PLANNING OF LNG DISTRIBUTION SCHEME FOR INDONESIA TOURISM DEVELOPMENT CORPORATION (ITDC) IN NUSA DUA, BALI

BAGUS SETIAWAN ROZMIRA PUTRA
NRP. 04211741000033

SUPERVISORS:
FADILLA INDRAYUNI PRASTYASARI, S.T., M.Sc
Dr. EMMY PRATIWI, S.T.

DEPARTMENT OF MARINE ENGINEERING
FACULTY OF MARINE TECHNOLOGY
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
SURABAYA
2020

PERENCANAAN SKEMA DISTRIBUSI LNG UNTUK *INDONESIA TOURISM DEVELOPMENT CORPORATION (ITDC)* DI NUSA DUA, BALI

BAGUS SETIAWAN ROZMIRA PUTRA
NRP. 04211741000033

PEMBIMBING:
FADILLA INDRAYUNI PRASTYASARI, S.T., M.Sc
Dr. EMMY PRATIWI, S.T.

DEPARTEMEN TEKNIK SISTEM PERKAPALAN
FAKULTAS TEKNOLOGI KELAUTAN
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
SURABAYA
2020

"We hereby declare that we have read this thesis and in our opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Engineering."

Signature : ……..……
Supervisor I : FADILLA INDRAYUNI PRASTYASARI, S.T., M.Sc
NIP. : 1995201712047
Date : 3rd MARCH 2021

Signature : ……..……
Supervisor II : Dr. EMMY PRATIWI, S.T.
NUP. : 1993201972057
Date : 3rd MARCH 2021

Endorsed by Head of Marine Engineering Department:

Signature : ……..……
Head of Department : BENY CAHYONO, S.T., M.T., Ph. D
NIP./NPP. : 197903192008011008
Date : 5th MARCH 2021

PLANNING OF LNG DISTRIBUTION SCHEME FOR INDONESIA TOURISM DEVELOPMENT CORPORATION (ITDC) IN NUSA DUA, BALI

BAGUS SETIAWAN ROZMIRA PUTRA

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Bachelor of Engineering
Reliability, Availability, Management
and Safety (RAMS)

Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember
MARCH 2021

This page is intentionally left blank

"I declare that this thesis entitled *PLANNING OF LNG DISTRIBUTION SCHEME FOR INDONESIA TOURISM DEVELOPMENT CORPORATION (ITDC) IN NUSA DUA, BALI* is the result of my own research except as cited in the references. This thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree."

Signature : ……..……
Name : BAGUS SETIAWAN ROZMIRA PUTRA
NRP. : 04211741000033
Date : 3rd MARCH 2021

This page is intentionally left blank

ACKNOWLEDGMENT

In this section, the author would like to praise and thanks to God for giving the knowledge and strength in order to complete this Bachelor Thesis entitled "PLANNING OF LNG DISTRIBUTION SCHEME FOR INDONESIA TOURISM DEVELOPMENT CORPORATION (ITDC) IN NUSA DUA, BALI". In expectation, the result of this Bachelor Thesis would be beneficial for author and surroundings that involves in this aspect.

Also, the author would give the warmest regards and appreciation for those who had helped and contributed highly by guiding and providing knowledge in this completion of this Bachelor Thesis.

1. Author's beloved Parents and Sister, Herros Herryawan, Anak Agung Ayu Mirah Permatasari, and Apt. Ayu Intansari Rozmiramadhani Putri, S.Farm., who always give prayer and support during the process of this Bachelor Thesis
2. Beny Cahyono, S.T., M.T., Ph. D as the Head of Marine Engineering Department, Marine Technology Faculty of Institut Teknologi Sepuluh Nopember
3. Fadilla Indrayuni P., ST., M.Sc. and Dr. Emmy Pratiwi, S.T., M.T. as the supervisor who guide and enlightened with knowledge, motivation, and encouragement since the beginning of this Bachelor Thesis
4. Prof. Dr. Ketut Buda Artana, S.T., M.Sc. as the Head of RAMS Laboratory
5. A.A.B. Dinariyana D.p., S.T., MES, Ph. D, Dr. Eng. Dhimas Widhi Handani, S.T., M.Sc, Raja Oloan Saut Gurning, ST., M.Sc., Ph.D, and Taufik Fajar Nugroho, S.T., M.Sc. as the lecture of RAMS Laboratory
6. Prof. Semin, S.T., M.T., Ph.D. as author's supervisor lecturer
7. A.A. Istri Ratna Dewi as President Director of PT ITDC Nusantara Utilitas and Putu Wedastra Putra for giving an extraordinary knowledge in terms of hospitality to support this Bachelor Thesis
8. Mr. Ari Pramana from Dinas Perhubungan Provinsi Bali for giving a further enlighten regarding the transportation view in this Bachelor Thesis
9. All colleagues and family of RAMS Laboratory who guided and provided with a lot of references
10. Author's four horsemen squad, Mahsa Gyda Rahma, Muhammad Ilham Zakaria, and Kezia Kinantya Atinirra Simson that always been supporting each other
11. Risa Nurachmah Harahap as author beloved girlfriend, who always support and giving prayers during the process of this Bachelor Thesis
12. Pande Pramudya Deva, Rahmania Indri Adhyaksa, Reza N, Dipto Pratomo Nugroho and beloved UKAFO Member as author beloved best friend
13. And all beloved Double Degree Class of 2017 who has giving a full support since the beginning of this college

Authors realize that there is no such a perfect writing, and author is expecting with inputs and suggestion for this research. In expectation, this study would become a beneficial matter, not only for the author but for the benefit of others as well.

Bali, 2021

Bagus Setiawan Rozmira Putra

ABSTRACT

Foreign tourists in Indonesia are increasing every year from 2014 until 2018, reaching 14% per year which is the usage of energy for hospitality also increased. Bali already using Liquified Natural Gas (LNG) as the main source of energy for power plant that supplied from LNG Terminal Benoa up to 50 MMSCFD. To maximize the usage of LNG in Bali, distributing the LNG for hospitality in Indonesia Tourism Developer Corporation (ITDC) is planned. Planning of LNG distribution scheme is to achieve best scenario and determine the equipment on each facility with considering the risk of transportation and the facility. The LNG distribution scheme for ITDC will be from LNG Filling Station in Benoa to fill LNG ISO Tank that will be carried with Truck to Small-Scale Gas Station (SSGS) near ITDC as the regasification unit, then the gas will be distributed to each facility using Pipeline Natural Gas (PNG). Risk assessment road transport started from hazard identification using What-If Analysis and the potential hazard is road accident collision. Then, the frequency of a Collision is using accident report data and the consequences analysis is from the road lethal area. On risk level mapping using The Netherlands f/N Curve standard, truck route A are in Tolerability Region A and B, which chosen as the truck route. Risk assessment on LNG Facility started from Hazard and Operability Study (HAZOP) and the potential hazard is fire. Then, analysing the frequency of hazard event using Fault Tree Analysis (FTA) and Event Tree Analysis (ETA) and resulting 3 hazard events, Jet Fire, Flash Fire, and Gas Dispersion with 3 bore scenarios, 5 mm, 15 mm, and 30 mm. The consequences analysis is using fire modelling software to obtain the thermal flux range on each hazard event that occur which has a fatal impact on humans in LNG facility area. On risk mapping using f/N Curve UK-HSE showing that Jet Fire is in ALARP area and Flash Fire is in ALARP area and 3 scenarios in Unacceptable area. Mitigation using Layer of Protection Analysis (LOPA) by adding a gas detector, pressure alarm, and temperature alarm to decrease the frequencies.

Keywords: LNG, Distribution, Risk Assessment, f/N Curve, Fire Modelling

This page is intentionally left blank

ABSTRAK

Wisatawan mancanegara di Indonesia mengalami peningkatan setiap tahun dari tahun 2014 hingga 2018 mencapai 14% pertahun yang mana penggunaan energi untuk perhotelan juga meningkat. Bali sudah menggunakan *Liquified Natural Gas* (LNG) sebagai sumber energi utama pembangkit yang disuplai dari Terminal LNG Benoa hingga 50 MMSCFD. Untuk memaksimalkan penggunaan LNG di Bali, pendistribusian LNG untuk fasilitas di *Indonesia Tourism Developer Corporation* (ITDC) direncanakan. Perencanaan skema distribusi LNG adalah untuk mencapai skenario terbaik dan menentukan peralatan pada masing-masing fasilitas dengan mempertimbangkan resiko transportasi dan fasilitas tersebut. Skema pendistribusian LNG untuk ITDC akan dilakukan dari *LNG Filling Station* di Benoa untuk mengisi *LNG ISO Tank* yang akan diangkut dengan Truk ke *Small-Scale Gas Station* (SSGS) di dekat ITDC sebagai unit regasifikasi, selanjutnya gas akan didistribusikan ke masing-masing fasilitas menggunakan *Pipeline Natural Gas* (PNG). Penilaian risiko transportasi darat dimulai dari identifikasi bahaya menggunakan *What-If Analysis* dan potensi bahayanya adalah menabrak kendaraan lain di jalan raya. Kemudian frekuensi kecelakaan menggunakan data laporan kecelakaan dan analisis akibatnya dari menganalisis daerah jalan yang bahaya. Pada pemetaan tingkat risiko menggunakan standar *The Netherlands f/N Curve*, jalur truk A berada pada *Tolerabilitas Region A* dan *B* sehingga dipilih sebagai jalur truk. Penilaian risiko pada Fasilitas LNG dimulai dari *Hazard and Operability Study* (HAZOP) dan potensi bahayanya adalah kebakaran dan ledakan. Kemudian dilakukan analisis frekuensi kejadian bahaya menggunakan *Fault Tree Analysis* (FTA) dan *Event Tree Analysis* (ETA) dan menghasilkan 3 kejadian bahaya yaitu *Jet Fire, Flash Fire, dan Gas Dispersion* dengan 3 skenario kebocoran, 5 mm, 15 mm, dan 30 mm. Analisis konsekuensi menggunakan software pemodelan kebakaran untuk mendapatkan range fluks termal pada setiap kejadian bahaya yang terjadi yang berdampak fatal bagi manusia di area fasilitas LNG. Pada pemetaan resiko menggunakan *f/N Curve UK-HSE* yang menunjukkan bahwa *Jet Fire* berada di area *ALARP* dan *Flash Fire* berada di area *ALARP* dan juga 3 skenario berada di area *Unacceptable*. Mitigasi menggunakan *Layer of Protection Analysis (LOPA)* dengan menambahkan *gas detector, pressure alarm, dan temperature alarm* untuk menurunkan frekuensi.

Kata Kunci: LNG, Distribusi, Penilaian Risiko, *f/N Curve*, Pemodelan Kebakaran

This page is intentionally left blank

TABLE OF CONTENTS

ACKNOWLEDGMENT v
ABSTRACT vii
ABSTRAK ix
TABLE OF CONTENTS xi
LIST OF FIGURES xv
LIST OF TABLES xvii
LIST OF ABBREVIATIONS xxi
LIST OF SYMBOLS xxiii
CHAPTER 1 INTRODUCTION 1
1.1 Research Background 1
1.2 Problem Statement 2
1.3 Research Objectives 3
1.4 Problems Limitation 3
1.5 Research Benefit 3
CHAPTER 2 LITERATURE REVIEW 5
2.1 Introduction 5
2.2 Natural Gas in Indonesia 5
2.3 Liquified Natural Gas (LNG) 6
2.4 LNG Supply Chain 8
2.5 LNG Filling Station 9
2.6 Transporting Natural Gas 10
2.7 International Standards Organization (ISO) Tank 11
2.8 Pipeline Natural Gas (PNG) 13
2.9 Hospitality (Hotel & Villa) 14
2.10 Natural Gas Conversion 15
2.11 Risk Assessment 16
2.11.1 Hazard Identification (HAZID) 16
2.11.2 Hazard Identification Methods 17
2.11.3 Risk Assessment of Transporting Dangerous Goods by Road 18
2.11.4 Risk Assessment of LNG Facility 19
2.11.5 Fault Tree Analysis (FTA) 20
2.11.6 Event Tree Analysis (ETA) 21
2.11.7 Fire Modelling 21
2.11.8 f/N Curve 22
2.11.9 Layer of Protection Analysis (LOPA) 24
CHAPTER 3 RESEARCH METHODOLOGY 25
3.1 Introduction 25
3.2 Research Flowchart 25
3.3 Problem Identification 26

3.4 Literature Study 27
3.5 Data Collection 27
3.6 Design LNG Distribution Scheme 27
3.7 Risk Assessment of Transportation for LNG Distribution Scheme 27
3.8 Risk Assessment of LNG Facility 27
3.9 Conclusion and Suggestion 28
CHAPTER 4 RESULTS AND DISCUSSION 29
4.1 Introduction 29
4.2 List of Hotels and Villas in ITDC Nusa Dua, Bali 29
4.3 List of Other Facilities in ITDC Nusa Dua, Bali 30
4.4 Location of Facilities in ITDC Nusa Dua, Bali 30
4.5 Gas Consumption Analysis of ITDC Nusa Dua, Bali 31
4.6 LNG Capacity Analysis in LNG Terminal Benoa 32
4.7 Matrix Distance 34
4.8 Design LNG Distribution Scheme 37
4.8.1 Small-Scale Gas Station (SSGS) 41
4.8.2 LNG Truck and LNG ISO Tank 46
4.8.3 LNG Truck Route 47
4.8.4 Pipeline Natural Gas (PNG) 50
4.8.5 LNG Filling Station 54
4.8.6 Summary of LNG Distribution Scheme 55
4.9 Road Transport Risk Assessment 59
4.9.1 Accident Report 59
4.9.2 Hazard Identification (What-If Analysis) 64
4.9.3 The Frequency of Collision 66
4.9.4 Number of Fatalities 72
4.9.5 f/N Curve (The Netherlands) 76
4.10 Road Transport Risk Assessment (After 15 Years) 79
4.10.1 The Frequency of Collision 79
4.10.2 Number of Fatalities 82
4.10.3 f/N Curve (The Netherlands) 84
4.11 LNG Facility Risk Assessment 85
4.11.1 LNG Filling Station P&ID 85
4.11.2 The Layout of Small-Scale Gas Station 86
4.11.3 Small-Scale Gas Station P&ID 88
4.11.4 Environmental Data 89
4.11.5 Crew Data 89
4.11.6 Hazard Identification (HAZOP) 90
4.11.7 Guide Word 93
4.11.8 Deviation 93
4.11.9 HAZOP Worksheet 94
4.11.10 Frequency Analysis 115

4.11.11 Valve Leakage Frequency 115
4.11.12 Pipe Leakage Frequency 117
4.11.13 Pump Leakage Frequency 120
4.11.14 Indicator and Safeguard Leakage Frequency 122
4.11.15 Component Failure Frequency 124
4.11.16 Indicator and Safeguard Failure Frequency 126
4.11.17 Fault Tree Analysis (FTA) 128
4.11.18 Event Tree Analysis (ETA) 129
4.11.19 Consequences Analysis 131
4.11.20 Jet Fire Consequences Analysis 131
4.11.21 Flash Fire Consequences Analysis 134
4.11.22 f/N Curve (UK-HSE) 136
4.11.23 Mitigation 139
CHAPTER 5 CONCLUSION AND SUGGESTION 149
5.1 Conclusion 149
5.2 Suggestion 151
REFERENCES 153
BIOGRAPHY 261

This page is intentionally left blank

LIST OF FIGURES

Figure 1.1 Number of Foreign Visitors Arriving Directly To Bali, 2014-2018 1
Figure 2.1 Percentage of World Natural Gas Reserves 5
Figure 2.2 Natural Gas Reserves in Indonesia 6
Figure 2.3 LNG Supply Chain 8
Figure 2.4 LNG Supply Chain Plan for ITDC in Nusa Dua, Bali 9
Figure 2.5 FRU Lumbung Dewata 10
Figure 2.6 LNG Truck 11
Figure 2.7 Cryogenic ISO Tank 40 feet 11
Figure 2.8 Pipeline Natural Gas in Morocco 13
Figure 2.9 Natural Gas for Hospitality 14
Figure 2.10 The Location of Hotel & Villa in ITDC Nusa Dua 15
Figure 2.11 FTA Construction 20
Figure 2.12 ETA Construction 21
Figure 2.13 Fire Modelling Software (ALOHA) 22
Figure 2.14 f/N Curve UK-HSE 23
Figure 3.1 Research Flowchart 26
Figure 4.1 Location of Facilities in ITDC Nusa Dua, Bali 30
Figure 4.2 Location of LNG Terminal Benoa 33
Figure 4.3 LNG Distribution Flow Model 37
Figure 4.4 The Location of Small-Scale Gas Station 38
Figure 4.5 LNG Distribution Scheme A 39
Figure 4.6 LNG Distribution Scheme B 40
Figure 4.7 SSGS Flow Diagram 42
Figure 4.8 Truck Route A 49
Figure 4.9 Truck Route B 49
Figure 4.10 Natural Gas Pipeline Layout 50
Figure 4.11 LNG Filling Station Flow Diagram 54
Figure 4.12 LNG Distribution Scheme A Layout 56
Figure 4.13 LNG Distribution Scheme B Layout 56
Figure 4.14 F/N Curve Road Transport (Truck Route A) 76
Figure 4.15 F/N Curve Road Transport (Truck Route B) 78
Figure 4.16 f/N Curve Truck Route in 2035 84
Figure 4.17 LNG Filling Station P&ID 86
Figure 4.18 The Layout of SSGS 87
Figure 4.19 SSGS P&ID LNG ISO Tank to AAV 88
Figure 4.20 SSGS P&ID AAV to CNG Compressor 88
Figure 4.21 Node 1 & Node 2 of LNG Filling Station P&ID 91
Figure 4.22 Node 3 & Node 4 of SSGS P&ID 92
Figure 4.23 Node 4 of SSGS P&ID 92
Figure 4.24 Fault Tree Analysis of Node 1 Scenario 5 mm 129

Figure 4.25 Event Tree Analysis of Node 1 Scenario 5 mm 130
Figure 4.26 Fire Modelling of Jet Fire on Node 3 Scenario 15 mm.....132
Figure 4.27 Jet Fire of Node 3 Scenario 15 mm.....133
Figure 4.28 Fire Modelling of Flash Fire on Node 4 Scenario 15 mm.....134
Figure 4.29 Flash Fire of Node 4 Scenario 15 mm.....135
Figure 4.30 f/N Curve of Jet Fire Scenario 15 mm 136
Figure 4.31 f/N Curve of Flash Fire Scenario 15 mm 138

LIST OF TABLES

Table 2.1 Properties of Natural Gas 7
Table 2.2 Cryogenic ISO Tank Specification 12
Table 2.3 Natural Gas Conversion 15
Table 2.4 Acceptability Criterion of The Risk (The Netherlands) 23
Table 4.1 List of Hotels and Villas in ITDC Nusa Dua, Bali 29
Table 4.2 List and Location of Other Facilities in ITDC 30
Table 4.3 Data of Gas Consumption 31
Table 4.4 Gas Consumption Conversion 32
Table 4.5 LNG Terminal Benoa Capacity 33
Table 4.6 Distance Matrix (Using Toll) 34
Table 4.7 Distance Matrix (Not Using Toll) 35
Table 4.8 Detail of LNG Distribution Scheme 38
Table 4.9 Route Calculations A 42
Table 4.10 Route Calculations B 43
Table 4.11 20 ft ISO Tank Specification 44
Table 4.12 Reach Stacker Crane Specification 44
Table 4.13 Requirements for Regasification Unit 45
Table 4.14 LNG Pump Specification for SSGS 46
Table 4.15 Truck Specification 46
Table 4.16 Land Transportation Network System 47
Table 4.17 Road Dimension 48
Table 4.18 Data and Design Parameters for Natural Gas Pipeline 52
Table 4.19 Pipe Diameter 53
Table 4.20 Pipeline Specification 53
Table 4.21 LNG Pump Specification for LNG Filling Station 55
Table 4.22 Summary LNG Distribution Scheme A 57
Table 4.23 Summary LNG Distribution Scheme B 58
Table 4.24 Accident Report In September 2018 59
Table 4.25 Summary Accident Report In 2018 62
Table 4.26 What-If Analysis Sheet 64
Table 4.27 Summary Accident Report From 2018 to 2019 66
Table 4.28 Road Length 67
Table 4.29 Total Vehicle 67
Table 4.30 Basic Frequency *y0* 68
Table 4.31 Local Enhancing Parameters *(hj)* 68
Table 4.32 Local Enhancing Parameters on Raya Pelabuhan Benoa Road 70
Table 4.33 Local Enhancing Parameters on Truck Route 70
Table 4.34 The Expected Frequency 71
Table 4.35 The Frequency of a Collision (Truck Route A) 71
Table 4.36 The Frequency of a Collision (Truck Route B) 72

Table 4.37 The Vehicle Density 73
Table 4.38 The Road Lethal Area (Truck Route A) 74
Table 4.39 The Road Lethal Area (Truck Route B) 74
Table 4.40 The Fatality Number *Ns* (Truck Route A) 74
Table 4.41 The Fatality Number *Ns* (Truck Route B) 75
Table 4.42 Risk Mapping Road Transport (Truck Route A) 77
Table 4.43 Risk Mapping Road Transport (Truck Route B) 79
Table 4.44 Number of Vehicles in Bali (2014-2019) 80
Table 4.45 Number of Traffic Accidents in Bali (2014-2019) 80
Table 4.46 Number of Vehicles in 2035 80
Table 4.47 Number of Accidents in 2035 81
Table 4.48 The Basic Frequency *y0* 81
Table 4.49 The Expected Frequency *yi* 82
Table 4.50 The Frequency of Collision 82
Table 4.51 The Vehicle Density in 2035 83
Table 4.52 The Fatality Number *Ns* 83
Table 4.53 Risk Mapping Road Transport 85
Table 4.54 Plant and Sitting Layout 86
Table 4.55 Environmental Data 89
Table 4.56 Number of Crew 89
Table 4.57 Guide Word Description 93
Table 4.58 HAZOP Deviation 93
Table 4.59 HAZOP Node 1 95
Table 4.60 HAZOP Node 2 99
Table 4.61 HAZOP Node 3 104
Table 4.62 HAZOP Node 4 110
Table 4.63 Leak Scenario 116
Table 4.64 Valve Leakage Frequency on Node 1 116
Table 4.65 Valve Leakage Frequency on Node 2 116
Table 4.66 Valve Leakage Frequency on Node 3 117
Table 4.67 Valve Leakage Frequency on Node 4 117
Table 4.68 Pipe Leak Scenario 118
Table 4.69 Pipeline Leakage Frequency on Node 1 118
Table 4.70 Pipeline Leakage Frequency on Node 2 119
Table 4.71 Pipeline Leakage Frequency on Node 3 119
Table 4.72 Pipeline Leakage Frequency on Node 4 120
Table 4.73 Pump Leak Scenario 121
Table 4.74 Pump Leakage Frequency on Node 1 121
Table 4.75 Pump Leakage Frequency on Node 3 121
Table 4.76 Indicator and Safeguard Leak Scenario 122
Table 4.77 Indicator and Safeguard Leakage Frequency on Node 1 123
Table 4.78 Indicator and Safeguard Leakage Frequency on Node 2 123
Table 4.79 Indicator and Safeguard Leakage Frequency on Node 4 124

Table 4.80 Component Failure Frequency on Node 1 124
Table 4.81 Component Failure Frequency on Node 2 125
Table 4.82 Component Failure Frequency on Node 3 125
Table 4.83 Component Failure Frequency on Node 4 126
Table 4.84 Indicator and Safeguard Failure Frequency on Node 1.....126
Table 4.85 Indicator and Safeguard Failure Frequency on Node 2.....127
Table 4.86 Indicator and Safeguard Failure Frequency on Node 4.....127
Table 4.87 Fault Tree Analysis Recapitulation 129
Table 4.88 Hazard Fire Probability 130
Table 4.89 Event Tree Analysis Recapitulation 131
Table 4.90 Threat Zone of Jet Fire 132
Table 4.91 Consequences Analysis of Jet Fire 133
Table 4.92 Threat Zone of Flash Fire 134
Table 4.93 Consequences Analysis of Flash Fire.....135
Table 4.94 Risk Mapping of Jet Fire 137
Table 4.95 Risk Mapping of Flash Fire.....139
Table 4.96 Hazard Event for The Mitigation Plan 140
Table 4.97 LOPA Worksheet Jet Fire Node 1 at 5 mm.....141
Table 4.98 LOPA Worksheet Jet Fire Node 2 at 5 mm.....142
Table 4.99 LOPA Worksheet Jet Fire Node 3 at 5 mm.....143
Table 4.100 LOPA Worksheet Jet Fire Node 4 at 5 mm.....144
Table 4.101 LOPA Worksheet Flash Fire Node 1 at 5 mm 145
Table 4.102 LOPA Worksheet Flash Fire Node 1 at 15 mm 146
Table 4.103 LOPA Worksheet Flash Fire Node 1 at 30 mm 147
Table 4.104 LOPA Worksheet Flash Fire Node 3 at 5 mm 148

This page is intentionally left blank

LIST OF ABBREVIATIONS

AAV	:	Ambient Air Vaporizer
ALARP	:	As Low As Reasonably Practicable
BPS	:	*Badan Pusat Statistik*
BS	:	British Standard
BOG	:	Boil-Off Gas
CNG	:	Compressed Natural Gas
DNV	:	Det Norske Veritas
ETA	:	Event Tree Analysis
FB	:	Front to Back
FF	:	Front to Front
FS	:	Front to Side
FSRU	:	Floating Storage Regasification Unit
FRU	:	Floating Regasification Unit
FTA	:	Fault Tree Analysis
HAZID	:	Hazard Identification
HAZOP	:	Hazard and Operability Study
IEC	:	International Electrotechnical Commission
ITDC	:	Indonesia Tourism Development Corporation
IRR	:	Internal Rate of Return
ISO	:	International Standards Organization
JIS	:	Japanese Industrial Standard
LEL	:	Lower Explosive Limit
LNG	:	Liquified Natural Gas
LPG	:	Liquified Petroleum Gas
MAD	:	Major Damage
MAI	:	Major Injury
MCDM	:	Multiple-Criteria Decision-Making
MID	:	Minor Damage
MII	:	Minor Injury
MMBTU	:	Million British Thermal Units
MMSCFD	:	Million Standard Cubic Feet per Day
MT	:	Million Tonnes
MTPA	:	Million Tonnes Per Annum
MTPY	:	Million Tonnes Per Year
MW	:	Megawatt
NNW	:	North North West
NFPA	:	National Fire Protection Association
NG	:	Natural Gas

NPV	:	Net Present Value
OREDA	:	Offshore & Onshore Reliability Data
P&ID	:	Piping and Instrumentation Diagram
PKN	:	*Pusat Kegiatan Nasional*
PLTDG	:	*Pembangkit Listrik Tenaga Diesel-Gas*
PNG	:	Pipeline Natural Gas
RCT	:	Risk Contribution Tree
SS	:	Side to Side
SSGS	:	Small-Scale Gas Station
TSCF	:	Trillion of Standard Cubic Feet of Gas
VCE	:	Vapor Cloud Explosion

LIST OF SYMBOLS

fi	-	The frequency of an accident (per year)
yi	-	The expected frequency on ith road stretch (accident km−1 per vehicle)
Li	-	The road length (km)
ni	-	The vehicle number (vehicle)
y0	-	The basic frequency (accident km−1 per vehicle)
hj	-	The local enhancing/mitigating parameters
Ns	-	The fatality number (fatalities)
v	-	The vehicle density on the road area (vehicle m−2)
k	-	The average vehicle occupation factor
AL,1	-	the road lethal area (m^2)
h1	-	Depending on the geometry of the road segment (straight, twisting, etc.)
h2	-	Depending on the slope
h3	-	Depending on the number and width of lanes
h4	-	Depending on weather conditions
h5	-	Depending on the flow of traffic (congestion)
h6	-	Depending on the type of road (tunnel, bridge, etc.)
Qb	-	Flow rate (ft^3/day)
Tb	-	Base Temperature (degrees Rankin)
Pb	-	Base Pressure (psia)
P1	-	Inlet Pressure (psia)
P2	-	Outlet Pressure (psia)
L	-	Pipe Length (miles)
D	-	Internal Diameter (inches)
G	-	Specific gravity of the natural gas relative to air
Tavg	-	Average Temperature (degrees Rankin)
Pavg	-	Average Pressure (psia)
Z	-	The compressibility factor of the natural gas at the average temperature and pressure of the gas in the pipeline
ΔH	-	Elevation
E	-	Pipeline Efficiency
Dwe	-	The Weymouth Equation Diameter
Dpa	-	The Panhandle A Equation Diameter
Dpb	-	The Panhandle B Equation Diameter
Q	-	Flow rate (m^3/h)
V	-	Volume (m^3)
t	-	Time (h)
F	-	The frequency of leaks (per valve year) exceeding size d
C,m	-	The constants representing hole size distribution
a,n	-	The constants representing equipment size dependency

Frup	-	The additional rupture frequency (per valve year)
D	-	The component diameter (mm)
d	-	The hole diameter (mm)

This page is intentionally left blank

This page is intentionally left blank

CHAPTER 1

INTRODUCTION

1.1 Research Background

Indonesia is well known by other countries as a country with beautiful nature and culture in Asia. Indonesia is an archipelagic country with covering an area 1,905,000 km² does indeed have a charming landscape, from Aceh to Papua. The average growth of foreign tourists to Indonesia in the last five years, from 2014 until 2018, reached 14% per year (Badan Pusat Statistik (BPS), 2019). Bali is one of the islands in Indonesia which has a higher level of foreign tourists than other provinces, where the number of foreign tourists who come directly to Bali is 6,070,473 foreign tourists in 2018 from a total of 15.81 million foreign tourists come to Indonesia. From Figure 1.1, it is showing that foreign tourist is increasing every year and in 2018, the growth is 6.54% from 2017 (Badan Pusat Statistik Provinsi Bali, 2019).

