CONTENTS

APPROVAL PAGE

SELF DECLARATION AGAINST PLAGIARISM

ABSTRACT **iv**

ACKNOWLEDGEMENTS **v**

PREFACE **vi**

CONTENTS **vii**

LIST OF FIGURES **x**

LIST OF TABLES **xi**

LIST OF ABBREVIATION **xii**

1 INTRODUCTION **1**

1.1 Background 1
1.2 Problem Identification 2
1.3 Research Objectives 3
1.4 Scope of Work 4
1.5 Research Methodology 4
1.6 Structure of The Thesis 5

2 BASIC CONCEPT **6**

2.1 Introduction of UIC 6
2.1.1 Introduction of 5GRAIL Project 7
2.1.2 Use of 3GPP technologies by Railways 8
2.1.3 Introduction of FRMCS 9
2.1.4 The benefits of adopting a 5G-based FRMCS. 10
2.1.5 Understanding on ETSI TR 103 554-2 12
2.2 The Concept of 5G Railways 13
2.3 Introduction of ETCS and CTCS 13
2.4 The Concept of Fractional Frequency Reuse 16

2.5 Understanding on Spectrum Use and Efficiency 17
2.6 Introduction of Radio Link Budget 18
2.6.1 Maximum Allowable Path Loss 19
2.6.2 Propagation Model in 5G System 19
2.6.2.1 The Concept of Urban Macro Propagation Model 20
2.6.2.2 The Concept of Rural Macro Propagation Model . 21
2.7 Development of Railway in Indonesia 22
2.8 Spectrum Management in Indonesia 23
2.8.1 Overview of TASFRI 24
2.8.2 Spectrum Fee in Indonesia 24
2.8.2.1 Apparatus License 25
2.8.2.2 Bandwidth License 25
2.8.2.3 Class License 26
2.9 Investment Feasibility Analysis 26
2.9.1 Net Present Value 26
2.9.2 Internal Rate of Return 27
2.9.3 Payback Period 27

3 SYSTEM MODEL 28
3.1 Research Area 28
3.2 Spectrum Utilization Efficiency 29
3.3 Spectrum Fee Analysis 30
3.4 Economic Evaluation 30
3.4.1 CAPEX, OPEX, and Revenue 31
3.4.2 Net Present Value 32
3.4.3 Internal Rate of Return 33
3.4.4 Payback Period 33
3.5 Coverage Planning 33
3.5.1 Link Budget Calculation 33
3.5.2 Propagation Model Analysis 34
3.5.3 Measurement of Cell Radius 34
3.5.4 Calculation of the Number of Base Stations 35

4 EVALUATION AND ANALYSIS 37
4.1 Business Performance of Railway Operator in Indonesia 37
4.2 Radio-frequency Spectrum Management in Indonesia 39
4.3 Spectrum Fee Analysis 40
4.4 Analysis on SUE 42

4.5 Migrating towards FRMCS in Europe 44
4.6 Link Budget and Coverage Planning Analysis 46
4.7 Cost Investment Analysis 48
4.8 Evaluation of Risks in FRMCS Deployment 51

5 CONCLUSION **55**
5.1 Conclusion 55
5.2 Future Works 56

REFERENCES **57**