2.                                   | Research Site and Link Characteristics .....                       | 40 |
| 3.3.                                   | System Parameters and Assumptions .....                            | 41 |
| 3.3.1.                                 | FSO Link Design Parameters for Simulation.....                     | 43 |
| 3.3.2.                                 | Microwave System Parameters .....                                  | 45 |
| 3.3.3.                                 | General Assumptions .....                                          | 47 |
| 3.4.                                   | Data Collection.....                                               | 48 |
| 3.5.                                   | Analysis Method.....                                               | 49 |
| 3.5.1.                                 | Performance Analysis (BER).....                                    | 49 |
| 3.5.2.                                 | Smart Switching Modelling and Simulation .....                     | 51 |
| 3.6.                                   | Equipment and Software .....                                       | 52 |
| CHAPTER IV RESULT AND ANALYSIS.....    |                                                                    | 53 |
| 4.1.                                   | Comparative Topographical Analysis for (FSO) and Microwave.....    | 53 |
| 4.1.1.                                 | Analysis of the Path to STO Telkom Klojen.....                     | 53 |
| 4.1.2.                                 | Analysis of the Path to STO Telkom Gunung Kawi .....               | 55 |
| 4.1.3.                                 | Comparative Conclusion and Recommendation .....                    | 56 |
| 4.2.                                   | Simulation Parameter Settings.....                                 | 57 |
| 4.2.1.                                 | Communication System Parameters.....                               | 57 |
| 4.2.2.                                 | Microwave System Parameters .....                                  | 59 |
| 4.2.3.                                 | Link Parameters, Environment, and <i>Path Loss Model</i> .....     | 60 |
| 4.2.4.                                 | Path Loss Model and Additional Assumptions .....                   | 61 |
| 4.3.                                   | FSO Implementation .....                                           | 62 |
| 4.3.1.                                 | Input Parameter .....                                              | 62 |
| 4.3.2.                                 | Core Computation .....                                             | 64 |
| 4.3.3.                                 | Results Initialization and Conversion .....                        | 66 |
| 4.3.4.                                 | Plotting Results .....                                             | 67 |
| 4.4.                                   | Technical Performance Analysis.....                                | 67 |
| 4.4.1.                                 | FSO System Performance in Various Weather Scenarios.....           | 68 |

|                           |                                                                      |    |
|---------------------------|----------------------------------------------------------------------|----|
| 4.4.2.                    | Performance of Microwave Systems in Various Weather Scenarios .....  | 69 |
| 4.4.3.                    | FSO vs. Performance Comparison Microwave.....                        | 72 |
| 4.4.4.                    | Climate Data Analysis and Categorization of Weather Conditions ..... | 76 |
| 4.5.                      | Economic Analysis .....                                              | 79 |
| 4.5.1.                    | CAPEX Calculation .....                                              | 80 |
| 4.5.2.                    | OPEX Estimation .....                                                | 82 |
| 4.5.3.                    | Internet Service Adoption Projection .....                           | 84 |
| 4.5.4.                    | ARPU Projection.....                                                 | 85 |
| 4.5.5.                    | Business Plan Modelling.....                                         | 86 |
| 4.5.6.                    | Feasibility Business Analysis.....                                   | 89 |
| 4.5.7.                    | What-If Scenario Analysis .....                                      | 90 |
| CHAPTER V CONCLUSION..... |                                                                      | 93 |
| 5.1.                      | Conclusions .....                                                    | 93 |
| 5.2.                      | Reflections and Research Limitations .....                           | 95 |
| 5.3.                      | Recommendations and Future Works.....                                | 95 |
| REFERENCES .....          |                                                                      | 96 |