Figure 1.1 Number of Foreign Visitors Arriving Directly To Bali, 2014-2018
(Source: (Badan Pusat Statistik Provinsi Bali, 2019))

Along with the increasing level of foreign tourists in Bali, it will be affecting the demand for hospitality in Bali. In 2018, the number of classified hotels in Bali with Class *(Hotel Bintang)* is 551 hotels with a prediction average growth of the hotel industry around 1.1% per year (Badan Pusat Statistik Provinsi Bali, 2019). Bali in the future will be applying "Bali Clean and Green Province", therefore the Government in Bali wants industry and hospitality to use natural gas as the main source of energy to reduce carbon emissions 26% (Badan Lingkungan Hidup Provinsi Bali, 2011). The usage of a cleaner source of energy, such as natural gas and renewable, is preferable and produces less emission. Natural gas can be used as alternative source of energy with several advantages including natural gas prices are cheaper than diesel or diesel oil prices (Santoso, 2014). To maximize the usage of natural gas to domestic, Indonesia's Government will be stop exporting gas to Singapore through pipe to optimize gas utilization to fulfil Indonesia gas demand (Pusat Pengkajian Industri Proses dan Energi (PPIPE), Badan Pengkajian dan Penerapan Teknologi (BPPT), 2020).

PLTDG Pesanggaran is one of the power plants in Bali that already applying "Bali Clean and Green Province" by using natural gas as main source of energy. PT. Pelindo Energi Logistik cooperate with PT. Humpus Transportasi Kimia, PT Jaya Samudera Karunia, and PT Pelabuhan Indonesia III (Persero) providing LNG transportation, LNG store, LNG regasification, and LNG distribution service for PLTDG Pesanggaran with capacity 200 MW owned by PT. Indonesia Power. PT. Pelindo Energi Logistik founded because PLTD Pesanggaran switch from diesel fuel to natural gas for reducing emission in Bali province. Since 2016, PT Pelindo Energi Logistik supply up to 50 mmscfd of natural gas for PLTDG Pesanggaran (250 MW) (PT. Pelindo Energi Logistik (PEL), 2019).

As time goes by, not only power plants and industry that will be using natural gas as the main source of energy. But hospitality, housing, and transportation must be planned to use cleaner sources of energy to maximize the usage of natural gas also actualize Bali's Government about the "Bali Clean and Green Province" plan. In this bachelor thesis, hospitality in Bali especially for facilities of PT. Indonesia Tourism Development Corporation (ITDC) in Nusa Dua is the next sector that will be studied to be supplied with Liquified Natural Gas (LNG) from Benoa (PT.PEL), to achieve the best scenario of LNG distribution scheme with considering the risk of the transportation and the facility.

1.2 Problem Statement

From the exposure of the background above, the problem of this research are:

1. How to design an LNG distribution scheme for ITDC in Nusa Dua, Bali?
2. How to determine equipment for the LNG distribution scheme?
3. How to do a risk assessment for selected LNG distribution scheme for ITDC in Nusa Dua, Bali?

1.3 Research Objectives

From the exposure of the problem formulation above, the objectives of this research are:

1. To design an LNG distribution scheme for ITDC in Nusa Dua, Bali.
2. To determine equipment for the LNG distribution scheme
3. To do a risk assessment of the LNG distribution scheme for ITDC in Nusa Dua, Bali.

1.4 Problems Limitation

From the exposure of the research objectives above, the limitation of this research are:

1. LNG supplied from Benoa (PT. Pelindo Energi Logistik (PEL)).
2. Gas demands of facilities at PT. Indonesia Tourism Development Corporation (ITDC) Nusa Dua, Bali.
3. The risks that will be measured are the risk of transportation and risk of the facility of the LNG distribution scheme for ITDC in Nusa Dua, Bali.

1.5 Research Benefit

From the exposure of the research purposes above, the benefits of this research are:

1. This research will provide an overview of the process of designing the LNG distribution scheme for ITDC in Nusa Dua, Bali.
2. This research will provide recommendation for the LNG distribution scheme for ITDC in Nusa Dua, Bali by considering the risk of the transportation.

This page is intentionally left blank

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

All literature and references related to this bachelor research are provided in this chapter. References are obtained from various sources, such as scientific papers, journals, seminars, books, recent or updated reports, or other references that related to this bachelor research. There are several points basic theories and concept behind that will support this bachelor thesis, which is Natural Gas in Indonesia, Liquified Natural Gas, LNG Supply Chain, LNG Filling Station, Transporting Natural Gas, International Standards Organization (ISO) Tank, Pipeline Natural Gas (PNG), Hospitality (Hotel & Villa), Natural Gas Conversion, and Risk Assessment method.

2.2 Natural Gas in Indonesia

Figure 2.1 Percentage of World Natural Gas Reserves
(Source: (Kementrian Energi dan Sumber Daya Mineral Direktorat Jenderal Minyak dan Gas Bumi, 2018))

Indonesia is knowingly as a maritime country in South-East Asia and has a lot of natural resource of oil and gas spread in its sea. In three decades, Indonesia has become one of the countries in the world as largest LNG exporters (Purwanto, 2016). In Indonesia, natural gas is one of three prime source of energy that are widely used in Indonesia after crude oil and coal. Many companies in Indonesia have exploit, producing, distributing, and using natural gas as source of energy. Although, in Indonesia, many companies and industry still using conventional oil as their main source of energy. Since

industry revolution, the use of oil and coal have severely impacted the environment. Thus, usage of cleaner source of energy, such as natural gas and renewable, is preferable and produce less emission.

From Figure 2.1, it is showing the percentage of world gas reserves and Indonesia has been producing and exporting natural gas (LNG) since 1977 with percentage of world gas reserves is 1.53%. Natural gas in Indonesia expected will be run out 49 years from now (Kementrian Energi dan Sumber Daya Mineral Direktorat Jenderal Minyak dan Gas Bumi, 2018). In Indonesia, natural gas reserves are much bigger than fossil fuel reserves. There are 77.29 Trillion of Standard Cubic Feet of Gas (TSCF) of natural gas reserves in Indonesia per 1 January 2019 with average gas production from 2012-2017 is 2.9 TSCF/year. The usage of natural gas for domestic is increasing with average around 7.8% from 2013 until 2017. The percentage of exporting natural gas in 2019 is 35.11% and it is expected in the future to be reduced to increasing usage of natural gas for domestic. In 2019, the percentage of natural gas for domestic is 64.89% and can exceed the target 64% (Direktorat Jenderal Minyak dan Gas Bumi Kementrian Energi dan Sumber Daya Mineral, 2020). Natural gas reserves across Indonesia from Aceh to Papua per January 1st, 2019, can be seen on Figure 2.2. From the Figure 2.2, proven gas reserves per January 1st, 2019, is around 49.74 TSCF, potential gas reserves is 27.55 TSCF.

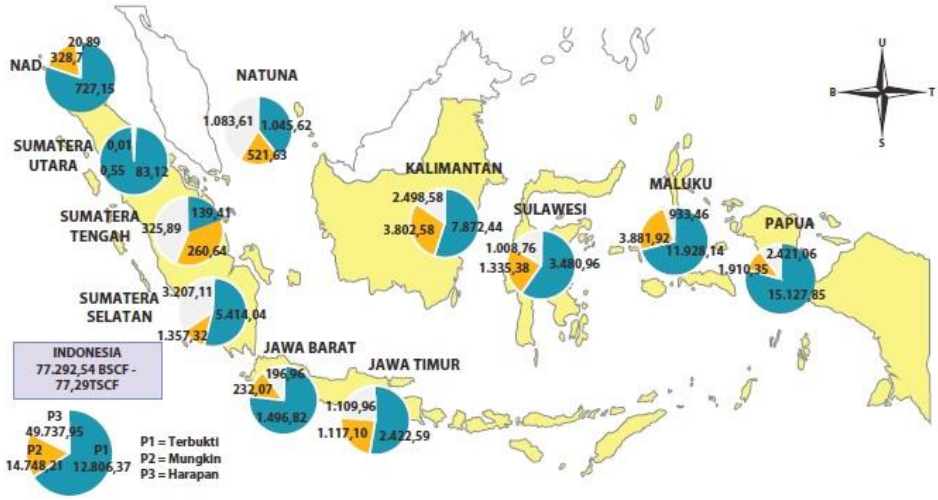


Figure 2.2 Natural Gas Reserves in Indonesia
(Source: (Direktorat Jenderal Minyak dan Gas Bumi Kementrian Energi dan Sumber Daya Mineral, 2020))

2.3 Liquified Natural Gas (LNG)

Liquified natural gas is a liquid form of natural gas. LNG (Liquified Natural Gas) is natural gas (Methane-CH_4) that have been processed to relive the purity and heavy hydrocarbon through desulfurization and dehydration, and then condensed into liquid at atmosphere pressure by cooling it until the temperature hit around -160 degree Celsius (-

260-degree Fahrenheit). LNG is containing 1/600 from natural gas at certain temperature and certain pressure. Because LNG is in liquid form, it is more efficient to be transported far away and more economical. After the natural gas proceed the liquefaction process, the gas will be colourless, odourless, non-toxic, tasteless, shapeless, and the gas is not containing sulphur oxide and ash (Budiyanto, Riadi, Buana, & Kurnia, 2020). The advantage of using liquified natural gas as fuel is environmentally friendly because of its lower carbon content compared to crude fuels which are currently still widely used and can reduce sulphur oxide (SOx) (Herdzik, 2011).

Table 2.1 Properties of Natural Gas

Properties	**Value**
Relative molar mass	*17-20*
Carbon content, weight %	*73.3*
Hydrogen content, weight %	*23.9*
Oxygen content, weight %	*0.4*
Hydrogen/carbon atomic ratio	*3-4*
Relative density, 15 degree Celsius	*0.72-0.81*
Boiling point, degree Celsius	*-162*
Autoignition temperature, degree Celsius	*540-560*
Octane number	*120-130*
Methane number	*69-99*
Stoichiometric air/fuel ratio, weight	*17.2*
Vapor flammability limits, volume %	*5-15*
Flammability limits	*0.7-2.1*
Lower heating/calorific value, MJ/kg	*38-50*
Stoichiometric lower heating value, MJ/kg	*2.75*
Methane concentration, volume %	*80-99*
Ethane concentration, volume %	*2.7-4.6*
Nitrogen concentration, volume %	*0.1-15*
Carbon dioxide concentration, volume %	*1-5*
Sulfur concentration, weight % ppm	*<5*
Specific CO2 formation, g/MJ	*38-50*

(Source: (Mokhatab, A. Poe, & Y. Mak, 2015))

According to Table 2.1, Natural Gas has composition 80% - 99% methane, 2.7% – 4.6% ethane, 0.1 – 1.5% nitrogen and other compounds. Liquified natural gas has high contain of calories (12000 kkal/kg) compared to other fossil fuels such as petroleum and coal. Liquified natural gas is a clean source of energy because it contains less nitrogen oxides (20-37%) and carbon dioxide (57%) compared to coal. Also, 1 KWH of gas (LNG) energy contains 446 grams of CO2 (Artana & Soegiono, 2006).

Liquified Natural Gas is basically an alternative method of delivering gas from producers to consumers. There are several technical methods to transporting natural gas, which are pipelines, liquified natural gas (LNG), compressed natural gas (CNG), gas-to-

liquids, gas-to-solids, and gas-to-wire. Liquified natural gas is more flexibility, diversity and security of supply advantages over pipeline alternatives (Mokhatab, A. Poe, & Y. Mak, 2015).

2.4 LNG Supply Chain

LNG supply chain is a process of exploiting, processing / producing, storing, distributing LNG from natural gas source to natural gas consumer or user. In general LNG supply chain consists of:

a. Natural gas well : Source of natural gas to be extracted
b. Liquefaction plant/unit : Processing natural gas into LNG
c. Loading terminal ship : Storage and terminal to load LNG to
d. LNG Carrier : Mode of distribution (Ship)
e. Receiving terminal from ship : Storage and terminal to unload LNG
f. Regasification plant/unit (vapour) : Processing LNG into natural gas
g. End user : User or consumers of natural gas

Figure 2.3 LNG Supply Chain
(Source: (Government of Canada, 2020))

Liquified natural gas supply chain scheme can be seen in Figure 2.3. LNG supply chain is designed considering all component of LNG supply chain, because each component will affect other adjacent component of LNG supply chain. After knowing the demand and source of gas in LNG supply chain, other part of LNG supply chain can be calculated to give the optimum income for the whole LNG supply chain. Each chain in LNG supply chain can be optimized to give most cost efficient to LNG and may make LNG price lower to attract more consumers.

From Figure 2.4, it is showing the big picture of supply chain scheme for hotels and villas in Nusa Dua. The origin of LNG is from LNG storage in Benoa, with

assumption there is enough capacity for supply LNG for hotels and villas in Nusa Dua. Then, the LNG is transported either with piping system or trucking to end user in Nusa Dua. In this research will be studied how to choose two or more alternatives for LNG distribution scheme.

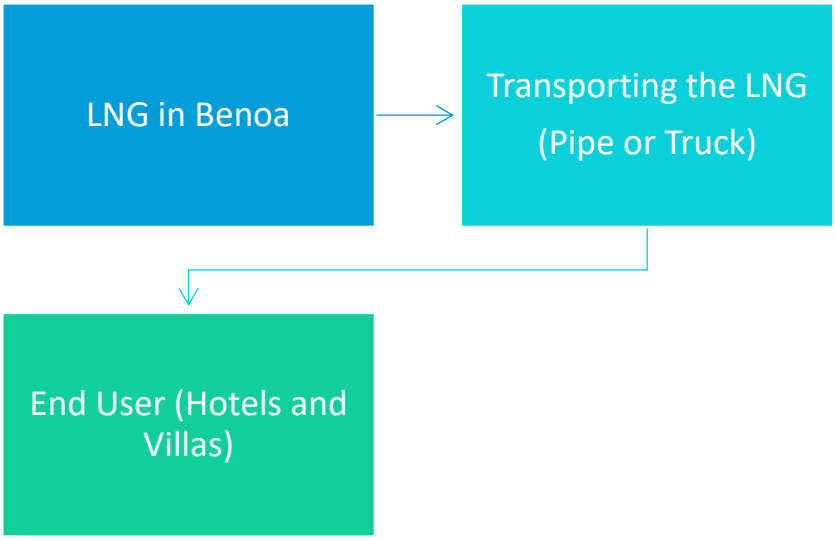


Figure 2.4 LNG Supply Chain Plan for ITDC in Nusa Dua, Bali

2.5 LNG Filling Station

In 2014, PT. Pelindo Energi Logistik established in Surabaya as a company that focus on logistic of gas, fuel, and waste treatment as subsidiary of PT. Pelindo III Group. PT. Pelindo Energi Logistik providing shipping, storing LNG, LNG regasification, and LNG distribution service for PLTDG Pesanggaran with capacity 200 MW owned by PT. Indonesia Power. PT. Pelindo Energi Logistik founded because PLTD Pesanggaran switch from diesel fuel to natural gas for reducing emission in Bali province. PT Pelindo Energi Logistik develop mini-LNG terminal in Benoa Port. This receiving terminal located on area owned by PT. Pelindo III. Mini LNG Terminal in Benoa Port use FSRU (Floating Storage Regasification Unit) to store Liquified Natural Gas and FRU (Floating Regasification Unit) to regasification LNG from liquid form to gas form. FSRU Karunia Dewata owned by PT Jaya Samudera Karunia and FRU owned by PT. Pelindo Energi Logistik. Since 2016, PT Pelindo Energi Logistik supply PLTDG Pesanggaran (250 MW) with natural gas using pipeline along 3600 m, which is the supply up to 50 mmscfd of natural gas.

Figure 2.5 FRU Lumbung Dewata

(Source: (PT. Pelindo Energi Logistik (PEL), 2019))

PT. Pelindo Energi Logistik in the future will be built onshore LNG storage tank. In this research plan, the LNG Filling Station will be planned near LNG Terminal in Benoa Port with assumption there is enough capacity for gas demand for hospitality in Nusa Dua. The purpose of LNG Filling Station is to be a place to filling the cryogenic tank on truck with LNG to transporting LNG to Nusa Dua Planning LNG Filling Station must be considering the safety of the infrastructure for environment.

2.6 Transporting Natural Gas

Transporting natural gas from gas well to end-user is essential and many researcher and technologies has been studied to develop new methods to transporting natural gas to end-user to achieve minimum cost. The list of current methods for transporting natural gas is Pipeline (PNG), Liquified Natural Gas (LNG), Compressed Natural Gas (CNG), Gas to Hydrates (GTH), Gas to Liquids (GTL), Gas to Commodity (GTC), and Gas to Wire (GTW) (Akram & Andrzej, 2015). In this research, there are 2 option for transporting the Liquified Natural Gas (LNG) which are using Pipeline or Truck. The truck will be carrying the Cryogenic ISO Tank. There are two size of Cryogenic ISO Tank, 20 ft, and 40 ft.

Figure 2.6 LNG Truck
(Source: (Java Energy Semesta, 2015))

2.7 International Standards Organization (ISO) Tank

Figure 2.7 Cryogenic ISO Tank 40 feet
(Source: (PT. Melia Energi Nusantara & Melia Holdings PTE LTD., 2018))

ISO Tank is a container usually used for carrying gas, pressurized dry bulk or bulk liquid through various mode of transportation such as road, railway, or sea. Cryogenic tank is an ISO tank type specially for liquified natural gas or for cryogenic liquids. Cryogenic tank is made of the stainless steel and carbon steel. Cryogenic ISO Tank has two walls with suitable insulation to obtain highest level of thermal insulation efficiency (Lisowski & Czyzycki, 2011). Compared to CNG (Compressed Natural Gas), the

pressure of LNG in Cyrogenic ISO Tank is much lower than CNG, the pressure is around 6-10 bar and the pressure for CNG is 250 bar (Santoso, 2014). Cryogenic ISO Tank in Indonesia usually used to supply LNG to regions across Indonesia that need gas. On Table 2.2, there are 2 Cryogenic ISO Tank sizes, 20 ft, and 40 ft also it is showing the specification of each size.

Table 2.2 Cryogenic ISO Tank Specification

Cryogenic ISO Tank 20 feet	
Product name	20 feet T75 Cryogenic Tank Container
Design specification	1. ASME VIII DIV 1-ED2013
	2. T75 UN PROTABLE TANK,
	IMDG, TIR, CSC, TC
	3. RID/ADR 1496-3
Geometric volume	20.37 m3
Working pressure	10 Bar
Design temperature	-196 Degree Celsius
Filling medium	LNG, ethylene, ethane, liquid
	oxygen,liquid nitrogen, liquid
	argon
Tank material	Liner SA-240M304
	Tank Shell SA-516M
Insulation type	High 12acuum multi-layers spiral
	wound insulation
Country of origin	China
Tank weight	11.500 kg
	(Continued from Previous Table)
Overall size	6058 x 2438 x 2591 mm
Holding Times	10 Days at 98% Fill

Cryogenic ISO Tank 40 feet	
Product name	40 feet T75 Cryogenic Tank Container
Design specification	1. ASME VIII DIV 1-ED2013
	2. T75 UN PROTABLE TANK,
	IMDG, TIR, CSC, TC
	3. RID/ADR 1496-3
Geometric volume	43,5 m3
Working pressure	10 Bar
Design temperature	-196 Degree Celsius

(Continue to the next page)

(Continued from previous page)

Filling medium	LNG, ethylene, ethane, liquid
	oxygen,liquid nitrogen, liquid
	argon
Tank material	Liner SA-240M304
	Tank Shell SA-516M
Insulation type	High vacum multi-layers spiral
	wound insulation
Country of origin	China
Tank weight	22000 kg
Overall size	12200 x 2438 x 2591 mm
Holding Times	10 Days at 98% Fill

(Source: (Chart Industries, 2013))

2.8 Pipeline Natural Gas (PNG)

Figure 2.8 Pipeline Natural Gas in Morocco
(Source: (Construction Review Online, 2020))

The pipeline network is used as a means of transportation for fluids (liquid or gas), mixed of liquid, solid, and fluid-solid mixture (Erlangga, 2015). Transporting natural gas to end users thousands of miles away is one of the functions of the pipeline. Pipeline method is not flexible, but it is a very convenient method for transporting natural gas (Mokhatab, A. Poe, & Y. Mak, 2015).

For short distance, usage of pipeline to transporting the natural gas is more feasible and more economical. The disadvantage is, if the pipeline has to be shut down or under-

maintenance or service, the natural gas will be not delivered to end-user and the regasification plant have to be shut down. In this research, pipeline can be considered to transporting the natural gas to ITDC in Nusa Dua, Bali which will be discussed in next chapter.

2.9 Hospitality (Hotel & Villa)

Figure 2.9 Natural Gas for Hospitality
(Source: (Center, 2019))

Hospitality is an act of kindness from company or organisations to welcoming and providing basic needs of customers such as food, drink, and accommodation (ANTOR (HK), 2013). In Bali, hospitality industry is a promising industry for developer and businessperson. Foreign tourists come directly to Bali specifically, is increasing every year. Because of the increasing of the foreign tourists, hospitality demand also growing simultaneously. There are 551 classified hotels in Bali by hotel class in 2018 and there are 78,801 rooms available (Badan Pusat Statistik Provinsi Bali, 2019). To maximize the usage of natural gas in Bali also support the Bali's Government about "Bali Clean and Green Province", supplying natural gas to hospitality must be studied. Natural gas for hospitality can be used for water heating, HVAC, cooking, hot water production, etc (Styles, Schonberger, & Galvez Martos, 2017).

In the Figure 2.10, it is showing the location of hotel and villa in PT. ITDC Area. There are 18 hotels and villas. There are Melia Bali Hotel, Laguna Hotel, Grand Hyatt, Sofitel Hotel and Resort, Mercure Nusa Dua, Ayodya Hotel, Grand Whiz Hotel Nusa Dua, The Grand Bali, St. Regis Hotel, Inaya Hotel, Nusa Dua Beach Hotel, Club Med, Novotel Nusa Dua, Kayumanis Nusa Dua, Amartera Villa, The Westin, Awarta Villa, and Courtyard by Marriot. In ITDC Nusa Dua area, there are several facilities other than hotel and villa, such as BIMC Hospital, Bali Nusa Dua Theatre, Bali National Golf, The Bay Bali, Bali Nusa Dua Convention Center, BICC, M-Spa, Bali Collection, and Museum Pasifika (Indonesia Tourism Development Corporation (ITDC), 2018).

Figure 2.10 The Location of Hotel & Villa in ITDC Nusa Dua
(Source: Google Earth Pro)

2.10 Natural Gas Conversion

In order to simplify to know the natural gas demand from hotels and villas in PT. ITDC Nusa Dua, unit conversion to natural gas need to be known. In this research, the unit conversion of LNG is on Table 2.3, presented below:

Table 2.3 Natural Gas Conversion

1 kilowatt-hour (kWh)	= 0.0034 mmBtu
1 Tonne of LNG	= 52 mmBtu
1 Tonne of LNG	= 2 m^3 LNG
1 MMSCF	= 35 m^3 LNG
1 MTPY	= 140 MMSCFD
1 m^3 LNG	= 600 m^3 Gas
1 m^3 LNG	= 24.02 mmBtu

(Source: (International Gas Union, 2012))

2.11 Risk Assessment

Risk assessment is intended to determine the risk acceptability that has been evaluated and measured on the basis of a comparison of the requirements or parameters determining risk tolerability (Kontovas, 2005). In risk assessment, it is consist of risk analysis and risk evaluation. The purpose of the risk assessment is to evaluate the frequency and consequences for evaluating the risk value (Purnomo, 2019). Risk Assessment includes studying how a hazard occurs or developing an interactive and statement that causes an accident. There are several stages of risk level, which are (Dewi, 2013):

1. Risks that cannot be justified or accepted, except in extraordinary circumstances (intolerable)
2. The risks that have been created are so small that no further precautions are needed
3. Risk whose level falls between the intorelable and negligible level (as low as reasonably practicable = ALARP).

The construction and qualification / calculation of the standard risk assessment techniques used for a risk model can be made of fault trees and event trees, which are combined in a risk contribution tree (RCT). The calculation is performed using accident and failure data and other information sources, which are adjusted to the level of the analysis.

2.11.1 Hazard Identification (HAZID)

Hazard is a potential that can cause accidents to human safety, the environment, and equipment. Hazard can be physical, activity, or material. Hazard Identification (HAZID) is the process of recognizing the dangers that may occur regardless of what is accepted or not accepted that occurs (Pratama, Artana, & Baliwangi, 2010). In the hazard identification process used to identify all possible situations in which a person may be exposed to injury, illness or disease, the types of hazards that may arise and how to manage those hazards. There are several factor that can cause hazard in a system or facility (Budiarta, 2020):

a. System failure
b. Operational problem
c. Human factor
d. External factor

2.11.2 Hazard Identification Methods

To transporting the Liquified Natural Gas from LNG Terminal Benoa to Indonesia Tourism Development Corporation (ITDC), there are 2 options that can be used, which are Pipe or Truck. According to (Batarlienė, 2018), when transporting hazardous freight, there are two major risk factors, which are:

a. Possible road accidents;
b. Possible harm.

She also stated that both hazardous freight shipment risk factors are related, since harm would be caused when you have an accident, but harm is not always a simple reason for an accident. There are several external factors that can harm transport dangerous freight, which are:

a. Traffic
b. Road Dimension
c. Terrorrist Attack
d. Weather
e. Road Accidents
f. Natural Disasters
g. Environment Condition
h. Road Purposes or Class

In this bachelor thesis, the method that will be used to identifying hazard in road transport is What-If Analysis methods. What-if analysis is an approach to brainstorming that uses structured questioning that generates qualitative explanations of potential problems as well as lists of problem mitigation suggestions (Kontovas, 2005). What if analysis methods apply to any type of system, process, or activity. First must identify possible event or failure that can cause potential hazard, then determine the possible cause, then determine the consequences if the possible event occurs that can lead to negative impact to environment or social.

Also, the method that will be used to identifying hazard in LNG facility is Hazard and Operability Study (HAZOP). HAZOP Analysis is a method for recognizing dangers or hazards that could impact safety and operability of a system based on the use of guidewords. This method can be used for identifying hazard in continuous systems (Kontovas, 2005). A common list of guidewords is used to prompt experts to recognise deviations from the design intention. Experts consider potential causes and consequences for each credible deviation and whether additional precautions should be recommended. The conclusions are recorded in a standard format during the sessions.

2.11.3 Risk Assessment of Transporting Dangerous Goods by Road

In this Bachelor Thesis, the scope of the risk assessment is only on the transportation. To do the risk assessment of transporting dangerous goods by road is referring to (Fabiano, Curro, Palazzi, & Pastorino, 2002). (Fabiano, Curro, Palazzi, & Pastorino, 2002) described a method to measure the frequency of road accidents involving hazardous goods on highways in relation to the main topic of this paper. All types of road accidents were referred to by (Fabiano, Curro, Palazzi, & Pastorino, 2002), PDO-s (accidents with property damage only) are also included. They have established that the frequency depends on: geometric factors; slopes; lane number / width; road section types (straight, curve, tunnel or bridge); weather; flow of traffic. The frequency of an accident can be expressed by the following equations on the i-th road stretch:

$$fi = \gamma i \; Li \; ni \tag{2.1}$$

$$\gamma i = \gamma 0 \sum_{j=1}^{6} hj \tag{2.2}$$

Where:

γi = the expected frequency on ith road stretch (accident km−1 per vehicle)

Li = the road length (km)

ni = the vehicle number (vehicle)

$\gamma 0$ = the basic frequency (accident km−1 per vehicle)

hj = the local enhancing/mitigating parameters.

The number of NS casualties caused by an accident that occurs according to scenario S can be determined according to the following equations on the ith road stretch:

$$Ns = k(\upsilon AL, 1) \tag{2.3}$$

Where:

NS = the fatality number (fatalities)

v = the vehicle density on the road area (vehicle m−2)

k = the average vehicle occupation factor

$AL,1$ = the road lethal area (m2)

The parameters hj defined by (Fabiano, Curro, Palazzi, & Pastorino, 2002) are: h1, depending on the geometry of the road segment (straight, twisting, etc.); h2, depending on the slope; h3, depending on the number and width of lanes; h4, depending on weather

conditions; h5, depending on the flow of traffic (congestion); h6, depending on the type of road (tunnel, bridge, etc.).

2.11.4 Risk Assessment of LNG Facility

Fire is one of the hazards that can harm or give significant concequences in a system or a facility. Fire is a chemical process, a fast oxidation process that generates heat and light. There are 3 factors that can made a fire:

a. Oxygen
b. Combustible material
c. Heat

There are several type of fire that can happen in a system or a facility, which are (Putra, 2019):

a. Jet Fire
   Jet Fire is an occurrence that happens when gas is compressed or liquefied by a leak in a component or in a system. Fire can be happen if there is a gas spark and flammable gas mixed with oxygen. This accident can be happen in transferring gas in liquid phase and if there is a leakage, gas will be flow out.

b. Flash Fire
   Flash fire is a fire that appears briefly with a duration of only 0 to 5 seconds. There are 2 things that cause flash fire, the first is the collection of flammable gas/vapor that comes from dispersion gas. The second is because there is a collection of hydrocarbons or LNG in the liquid phase forming a pool which is commonly called a pool fire.

c. Gas Dispersion
   Gas dispersion in the pipeline or other components may be caused by gas leakage. If the gas condition flows under high-pressure conditions, this work accident will occur. Gas dispersion damage normally affects human health because the oxygen content is polluted by gas leakage.

2.11.5 Fault Tree Analysis (FTA)

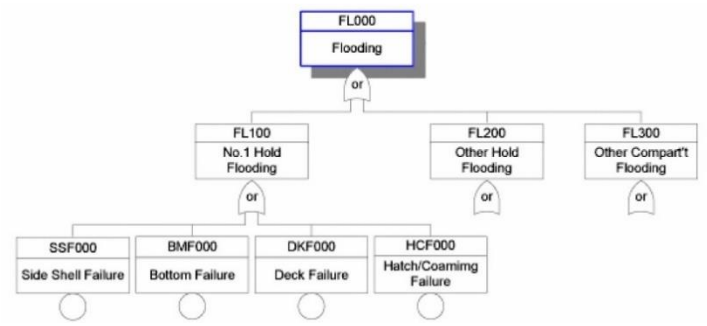


Figure 2.11 FTA Construction
(Source: (Kontovas, 2005))

A Fault Tree is a logic diagram showing the causal relationship between events that cause the occurrence of a higher-level event singly or in combination (Kontovas, 2005). This methods usually used to to evaluating process failure system qualitatively. Usually, the FTA construction begins with the top event and works towards the basic events. It considers what conditions are required to generate the event for each event, and represents these as events at the next level down. If a higher event can be caused by any one of many events, they are joined by an OR gate. They are joined with an AND gate if two or more events have to occur in combination. In FTA, there are several terms that need to be noted, which are (Baskoro, 2019):

a. Events are variations that are not included in a part of the system from a normal state.
b. The top event is an unwanted event at the "peak" that will be further investigated by using logic gates to evaluate cause and frequency against other basic events.
c. Logic gates are relations between inputs that are logical (event below). AND (and) gates or OR (or) gates reflect this logical relation.
d. Transferred event is the triangle used for the move. This symbol means that on another page there is a further explanation of the incident.
e. Undeveloped events are simple events which, because of the availability of knowledge, will not be further established.
f. Basic events are unexpected events that are considered

2.11.6 Event Tree Analysis (ETA)

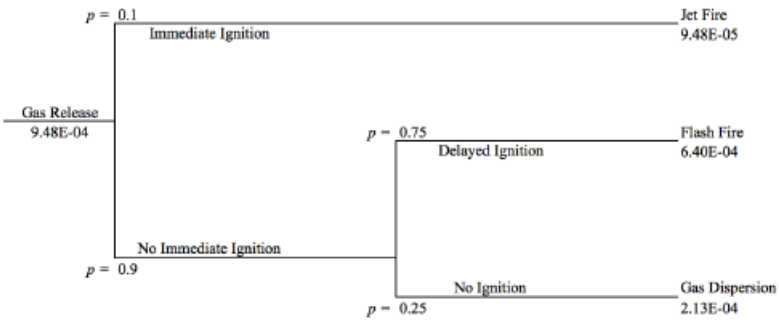


Figure 2.12 ETA Construction
(Source: (Baskoro, 2019))

An Event Tree is a logic diagram used to evaluate the implications of an accident, a mistake or an unintended incident. (Kontovas, 2005). Event tree analysis (ETA) is a logical representation of the different events that an initiating event may follow. It utilizes branches to demonstrate the different possibilities that can occur at each level. It can also be used to calculate the probabilities of failure, where multiple contributory factors can occur only sequentially in time. This method is used to perform a reliability analysis on a system where all components are operating continuously and on a system that is in standby position (Artana & Dinariyana, 2013). The figure 2.12., it is showing one of the ETA construction.

2.11.7 Fire Modelling

In this Bachelor Thesis, a fire modelling software is used. The function of this software is to analyzing the consequences to the humans in LNG facility area. The purpose of the consequences analysis is to obtaining the fire range if the hazard event occured. The fire modelling software that will be used is ALOHA software. ALOHA can be used on each fire modelling scenario with various parameters such as diameter of the pipe, diameter of the hole, environmental data, etc.

After inputting the parameters, it can produce a mapping of the thermal flux of the fire on various scenario with various parameters. This fire modeling is very helpful for the user to do a quantitative risk assessment because it produces several values that can be used as further calculations.

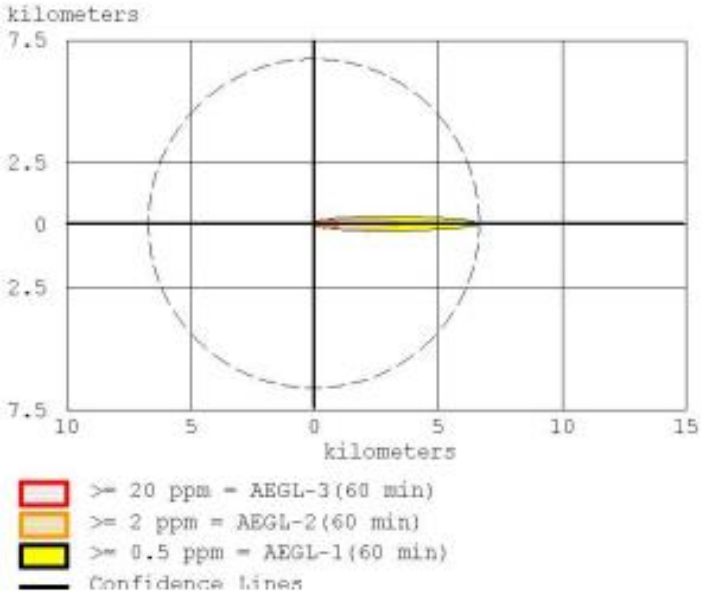


Figure 2.13 Fire Modelling Software (ALOHA)
(Source: (Bhattacharya & Kumar, 2015))

2.11.8 f/N Curve

f/N Curve is a type of risk representation used on the basis of the amount of affected population of the system suffering injury or other types of failure (Kontovas, 2005). The risk mapping for risk assessment of road transport in this bachelor thesis adopted from The Netherlands f-N Curve standard, and the risk mapping for risk assessment of LNG facility is using f/N Curve UK-HSE.

UK-HSE standard can be used for LNG facility in population area because in regulation stated that the limits of HSE's responsibilities is on certain place of concern or harm directly or implicitly related to employment are protected by laws other than the HSW Act and are not covered by HSE. This includes consumer and food safety, safety at sea, rail and aviation, and most areas of environmental protection (Health and Safety Executive, 2013). HSE also stated that regasification and compression plant are covered in HSE standards (Health and Safety Executive, 2020). According to (Health and Safety Executive, 2015), the regulation is covering serious danger to the environment includes accidents with the potential to result in: damage to designated areas, habitats, or populations of species within the areas.

The consequences resulting from the f-N Curve risk mapping are the consequences of human life (societal risk). The f-N curve itself is the result of the relationship between

the cumulative frequency per year (F) and the number of fatalities (N) or known as a societal risk which is the impact of an event. Example of F/N Curve UK-HSE is shown on the figure below and the criterion of The Netherlands f-N Curve standard schematized is shown on the table below.

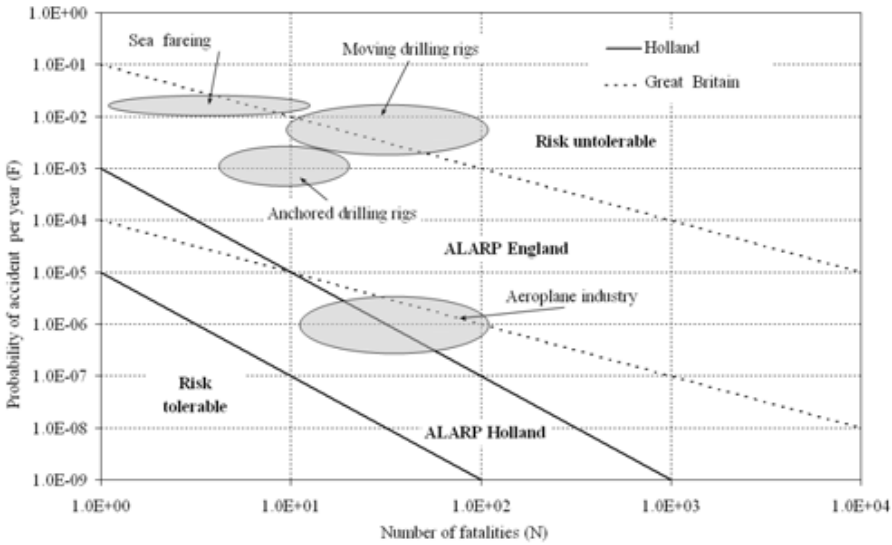


Figure 2.14 f/N Curve UK-HSE
(Source: (Gucma, 2009))

Table 2.4 Acceptability Criterion of The Risk (The Netherlands)

Acceptability Criterion of The Risk		
Evaluation of the risk	Criterion	Explanation
Acceptable Risk	P<(10^-5/N^2)	No need for detailed studies. Check that risk mantains at this level.
Tolerability region A	(10^-5/N^2)<P<(10^-4/N^2)	Tolerable risk if cost of reduction would exceed the improvements gained
Tolerability region B	(10^-4/N^2)<P<(10^-3/N^2)	Tolerable only if risk reduction is impracticable or if its cost is grossly in disproportion to the improvement gained
Unacceptable risk	P>(10^-3/N^2)	Risk intolerable: risk cannot be justified even in extraordinary circumstances

2.11.9 Layer of Protection Analysis (LOPA)

LOPA or Layer of Protection Analysis is a methodology to evaluating hazard and risk assessment. After obtaining the frequency and do the consequences analysis, it will be plotted to the f/n curve to determine the risk level on each scenario. If there is a hazard event in unacceptable area, a mitigation should be done. By using the LOPA method, the consequences of hazards and risks can be evaluated and provide protection from unacceptable risks. The purpose of LOPA is to ensure a layer of protection to anticipate risks from emerging hazards.

CHAPTER 3

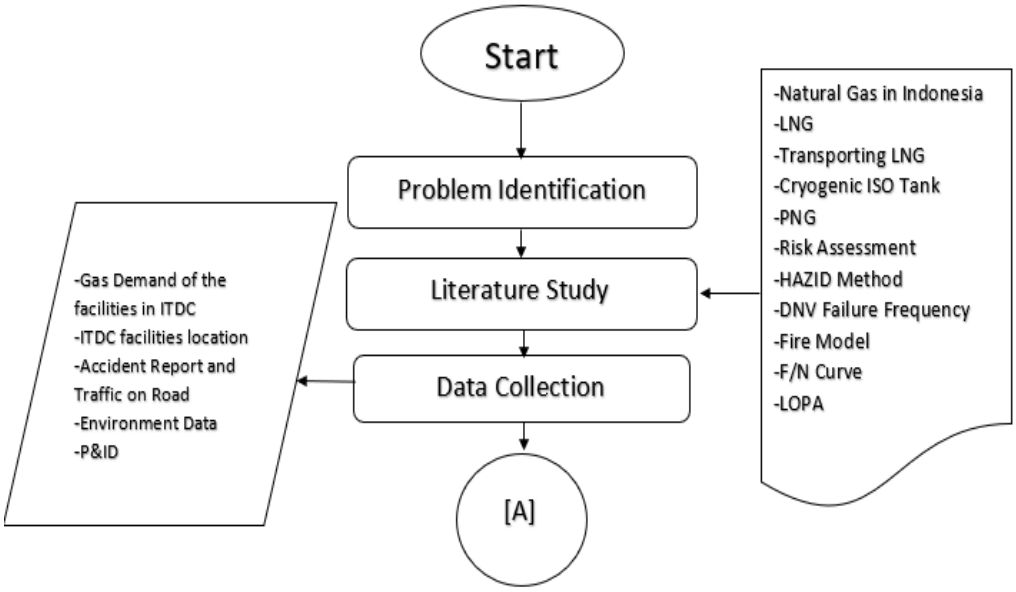
RESEARCH METHODOLOGY

3.1 Introduction

Steps or stages of this bachelor thesis to answering all research problems also to achieve the research objectives is provided in this chapter. In this research methodology, there are several steps need to be followed, which are, Problem Identification, Literature Study, Data Collection, Design LNG Distribution Scheme, Risk Assessment of the Transportation, and Conclusion and Suggestion.

3.2 Research Flowchart

In this bachelor thesis, it certainly requires a structured process so that the work process is more focused. In this research methodology chapter will discuss step by step the process of the final project. The following are the research flowchart for this bachelor thesis:



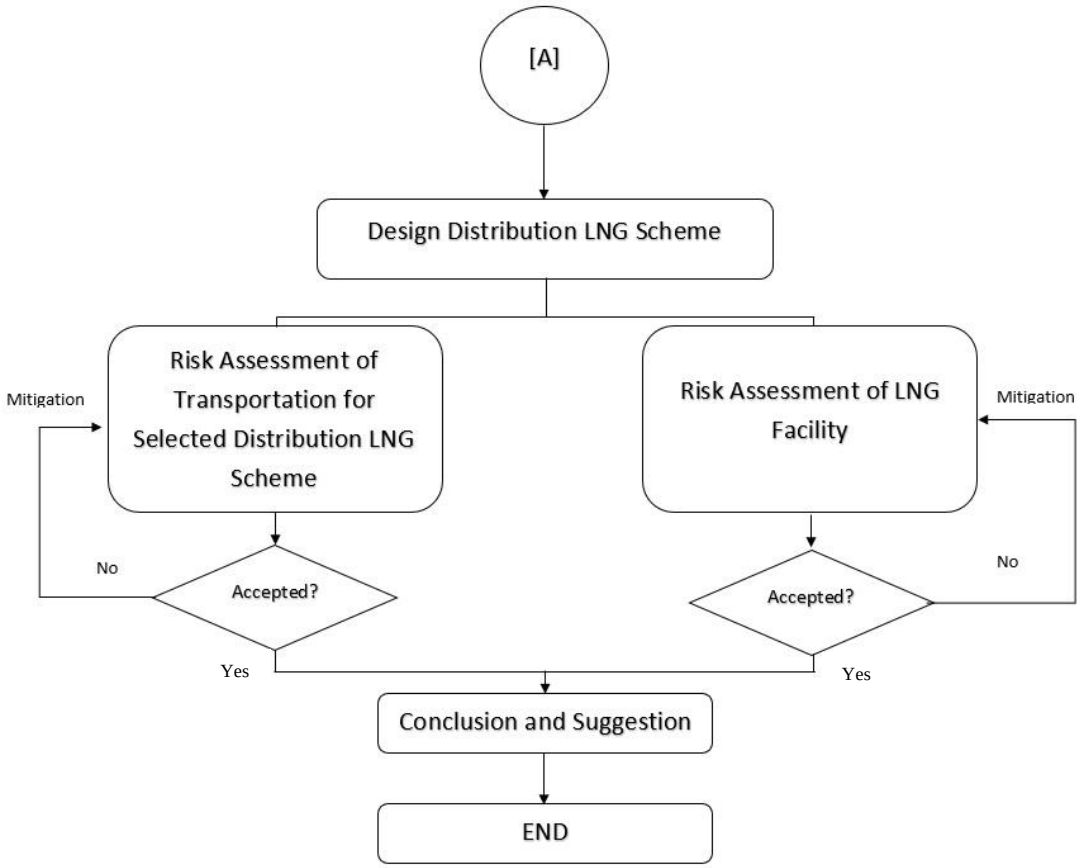


Figure 3.1 Research Flowchart

3.3 Problem Identification

The first stages in this bachelor thesis are to identify the problems to be discussed and will be the background in this bachelor thesis. The problem is Bali in the future want to maximize the usage of natural gas for all sector such as industry, hospitality, power plant, transportation and other sector that need gas as source of energy but until today, only power plant in Pesanggaran that using natural gas as source of energy. The purpose of this research is to maximize the usage of natural gas in Bali with studying supply natural gas for hospitality and other facilities of ITDC in Nusa Dua, Bali to achieve best methods to transport the natural gas with considering the risk.

3.4 Literature Study

In this bachelor thesis, problem to be solved is about determining the distribution LNG scheme for ITDC in Nusa Dua, Bali. After the problem is found, the next step is a literature study. At this stage, the search for supporting references is carried out to solve the problem. Literature studies can come from journals, papers, internet, thesis, or books related to the problems to be resolved.

3.5 Data Collection

Data collection is needed to support this research. Data that needed are list and location hotel and villa of ITDC in Nusa Dua, Bali; environment data; piping and instrumentation diagram; traffic data; accident data road transport and the gas consumption or gas demand of hotels and villas of ITDC in Nusa Dua, Bali. This data can be used to help determining the distribution method, designing the distribution LNG scheme for ITDC in Nusa Dua, Bali and to do the risk assessment on road transport and LNG facility.

3.6 Design LNG Distribution Scheme

After previous step is done, the next step is to design the LNG distribution scheme based on gas demand of hotels and villas of ITDC in Nusa Dua, Bali. This purpose of this step is to find all alternatives method to transporting LNG from Benoa to ITDC in Nusa Dua, Bali. To transporting the LNG, there are two or more alternatives method, which are using pipeline or using truck (cryogenic ISO tank) or using combination (pipeline and truck) and determining the equipment on every facility to support the LNG Distribution Scheme.

3.7 Risk Assessment of Transportation for LNG Distribution Scheme

The risk assessment will be conduct for LNG distribution scheme. The purpose of the risk assessment is to evaluate the frequency and consequences for evaluating the risk value of selected LNG distribution scheme. The scope of risk assessment in this bachelor thesis is the transportation for selected LNG distribution Scheme. If the risk value is not accepted, risk assessment must be repeated with mitigation.

3.8 Risk Assessment of LNG Facility

The risk assessment will be conduct for LNG Facility. The purpose of the risk assessment is to evaluate the frequency and consequences for evaluating the risk value of

LNG Facility. The scope of risk assessment in this bachelor thesis is the fire risk assessment of LNG Facility. If the risk value is not accepted, risk assessment must be repeated with mitigation.

3.9 Conclusion and Suggestion

The result from all of this project's phases will be drawn at the end of this project. The conclusion will answer the problem identified in this project. The conclusion is drawn from the progress achieved from the start to the end of the project. Suggestion for completing the project will be given at the end of this project. Suggestions are expected to strengthen future research and provide a solution to similar issues at various locations in Bali.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter it will be discuss more about designing the Liquified Natural Gas distribution scheme for Indonesia Tourism Development Corporation (ITDC) in Nusa Dua, Bali based on the gas consumption of each facilities. There will be also determining the equipment on each facility to support the LNG distribution and do the risk assessment for the transportation and the LNG facility.

4.2 List of Hotels and Villas in ITDC Nusa Dua, Bali

For this bachelor thesis, the study case is the hotels and villa of ITDC in Nusa Dua, Bali. According to (Indonesia Tourism Development Corporation (ITDC), 2018), there are 18 hotels and villas in ITDC, Nusa Dua, Bali. The list is presented on the Table 4.1.

Table 4.1 List of Hotels and Villas in ITDC Nusa Dua, Bali

No.	Name of Hotel/Villa
1	Melia Bali Hotel
2	Laguna Hotel
3	Grand Hyatt
4	Sofitel Hotel and Resort
5	Mercure Nusa Dua
6	Ayodya Hotel
7	Grand Whiz Hotel Nusa Dua
8	The Grand Bali
9	St. Regis Hotel
10	Inaya Hotel
11	Nusa Dua Beach Hotel
12	Club Med
13	Novotel Nusa Dua
14	Kayumanis Nusa Dua
15	Amartera Villa
16	The Westin
17	Awarta Villa
18	Courtyard by Marriot

(Source: (Indonesia Tourism Development Corporation (ITDC), 2018))

4.3 List of Other Facilities in ITDC Nusa Dua, Bali

According to (Indonesia Tourism Development Corporation (ITDC), 2018), there are also other facilities in ITDC Nusa Dua, Bali. The list is presented on the Table 4.2.

Table 4.2 List and Location of Other Facilities in ITDC

No.	Other Facilities in ITDC Nusa Dua
19	Devdan Show
20	BIMC Siloam Nusa Dua
21	Bali Nusa Dua Convention Center

(Source: (Indonesia Tourism Development Corporation (ITDC), 2018))

4.4 Location of Facilities in ITDC Nusa Dua, Bali

According to Google Maps, the distance between LNG Terminal Benoa with ITDC Nusa Dua Area is around 13.3 km with tolls, and the distance without tolls is around 21.7 km. There are 21 facilities in ITDC Nusa Dua, Bali that will be using gas as their main source of energy. The location of hotels and villas is showed on the Figure 4.1.

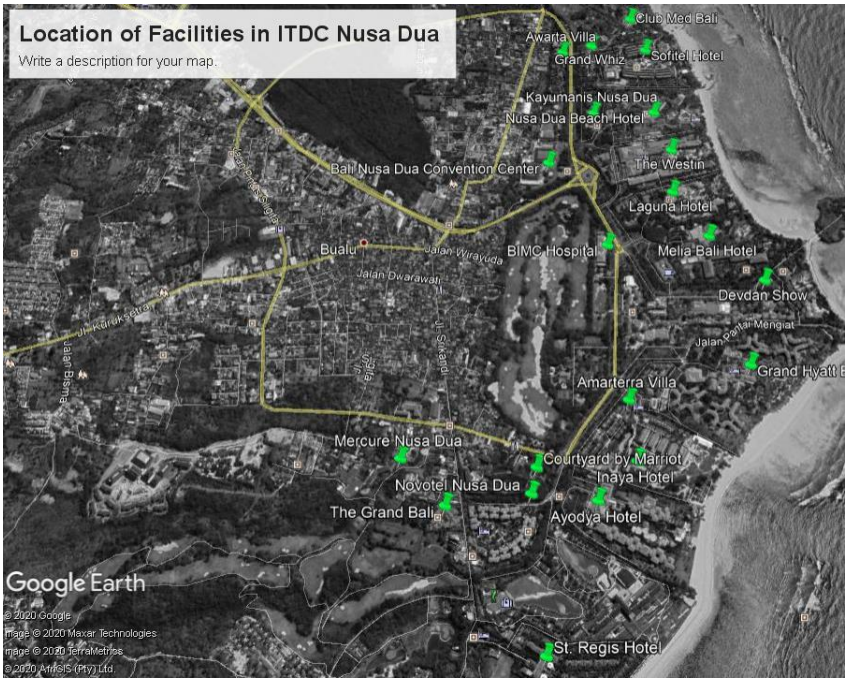


Figure 4.1 Location of Facilities in ITDC Nusa Dua, Bali

4.5 Gas Consumption Analysis of ITDC Nusa Dua, Bali

In this Bachelor Thesis, the gas demand adjusts to the needs and gas consumption of hotels and villas in ITDC Nusa Dua, Bali. The data of the gas demand of ITDC Nusa Dua, Bali is showed in Table 4.3 below. This data is obtained directly from ITDC Nusantara Utilitas.

Table 4.3 Data of Gas Consumption

No.	Facilities in ITDC Nusa Dua	Gas Consumption/Month (kg LPG)	Tonnes LNG/Year
1	Melia Bali Hotel	6500	69,108
2	Laguna Hotel	9000	95,688
3	Grand Hyatt	11500	122,268
4	Sofitel Hotel and Resort	6000	63,792
5	Mercure Nusa Dua	4000	42,528
6	Ayodya Hotel	6075	64,5894
7	Grand Whiz Hotel Nusa Dua	1250	13,29
8	The Grand Bali	10000	106,32
9	St. Regis Hotel	10000	106,32
10	Inaya Hotel	25000	265,8
11	Nusa Dua Beach Hotel	24000	255,168
12	Club Med	6000	63,792
13	Novotel Nusa Dua	3500	37,212
14	Kayumanis Nusa Dua	1800	19,1376
15	Amartera Villa	1500	15,948
16	The Westin	10000	106,32
17	Awarta Villa	1530	16,26696
18	Courtyard by Marriot	3500	37,212
19	Devdan Show	144	1,531008
20	BIMC Siloam Nusa Dua	100	1,0632
21	Bali Nusa Dua Convention Center	1970	20,94504
	Total	**143369**	**1524,299208**

From Table 4.3, the total of the gas consumption per month in kg is 143369 kg of LPG (Liquified Petroleum Gas) per month, or equivalent to 1524.299 Tonnes LNG (Liquified Natural Gas) per year. The total facilities in ITDC Nusa Dua, that will be using natural gas are 21 facilities. The highest gas consumption is in Inaya Hotel with 25000 kg LPG per month, or equivalent to 265.8 Tonnes LNG/year and the lowest gas consumption is in Devdan Show with 144 kg LPG per month, or equivalent to 1.53 Tonnes LNG/year.

After the total gas consumption of each facility in ITDC Nusa Dua, Bali obtained, the conversion to LNG consumption can be done. The conversion of the total gas consumption to know the gas consumption in LNG (Liquified Natural Gas) referring to (International Gas Union, 2012), it is showed in the Table 4.4.

Table 4.4 Gas Consumption Conversion

Total Gas Consumption	143369,00	*kg LPG/month*
Gas Consumption After Conversion	1720428,00	*kg LPG/year*
	0,0017	*MT LPG/year*
	1720,43	*Tonnes LPG/year*
	1524,30	*Tonnes LNG/year*
	81367,09	*mmBtu*
	0,0015	*MTPA LNG*
	0,2132	*mmscfd*
	7,46	*m3 LNG/day*
	4364,25	*Nm3 Gas/day*

From the table, it is showing the gas consumption in Million Tonnes LPG per year is 0.0017 MT LPG/year. The conversion from MT LPG/year to Tonnes LNG/year is multiplied by 886000 and the result is 1524.3 Tonnes LNG/year. The result of Million British Thermal Unit (mmBtu) is multiplied Tonnes LNG/year by 53.38 and the result is 81367.09 mmBtu. To know the Million Tonnes Per Annum (MTPA) is divided the Tonnes LPG/year by 1130000 and the result is 0.0015 MTPA LNG. The result of mmscfd is multiplied MTPA LNG by 140, and the result is 0.2132 mmscfd. The m3 LNG/day is multiplied mmscfd by 35, and the result is 7.46 m3 LNG/day. After the gas demand is obtained, the requirement for each section in LNG distribution scheme can be determined.

4.6 LNG Capacity Analysis in LNG Terminal Benoa

In this Bachelor Thesis, the source of the Liquified Natural Gas is in LNG Terminal Benoa which handled by PT. Pelindo Energi Logistik (PEL). PT. Pelindo Energi Logistik provides PLTDG Pesanggaran with a capacity of 200 MW, owned by PT, with shipping, storage of LNG, LNG regasification and LNG distribution services. Indonesia Electricity. PT. Pelindo Energi Logistik was founded in the province of Bali since PLTD Pesanggaran switched from diesel fuel to natural gas to minimize emissions. PT Pelindo Energi Logistik has been supplying PLTDG Pesanggaran (250 MW) with natural gas using a 3600 m pipeline since 2016, supplying up to 50 mmscfd of natural gas.

Table 4.5 LNG Terminal Benoa Capacity

LNG Terminal Benoa		
Information	*Value*	*Unit*
Capacity	26000	m³
	50	mmscfd

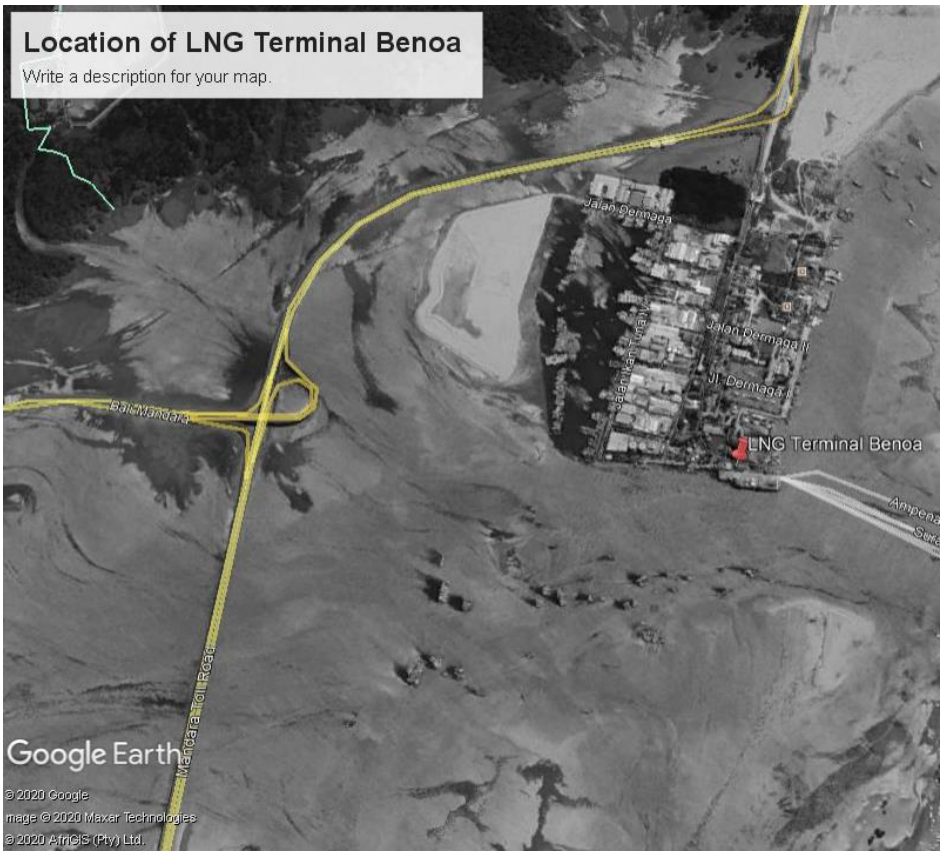


Figure 4.2 Location of LNG Terminal Benoa

From the Table 4.5., the capacity of the FSRU Karunia Dewata in LNG Terminal Benoa is 26000 m³ or 50 mmscfd. Therefore, the gas demand from facilities in ITDC Nusa Dua of 0.2132 mmscfd can be fulfilled by supplying the LNG from LNG Terminal Benoa and it is more than enough. After the location of each facilities and location of LNG source known, then the distance between each facility and the LNG source can be easily identified.

4.7 Matrix Distance

The matrix distance between the origin (PT. Pelindo Energi Logistik (PEL)) and end-user in ITDC Nusa Dua, Bali is showed on the table below and the numbering is referring to Table 4.1. and Table 4.2.

Table 4.6 Distance Matrix (Using Toll)

Distance Matrix (Using Toll) (kilometres)																						
x	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
0	0	12,9	12,8	13,8	12,6	12,4	12,8	11,6	12,4	13,1	13,6	12,3	11,8	12,8	12,1	13,4	12,3	11,8	12,8	12,6	12	12,1
1	12,9	0	0,45	1,4	1,4	2	1,6	1,3	2	2,3	1,4	1,2	1,5	1,5	1	1,1	0,75	1,3	1,5	0,85	0,45	1,1
2	12,8	0,45	0	1,4	1,4	2	1,6	1,2	2	2,6	1,3	1,2	1,4	1,4	1	1	0,7	1,2	1,4	1	0,4	1
3	13,8	1,4	1,4	0	2,4	1,8	1,4	2,2	1,8	2,5	1,2	2,1	2,4	1,3	1,9	0,9	1,7	2,2	1,3	1,3	1,2	2
4	12,6	1,4	1,4	2,4	0	2,7	2,3	1	2,7	3,4	2,1	0,8	1,2	2,2	0,45	1,8	0,75	1	2,2	1,7	1,1	0,8
5	12,4	2	2	1,8	2,7	0	1,1	2,7	0,45	1,1	1,6	2,6	2,9	1	2,4	1,3	2,1	2,7	1	2,3	1,7	3,1
6	12,8	1,6	1,6	1,4	2,3	1,1	0	2,1	1	1,7	1	2,1	2,3	0,35	1,9	0,75	1,6	2,1	0,5	1,8	1,2	1,9
7	11,6	1,3	1,2	2,2	1	2,7	2,1	0	2,6	3,2	1,9	0,75	0,18	2	0,55	1,6	0,65	0,17	2	1,6	1	0,6
8	12,4	2	2	1,8	2,7	0,45	1	2,6	0	0,75	1,6	2,6	2,9	1	2,4	1,3	2,1	2,7	1	2,3	1,7	2,5
9	13,1	2,3	2,6	2,5	3,4	1,1	1,7	3,2	0,75	0	2,2	3,2	3,5	1,6	3,1	1,9	1,8	3,3	1,6	3	2,4	3,1
10	13,6	1,4	1,3	1,2	2,1	1,6	1	1,9	1,6	2,2	0	1,9	2,2	1,1	1,7	1,1	1,5	2	1,1	1,7	1	1,8
11	12,3	1,2	1,2	2,1	0,8	2,6	2,1	0,75	2,6	3,2	1,9	0	0,9	1,9	0,4	1,5	0,35	0,7	1,9	1,5	0,9	0,55
12	11,8	1,5	1,4	2,4	1,2	2,9	2,3	0,18	2,9	3,5	2,2	0,9	0	2,2	0,75	1,8	0,85	0,35	2,2	1,8	1,2	0,8
13	12,8	1,5	1,4	1,3	2,2	1	0,35	2	1	1,6	1,1	1,9	2,2	0	1,9	0,75	1,6	2,1	0,45	1,8	1,2	1,9
14	12,1	1	1	1,9	0,45	2,4	1,9	0,55	2,4	3,1	1,7	0,4	0,75	1,9	0	1,3	0,3	0,55	1,7	1,3	0,7	0,35
15	13,4	1,1	1	0,9	1,8	1,3	0,75	1,6	1,3	1,9	1,1	1,5	1,8	0,75	1,3	0	1,2	1,8	0,85	1,4	0,8	1,6

(Continue to the next page)

(Continued from previous page)

16	12,3	0,75	0,7	1,7	0,75	2,1	1,6	0,65	2,1	1,8	1,5	0,35	0,85	1,6	0,3	1,2	0	0,65	1,5	1,1	0,5	0,45
17	11,8	1,3	1,2	2,2	1	2,7	2,1	0,17	2,7	3,3	2	0,7	0,35	2,1	0,55	1,8	0,65	0	2	1,6	1	1,6
18	12,8	1,5	1,4	1,3	2,2	1	0,5	2	1	1,6	1,1	1,9	2,2	0,45	1,7	0,85	1,5	2	0	1,9	1,2	2
19	12,6	0,85	1	1,3	1,7	2,3	1,8	1,6	2,3	3	1,7	1,5	1,8	1,8	1,3	1,4	1,1	1,6	1,9	0	0,7	1,4
20	12	0,45	0,4	1,2	1,1	1,7	1,2	1	1,7	2,4	1	0,9	1,2	1,2	0,7	0,8	0,5	1	1,2	0,7	0	0,75
21	12,1	1,1	1	2	0,8	3,1	1,9	0,6	2,5	3,1	1,8	0,55	0,8	1,9	0,35	1,6	0,45	0,6	2	1,4	0,75	0

Table 4.2., the route used is to use a toll from origin to end-user, but from end-user to another, it is not necessary to use toll and Table 4.3. are the table for the route that is not using toll.

Table 4.7 Distance Matrix (Not Using Toll)

Distance Matrix (With Toll) (kilometres)																						
x	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
0	0	21,3	21,3	22,2	21	20,8	21,2	20	20,8	21,5	22	20,7	20,2	21,2	20,6	21,8	20,7	20,2	21,3	21,1	20,5	20,6
1	21,3	0	0,45	1,4	1,4	2	1,6	1,3	2	2,3	1,4	1,2	1,5	1,5	1	1,1	0,75	1,3	1,5	0,85	0,45	1,1
2	21,3	0,45	0	1,4	1,4	2	1,6	1,2	2	2,6	1,3	1,2	1,4	1,4	1	1	0,7	1,2	1,4	1	0,4	1
3	22,2	1,4	1,4	0	2,4	1,8	1,4	2,2	1,8	2,5	1,2	2,1	2,4	1,3	1,9	0,9	1,7	2,2	1,3	1,3	1,2	2
4	21	1,4	1,4	2,4	0	2,7	2,3	1	2,7	3,4	2,1	0,8	1,2	2,2	0,45	1,8	0,75	1	2,2	1,7	1,1	0,8
5	20,8	2	2	1,8	2,7	0	1,1	2,7	0,45	1,1	1,6	2,6	2,9	1	2,4	1,3	2,1	2,7	1	2,3	1,7	3,1
6	21,2	1,6	1,6	1,4	2,3	1,1	0	2,1	1	1,7	1	2,1	2,3	0,35	1,9	0,75	1,6	2,1	0,5	1,8	1,2	1,9
7	20	1,3	1,2	2,2	1	2,7	2,1	0	2,6	3,2	1,9	0,75	0,18	2	0,55	1,6	0,65	0,17	2	1,6	1	0,6
8	20,8	2	2	1,8	2,7	0,45	1	2,6	0	0,75	1,6	2,6	2,9	1	2,4	1,3	2,1	2,7	1	2,3	1,7	2,5
9	21,5	2,3	2,6	2,5	3,4	1,1	1,7	3,2	0,75	0	2,2	3,2	3,5	1,6	3,1	1,9	1,8	3,3	1,6	3	2,4	3,1

(Continue to the next page)

(Continued from previous page)

10	22	1,4	1,3	1,2	2,1	1,6	1	1,9	1,6	2,2	0	1,9	2,2	1,1	1,7	1,1	1,5	2	1,1	1,7	1	1,8
11	20,7	1,2	1,2	2,1	0,8	2,6	2,1	0,75	2,6	3,2	1,9	0	0,9	1,9	0,4	1,5	0,35	0,7	1,9	1,5	0,9	0,55
12	20,2	1,5	1,4	2,4	1,2	2,9	2,3	0,18	2,9	3,5	2,2	0,9	0	2,2	0,75	1,8	0,85	0,35	2,2	1,8	1,2	0,8
13	21,2	1,5	1,4	1,3	2,2	1	0,35	2	1	1,6	1,1	1,9	2,2	0	1,9	0,75	1,6	2,1	0,45	1,8	1,2	1,9
14	20,6	1	1	1,9	0,45	2,4	1,9	0,55	2,4	3,1	1,7	0,4	0,75	1,9	0	1,3	0,3	0,55	1,7	1,3	0,7	0,35
15	21,8	1,1	1	0,9	1,8	1,3	0,75	1,6	1,3	1,9	1,1	1,5	1,8	0,75	1,3	0	1,2	1,8	0,85	1,4	0,8	1,6
16	20,7	0,75	0,7	1,7	0,75	2,1	1,6	0,65	2,1	1,8	1,5	0,35	0,85	1,6	0,3	1,2	0	0,65	1,5	1,1	0,5	0,45
17	20,2	1,3	1,2	2,2	1	2,7	2,1	0,17	2,7	3,3	2	0,7	0,35	2,1	0,55	1,8	0,65	0	2	1,6	1	1,6
18	21,3	1,5	1,4	1,3	2,2	1	0,5	2	1	1,6	1,1	1,9	2,2	0,45	1,7	0,85	1,5	2	0	1,9	1,2	2
19	21,1	0,85	1	1,3	1,7	2,3	1,8	1,6	2,3	3	1,7	1,5	1,8	1,8	1,3	1,4	1,1	1,6	1,9	0	0,7	1,4
20	20,5	0,45	0,4	1,2	1,1	1,7	1,2	1	1,7	2,4	1	0,9	1,2	1,2	0,7	0,8	0,5	1	1,2	0,7	0	0,75
21	20,6	1,1	1	2	0,8	3,1	1,9	0,6	2,5	3,1	1,8	0,55	0,8	1,9	0,35	1,6	0,45	0,6	2	1,4	0,753	0

4.8 Design LNG Distribution Scheme

In this Bachelor Thesis, the distribution flow model is showed in the Figure 4.3. The LNG will be carried from LNG Terminal in Benoa with truck that will be installed with ISO Tank. LNG Filling Station will be placed in LNG Terminal Benoa Area because this facility is to fill the ISO Tank. The truck will be transporting the LNG to Small Scale Gas Station in ITDC Nusa Dua, Bali area. In Small Scale Gas Station (SSGS), there will be an LNG Storage and Regasification Facilities. After the LNG is processed to change the LNG phase from liquid phase back to gas phase, the natural gas is distributed directly to each facility with pipelines.

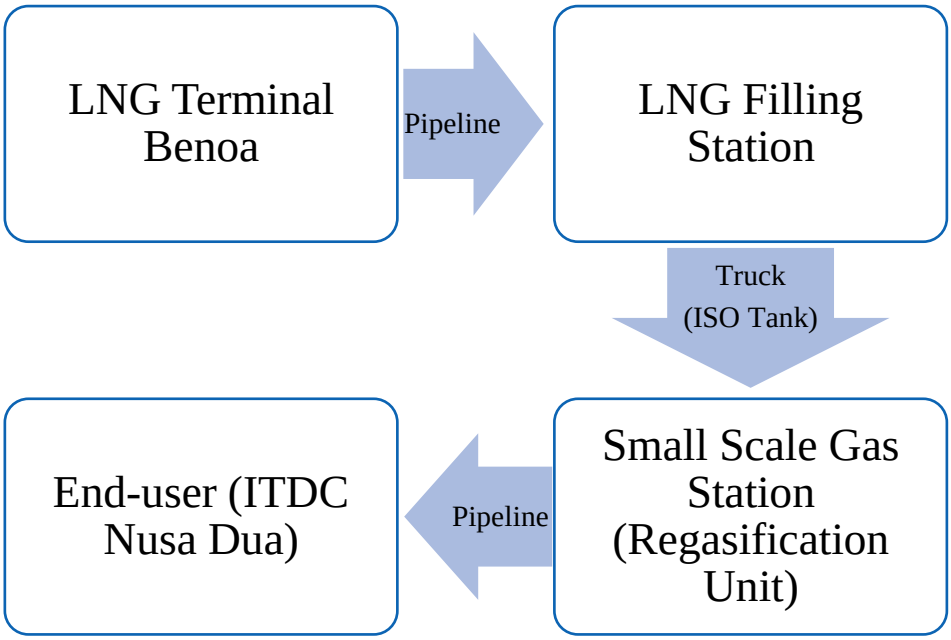


Figure 4.3 LNG Distribution Flow Model

After the flow model is designed, the location of Small-Scale Gas Station must be determined. The location of small-scale gas station will be placed near ITDC Nusa Dua, Bali. From the Figure 4.4, it is showing the location of small-scale gas station for ITDC Nusa Dua, Bali.

Figure 4.4 The Location of Small-Scale Gas Station

From the figure above, the location is on the left side of Pratama Raya Street if the truck came from By-Pass Ngurah Rai Street. Small-scale gas station also is on the right side of Lagoon ITDC Nusa Dua and near The Nest Hotel by Danapati. The area of SSGS that will be used is 4978.1 m². This location is chosen because it is not interrupting the traffic, the location is across from residential area and it is under ITDC Nusa Dua, Bali authority. There will be 2 alternatives for the truck route and the detail for this LNG distribution scheme for ITDC Nusa Dua, Bali, can be seen in the Figure 4.5 and Table 4.8.

Table 4.8 Detail of LNG Distribution Scheme

Detail of LNG Distribution Scheme		
Information	*Value*	*Unit*
Road Length (LNG Filling Station - Small Scale Gas Station) A	11,3	km
Road Length (LNG Filling Station - Small Scale Gas Station) B	19,5	km
Pipeline Length (Small Scale Gas Station - Each Facility)	8,42	km

From the figure below, it is showing the LNG Distribution Scheme A which using Mandara Toll and “Blue Line” will be using Truck to carry the ISO Tank from LNG Filling Station to Small-Scale Gas Station, and the “Yellow Line” will be using Pipeline for distributing the Natural Gas after it is processed in Small-Scale Gas Station to each facility in ITDC Nusa Dua, Bali.

Figure 4.5 LNG Distribution Scheme A

From the figure below, it is showing the LNG Distribution Scheme B which not using Mandara Toll and “Blue Line” will be using Truck to carry the ISO Tank from LNG Filling Station to Small-Scale Gas Station, and the “Yellow Line” will be using Pipeline for distributing the Natural Gas after it is processed in Small-Scale Gas Station to each facility in ITDC Nusa Dua, Bali. The detail of the components in each facility can be determined.

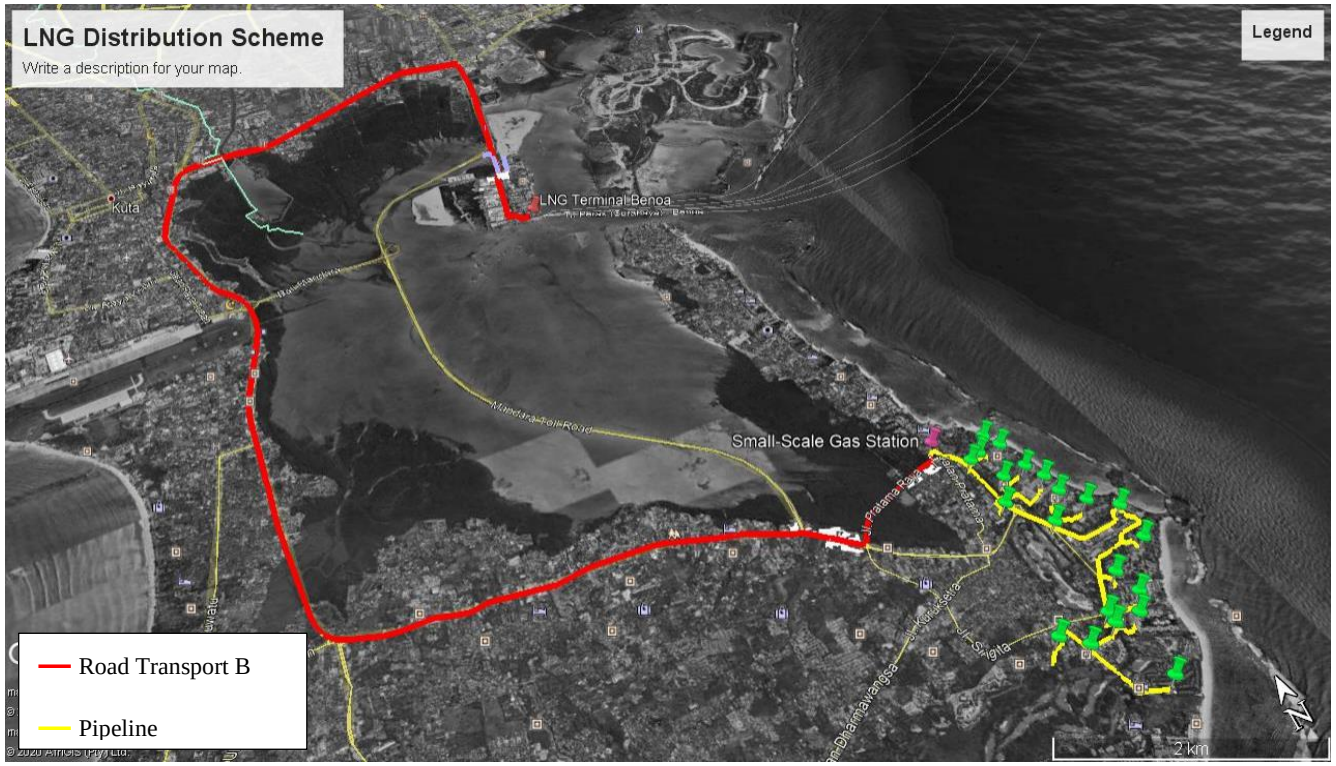


Figure 4.6 LNG Distribution Scheme B

4.8.1 Small-Scale Gas Station (SSGS)

Small-scale gas station is a facility to store LNG, LNG regasification, and distributing the natural gas directly to each facilities that need gas in ITDC Nusa Dua, Bali. Therefore, the small-scale gas station need to follow the standard of NFPA 59A. NFPA 59A is a standard that provides minimum fire protection, safety, and related requirements for the location, design, construction, security, operation, and maintenance of liquefied natural gas (LNG) plants (National Fire Protection Association, 2019). According to (National Fire Protection Association, 2019), there are several sections that need to be noted, which are:

a. Plant Siting and Layout
   This standard is used for design purposes, location, construction, operation, and maintenance at each location of natural gas liquefaction, storage, transfer, evaporation, and distribution. This standard is used for all LNG storage tank containers including insulation system applications.
b. Storage Tank
   Set the tank height, the height of the tank protection embankment, the distance between the inner wall and the outer wall surface of the tank, and the allowable fluid level at the top of a tank
c. Unloading Facility
   Adjust the distance of the loading and unloading pipes at the jetty, cooling at the pipe joints, and the distance between loading and unloading equipment.
d. Process Equipment
   Regulate safety pressure on pumps and compressors, separate handling between BOG compressors and storage tanks, use of ventilation systems, and use of valves
e. Vaporizer
   Regulate the heat classification of the vaporizer system, environmental temperature classification, manifold vaporizer, control of the vaporizer unit, valve valves, distance of the vaporizer to LNG storage tanks and other facilities.

To determined the equipments in Small-Scale Gas Station, the flow diagram in SSGS must be designed. The flow diagram of Small-Scale Gas Station is represented on the figure below. From the flow diagram below, the LNG will be store in ISO Tank, then transferred with LNG Pump to the Regasification Unit (Vaporizer), to be processed to change the LNG state from liquid phase back to gas phase. The “Green Arrow” indicates that the natural gas is in liquid phase (LNG) and the “Yellow Arrow” indicates that the natural gas is in gas phase. After the LNG processed in regasification unit, the natural gas

transferred using natural gas pipeline directly to the end-user or facilities in ITDC Nusa Dua, Bali.

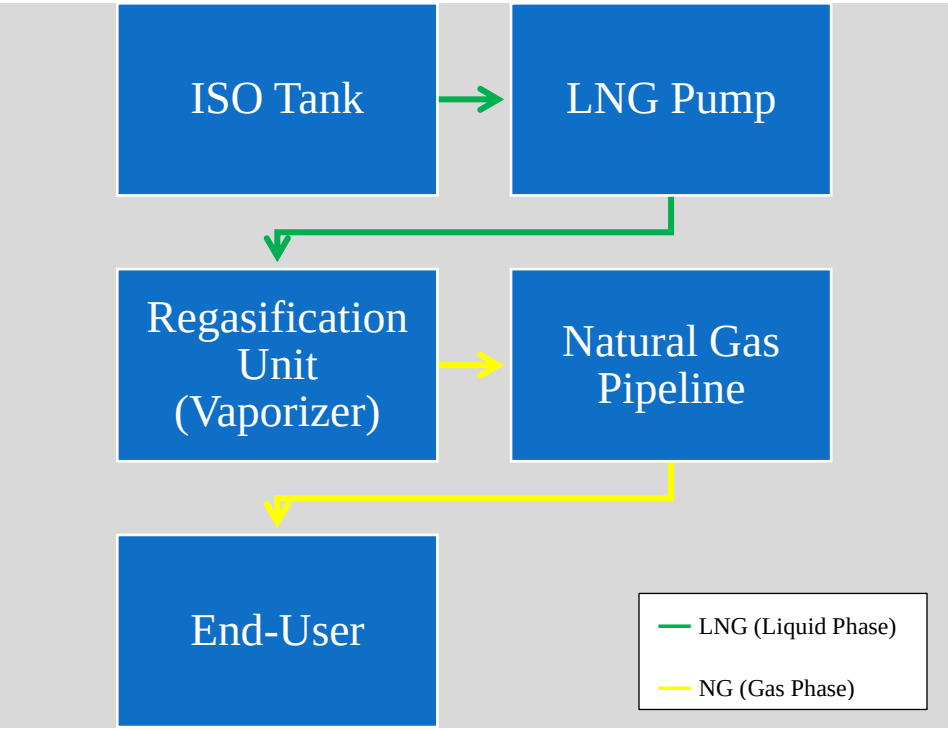


Figure 4.7 SSGS Flow Diagram

To determined the size of the ISO tank in Small-Scale Gas Station, there are several aspects that need to be noted, such as duration on the road, trip of the truck in a year, etc. This aspects will affect the size of the ISO tank for Small-Scale Gas Station. The gas demand in ITDC Nusa Dua Bali is 0.2132 mmscfd and supply from LNG Terminal Benoa assumpted sufficient from demand. The size of the ISO Tank must be greater than or equivalent to the gas demand in ITDC Nusa Dua, Bali. Before calculating what is the capacity of storage, route and truck calculations for each alternatives must be known.

Table 4.9 Route Calculations A

LNG Terminal Benoa - Small-Scale Gas Station		
Information	*Value*	*Unit*
Road Length LNG Distribution A	11,3	km

(Continue to the next page)

(Continued from previous page)

Gas Demand	0,2132	mmscfd
	7,46	m³/day
	2722,9	m³/year
Duration on the Road	20	minutes
Loading Time	60	minutes
Forward Trip	80	minutes
Unloading Time	60	minutes
Backward Trip	80	minutes
Total Time Forward and Backward	160	minutes
	0,11	day
Standby Time	2,4	days
Total Time / Round Trip	2,51	days
Round Trip / Year	145	times/year

Table 4.10 Route Calculations B

LNG Terminal Benoa - Small-Scale Gas Station		
Information	*Value*	*Unit*
Road Length LNG Distribution B	19,5	km
Gas Demand	0,2132	mmscfd
	7,46	m³/day
	2722,9	m³/year
Duration on the Road	35	minutes
Loading Time	60	minutes
Forward Trip	95	minutes
Unloading Time	60	minutes
Backward Trip	95	minutes
Total Time Forward and Backward	190	minutes
	0,13	day
Standby Time	2,4	days
Total Time / Round Trip	2,53	days
Round Trip / Year	145	times/year

The size of the ISO Tank that will be carried with Truck from LNG Filling Station to Small-Scale Gas Station is 20 ft or 20.37 m³. Therefore, the size of the ISO Tank in Small-Scale Gas Station must be greater than or equivalent to 20.37 m³. The ISO Tank

10 ft can be used in this facility but the round trip per year will be 365 times/year which can increasing the vehicle density of the traffic.

In this facility, there will be 2 ISO Tank with capacity 20.37 m³ that will be installed and fulfil the gas consumption in ITDC Nusa Dua, Bali for 2.5 days. 1 ISO Tank will be replaced with a full tank of LNG for every 2-2.5 days. The specification of the ISO Tank is on the table below.

Table 4.11 20 ft ISO Tank Specification

Cryogenic ISO Tank 20 feet	
Product name	20 feet T75 Cryogenic Tank Container
Design specification	1. ASME VIII DIV 1-ED2013
	2. T75 UN PROTABLE TANK,
	IMDG, TIR, CSC, TC
	3. RID/ADR 1496-3
Geometric volume	20.37 m3
Working pressure	10 Bar
Design temperature	-196 Degree Celsius
Filling medium	LNG, ethylene, ethane, liquid
	oxygen,liquid nitrogen, liquid
	argon
Tank material	Liner SA-240M304
	Tank Shell SA-516M
Insulation type	High 44 vacuum multi-layers spiral
	wound insulation
Country of origin	China
Tank weight	11.500 kg
Overall size	6058 x 2438 x 2591 mm
Holding Times	10 Days at 98% Fill

According to Table 4.11, the holding times under perfect conditions for LNG is 10 days at 98% fill, therefore there is no need a BOG system. To replace the ISO Tank in Small-Scale Gas Station, a reach stacker crane is needed to lift the empty ISO Tank and then replaced with full of LNG-ISO Tank. The ISO Tank weight according to Table 4.11 is 11500 kg or 11.5 ton. Therefore, the reach stacker crane based on the load of the cargo or the ISO Tank weight. The specification for the reach stacker crane is on the table below.

Table 4.12 Reach Stacker Crane Specification

Reach Stacker Crane		
Information	*Value*	*Unit*
Series	SRST50H1-H	-

(Continue to the next page)

(Continued from previous page)

Max Load	50	*ton*
Max Hoisting Height	15100	*m*
Max Hoisting Speed (Non-Load/Load)	420 / 250	*mm/s*
Max Travel Speed (Non-Load/Load)	25 / 21	*km/h*
Working Pressure of Hydraulic System	260	*bar*
Overall Length	10580	*mm*
Overall Width	4188	*mm*
Overall Height	4770	*mm*

The capacity of this Small-Scale Gas Station according to the gas consumption of ITDC Nusa Dua, Bali is 0.2132 mmscfd. Therefore, there are two types of vaporizer that can be used, which are (Katili, Artana, & Dinariyana D.P., 2016):

a. Ambient Air Vaporizer (AAV)
b. Open Rack Vaporizer (ORV)

The chosen vaporizer type for this facility is Ambient Air Vaporizer because the average weather in Small-Scale Gas Station area is from 28 degrees Celsius to 31 degrees Celsius and the location of this facility is far from the sea. The requirements for regasification unit is on the table below.

Table 4.13 Requirements for Regasification Unit

Requirements for Regasification Unit		
Information	*Value*	*Unit*
Required Capacity	0,21	*mmscfd*
	7,46	*m3 LNG/day*
	0,31083	*m3 LNG/hour*
Required Capacity	4364,25	*Nm3 Gas/day*
	181,84	*Nm3 Gas/hour*
Operation Time	24	*hours/day*
Vaporizer Capacity	3-200000	*Nm3/hour*
Working Pressure	1,6-25	*Mpa*

After choosing the vaporizer for regasification, LNG pumps are used to supply the LNG from LNG storage tank to vaporizers. LNG pump capacity is based on the capacity

required from gas consumption and pressure from vaporizers. There will be 2 LNG pumps. The LNG pump specification is showed on the table below.

Table 4.14 LNG Pump Specification for SSGS

LNG Pump		
Information	*Value*	*Unit*
Pump Model	SLP-24/90	-
Pump Type	Centrifugal	-
Flow Rate	24	m3/h
Head	189	m
	1,85	Mpa
Speed	3950	r/min
Power	11	kW (LNG)

4.8.2 LNG Truck and LNG ISO Tank

The truck will be carrying LNG ISO Tank is chosen to transport the LNG from LNG Terminal Benoa to Small-Scale Gas Station in ITDC Nusa Dua, Bali. According to the gas consumption of facilities in ITDC Nusa Dua, Bali, the gas demand is 7.46 m^3/day, and the size of the ISO Tank is 20 ft or in m^3 is 20.37 m^3. From the Table 2.2., for 20 ft in m^3 is 20.37 m^3, and for 40 ft in m^3 is 43.5 m^3. The specification of the LNG Truck is showed on Table 4.13

Table 4.15 Truck Specification

Truck	
Information	*Value*
Truck Model	SKW9402GYY
Shape	Flatbed
Tire Number	12
Condition	New
Transport Package	In Nude
Origin	Liangshan Shandong China
Independent Suspension Type	Air Suspension
Axle Number	4

(Continue to the next page)

(Continued from previous page)

Self-Dumping	Discharging System
Material	Steel
Dimension	12000x2500x3810
Specification	CCC SGS
HS Code	3708960665

4.8.3 LNG Truck Route

The route of the LNG Truck must be considered. There are several considerations to design the route of the LNG Truck to carry the LNG ISO Tank to Small-Scale Gas Station in ITDC Nusa Dua, Bali, which are:

a. Truck Overall Dimension

b. Road Dimension

c. Road Purposes

According to (BUPATI BADUNG, 2013), there are several regulations for defining the road purposes, that must be obeyed about *"Sistem Jaringan Transportasi Darat Pasal 11"* before designing a route for an LNG truck, which are showed on the table below.

Table 4.16 Land Transportation Network System

No.	Road Network	Area
1	Freeway Network	Kuta-Bandar Udara Ngurah Rai
		Kuta-Denpasar-Tohpati
		Nusa Dua Toll-Bandar Udara Ngurah Ra-Benoa
2	Primary arterial road network	Simpang Kuta – Tugu Ngurah Rai;
		Tugu Ngurah Rai – Simpang Bandar Udara Ngurah Rai;
		Simpang Kuta – Simpang Pesanggaran.
3	Primary collector road network 1	Tugu ngurah rai- Nusa dua
		Denpasar – Tuban.
4	Special Road	Road network within the Nusa Dua Tourism Area (Bali Tourism Development Corporation);

From Table 4.16, the areas in the table are several alternative routes that can be traversed by trucks and included in the regulation. "Freeway Network" is public roads

for continuous traffic with full control of the entrance and without any level intersections and equipped with road fences. “Primary Arterial Road Network” is public roads that connect efficiently between PKNs or between PKN (*Pusat Kegiatan Nasional*) and Regional activity centres. PKN or *Pusat Kegiatan Nasional* is an urban area that serves to serve international, national, or several provincial scale activities that has function as a centre for industrial activities and services on a national scale or serving several provinces. The primary arterial roads in the Regency Region are part of the public roads that connect PKN in East Java Province with Bali Province, NTB Province and with other PKN as well as roads to Ngurah Rai Airport. “Primary Collector Road Network 1” is public roads that connect efficiently between PKN and local activity centers, between Regional activity centers, or between Regional activity centers and local activity centers. Primary collector road 1 is the primary collector road, the management of which is the responsibility of the Government. “Special Road” is a road that is built and maintained by individuals, companies, or other business entities to serve their own interests (BUPATI BADUNG, 2013).

Table 4.17 Road Dimension

Road Dimension		
Road Name	*Width (m)*	*Height (m)*
Raya Pelabuhan Benoa Road	5	-
Mandara Toll Road	6,3	4,2
By-Pass Ngurah Rai Road	6,3	-
Pratama Raya Road	5	-

Therefore, all road alternatives that mentioned in the table can be used as route for the Truck to carry ISO Tank. Thus, the road dimension can be determined. Road dimension can be seen in the Table 4.17 and it is surveyed manually. The truck overall dimension in *length x width x height*, is *12000 x 2500 x 3810 (milimeters)*. Based on the road dimension in the table above, the truck can pass the route. Therefore, referring to the regulations about *“Sistem Jaringan Transportasi Darat Pasal 11”* and the road dimension, the route for the truck is on the Figure 4.8.

From the figure below, it is showing the plan of the route (Truck Route A) that the truck will go through to carry the LNG ISO Tank from LNG Terminal Benoa (PT. Pelindo Energi Logistik (PEL)), in Benoa Port, to Small-Scale Gas Station with consideration of the Road Purposes, Road Dimension, Truck Overall Dimension, and Road Condition. The distance from LNG Terminal Benoa to Small-Scale Gas Station is 11.2 km and the maximum speed of the Truck will be 40 km/h. Therefore, the time required is around 16-20 minutes. The truck will departure from LNG Filling Station, then head west on Dermaga Pelabuhan Street and continue on the Raya Pelabuhan Benoa Street for 1.36 km. After that, use the left lane to take the ramp to Mandara Toll Road and continue to that road for 7.77 km. Then, use the left 2 lanes to turn left onto By-Pass

Ngurah Rai Street. After around 481 m, turn left onto Pratama Raya Street, and continue to that road for 1.23 km. The Small-Scale Gas Station is on the left side of the Pratama Raya Street, also on the right side of the ITDC Nusa Dua Lagoon. Then, for the Truck Route B, it is still similar, but this alternative route will not be using the Mandara Toll Road.

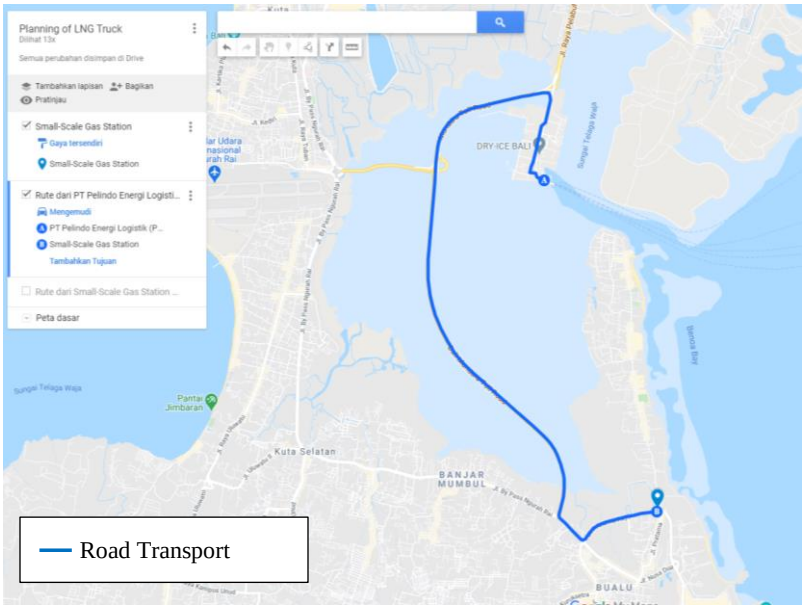


Figure 4.8 Truck Route A

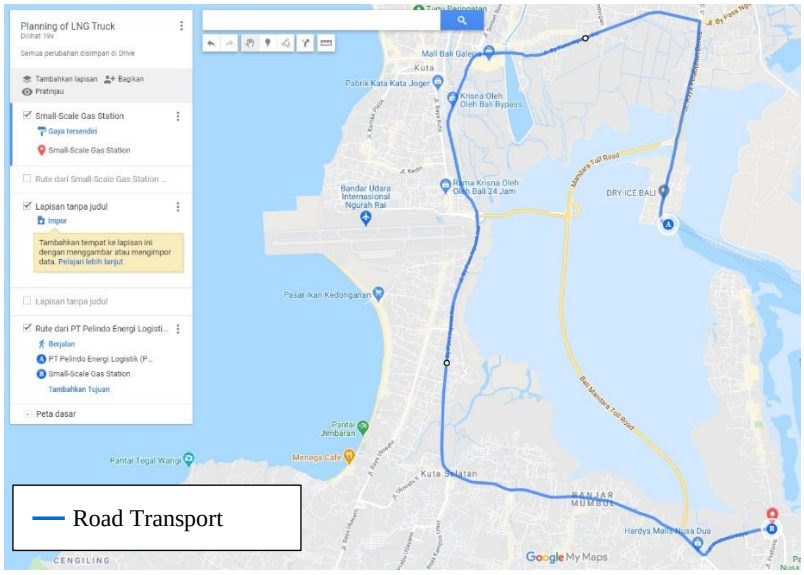


Figure 4.9 Truck Route B

4.8.4 Pipeline Natural Gas (PNG)

Pipeline can be used as a transportation to transfer the natural gas after it is processed to the end-user. The design of the pipeline from Small-Scale Gas Station to each facilities in ITDC Nusa Dua, Bali can be seen on the figure below.

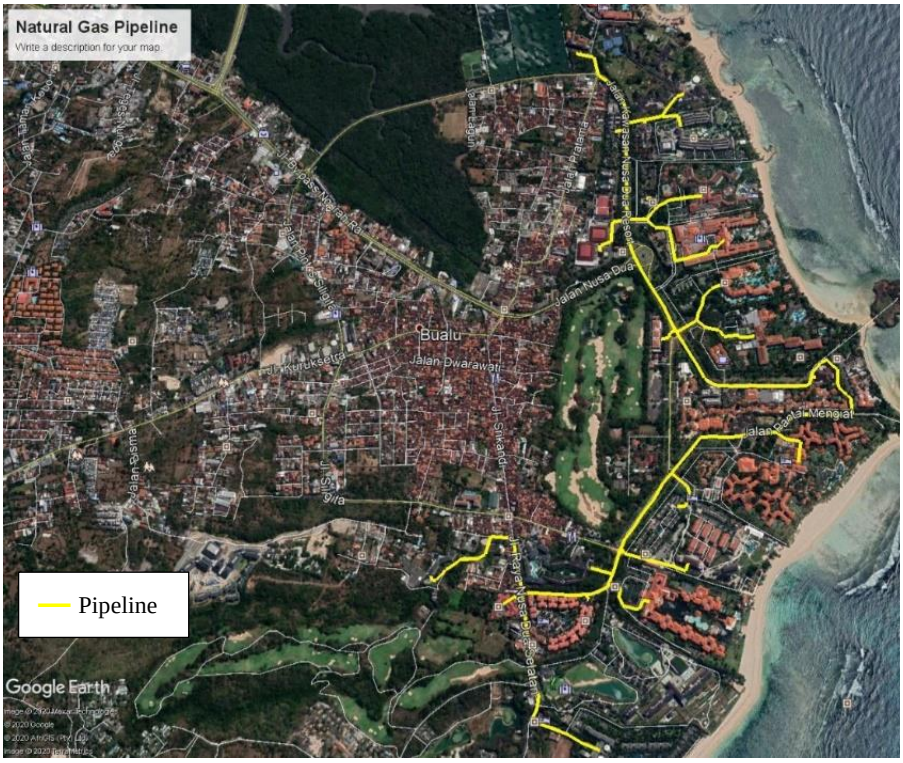


Figure 4.10 Natural Gas Pipeline Layout

According to (Bengston, PhD, PE, 2016), there are several formulations that can be used to calculating the diameter of the pipe. The equations used in calculating the diameter of a gas pipe are as follows:

1. The Weymouth Equation

$$Qb = 433.5 \times \left(\frac{T_b}{P_b}\right) \times \left[\frac{{P_1}^2 - {P_2}^2}{GLTZ}\right]^{0.5} \times D^{2.667} \times E \quad (4.1)$$

2. The Panhandle A Equation

$$Qb = 435.87 \times \left(\frac{T_b}{P_b}\right)^{1.0788} \times \left[\frac{{P_1}^2 - {P_2}^2 - \frac{0.0375 \times G \times (h2 - h1) \times {P_{avg}}^2}{Tavg - Zavg}}{G^{0.8539} \times L \times Tavg \times Zavg}\right]^{0.5394} \times D^{2.6182} \times E \quad (4.2)$$

3. The Panhandle B Equation

$$Qb = 737 \times \left(\frac{T_b}{P_b}\right)^{1.020} \times \left[\frac{{P_1}^2 - {P_2}^2 - \frac{0.0375 \times G \times (h2 - h1) \times {P_{avg}}^2}{Tavg - Zavg}}{G^{0.8539} \times L \times Tavg \times Zavg}\right]^{0.51} \times D^{2.53} \times E \quad (4.3)$$

Where,

Qb = Flow rate (ft³/day)

Tb = Base Temperature (degrees Rankin)

Pb = Base Pressure (psia)

P1 = Inlet Pressure (psia)

P2 = Outlet Pressure (psia)

L = Pipe Length (miles)

D = Internal Diameter (inches)

G = Specific gravity of the natural gas relative to air

Tavg = Average Temperature (degrees Rankin)

Pavg = Average Pressure (psia)

D = Internal Diameter (inches)

Z = The compressibility factor of the natural gas at the average temperature and pressure of the gas in the pipeline

H2 = Terminus Elevation (ft)

H1 = Origin Elevation (ft)

E = Pipeline Efficiency

On the table below is the data and design parameters to help calculating the diameter of the pipeline.

Table 4.18 Data and Design Parameters for Natural Gas Pipeline

Pipeline Data and Design Parameters			
Information	*Symbol*	*Value*	*Unit*
Pipeline Length	*L*	8,42	*km*
		5,22	*miles*
Gas Flow Rate	*Q*	4364,25	*Nm3 Gas/day*
		154213,78	*ft3 Gas/day*
Base Pressure	*Pb*	0,10	*Mpa*
		14,70	*Psia*
Inlet Pressure	*P1*	1,85	*Mpa*
		268,32	*Psia*
Outlet Pressure	*P2*	0,70	*Mpa*
		101,53	*Psia*
Average Pressure	*Pavg*	184,93	*Psia*
		170,23	*Psig*
Average Temperature	*Tavg*	536,67	*Degrees Rankin*
Specific Gravity of N. Gas	*G*	0,65	-
Compressibility Factor of the Natural Gas	*Z*	0,92	-
Elevation	ΔH	1	*ft*
Pipeline Efficiency	*E*	0,85	-
Base Temperature	*Tb*	520,00	*Degrees Rankin*

The total length of the pipeline to distribute the natural gas from Small-Scale Gas Station directly to each facility in ITDC Nusa Dua, Bali is 8.42 km or 5.22 miles. The length of the pipeline is obtained using Google Earth Pro application, by make a pathway as in the Figure 4.10 above. The gas flow rate is 4364.25 Nm³/day or 154213.78 ft³/day. According to (Bengston, PhD, PE, 2016), the base pressure and the base temperature will be, 14.7 psia and 520 degrees Rankin.

Compressibility factor (*Z*) of the natural gas is the compressibility factor of the natural gas at the average temperature and pressure of the gas in the pipeline. This equation can be used because the average natural gas pressure is greater than 100 psig. For this case, the value of the *Z* is 0.92, which the equations are mentioned below.

$$Z = \frac{1}{1+\frac{Pavg\ 344400(10)^{1.785G}}{T_{avg}^{3.825}}} \tag{4.4}$$

Where,

Z = Compressibility factor (dimensionless)

Pavg = Average Pressure (psig)

Tavg = Average Temperature (degrees Rankin)

G = Specific gravity of the natural gas relative to air

The results of the calculation of the inner diameter of the pipe based on the Weymouth, Panhandle A, Panhandle B equation with the above parameter data and assumptions are as follows:

Table 4.19 Pipe Diameter

Pipe Diameter			
Information	*Symbol*	*Value*	*Unit*
The Weymouth Equation Diameter	*Dwe*	1,285053423	inch
The Panhandle A Equation Diameter	*Dpa*	1,110497476	inch
The Panhandle B Equation Diameter	*Dpb*	1,025190491	inch

The calculation results of each of these equations look different because each equation uses a different approach. The chosen pipe diameter is the Weymouth Equation because it is the nearest value for the diameter with the availability of sizes on the market. The pipeline is using the Japanese Industrial Standard with code JIS G3452. The material of the pipe is carbon steel pipes. The required inside diameter is 1.29 inch or 32.64 mm. The outside diameter of the pipe us 42.7 mm with wall thickness 3.5 mm. Therefore, the inside diameter of the pipe is 35.7 mm. The details of pipeline specification are shown on the table below.

Table 4.20 Pipeline Specification

Pipeline Specification		
Information	*Value*	*Unit*
Pipeline Length	8,42	*km*
	5,22	*miles*
Required Inside Diameter	1,29	*inch*
	32,64	*mm*
Pipe Standard	JIS G3452	-
Pipe Material	Carbon Steel	
Nominal Diameter (A)	32	-

(Continue to the next page)

(Continued from previous page)

Nominal Diameter (B)	1 1/4	-
Outside Diameter	42,7	*mm*
Wall Thickness	3,5	*mm*
Inside Diameter	35,7	*mm*

4.8.5 LNG Filling Station

The location of the LNG Filling Station is near the LNG Terminal Benoa (PT. Pelindo Energi Logistik (PEL)). The flow diagram of LNG Filling Station can be seen in the Figure 4.11. LNG that stored in FSRU Karunia Dewata will be transferred using pipeline directly to LNG Filling Station to filling the ISO Tank that will be carried with Truck to ITDC Nusa Dua, Bali. The type of this LNG Filling Station is skid-mounted station, because the gas demand is not too high, the construction period is shorter, and the investment is less compared with standard station according to (LI, LI, YU, & BAO, 2017). Because of this LNG Filling Station only for filling the ISO Tank, vaporizer is not included. LNG from FSRU Karunia Dewata will be pumped to LNG Filling Station with LNG pumps. The "Green Arrow" indicates that the natural gas is in liquid phase (LNG).

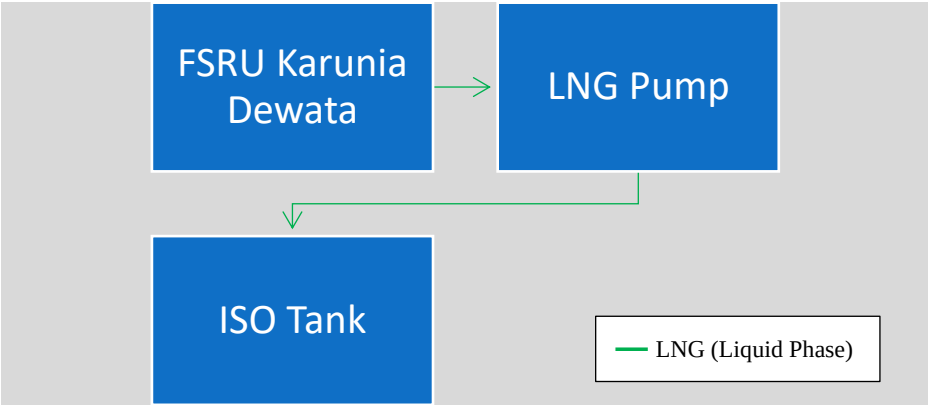


Figure 4.11 LNG Filling Station Flow Diagram

The capacity of the pump can be calculated with the Equation 4.6.

$$Q = \frac{V}{t} \tag{4.5}$$

Where,

Q = Flow rate (m^3/h)

V = Volume (20.37 m^3)

t = Time (1 h)

The size of the ISO Tank will be 20 ft and the volume is 20.37 m³. The time in this equation is assumption, the ISO Tank will be full with LNG in 60 minutes or 1 hour. Then, the flow rate is 20.37 m³/h. The pump chosen for LNG Filling Station is informed in Table 4.21 The flow rate of the LNG pump is 24 m³/h with head 90 m. The type of the LNG Pump is centrifugal pump with high pressure for low temperature liquid (cryogenic pump).

Table 4.21 LNG Pump Specification for LNG Filling Station

LNG Pump		
Information	*Value*	*Unit*
Pump Model	SLP-24/90	-
Pump Type	Centrifugal	-
Flow Rate	24	m3/h
Head	90	m
Speed	2935	r/min
Power	11	kW (LNG)

In LNG Filling Station system, the LNG from FSRU Karunia Dewata will passing through several pressure indicators and temperature indicators as well as several valves such as hand valve, check valve, ball valve, pressure safety valve, shut down valve and also emergency shutdown. Furthermore, before the LNG entering the ISO Tank, there is a metering to collect the amount of LNG being transferred to LNG ISO Tank which can be controlled by a Digital Control Valve.

4.8.6 Summary of LNG Distribution Scheme

From the previous sub-chapter, the LNG Distribution Scheme for ITDC Nusa Dua, Bali, only requires 1 truck, which can carry 1 ISO tank sized 20 ft or 20.37 m³ with route course starting from LNG Filling Station which near the LNG Terminal Benoa to Small-Scale Gas Station with total road distance 11.3 km for truck route A, and total road distance 19.5 km for truck route B. The road transport is indicated with “Blue Line” that can be seen on Figure 4.12. Then, from Small-Scale Gas Station to each facility in ITDC Nusa Dua, Bali, is using pipeline with total length 8.42 km.

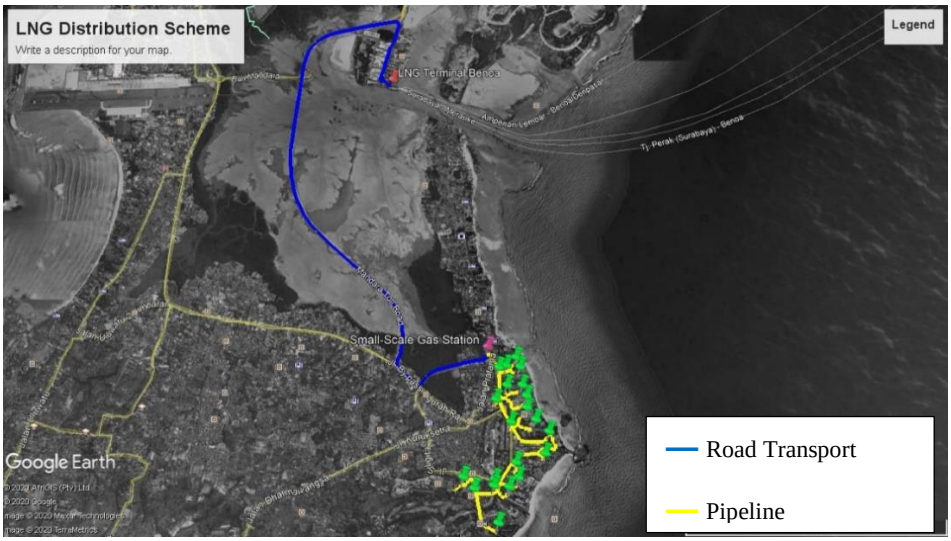


Figure 4.12 LNG Distribution Scheme A Layout

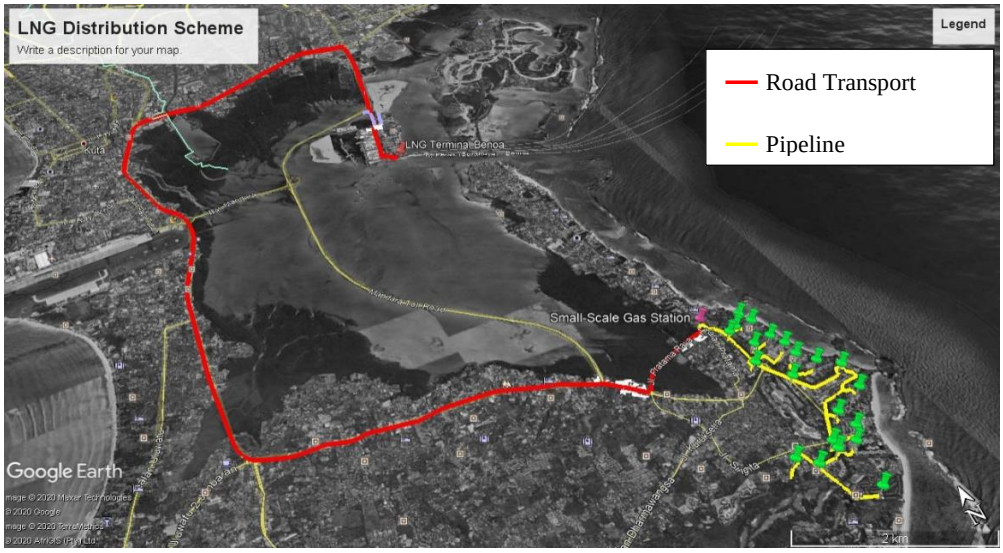


Figure 4.13 LNG Distribution Scheme B Layout

The pipeline is indicated with “Yellow Line” The overall distance from LNG Distribution Scheme A is 19.72 km and from LNG Distribution Scheme B is 27.92 km. The total gas demand in ITDC Nusa Dua, Bali is 7.46 m^3/day or 0.2132 mmscfd with duration on the road per round trip is 0.67 hour (A) and 1.17 hours (B), and the total time per round trip in which the duration on the road is added with loading-unloading time (2

hours), idle time (2.4 days or 57.6 hours).Thus, the total duration per round trip is 2.5 days or 60 hours and the total round trip for road transport in a year is 144 or 145 times per year.

Table 4.22 Summary LNG Distribution Scheme A

Summary LNG Distribution Scheme A		
Road Transport (Truck)		
Information	*Value*	*Unit*
Truck (ISO Tank Size)	20,00	*ft*
	20,37	*m3*
Road Length (LNG Filling Station - Small Scale Gas Station) A	11,30	*km*
Gas Demand	7,46	*m3/day*
Duration on the Road	20	*minutes*
Total Time Forward and Backward	160	*minutes*
Standby Time	2,4	*days*
Total Time / Round Trip	2,5	*days*
Round Trip / Year	145	*times/year*
Natural Gas Pipeline		
Information	*Value*	*Unit*
Pipeline Length (Small Scale Gas Station - Facilities in ITDC Nusa Dua)	8,42	*km*
Gas Flow Rate	154213,78	*ft3 Gas/day*
Pipe Standard	JIS G3452	-
Pipe Material	Carbon Steel	
Nominal Diameter (A)	32	-
Nominal Diameter (B)	1 1/4	-
Outside Diameter	42,7	*mm*
Wall Thickness	3,5	*mm*
Inside Diameter	35,7	*mm*

Table 4.23 Summary LNG Distribution Scheme B

Summary LNG Distribution Scheme B		
Road Transport (Truck)		
Information	*Value*	*Unit*
Truck (ISO Tank Size)	20,00	*ft*
	20,37	*m3*
Road Length (LNG Filling Station - Small Scale Gas Station) B	19,5	*km*
Gas Demand	7,46	*m3/day*
Duration on the Road	35	*minutes*
Total Time Forward and Backward	190	*minutes*
Standby Time	2,4	*days*
Total Time / Round Trip	2,5	*days*
Round Trip / Year	145	*times/year*
Natural Gas Pipeline		
Information	*Value*	*Unit*
Pipeline Length (Small Scale Gas Station - Facilities in ITDC Nusa Dua)	8,42	*km*
Gas Flow Rate	154213,78	*ft3 Gas/day*
Pipe Standard	JIS G3452	-
Pipe Material	Carbon Steel	
Nominal Diameter (A)	32	-
Nominal Diameter (B)	1 1/4	-
Outside Diameter	42,7	*mm*
Wall Thickness	3,5	*mm*
Inside Diameter	35,7	*mm*

4.9 Road Transport Risk Assessment

4.9.1 Accident Report

To do the risk assessment of the road transport, it is important to collect data from accident report because the data can support the essential step in the risk assessment, which is finding the accident frequency *fi*. FA in the table below indicates fatality, MAI indicates a major injury, MII indicates a minor injury, MAD indicates major damage, MID indicates minor damage, FF indicates front-front, SS indicates side-side, FS indicates front-side, and FB indicates front-back. T in the table below indicates truck, B indicates Bus, C indicates car, P indicates Pick-up, and M indicates motorcycle. The accident report in September 2018 is shown in the table below.

Table 4.24 Accident Report In September 2018

September																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	T	B	C	P	M
96	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Median Ulun Suwi Jimbaran	1		1	2		3			1						2
97		Jl. By Pass Ngurah Rai Simpang Taman Griya Jimbaran	1		1	1		1			1						1

(Continue to the next page)

(Continued from the previous page)

98	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Depan Kantor Notaris KM 5	1		1			1			1						2
99		Jl. By Pass Ngurah Rai Depan Hotel The Griya Sanur	1		1	1		2			1						2
100		Jl. By Pass Ngurah Rai Depan Lab Bali Stone KM 7	1			1		1				1	1				1
101		Jl. By Pass Ngurah Rai TL Taman Griya	1			3		3		1							1
102		Jl. By Pass Ngurah Rai Banjar Mumbul Kuta Selatan	1			2		2				1					2
103		Jl. By Pass Ngurah Rai Simpang Trec Kedonganan	1			1		2				1	1				1

(Continue to the next page)

(Continued from the previous page)

104	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Simpang 4 Jl Danau Buyan	1			2		2			1						2
105		Jl. By Pass Ngurah Rai TL GBB KM 7 Sanur	1			1		1			1						2
106	Jl. Pratama Raya	Jl. Pratama Depan Rumah makan Rindu Rasa	1			2		2			1						2
107	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
108	Jl. Toll Bali Mandara	Jl. Tol Bali Mandara KM B 2800 Nusa Dua	1		1	1		2				1					2
Total (Jl. By Pass Ngurah Rai)			10	0	4	14	0	18	0	1	6	3	2	0	0	0	16
Total (Jl. Pratama Raya)			1	0	0	2	0	2	0	0	1	0	0	0	0	0	2
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			1	0	1	1	0	2	0	0	0	1	0	0	0	0	2
Total (September)			12	0	5	17	0	22	0	1	7	4	2	0	0	0	20

The accident report obtained from local police department, Polres Denpasar. Time span of the accident report is from early 2018 to late 2019. The accident reports collected referring to the plan of the truck route, which are, Raya Pelabuhan Benoa Road, Mandara

Toll Road, By Pass Ngurah Rai Road, and Pratama Raya Road. The detail of accident reports in September 2018 is shown in the Table 4.24. In September 2018, there are 10 accidents in By Pass Ngurah Rai Road, 1 accident in Pratama Raya Road, 1 accident in Mandara Toll Road, and zero accident in Raya Pelabuhan Benoa Road. The total vehicle involved in accident report September 2018 is 22 vehicles.

Table 4.25 Summary Accident Report In 2018

Summary Accident Report In 2018																	
No	Description	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
			FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
1	Total Accident in 2018 (Jl. By Pass Ngurah Rai)	106	31	30	91	3	157	6	25	36	37	26	3	27	12	133
2	Total Accident in 2018 (Jl. Pratama Raya)	1	0	0	2	0	2	0	0	1	0	0	0	0	0	2
3	Total Accident in 2018 (Jl. Raya Pelabuhan Benoa)	4	0	3	3	0	7	0	0	3	1	0	1	0	1	6
4	Total Accident in 2018 (Jl. Toll Bali Mandara)	3	1	2	2	0	6	0	0	1	2	1	0	1	0	4
5	Total Accident in 2018	114	32	35	98	3	172	6	25	41	40	27	4	28	13	145

From the Table 4.25, it is showing the summary accident report in 2018. The highest number of accidents is on By Pass Ngurah Rai Road, which is 106 accidents on that road and the lowest number of accidents is on Pratama Raya Road, which only 1 accident on that road. The total vehicle involved in accident is 197 vehicles. Motorbike is the highest number of involved vehicle in accident and truck is on the third number of involved vehicle in accident. Therefore, the total accident in 2018 is 114 accidents on specific road that mentioned on the table. The accident report in 2019 is attached in this bachelor thesis.

4.9.2 Hazard Identification (What-If Analysis)

Hazard Identification (HAZID) is the process of recognizing the dangers that may occur regardless of what is accepted or not accepted that occurs (Pratama, Artana, & Baliwangi, 2010). In the hazard identification process used to identify all possible situations in which a person may be exposed to injury, illness or disease, the types of hazards that may arise and how to manage those hazards. What-if analysis is an approach to brainstorming that uses structured questioning that generates qualitative explanations of potential problems as well as lists of problem mitigation suggestions (Kontovas, 2005). In order to define hazard in the transport of the ISO Tank by Truck, this bachelor thesis will use What-If Analysis. Generally, these methods apply to any type of system, process, or activity. The What-If Analysis sheet is showed in the table below.

Table 4.26 What-If Analysis Sheet

What-If	Causes	Consequences	Safeguards	Comments	Recommendation
The air brake system fail?	failure of valves	Unable to brake or slow down the truck which can lead to a road accident	Install air brake system indicator	Not Acceptable	Periodical check equipment before starting operation and maintain the condition of the equipment
	failure of air compressor				
	failure of pipes				
	the driver lack of experience		Training		The driver should be trained properly
The truck suspension fail?	leaf spring is cracked	Pulling the truck to one side which can lead to a road accident	Install truck suspension system indicator	Not Acceptable	Periodical check equipment before starting operation and maintain the condition of the equipment
	failure of shock absorber				
	failure of stabilizer				
The truck steering system fail?	failure of steering shaft	Unable to control the truck which can lead to a road accident	Install truck steering system indicator	Not Acceptable	Periodical check equipment before starting operation and maintain the condition of the equipment
	failure of steering gear box				
	failure of pitman arm				
	failure of drag link				
	failure of tie rod				

(Continue to the next page)

(Continued from the previous page)

What-If	Causes	Consequences	Safeguards	Comments	Recommendation
The lighting system fail?	lighting system outages	The driver unable to see road clearly which can lead to a road accident	Maintenance	Not Acceptable	Periodical check equipment before starting operation and maintain the condition of the equipment
The truck tire fail?	road condition	The truck can skidding which can lead to a road accident	Check weather condition	Not Acceptable	Periodical check equipment before starting operation and maintain the condition of the equipment
	tire over pressure	The tire will blowout which can lead to a road accident	Maintenance		
	tire under pressure				
	poor alignment	Pulling the truck to one side which can lead to a road accident			
The driver fatigue?	Overworking	The driver cannot control the truck well which can lead to a road accident	Procedures	Not Acceptable	The driver must be more than one and scheduled

In the What-If Analysis sheet from Table 4.26, the analysis is using a brainstorming approach start with "what if" question to determine what can go wrong and identifying the consequences while transporting the ISO Tank with Truck from LNG Filling Station to Small-Scale Gas Station. There are several possible events that can lead to undesired events with several possible causes. In the tire overpressure will make the driver cannot control the truck because the truck tire is failing which can lead to a road accident. Failure of air compressor is also possible and makes the driver unable to brake or slow down the truck which causes the possibility of road accident. Therefore, the potential hazard in road transport is road accident collision.

4.9.3 The Frequency of Collision

After the accident report in specific road that will be the truck route to transport the ISO Tank from LNG Filling Station to Small-Scale Gas Station obtained, the frequency of an accident collision *fi* can be determined. Frequency analysis can be done by knowing the failure probability of an component in a system or activity that can cause failure. The frequency of a Collision will be determined. According to (Fabiano, Curro, Palazzi, & Pastorino, 2002), the frequency of a Collision can be expressed by the following equations on the i-th road stretch:

$$fi = \gamma i \; Li \; ni \tag{4.6}$$

$$\gamma i = \gamma 0 \sum_{j=1}^{6} hj \tag{4.7}$$

Where:

γi = the expected frequency on ith road stretch (accident km−1 per vehicle)

Li = the road length (km)

ni = is the vehicle number (vehicle)

$\gamma 0$ = the basic frequency (accident km−1 per vehicle)

hj = the local enhancing/mitigating parameters.

In using the accident frequency formula, there are provisions that must be considered, such as the basic frequency. The basic frequency can be obtained from accident report on specific road. The accident report that will be use in this bachelor thesis is from early 2018 to late 2019. The total accident from 2018 to 2019 on specific road is shown on the table below.

Table 4.27 Summary Accident Report From 2018 to 2019

Summary Accident Report From 2018 to 2019						
Description	Number of Events	Involved Vehicle				
		Truck	Bus	Car	Pick-Up	Motorbike
Total Accident (Jl. By Pass Ngurah Rai)	181	42	5	54	18	235
Total Accident (Jl. Pratama Raya)	4	0	0	2	0	7
Total Accident(Jl. Raya Pelabuhan Benoa)	5	0	1	0	2	7
Total Accident in(Jl. Toll Bali Mandara)	4	1	0	1	0	5
Total Accident	194	43	6	57	20	254

From the table above, it is showing the summary accident report from 2018 to 2019 on specific road that will be passed for Truck to carrying the ISO Tank from LNG Filling Station to Small-Scale Gas Station. The highest number of accidents is on By Pass Ngurah Rai Road with 181 accidents, and the lowest number of accidents is on Pratama Raya Road and Toll Bali Mandara with 4 accidents on each road in the past 2 years. The number of events in By Pass Ngurah Rai Road in the past 2 years is, 181 accidents with highest total involved vehicle is 354 vehicles. The lowest involved vehicle is on Toll Bali Mandara with 7 vehicles. To obtain the basic frequency on each road, the road length of each road must be determined. The road length of each road is shown on the table below.

Table 4.28 Road Length

Road Length	
Road Name	*Length (km)*
Raya Pelabuhan Benoa Road	3,4
Mandara Toll Road	12,7
By Pass Ngurah Rai Road	23
Pratama Raya Road	3,4

From the table above, it is showing the road length on each road. The road length of Raya Pelabuhan Benoa Road is 3.4 km, Mandara Toll Road is 12.7 km, Pratama Raya Road is 3.4 km, and the longest road length is on By Pass Ngurah Rai Road with 23 km. The total vehicle on truck route is using secondary data from (Irsyad & Negara, 2017). The total vehicle can be seen on the table below.

Table 4.29 Total Vehicle

Description	Total (vehicle/hour)	Total per Year
Raya Pelabuhan Benoa Road	1338	11945664
Mandara Toll Road	2167	19342512
By Pass Ngurah Rai Road	1774	15837585
Pratama Raya Road	941	8401248

After obtaining the total vehicle on truck route, the basic frequency can be determined. The basic frequency on specific road can be estimated and it is shown on the table below.

Table 4.30 Basic Frequency *y0*

No	Description	Number of Events (2 Years)	Total Vehicle (2 Years)	Road Length (km)	Basic Frequency (accident km−1 per vehicle)
1	Raya Pelabuhan Benoa Road	5	23891328	3,4	6,16,E-08
2	Mandara Toll Road	4	38685024	12,7	8,14,E-09
3	By Pass Ngurah Rai Road	181	31675170	23	2,48,E-07
4	Pratama Raya Road	4	16802496	3,4	7,00,E-08

After determine the basic frequency on each road, the local enhancing/mitigating parameters can be determined (*hj)*. The parameters will be referring to (Fabiano, Curro, Palazzi, & Pastorino, 2002). The parameters is shown on the table below.

Table 4.31 Local Enhancing Parameters *(hj)*

Parameter			Value
Intrinsic Characteristics	*h1*	Straight road	1
		Road bend (radius>200 m)	1,3
		Road bend (radius<200 m)	2,2
	h2	Plane road	1
		Slope road (gradient<5%)	1,1

(Continue to the next page)

(Continued from the previous page)

Intrinsic Characteristics	*h2*	Steep slope road (gradient>5%)	1,2
		Downhill road (gradient<5%)	1,3
		Steep downhill road (gradient<5%)	1,5
	h3	Two lanes for each carriageway	1,8
		Two lanes and emergency lane for each carriageway	1,2
		Three lanes and emergency lane for each carriageway	0,8
	h6	Tunnel	0,8
		Bridge	1,2
Meteorological Conditions	*h4*	Fine Weather	1
		Rain	1,5
		Snow/ice	2,5
Traffic Characteristics	*h5*	Low intensity < 500 vehicle/h	0,8
		Medium intensity < 1250 vehicle per hour with heavy traffic < 125 truck per day	1
		High intensity > 1250 vehicle per hour	1,4
		High intensity > 1250 vehicle per hour with heavy traffic > 250 truck per day	2,4

From the table above, it is showing the value of *hj* on each specific road that will affecting the expected frequency on ith road stretch (accident km−1 per vehicle) *yi*. To determine the *hj* on specific road, it is done by surveyed manually and for the traffic characteristics *h5* is using secondary data from (Irsyad & Negara, 2017). The local enhancing/mitigating parameters on Raya Pelabuhan Benoa Road is shown on the table below. The *h1* on Raya Pelabuhan Benoa Road are straight road and there is a road bend with radius less than 200 m. The *h2* on Raya Pelabuhan Benoa Road is plane. The *h3* on Raya Pelabuhan Benoa Road is two lanes for each carriageway. The *h6* is none because there is no tunnel or bridge on that road. The meteorological conditions in Indonesia are fine weather and rain, and the traffic characteristics on that road is high intensity High intensity > 1250 vehicle per hour with heavy traffic > 250 truck per day.

Table 4.32 Local Enhancing Parameters on Raya Pelabuhan Benoa Road

Raya Pelabuhan Benoa Road			Value
Intrinsic Characteristics	*h1*	Straight road	1
		Road bend (radius>200 m)	-
		Road bend (radius<200 m)	-
	h2	Plane road	1
		Slope road (gradient<5%)	-
		Steep slope road (gradient>5%)	-
		Downhill road (gradient<5%)	-
		Steep downhill road (gradient<5%)	-
	h3	Two lanes for each carriageway	-
		Two lanes and emergency lane for each carriageway	-
		Three lanes and emergency lane for each carriageway	0,8
	h6	Tunnel	-
		Bridge	-
Meteorological Conditions	*h4*	Fine Weather	1
		Rain	1,5
		Snow/ice	-
Traffic Characteristics	*h5*	Low intensity < 500 vehicle/h	-
		Medium intensity < 1250 vehicle per hour with heavy traffic < 125 truck per day	-
		High intensity > 1250 vehicle per hour	-
		High intensity > 1250 vehicle per hour with heavy traffic > 250 truck per day	2,4
		Total	7,7

Table 4.33 Local Enhancing Parameters on Truck Route

Local Enhancing Parameters *(hj)*		
No	Description	*hj*
1	Raya Pelabuhan Benoa Road	7,7

(Continue to the next page)

(Continued from the previous page)

2	Mandara Toll Road	10,5
3	By Pass Ngurah Rai Road	10
4	Pratama Raya Road	8,6

From the table above, the highest local enhancing parameters is on Mandara Toll Road with *hj* value is 10.5, and the lowest local enhancing parameters is on Raya Pelabuhan Benoa Road with *hj* value is 7.7. The *hj* value on specific road is attached in attachment section. After the local enhancing parameters on truck route obtained as shown in the table above, the expected frequency *yi* can be determined. The expected frequency *yi* is shown on the table below.

Table 4.34 The Expected Frequency

No	Description	The Basic Frequency (accident km−1 per vehicle)	*hj*	The Expected Frequency *yi* (accident km−1 per vehicle)
1	Raya Pelabuhan Benoa Road	6,16,E-08	7,7	4,74,E-07
2	Mandara Toll Road	8,14,E-09	10,5	8,55,E-08
3	By Pass Ngurah Rai Road	2,48,E-07	10	2,48,E-06
4	Pratama Raya Road	7,00,E-08	8,6	6,02,E-07

After obtaining the expected frequency *yi*, the frequency of a Collision can be determined. The frequency of a Collision on 2 alternatives truck route can be seen in the table below.

Table 4.35 The Frequency of a Collision (Truck Route A)

No	Description	The Expected Frequency *yi* (accident km−1 per vehicle)	Road Length *Li* (km)	Vehicle Number *Ni*	The Frequency of a Collision
1	Raya Pelabuhan Benoa Road	4,74,E-07	0,98	1	4,65,E-07

(Continue to the next page)

(Continued from the previous page)

2	Mandara Toll Road	8,55,E-08	8,20	1	7,01,E-07
3	By Pass Ngurah Rai Road	2,48,E-06	0,45	1	1,12,E-06
4	Pratama Raya Road	6,02,E-07	1,20	1	7,23,E-07

The Truck Route A is using the Mandala Toll Road. From the table above, the highest frequency of a Collision is on By Pass Ngurah Rai Road B with value 1,12,E-06 accident per year. The road length *Li* in the table indicates how far the truck will pass through that road. The vehicle number *Ni* in the table indicates the Truck that will be carrying the ISO Tank.

Table 4.36 The Frequency of a Collision (Truck Route B)

No	Description	The Expected Frequency *yi* (accident km−1 per vehicle)	Road Length *Li* (km)	Vehicle Number *Ni*	The Frequency of a Collision
1	Raya Pelabuhan Benoa Road	4,74,E-07	2,88	1	1,37,E-06
2	By Pass Ngurah Rai Road	2,48,E-06	10,60	1	2,63,E-05
3	Pratama Raya Road	6,02,E-07	1,20	1	7,23,E-07

The Truck Route B is not using the Mandala Toll Road. From the table above, the highest frequency of a Collision is on By Pass Ngurah Rai Road B with value 2,63,E-05 accident per year.

4.9.4 Number of Fatalities

The number of fatalities *Ns* caused by a Collision that occurs can be determined according to the following equations on the ith road stretch:

$$Ns = k(\upsilon AL, 1) \tag{4.8}$$

Where:

Ns = the fatality number (fatalities)

v = the vehicle density on the road area (vehicle m−2)

k = the average vehicle occupation factor

$AL,1$ = the road lethal area (m²)

First must determine the fatality number *NS*, to determine the consequences for other road users. The average vehicle occupation factor (*k*) is referring to (U.S. Department of Transportation, 2020) which the value is 1.0. According to (Fabiano, Curro, Palazzi, & Pastorino, 2002), the vehicle density on the road area (vehicle m−2) can be obtained from average traffic per road area. Therefore the vehicle density can be seen on the table below.

Table 4.37 The Vehicle Density

Description	Average Traffic (vehicle/hour)	Length (m)	Width (m)	Road Area (m²)	The Vehicle Density on The Road Area (vehicle m−2)
Raya Pelabuhan Benoa Road	1338	3400	5	17000	0,078705882
Pratama Raya Road	941	3400	6,3	21420	0,043930906
By Pass Ngurah Rai Road	1774	23000	6,3	144900	0,012242395
Toll Bali Mandara Road	2167	12700	5	63500	0,03411811

The road lethal area indicates how far the truck will pass through crossroads or junctions because the portion of vehicles on junctions is higher. It is because a lot of vehicles stop and the road space is more less, which increases the chance of crashing into other vehicles. The length of the road is the length of the average junction on a specific road. The road lethal area AL,1 on Truck Route A and B are shown in the table below.

Table 4.38 The Road Lethal Area (Truck Route A)

No	Description	Length (m)	Width (m)	The Road Lethal Area *AL,1* (m²)
1	Raya Pelabuhan Benoa Road	136	5	680
2	Mandara Toll Road	52	6,3	327,6
3	By Pass Ngurah Rai Road	71	6,3	447,3
4	Pratama Raya Road	60	5	300

Table 4.39 The Road Lethal Area (Truck Route B)

No	Description	Length (m)	Width (m)	The Road Lethal Area *AL,1* (m²)
1	Raya Pelabuhan Benoa Road	196	5	980
2	By Pass Ngurah Rai Road	200	6,3	1260,0
3	Pratama Raya Road	60	5	300

After obtaining the road lethal area, the fatality number *NS* can be determined using Formula 4.9. The fatality number *Ns* on Truck Route A and B can be seen on the table below.

Table 4.40 The Fatality Number *Ns* (Truck Route A)

No	Description	On Route Density	The Road Lethal Area *AL,1* (m²)	The average vehicle occupation factor	The Fatality Number *Ns1*
1	Raya Pelabuhan Benoa Road	0,078706	320	1	25
2	Mandara Toll Road	0,034118	328	1	11
3	By Pass Ngurah Rai Road	0,012242	447	1	5
4	Pratama Raya Road	0,043931	300	1	13

Table 4.41 The Fatality Number *Ns* (Truck Route B)

No	Description	On Route Density	The Road Lethal Area *AL,1* (m^2)	The average vehicle occupation factor	The Fatality Number *Ns1*
1	Raya Pelabuhan Benoa Road	0,078706	980	1	77
2	By Pass Ngurah Rai Road	0,012242	1260	1	15
3	Pratama Raya Road	0,043931	300	1	13

4.9.5 f/N Curve (The Netherlands)

After the analysis of frequency and consequence analysis on a system, the steps taken are to conduct risk mapping. The risk mapping conducted in this bachelor thesis adopted from The Netherlands f-N Curve standard. The consequences resulting from the f-N Curve risk mapping are the consequences of human life (societal risk). The f-N curve itself is the result of the relationship between the frequency per year (f) and the number of fatalities (N) or known as a societal risk which is the impact of an event.

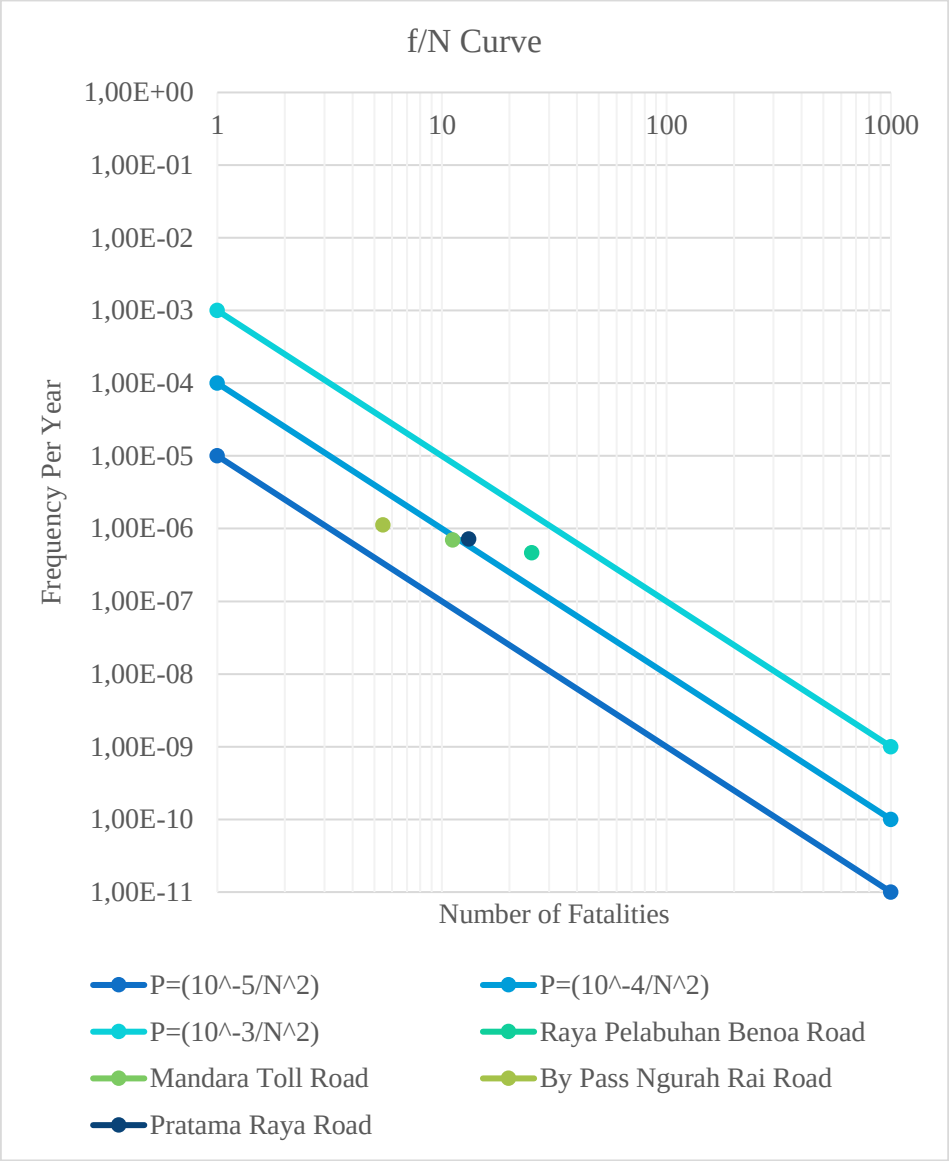


Figure 4.14 F/N Curve Road Transport (Truck Route A)

The figure above is the result of the risk mapping of the LNG road transport. The results of the frequency per year (f) are represented on the y-axis and the results of the number of fatalities (N) or known as a societal risk which is the impact of an event represented on the x-axis. In Figure 4.14, is the result of f/N Curve for the LNG road transport on Truck Route A.

In Table 4.42, is the recapitulation of the results of the risk mapping of LNG road transport. According to Figure 4.14, Mandara Toll Road and By Pass Ngurah Rai Road are on Tolerability Region A (T.R.A.). Raya Pelabuhan Benoa Road and Pratama Raya Road is on Tolerability Region B (T.R.B.), therefore there is no need to be mitigated.

Table 4.42 Risk Mapping Road Transport (Truck Route A)

Description	The Frequency of a Collision	Total Number of Fatalities	Risk Level			
			Acceptable	T.R.A.	T.R.B	Unacceptable
Raya Pelabuhan Benoa Road	4,65E-07	25			YES	
Mandara Toll Road	7,01E-07	11		YES		
By Pass Ngurah Rai Road	1,12E-06	5		YES		
Pratama Raya Road	7,23E-07	13			YES	

In the figure below, is the result of F/N Curve for the LNG road transport on Truck Route B.

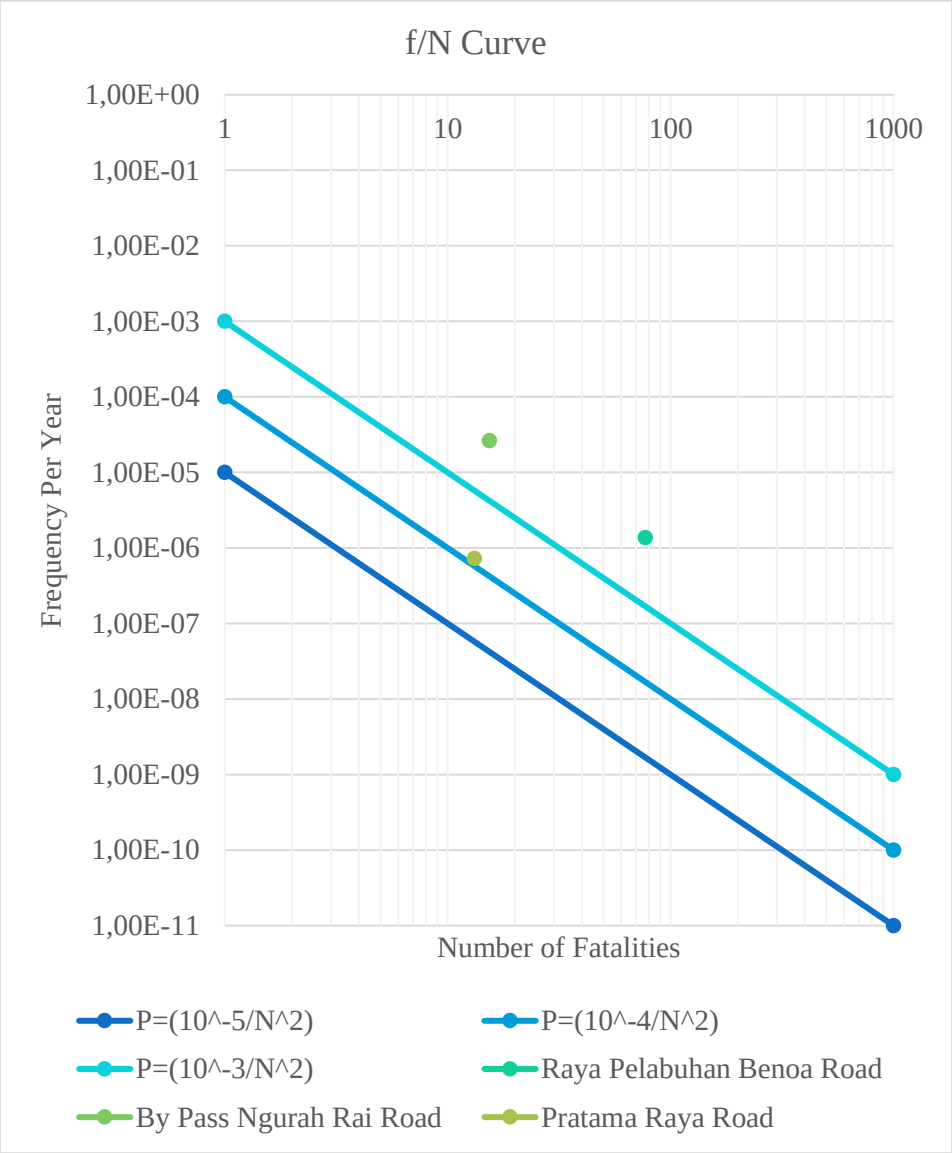


Figure 4.15 F/N Curve Road Transport (Truck Route B)

In

Table 4.43, is the recapitulation of the results of the risk mapping of LNG road transport. According to Figure 4.15, Raya Pelabuhan Benoa and By Pass Ngurah Rai Road are on unacceptable area. Pratama Raya Road is on Tolerability Region B (T.R.B). Therefore the route B need to be mitigated.

Table 4.43 Risk Mapping Road Transport (Truck Route B)

Description	The Frequency of a Collision	Total Number of Fatalities	Risk Level			
			Acceptable	T.R.A	T.R.B	Unacceptable
Raya Pelabuhan Benoa Road	1,37E-06	77				YES
By Pass Ngurah Rai Road	2,63E-05	15				YES
Pratama Raya Road	7,23E-07	13			YES	

After determining the risk mapping on truck route A and truck route B, the next step is selecting the truck route based on risk mapping and previous sub-chapter. There are several reasons to select the route A as the truck route, which are:

a. The frequency of a Collision on route A less than the frequency of a Collision on route B. It is because on frequency calculation, the longer the truck pass through the road, the frequency of a Collision on that road also increases.

b. Then, the consequences value from road accident on route A much smaller than route B because there are fewer intersections or junctions on route A than on route B.

c. On risk mapping by the Netherlands also still accepts route A where the roads on route A are in Tolerability region A and B. While route B, there are two roads in unacceptable areas and only one road in Tolerability region B.

4.10 Road Transport Risk Assessment (After 15 Years)

4.10.1 The Frequency of Collision

The assumption of this project is for 15 years contract, which the risk assessment of road transport in 2035 is needed to predict if the road still in feasible area or not. The growth of vehicles and growth of accident in Bali is needed using data. The growth of the vehicle in Bali is using data from 2014 until 2019, which the average growth of vehicle in Bali is 5.9%. The growth of the vehicle per year can be seen in the table below (Badan Pendapatan Provinsi Bali (Government Income Department of Bali Province), 2020). The number of vehicles from 2014 until 2019 is always increasing. The highest number of vehicles is in 2019, with a value 4352596 vehicles. The lowest number of vehicles is in 2014, with a value 3268112.

Table 4.44 Number of Vehicles in Bali (2014-2019)

Number of Vehicles in Bali (2014-2019)						
	2019	**2018**	**2017**	**2016**	**2015**	**2014**
Total	4352596	4117949	3907094	3725392	3505984	3268112

The growth of traffic accidents in Bali is using data from 2014 until 2019, which the average growth of traffic accidents in Bali is 8.6%. The growth of the traffic accidents per year can be seen in the table below (Kepolisian Daerah Bali (State Police of Bali Province), 2020).

Table 4.45 Number of Traffic Accidents in Bali (2014-2019)

Number of Traffic Accidents in Bali (2014-2019)						
	2019	**2018**	**2017**	**2016**	**2015**	**2014**
Total	2462	1824	1827	1580	1441	1737

After determining the growth of vehicles and traffic accidents in Bali, the number of vehciles and traffic accidents on specific road that has been determined before can be seen in the table below.

Table 4.46 Number of Vehicles in 2035

Description	Number of Vehicles/Year	Vehicle Increase Percentage/Year	Number of Vehicles in 2035
Raya Pelabuhan Benoa Road	11945664	5,9%	29899437
Mandara Toll Road	19342512	5,9%	48413401
By Pass Ngurah Rai Road	15837585	5,9%	39640734
Pratama Raya Road	8401248	5,9%	21027930

Table 4.47 Number of Accidents in 2035

Description	Number of Accident in 2019	Accident Increase Percentage/Year	Accident in 2035
Raya Pelabuhan Benoa Road	1	8,6%	4
Mandara Toll Road	1	8,6%	4
By Pass Ngurah Rai Road	75	8,6%	281
Pratama Raya Road	3	8,6%	11

After obtaining the number of vehicles and the number of accidents, the basic frequency can be determined. The basic frequency can be seen in the table below.

Table 4.48 The Basic Frequency *y0*

No	Description	Number of Accidents	Total Vehicle	Road Length (km)	Basic Frequency (accident km−1 per vehicle)
1	Raya Pelabuhan Benoa Road	4	33532783	3,4	3,29,E-08
2	Mandara Toll Road	4	54296544	12,7	5,44,E-09
3	By Pass Ngurah Rai Road	281	44457831	23	2,75,E-07
4	Pratama Raya Road	11	23583221	3,4	1,40,E-07

The basic frequency on each specific road can be seen in the table above. Then, the expected frequency can be determined. The local enhancing parameters can be seen in the Table 4.33. The expected frequency on route A in 2035 can be seen in the table below.

Table 4.49 The Expected Frequency *yi*

No	Description	The Basic Frequency (accident km−1 per vehicle)	*hj*	The Expected Frequency *yi* (accident km−1 per vehicle)
1	Raya Pelabuhan Benoa Road	3,29,E-08	7,7	2,53,E-07
2	Mandara Toll Road	5,44,E-09	10,5	5,71,E-08
3	By Pass Ngurah Rai Road	2,75,E-07	10	2,75,E-06
4	Pratama Raya Road	1,40,E-07	8,6	1,21,E-06

After determining the expected frequency *yi* on specific road, the frequency of collision can be determined. The road length *Li* in the table indicates how far the truck will pass through that road. The vehicle number *Ni* in the table indicates the Truck that will be carrying the ISO Tank. The frequency of collision can be seen in the table below.

Table 4.50 The Frequency of Collision

No	Description	The Expected Frequency *yi* (accident km−1 per vehicle)	Road Length *Li* (km)	Vehicle Number *Ni*	The Frequency of an Accident
1	Raya Pelabuhan Benoa Road	2,53,E-07	0,98	1	2,48,E-07
2	Mandara Toll Road	5,71,E-08	8,20	1	4,68,E-07
3	By Pass Ngurah Rai Road	2,75,E-06	0,45	1	1,24,E-06
4	Pratama Raya Road	1,21,E-06	1,20	1	1,45,E-06

4.10.2 Number of Fatalities

The number of fatalities on each road is using previous formulation. The growth of the vehicle density can be seen in the table below. The growth percentage is using data growth of vehicles from previous sub-chapter which the growth is 5.9% per year.

Table 4.51 The Vehicle Density in 2035

Description	Average Traffic (vehicle/hour)	Growth Percentage	Average Traffic (vehicle/hour)	The Vehicle Density On The Road Area (vehicle m−2)
Raya Pelabuhan Benoa Road	1338	5,9%	3348	0,196943909
Pratama Raya Road	941	5,9%	2355	0,109927289
By Pass Ngurah Rai Road	1774	5,9%	4439	0,030633863
Toll Bali Mandara Road	2167	5,9%	5421	0,085372958

The road lethal area indicates how far the truck will pass through crossroads or junctions because the portion of vehicles on junctions is higher. It is because a lot of vehicles stop and the road space is more less, which increases the chance of crashing into other vehicles. The length of the road is the length of the average junction on a specific road. The road lethal area is using previous sub-chapter. Therefore, the fatalities number can be obtained.

Table 4.52 The Fatality Number *Ns*

No	Description	On Route Density	The Road Lethal Area *AL,1* (m²)	The average vehicle occupation factor	The Fatality Number *Ns*
1	Raya Pelabuhan Benoa Road	0,196944	320	1	63
2	Mandara Toll Road	0,085373	328	1	28
3	By Pass Ngurah Rai Road	0,030634	447	1	14
4	Pratama Raya Road	0,109927	300	1	33

4.10.3 f/N Curve (The Netherlands)

After the analysis of frequency and consequence analysis on a system, the steps taken are to conduct risk mapping. The risk mapping conducted in this bachelor thesis adopted from The Netherlands f-N Curve standard. The consequences resulting from the f-N Curve risk mapping are the consequences of human life (societal risk). The f-N curve itself is the result of the relationship between the frequency per year (f) and the number of fatalities (N) or known as a societal risk which is the impact of an event.

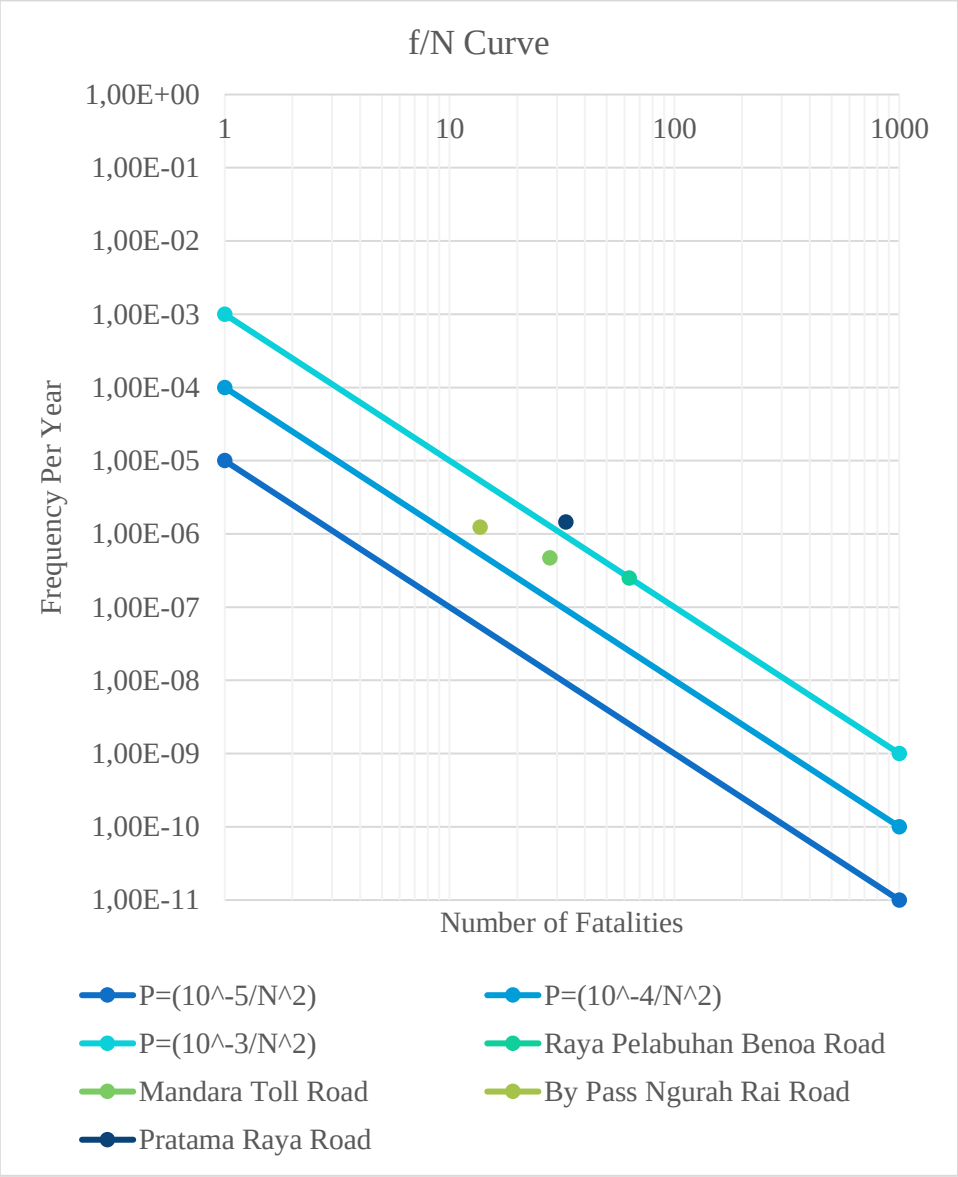


Figure 4.16 f/N Curve Truck Route in 2035

The figure above is the result of the risk mapping of the LNG road transport. The results of the frequency per year (f) are represented on the y-axis and the results of the number of fatalities (N) or known as a societal risk which is the impact of an event represented on the x-axis. In the figure above, is the result of f/N Curve for the LNG road transport on Truck Route A in 2035. In table below, is the recapitulation of the results of the risk mapping of LNG road transport.

Table 4.53 Risk Mapping Road Transport

Description	The Frequency of a Collision	Total Number of Fatalities	Risk Level			
			Acceptable	T.R.A	T.R.B	Unacceptable
Raya Pelabuhan Benoa Road	2,48E-07	63			YES	
Mandara Toll Road	4,68E-07	28			YES	
By Pass Ngurah Rai Road	1,24E-06	14			YES	
Pratama Raya Road	1,45E-06	33				YES

According to the figure above, Pratama Raya is on Unacceptable area. Mandara Toll Road, Raya Pelabuhan Benoa Road, and By Pass Ngurah Rai still in Tolerability Region B (T.R.B). This truck route still feasible for 15 years project because all route still in tolerability region B and only one road (Pratama Raya Road) is on unacceptable area. Therefore Pratama Raya Road in the future need to be mitigated in the future to decreasing the frequency of collision.

4.11 LNG Facility Risk Assessment

4.11.1 LNG Filling Station P&ID

LNG Filling Station is a facility to fill the empty ISO Tank that carried by Truck with full tank of Liquified Natural Gas. This facility located in Benoa Port. P&ID is a diagram of the pipe structure and the device instrumentation in the working system. In this Bachelor Thesis, P&ID of LNG Filling Station is used to evaluate the possible dangers that may exist. The figure below shows the P&ID of the LNG Filling Station P&ID.

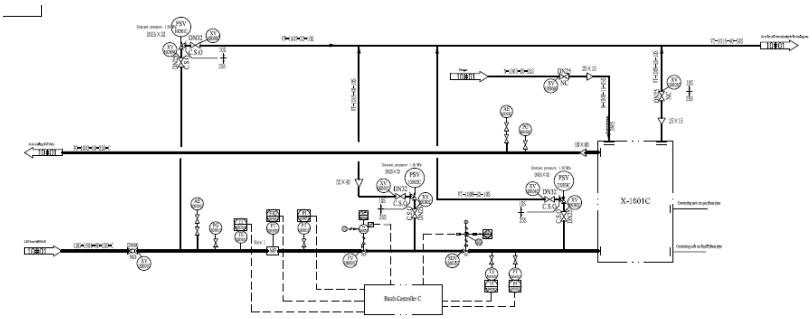


Figure 4.17 LNG Filling Station P&ID

4.11.2 The Layout of Small-Scale Gas Station

Small-scale gas station (SSGS) is a facility to store LNG, LNG regasification, and distributing the natural gas directly to each facilities that need gas in ITDC Nusa Dua, Bali using natural gas pipeline. In sub-chapter 4.8.1, the equipment that needed to process the Liquified Natural Gas is determined. Therefore, the layout of Small-Scale Gas Station is referring to equipments in sub-chapter 4.8.1. The sitting of each equipment and system in Small-Scale Gas Station (SSGS) must follow the NFPA 59A regulations.

NFPA 59A is a standard that provides minimum fire protection, safety, and related requirements for the location, design, construction, security, operation, and maintenance of liquefied natural gas (LNG) plants (National Fire Protection Association, 2019). According to (National Fire Protection Association, 2019), there is one section that must be noted, which is Plant Siting and Layout. In this section is used for design purposes, location, construction, operation, and maintenance at each location of natural gas liquefaction, storage, transfer, evaporation, and distribution. This standard is used for all LNG storage tank containers including insulation system applications. NFPA 59A provides requirements in the form of a minimum distance for each equipment which can be seen in the table below.

Table 4.54 Plant and Sitting Layout

Plant and Sitting Layout		
Description	Minimum Distance	Unit
Storage Tank		
Distance between storage tank	2,15	*m*

(Continue to the next page)

(Continued from previous page)

Distance between storage tank and property	30	*m*
Clear space for access to all isolation valves serving multiple containers	0,9	*m*
Vaporizer		
Distance between vaporizer and property	30	*m*
Distance between vaporizer and storage tank, process equipment, loading/unloading connection	15	*m*
Clearance between vaporizer	1,5	*m*
Process Equipment		
Distance between process equipment and property, storage tank and other ignition sources	15	*m*

The area of the SSGS is 4978.1 m². The layout of the Small-Scale Gas Station that already applying the standard of NFPA 59A, can be seen on the figure below.

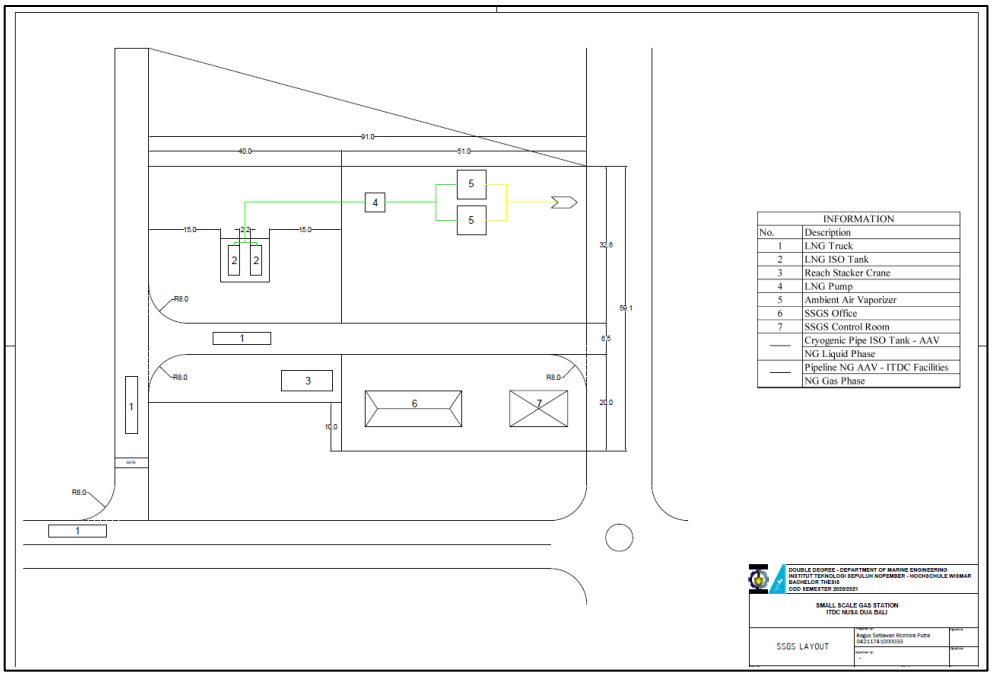


Figure 4.18 The Layout of SSGS

4.11.3 Small-Scale Gas Station P&ID

In this bachelor thesis, the P&ID using secondary data or similar data of SSGS, that can be seen on the figure below.

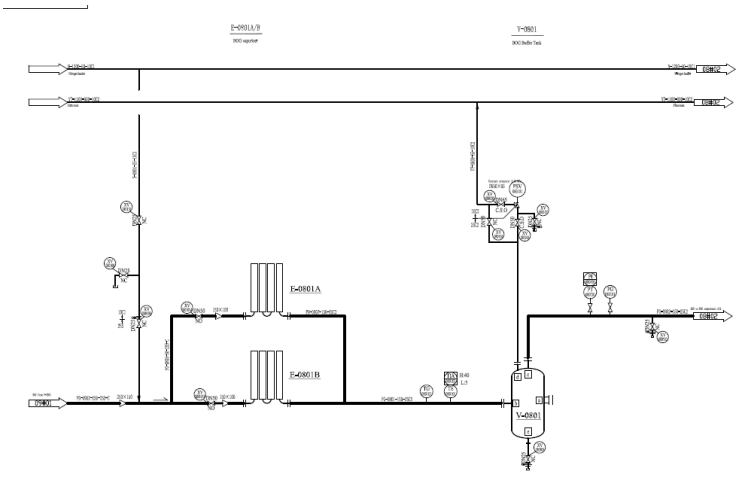


Figure 4.19 SSGS P&ID LNG ISO Tank to AAV

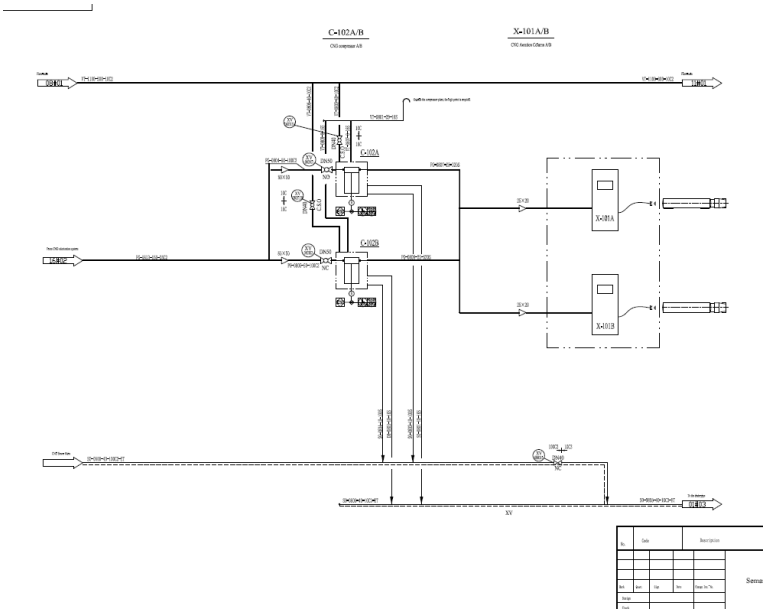


Figure 4.20 SSGS P&ID AAV to CNG Compressor

4.11.4 Environmental Data

The location of the LNG Filling Station is in LNG Terminal Benoa at Benoa Port, Bali and the location of the Small-Scale Gas Station is on Pratama Raya Road, on the right side of the ITDC Lagoon. The environmental data is needed to support this bachelor thesis. The environmental data of LNG Filling Station and Small-Scale Gas Station are shown in the table below (Badan Pusat Statistik Provinsi Bali, 2019).

Table 4.55 Environmental Data

Environmental Data		
Badung, Bali		
Description	Value	Unit
Min. Temperature	20	°C
Max. Temperature	34	°C
Min. Humidity	70	%
Max. Humidity	86	%
Min. Wind Velocity	4	knots
Avg. Wind Velocity	6	knots
Max. Wind Velocity	10	knots

4.11.5 Crew Data

The number of crew on each facility in LNG Filling station and Small-Scale Gas Station can be seen on the table below.

Table 4.56 Number of Crew

Number of Crew		
Place	Position	Total
LNG Filling Station	Operator Filling Station	2
	Maintenance and Inspection	2
	Office	1
	Security Guard	2
	ISO Tank Truck Driver	2
Small-Scale Gas Station	Head of SSGS	1
	Head of HRD	1
	Chief Engineering	1

(Continue to the next page)

(Continued from previous page)

Small-Scale Gas Station	Second Engineering	1
	Staff of Engineer	4
	Maintenance and Inspection	2
	Office Support	2
	Office Boy	2
	Security Guard	4

4.11.6 Hazard Identification (HAZOP)

In this bachelor thesis, hazard identification for LNG Filling Station and Small-Scale Gas Station are using Hazard and Operability Study or can be called HAZOP. This method is to identifying hazards in system that might give negative impact to operability and safety. HAZOP can be used for identifying hazard in continuous systems (Kontovas, 2005). The HAZOP sheet standard used referring to BS IEC 61882:2001 standards. First step to do the HAZOP is selecting the node. Node is a step to divides system into “nodes”. The following is the distribution of nodes in the system to be analyzed.

1. Node 1: LNG Filling Station System Part 1
   In Node 1 explain the LNG loading system from LNG Storage Tank to Flow Control Valve. The function of this loading system is to load or fill the empty LNG ISO Tank with Liquified Natural Gas from LNG Storage Tank to LNG ISO Tank. In transfering the LNG, there are several components, which are gate valve, check valve, ball valve, flange and globe valve. There are also several safeguards, which are temperature indicator, temperature element, flow transmitter, flow indicator, pressure indicator, pressure transmitter, and flow controller.
2. Node 2: LNG Filling Station System Part 2
   In Node 2 explain the LNG loading system from Flow Control Valve to LNG ISO Tank. The function of this loading system is to load or fill the empty LNG ISO Tank with Liquified Natural Gas from LNG Storage Tank to LNG ISO Tank. In transfering the LNG, there are several components, which are shutdown valve, pressure safety valve, and loading arm. There are also several safeguards, which are temperature indicator, temperature element, pressure indicator, and pressure transmitter.
3. Node 3: LNG ISO Tank to Ambient Air Vaporizer
   In Node 3 explain the LNG feed system from LNG ISO Tank to Ambient Air Vaporizer. The function of this feed system is to transfering the Liquified Natural Gas to be processed back to gas phase in Ambient Air Vaporizer. In

transfering the LNG, there are several components, which are gate valve, ball valve, LNG pump and ambient air vaporizer.

4. Node 4: Ambient Air Vaporizer to CNG Compressor
   In Node 4 explain the natural gas transfer after it processed in AAV, to be transfered to CNG Compressor. The function of this system is to transfering the Natural Gas to be distributed to ITDC Facilities. In transfering the natural gas, there are several components, which are ball valve, and CNG compressor. There are also several safeguards, which are temperature gauge, temperature element, temperature indicator, pressure indicator, pressure transmitter, and pressure gauge.

In the figure below are showing the node 1, node 2, node 3 and node 4 on P&ID of LNG Filling Station and Small-Scale Gas Station that has been selected.

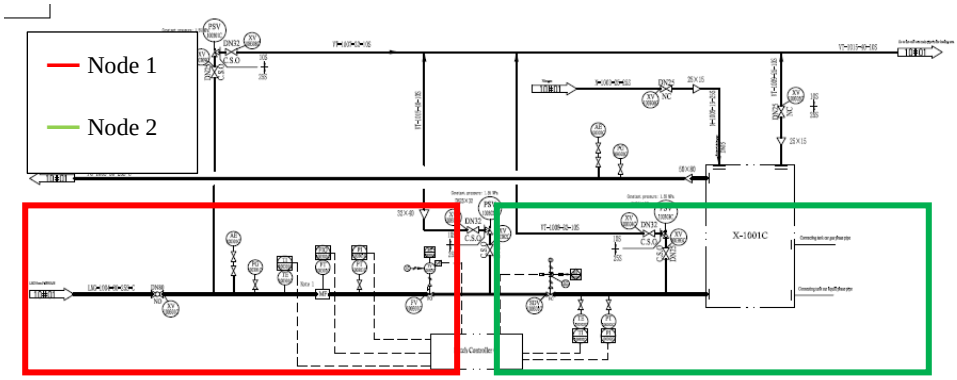


Figure 4.21 Node 1 & Node 2 of LNG Filling Station P&ID

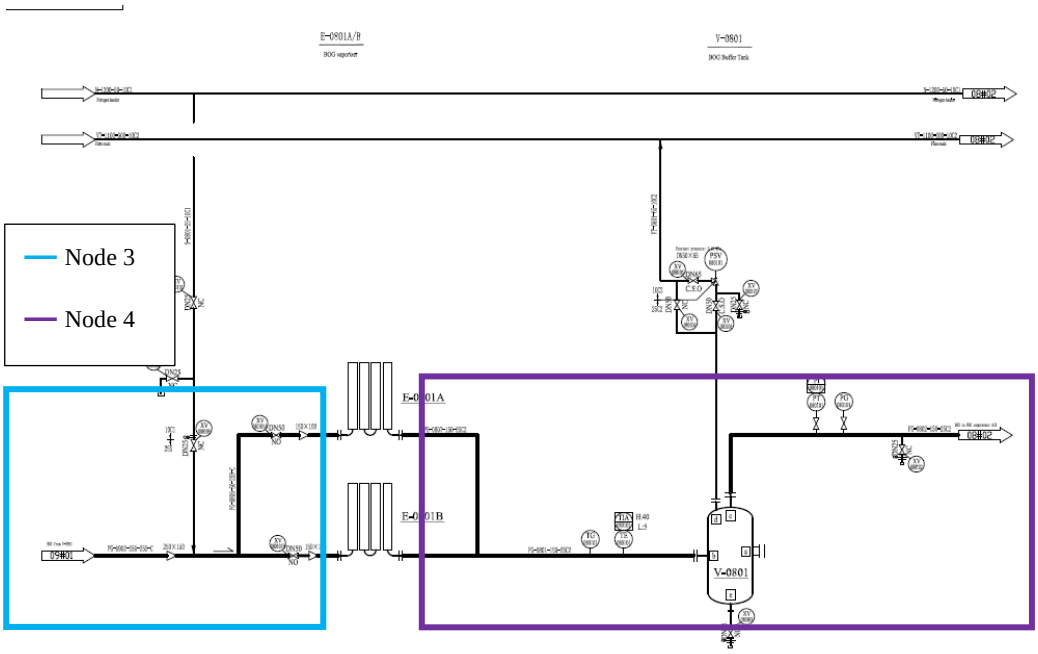


Figure 4.22 Node 3 & Node 4 of SSGS P&ID

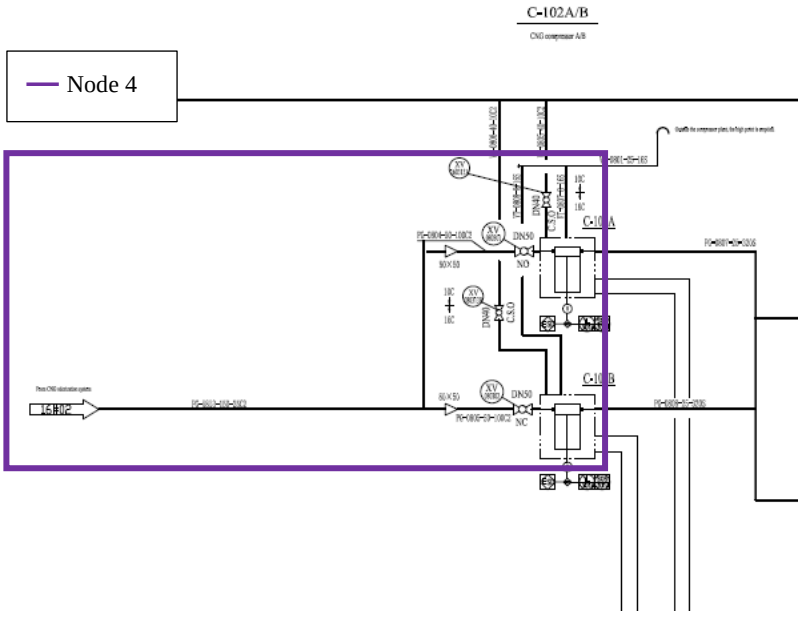


Figure 4.23 Node 4 of SSGS P&ID

4.11.7 Guide Word

Guide word is the keyword used to express the cause of a deviation. In HAZOP BS IEC 61882: 2001 the guide words used are no, more, less, as well as, part of, reverse, other than. The description on each guide word can be seen on the table below.

Table 4.57 Guide Word Description

No.	Guide Word	Description
1	NO OR NOT	Full negation of a system on design
2	MORE	Quantitative improvement
3	LESS	Quantitative derivation
4	AS WELL AS	Modified Quantitative increments
5	PART OF	Modified Quantitative derivation
6	REVERSE	The opposite logic of the system in design
7	OTHER THAN	Full replacement

(Source: HAZOP BS IEC 61882:2001)

4.11.8 Deviation

Deviation is a parameter used to check any aspect of an existing node. Deviation from P&ID applies to the words of the current guide. The element that can be used in the HAZOP are flow, temperature, pressure, and level. The implementation of each variation refers to HAZOP BS IEC 61882:2001 in Appendix E. Deviation distribution can be seen in the table below.

Table 4.58 HAZOP Deviation

No.	Deviation Type	Guide Word
1	Negative	NO
2	Quantitative Modification	MORE, LESS
3	Qualitative Modification	AS WELL AS, PART OF
4	Substitution	REVERSE, OTHER THAN
5	Time	EARLY, LATE
6	Order or sequence	BEFORE, AFTER

(Source: HAZOP BS IEC 61882:2001)

4.11.9 HAZOP Worksheet

In HAZOP worksheet, it is showing the potential of hazard event that might happen in the system with combining the guide word and the process parameters. There are several sections that need to be noted in HAZOP worksheet, which are:

a. Possible Cause

   Possible cause in HAZOP worksheet is a potential failure event of a component in the system that might lead to a hazard event.

b. Consequences

   Consequences in HAZOP worksheet is a negative impact to the system, environment, or human if the hazard event occurred.

c. Safeguard

   Safeguard in HAZOP worksheet is an equipment or component that give information that a system is functioning properly.

d. Comment

   Comment in HAZOP worksheet is a response that asks whether the incident with consequences is acceptable or unacceptable.

e. Action Required

   Action required in HAZOP worksheet is a recommendation given so that systems that experience potential failure will not occur.

The HAZOP worksheet for the Node 1: LNG Storage Tank to LNG ISO Tank and Node 2: LNG ISO Tank to CNG Compressor can be seen on the table in next page.

Table 4.59 HAZOP Node 1

Study Title		Node 1: LNG Filling Station System Part 1					
Drawing No.							
Team Composition							
Part Considered		System Flow from Storage Tank to Flow Control Valve					
Design Internet		Cargo: Liquified Natural Gas (LNG)			Destination : Flow Control Valve		Sheet of
		Source: LNG Storage Tank			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
1	No	No Flow	The ball valves closed (XV100301C/D)	There is no flow LNG Transfer from Storage Tank to ISO Tank	Flow Indicator and Transmitter (FIO100301C/D & FT100301C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The LNG Pump blocked (P-0901A/B)	There is no flow LNG Transfer from Storage Tank to ISO Tank	Flow Indicator and Transmitter (FIO100301C/D & FT100301C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The pipeline cracked (LNG-1004/5-80-25S-C)	The LNG released or exposured from the system that might lead to fire and explosion	Flow Indicator and Transmitter (FIO100301C/D & FT100301C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 1: LNG Filling Station System Part 1					
Drawing No.							
Team Composition							
Part Considered		System Flow from Storage Tank to Flow Control Valve					
Design Internet		Cargo: Liquified Natural Gas (LNG)			Destination : Flow Control Valve		Sheet of
		Source: LNG Storage Tank			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
	No	No Flow	The control valves closed (FV100301D/C)	There is no flow LNG Transfer from Storage Tank to ISO Tank	Flow Indicator and Transmitter (FIO100301C/D & FT100301C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
		No Pressure	System Leakage	The LNG released or exposured from the system that might lead to fire and explosion	Pressure Indicator and Transmitter (PI100301C/D & PT100301-C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
2	Less Flow	Less Flow	The ball valves leaked (XV100301C/D)	The LNG released or exposured from the system that might lead to fire and explosion	Flow Indicator and Transmitter (FIO100301C/D & FT100301C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 1: LNG Filling Station System Part 1					
Drawing No.							
Team Composition							
Part Considered		System Flow from Storage Tank to Flow Control Valve					
Design Internet		Cargo: Liquified Natural Gas (LNG)			Destination : Flow Control Valve		Sheet of
		Source: LNG Storage Tank			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
	Less Flow	Less Flow	The control valves leaked (FV100301D/C)	The LNG released or exposured from the system that might lead to fire and explosion	Flow Indicator and Transmitter (FIO100301C/D & FT100301C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
3	More	More Temperature	External Heat	The BOG value increased	Temperature Element and Indicator (TE100301-C/D & TI100301-C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
		More Pressure	All valves blocked	The flow will be over pressured that might lead to fire and explosion	Pressure Indicator and Transmitter (PI100301C/D & PT100301-C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 1: LNG Filling Station System Part 1					
Drawing No.							
Team Composition							
Part Considered		System Flow from Storage Tank to Flow Control Valve					
Design Internet		Cargo: Liquified Natural Gas (LNG)			Destination : Flow Control Valve		Sheet of
		Source: LNG Storage Tank			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
4	As well as	As well as corrosion	Environmental condition and age of the pipeline	The pipeline can ruptured that might lead to fire and explosion	None	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
5	Other than	Other than destination	Cracked valves	The LNG released or exposured from the system that might lead to fire and explosion	None	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

Table 4.60 HAZOP Node 2

Study Title		Node 2: LNG Filling Station System Part 2					
Drawing No.							
Team Composition							
Part Considered		System Flow from Flow Control Valve to LNG ISO Tank					
Design Internet		Cargo: Liquified Natural Gas (LNG)			Destination: LNG ISO Tank		Sheet of
		Source: Flow Control Valve			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
1	No	No Flow	The shutdown valve closed (100301C/D)	There is no flow LNG Transfer from Storage Tank to ISO Tank	Install Flowmeter	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The loading arm ball valves closed (X-1001C/D)	There is no flow LNG Transfer from Storage Tank to ISO Tank	Install Flowmeter	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The pipeline leaked (LNG-1004/5-80-25S-C)	The LNG released or exposured from the system that might lead to fire and explosion	Install Flowmeter	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 2: LNG Filling Station System Part 2					
Drawing No.							
Team Composition							
Part Considered		System Flow from Flow Control Valve to LNG ISO Tank					
Design Internet		Cargo: Liquified Natural Gas (LNG)			Destination: LNG ISO Tank		Sheet of
		Source: Flow Control Valve			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
	No	No Pressure	System Leakage	The LNG released or exposured from the system that might lead to fire and explosion	Pressure Indicator and Transmitter (PI100302C/D & PT100302-C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
2	Less	Less Flow	The shutdown valve opened (100301C/D)	The LNG released or exposured from the system that might lead to fire and explosion	Install Flowmeter	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The loading arm leaked (X-1001C/D)	The LNG released or exposured from the system that might lead to fire and explosion	Install Flowmeter	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 2: LNG Filling Station System Part 2					
Drawing No.							
Team Composition							
Part Considered		System Flow from Flow Control Valve to LNG ISO Tank					
Design Internet		Cargo: Liquified Natural Gas (LNG)			Destination: LNG ISO Tank		Sheet of
		Source: Flow Control Valve			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
	Less	Less Pressure	The shutdown valve opened (100301C/D)	The LNG released or exposured from the system that might lead to fire and explosion	Pressure Indicator and Transmitter (PI100302C/D & PT100302-C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The loading arm leaked (X-1001C/D)	The LNG released or exposured from the system that might lead to fire and explosion	Pressure Indicator and Transmitter (PI100302C/D & PT100302-C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The pipeline leaked (LNG-1004/5-80-25S-C)	The LNG released or exposured from the system that might lead to fire and explosion	Pressure Indicator and Transmitter (PI100302C/D & PT100302-C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 2: LNG Filling Station System Part 2					
Drawing No.							
Team Composition							
Part Considered		System Flow from Flow Control Valve to LNG ISO Tank					
Design Internet		Cargo: Liquified Natural Gas (LNG)			Destination: LNG ISO Tank		Sheet of
		Source: Flow Control Valve			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
3	More	More Pressure	Valves are blocked	The flow will be overpressured that might lead to fire and explosion	Pressure Indicator and Transmitter (PI100302C/D & PT100302-C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The loading arm blocked (X-1001C/D)	The flow will be overpressured that might lead to fire and explosion	Pressure Indicator and Transmitter (PI100302C/D & PT100302-C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
		More Temperature	External Heat	The BOG value increased	Temperature Element and Indicator (TE100302-C/D & TI100302-C/D)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 2: LNG Filling Station System Part 2					
Drawing No.							
Team Composition							
Part Considered		System Flow from Flow Control Valve to LNG ISO Tank					
Design Internet		Cargo: Liquified Natural Gas (LNG)			Destination: LNG ISO Tank		Sheet of
		Source: Flow Control Valve			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
4	As well as	As well as corrosion	Environmental condition and age of the pipeline	The pipeline can ruptured that might lead to fire and explosion	None	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
5	Other than	Other than destination	Cracked valves	The LNG released or exposured from the system that might lead to fire and explosion	None	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

Table 4.61 HAZOP Node 3

Study Title		Node 3: LNG ISO Tank to Ambient Air Vaporizer					
Drawing No.							
Team Composition							
Part Considered		System Flow from ISO Tank to AAV					
Design Internet		Cargo: Liquified Natural Gas			Destination: AAV		Sheet of
		Source: LNG ISO Tank			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
1	No	No Flow	The gate valves closed (XV080101A/B)	There is no flow LNG Transfer from ISO Tank to AAV	Install Flowmeter	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The LNG Pump leaked	There is no flow LNG Transfer from ISO Tank to AAV	Install Flowmeter	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 3: LNG ISO Tank to Ambient Air Vaporizer					
Drawing No.							
Team Composition							
Part Considered		System Flow from ISO Tank to AAV					
Design Internet		Cargo: Liquified Natural Gas			Destination: AAV		Sheet of
		Source: LNG ISO Tank			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
	No	No Flow	The LNG flexible hose leaked	The LNG released or exposured from the system that might lead to fire and explosion	Install Flowmeter	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The pipeline leaked (PG-0902-250-25S-C)	The LNG released or exposured from the system that might lead to fire and explosion	Install Flowmeter	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The pipeline leaked (PG-0806-150-25S-C)	The LNG released or exposured from the system that might lead to fire and explosion	Install Flowmeter	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 3: LNG ISO Tank to Ambient Air Vaporizer					
Drawing No.							
Team Composition							
Part Considered							
Design Internet		Cargo: Liquified Natural Gas			Destination: AAV		Sheet of
		Source: LNG ISO Tank			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
	No	No Pressure	System leakage	The LNG released or exposured from the system that might lead to fire and explosion	Install Pressure Indicator	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
2	Less	Less Flow	The gate valves leaked (XV080101A/B)	The LNG released or exposured from the system that might lead to fire and explosion	Install Flowmeter	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 3: LNG ISO Tank to Ambient Air Vaporizer					
Drawing No.							
Team Composition							
Part Considered		System Flow from ISO Tank to AAV					
Design Internet		Cargo: Liquified Natural Gas			Destination: AAV		Sheet of
		Source: LNG ISO Tank			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
	Less	Less Flow	The pipeline leaked (PG-0903-250-25S-C)	The LNG released or exposured from the system that might lead to fire and explosion	Install Flowmeter	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
		Less Flow	The pipeline leaked (PG-0806-150-25S-C)	The LNG released or exposured from the system that might lead to fire and explosion	Install Flowmeter	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
3	More	More Temperature	External Heat	The BOG value increased	Install Temperature Indicator	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 3: LNG ISO Tank to Ambient Air Vaporizer					
Drawing No.							
Team Composition							
Part Considered		System Flow from ISO Tank to AAV					
Design Internet		Cargo: Liquified Natural Gas			Destination: AAV		Sheet of
		Source: LNG ISO Tank			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
	More	More Pressure	The LNG Pump defunctional	The flow will be overpressured that might lead to fire and explosion	Install Pressure Indicator	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The gate valves blocked (XV080101A/B)	The flow will be overpressured that might lead to fire and explosion	Install Pressure Indicator	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
4	As well as	As well as corrosion	Environmental condition and age of the pipeline	The pipeline can ruptured that might lead to fire and explosion	None	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 3: LNG ISO Tank to Ambient Air Vaporizer					
Drawing No.							
Team Composition							
Part Considered		System Flow from ISO Tank to AAV					
Design Internet		Cargo: Liquified Natural Gas			Destination: AAV		Sheet of
		Source: LNG ISO Tank			Temperature: -164°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
5	Other than	Other than destination	Cracked valves	The LNG released or exposured from the system that might lead to fire and explosion	None	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

Table 4.62 HAZOP Node 4

Study Title		Node 4: Ambient Air Vaporizer to CNG Compressor					
Drawing No.							
Team Composition							
Part Considered		System Flow from AAV to CNG Compressor					
Design Internet		Cargo: Natural Gas			Destination Tank: CNG Compressor		Sheet of
		Source: AAV			Temperature: 25°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
1	No	No Flow	The ball valves closed (XV080301/2)	There is no flow NG Transfer from AAV to CNG Compressor	Flow Indicator and Transmitter (FIO100301A & FT100301A)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The pipeline leaked (PG-0803-150-25S-C2)	The NG released or exposured from the system that might lead to fire and explosion	Flow Indicator and Transmitter (FIO100301A & FT100301A)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The pipeline leaked (PG-0804/5-50-100C2)	The NG released or exposured from the system that might lead to fire and explosion	Flow Indicator and Transmitter (FIO100301A & FT100301A)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 4: Ambient Air Vaporizer to CNG Compressor					
Drawing No.							
Team Composition							
Part Considered		System Flow from AAV to CNG Compressor					
Design Internet		Cargo: Natural Gas			Destination Tank: CNG Compressor		Sheet of
		Source: AAV			Temperature: 25°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
		No Pressure	System leakage	The NG released or exposured from the system that might lead to fire and explosion	Pressure Gauge, Pressure Transmitter, and Pressure Indicator (PG/PT/PI-080101)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
2	Less	Less Flow	The ball valves leaked (XV080301/2)	The NG released or exposured from the system that might lead to fire and explosion	Flow Indicator and Transmitter (FIO100301A & FT100301A)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The pipeline leaked (PG-0803-150-25S-C2)	The NG released or exposured from the system that might lead to fire and explosion	Flow Indicator and Transmitter (FIO100301A & FT100301A)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 4: Ambient Air Vaporizer to CNG Compressor					
Drawing No.							
Team Composition							
Part Considered		System Flow from AAV to CNG Compressor					
Design Internet		Cargo: Natural Gas			Destination Tank: CNG Compressor		Sheet of
		Source: AAV			Temperature: 25°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
	Less	Less Flow	The pipeline leaked (PG-0804/5-50-100C2)	The NG released or exposured from the system that might lead to fire and explosion	Flow Indicator and Transmitter (FIO100301A & FT100301A)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
		Less Pressure	The ball valves leaked (XV080301/2)	The NG released or exposured from the system that might lead to fire and explosion	Pressure Gauge, Pressure Transmitter, and Pressure Indicator (PG/PT/PI-080101)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
			The pipeline leaked (PG-0803-150-25S-C2)	The NG released or exposured from the system that might lead to fire and explosion	Pressure Gauge, Pressure Transmitter, and Pressure Indicator (PG/PT/PI-080101)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 4: Ambient Air Vaporizer to CNG Compressor					
Drawing No.							
Team Composition							
Part Considered		System Flow from AAV to CNG Compressor					
Design Internet		Cargo: Natural Gas			Destination Tank: CNG Compressor		Sheet of
		Source: AAV			Temperature: 25°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
	Less	Less Pressure	The pipeline leaked (PG-0804/5-50-100C2)	The NG released or exposured from the system that might lead to fire and explosion	Pressure Gauge, Pressure Transmitter, and Pressure Indicator (PG/PT/PI-080101)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
3	More	More Pressure	The ball valves blocked (XV080301/2)	The flow will be overpressured that might lead to fire and explosion	Flow Indicator and Transmitter (FIO100301A & FT100301A)	Not Acceptable	Monitor and maintenance periodically to the system and the equipment
4	As well as	As well as corrosion	Environmental condition and age of the pipeline	The pipeline can ruptured that might lead to fire and explosion	None	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

(Continue to the next page)

(Continued from the previous page)

Study Title		Node 4: Ambient Air Vaporizer to CNG Compressor					
Drawing No.							
Team Composition							
Part Considered		System Flow from AAV to CNG Compressor					
Design Internet		Cargo: Natural Gas			Destination Tank: CNG Compressor		Sheet of
		Source: AAV			Temperature: 25°C		Pressure:
No	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
5	Other than	Other than destination	Cracked valves	The NG released or exposured from the system that might lead to fire and explosion	None	Not Acceptable	Monitor and maintenance periodically to the system and the equipment

4.11.10 Frequency Analysis

In this bachelor thesis, standard that used to determine the frequency analysis is Det Norske Veritas (DNV) Failure Frequencies Guidelines Process Equipment Leak Frequency Data for Use in Quantity Risk Assessment (QRA). Frequency analysis is a method to determine the probability of a failure of functioning of a component or a system that can initiate failure. If there is a failure of a component in a system, then it might be initiate a hazardous event. To do the frequency analysis, there are 2 methods that will be used, which are Fault Tree Analysis (FTA) and Event Tree Analysis (ETA). Fault Tree Analysis (FTA) is a construction begins with the top event and works towards the basic events, which the top event in this system is gas release. Event tree analysis (ETA) is a logical representation of the different events that an initiating event may follow. From hazard identification (HAZOP), all components can cause gas release. Therefore, it is necessary to calculate the failure data of a system in the form of leaks and system failures, which can cause gas release.

4.11.11 Valve Leakage Frequency

The frequency analysis started from determining the component leakage frequency in a system. In this bachelor thesis, the component leakage frequency referring to node that have been mentioned on previous sub-chapter. The component leakage frequency formula referring to Det Norske Veritas (DNV) Failure Frequencies Guidelines Process Equipment Leak Frequency Data for Use in Quantity Risk Assessment (QRA) can be seen below:

$$F(d) = C(1 + aD^n)d^m + Frup \tag{4.9}$$

Where:

F = the frequency of leaks (per valve year) exceeding size d

C,m = the constants representing hole size distribution

a,n = the constants representing equipment size dependency

Frup = the additional rupture frequency (per valve year)

D = the valve diameter (mm)

d = the hole diameter (mm)

There are provisions that must be considered, namely the leakage scenario to be analysed. The component leak data formula has each scenario. The scenario provisions that must be considered can be seen in the table below, where the formula can be used to find the frequency of the leak with the scenario of total leaks, full leaks and zero pressure.

Table 4.63 Leak Scenario

Scenario	*C*	*a*	*N*	*m*	*Frup*
Total Leaks	7,0,E-05	3,4,E-05	2	-0,76	1,0,E-05
Full Leaks	6,0,E-06	3,8,E-03	1,5	-1,17	0,0,E+00
Zero Pressure	1,0,E-08	6,8	1	-0,15	0,0,E+00

(Source: DNV Process Equipment Failure Frequencies, 2006)

The formula above can be used only to manual valves. The result for the component leakage frequency on every node can be seen on the table below.

Table 4.64 Valve Leakage Frequency on Node 1

Valve Leakage Frequency (Total Leaks)							
Node 1: LNG Filling Station System Part 1							
			Equipment Size		Leak Frequency/Hole Diameter (mm)		
No.	Description	Code	Value	unit	5	15	30
1	Ball Valve	XV-100301D	80	mm	3,51,E-05	2,09,E-05	1,64,E-05
2	Ball Valve	XV-100301C	80	mm	3,51,E-05	2,09,E-05	1,64,E-05
				Total	7,02,E-05	4,18,E-05	3,29,E-05

Table 4.65 Valve Leakage Frequency on Node 2

Valve Leakage Frequency (Total Leaks)							
Node 2: LNG Filling Station System Part 2							
			Equipment Size		Leak Frequency/Hole Diameter (mm)		
No.	Description	Code	Value	unit	5	15	30
1	Ball Valve	-	80	mm	3,51,E-05	2,09,E-05	1,64,E-05
2	Ball Valve	-	80	mm	3,51,E-05	2,09,E-05	1,64,E-05
				Total	7,02,E-05	4,18,E-05	3,29,E-05

Table 4.66 Valve Leakage Frequency on Node 3

Valve Leakage Frequency (Total Leaks)							
Node 3: LNG ISO Tank to Ambient Air Vaporizer							
			Equipment Size		Leak Frequency/Hole Diameter (mm)		
No.	Description	Code	Value	unit	5	15	30
1	Gate Valve	XV-080101A	35,7	mm	3,15,E-05	1,93,E-05	1,55,E-05
2	Gate Valve	XV-080101B	35,7	mm	3,15,E-05	1,93,E-05	1,55,E-05
				Total	6,30,E-05	3,87,E-05	3,10,E-05

Table 4.67 Valve Leakage Frequency on Node 4

Valve Leakage Frequency (Total Leaks)							
Node 4: Ambient Air Vaporizer to CNG Compressor							
			Equipment Size		Leak Frequency/Hole Diameter (mm)		
No.	Description	Code	Value	unit	5	15	30
1	Ball Valve	XV-080301	35,7	mm	3,15,E-05	1,93,E-05	1,55,E-05
2	Ball Valve	XV-080302	35,7	mm	3,15,E-05	1,93,E-05	1,55,E-05
				Total	6,30,E-05	3,87,E-05	3,10,E-05

4.11.12 Pipe Leakage Frequency

The pipe leakage frequency must be determined too in frequency analysis because it is the main component in a system to transfer the fluids. The formula for pipe leakage frequency showed below.

$$F(d) = C(1 + aD^n)d^m + Frup \quad (4.10)$$

Where:

F = the frequency of leaks (per valve year) exceeding size d

C,m = the constants representing hole size distribution

a,n = the constants representing equipment size dependency

Frup = the additional rupture frequency (per valve year)

D = the pipe diameter (mm)

d = the hole diameter (mm)

There are provisions that must be considered, namely the leakage scenario to be analysed. The component leak data formula has each scenario. The scenario provisions that must be considered can be seen in the table below, where the formula can be used to find the frequency of the leak with the scenario of total leaks, full leaks and zero pressure.

Table 4.68 Pipe Leak Scenario

Scenario	*C*	*a*	*N*	*m*	*Frup*
Total Leaks	3,7,E-05	1,0,E+03	-1,5	-0,74	3,0,E-06
Full Leaks	8,0,E-06	1,0,E+03	-1,3	-1,42	0,0,E+00
Zero Pressure	9,0,E-06	0	0	-0,5	1,0,E-06

(Source: DNV Process Equipment Failure Frequencies, 2006)

After obtained the pipe leakage frequency, it must be multiplied by the length of the pipe. The result of the pipe leakage frequency can be seen on the table below.

Table 4.69 Pipeline Leakage Frequency on Node 1

Pipeline Leakage Frequency (Total Leaks)							
Node 1: LNG Filling Station System Part 1							
			Equipment Size		Leak Frequency/Hole Diameter (mm)		
No.	Description	Code	Value	unit	5	15	30
1	Pipeline	-	200	mm	7,5,E-03	7,1,E-03	7,0,E-03
2	Pipeline	LNG-1005-80-25S-C	80	mm	2,8,E-03	2,3,E-03	2,2,E-03
3	Pipeline	LNG-1004-80-25S-C	80	mm	2,8,E-03	2,3,E-03	2,2,E-03
				Total	1,3,E-02	1,2,E-02	1,1,E-02

Table 4.70 Pipeline Leakage Frequency on Node 2

Pipeline Leakage Frequency (Total Leaks)							
Node 2: LNG Filling Station System Part 2							
			Equipment Size		Leak Frequency/Hole Diameter (mm)		
No.	Description	Code	Value	unit	5	15	30
1	Pipeline	LNG-1005-80-25S-C	80	mm	2,2,E-03	1,9,E-03	1,8,E-03
2	Pipeline	LNG-1004-80-25S-C	80	mm	2,2,E-03	1,9,E-03	1,8,E-03
3	Loading Arm	X-1001C	80	mm	5,6,E-04	4,7,E-04	4,4,E-04
4	Loading Arm	X-1001D	80	mm	5,6,E-04	4,7,E-04	4,4,E-04
				Total	5,6,E-03	4,7,E-03	4,4,E-03

Table 4.71 Pipeline Leakage Frequency on Node 3

Pipeline Leakage Frequency (Total Leaks)							
Node 3: LNG ISO Tank to Ambient Air Vaporizer							
			Equipment Size		Leak Frequency/Hole Diameter (mm)		
No.	Description	Code	Value	unit	5	15	30
1	Flexible Cryogenic Hose	-	35,7	mm	5,7,E-04	3,9,E-04	3,3,E-04
2	Pipeline	PG-0902/0806-250-25S-C	35,7	mm	5,3,E-03	3,6,E-03	3,1,E-03
				Total	5,9,E-03	4,0,E-03	3,4,E-03

Table 4.72 Pipeline Leakage Frequency on Node 4

Pipeline Leakage Frequency (Total Leaks)							
Node 4: Ambient Air Vaporizer to CNG Compressor							
			Equipment Size		Leak Frequency/Hole Diameter (mm)		
No.	Description	Code	Value	unit	5	15	30
1	Pipeline	PG-0803-150-25C2	35,7	mm	1,9,E-03	1,3,E-03	1,1,E-03
2	Pipeline	PG-0804-50-25C2	35,7	mm	3,2,E-04	2,2,E-04	1,8,E-04
3	Pipeline	PG-0805-50-25C2	35,7	mm	3,2,E-04	2,2,E-04	1,8,E-04
				Total	2,5,E-03	1,7,E-03	1,4,E-03

4.11.13 Pump Leakage Frequency

The pipe leakage frequency must be determined too in frequency analysis because it is the main component in a system to transfer the fluids. The formula for pipe leakage frequency showed below.

$$F(d) = Cd^m + Frup \tag{4.11}$$

Where:

F = the frequency of leaks (per valve year) exceeding size d

C,m = the constants representing hole size distribution

Frup = the additional rupture frequency (per valve year)

d = the hole diameter (mm)

There are provisions that must be considered, namely the leakage scenario to be analysed. The component leak data formula has each scenario. The scenario provisions that must be considered can be seen in the table below, where the formula can be used to find the frequency of the leak with the scenario of total leaks, full leaks and zero pressure.

Table 4.73 Pump Leak Scenario

Scenario	*C*	*m*	*Frup*
Total Leaks	6,5,E-03	-0,95	0,0,E+00
Full Leaks	1,8,E-03	-1,1	0,0,E+00
Zero Pressure	5,9,E-04	-0,43	0,0,E+00

(Source: DNV Process Equipment Failure Frequencies, 2006)

This formula only for determining the pump leakage frequency. The result of the pump leakage frequency on node 1 and 3, can be seen on the table below.

Table 4.74 Pump Leakage Frequency on Node 1

Pump Leakage Frequency (Total Leaks)							
Node 1: LNG Filling Station System Part 1							
			Equipment Size		Leak Frequency/Hole Diameter (mm)		
No.	Description	Code	Value	unit	5	15	30
1	LNG Pump	P-0901A	200	mm	1,41,E-03	4,96,E-04	2,57,E-04
2	LNG Pump	P-0901B	200	mm	1,41,E-03	4,96,E-04	2,57,E-04
				Total	2,82,E-03	9,92,E-04	5,14,E-04

Table 4.75 Pump Leakage Frequency on Node 3

Pump Leakage Frequency (Total Leaks)							
Node 3: LNG ISO Tank to AAV							
			Equipment Size		Leak Frequency/Hole Diameter (mm)		
No.	Description	Code	Value	unit	5	15	30
1	LNG Pump	-	35,7	mm	1,41,E-03	4,96,E-04	2,57,E-04
2	LNG Pump	-	35,7	mm	1,41,E-03	4,96,E-04	2,57,E-04
				Total	2,82,E-03	9,92,E-04	5,14,E-04

4.11.14 Indicator and Safeguard Leakage Frequency

The indicator and safeguard leakage frequency must be determined because it is having a function to give information the flowrate, pressure, temperature in the system. The formula for indicator and safeguard leakage frequency showed below.

$$F(d) = Cd^m + Frup \quad (4.12)$$

Where:

F = the frequency of leaks (per valve year) exceeding size d

C,m = the constants representing hole size distribution

Frup = the additional rupture frequency (per valve year)

d = the hole diameter (mm)

There are provisions that must be considered, namely the leakage scenario to be analysed. The component leak data formula has each scenario. The scenario provisions that must be considered can be seen in the table below, where the formula can be used to find the frequency of the leak with the scenario of total leaks, full leaks and zero pressure.

Table 4.76 Indicator and Safeguard Leak Scenario

Scenario	*C*	*m*	*Frup*
Total Leaks	6,1,E-04	-0,8	0,0,E+00
Full Leaks	2,3,E-04	-1,88	0,0,E+00
Zero Pressure	2,5,E-05	-0,44	0,0,E+00

(Source: DNV Process Equipment Failure Frequencies, 2006)

This formula only for determining the indicator and safeguard leakage frequency. The result of the indicator and safeguard leakage frequency can be seen on the table below.

Table 4.77 Indicator and Safeguard Leakage Frequency on Node 1

Indicator and Safeguard Leakage Frequency (Total Leaks)							
Node 1: LNG Filling Station System Part 1							
			Equipment Size		Leak Frequency/Hole Diameter (mm)		
No.	Description	Code	Value	unit	5	15	30
1	Pressure Gauge	PG-100301D	80	mm	1,68,E-04	6,99,E-05	4,01,E-05
2	Pressure Gauge	PG-100301C	80	mm	1,68,E-04	6,99,E-05	4,01,E-05
3	Temperature Indicator	TI-100301C	80	mm	1,68,E-04	6,99,E-05	4,01,E-05
4	Temperature Indicator	TI-100301D	80	mm	1,68,E-04	6,99,E-05	4,01,E-05
5	Flow Transmitter	FT-100301C	80	mm	1,68,E-04	6,99,E-05	4,01,E-05
6	Flow Transmitter	FT-100301D	80	mm	1,68,E-04	6,99,E-05	4,01,E-05
7	Pressure Indicator	PI-100301C	80	mm	1,68,E-04	6,99,E-05	4,01,E-05
8	Pressure Indicator	PI-100301D	80	mm	1,68,E-04	6,99,E-05	4,01,E-05
				Total	1,35,E-03	5,59,E-04	3,21,E-04

Table 4.78 Indicator and Safeguard Leakage Frequency on Node 2

Indicator and Safeguard Leakage Frequency (Total Leaks)							
Node 2: LNG Filling Station System Part 2							
			Equipment Size		Leak Frequency/Hole Diameter (mm)		
No.	Description	Code	Value	unit	5	15	30
1	Temperature Indicator	TI-100302C	80	mm	1,68,E-04	6,99,E-05	4,01,E-05
2	Temperature Indicator	TI-100302D	80	mm	1,68,E-04	6,99,E-05	4,01,E-05
3	Pressure Indicator	PI-100302C	80	mm	1,68,E-04	6,99,E-05	4,01,E-05
4	Pressure Indicator	PI-100302D	80	mm	1,68,E-04	6,99,E-05	4,01,E-05
				Total	6,73,E-04	2,80,E-04	1,61,E-04

Table 4.79 Indicator and Safeguard Leakage Frequency on Node 4

Indicator and Safeguard Leakage Frequency (Total Leaks)							
Node 4: AAV to CNG Compressor							
			Equipment Size		Leak Frequency/Hole Diameter (mm)		
No.	Description	Code	Value	unit	5	15	30
1	Temperature Gauge	TG-080101	35,7	mm	1,68,E-04	6,99,E-05	4,01,E-05
2	Temperature Indicator	TIA-080101	35,7	mm	1,68,E-04	6,99,E-05	4,01,E-05
3	Pressure Indicator	PI-080101	35,7	mm	1,68,E-04	6,99,E-05	4,01,E-05
4	Pressure Gauge	PG-080101	35,7	mm	1,68,E-04	6,99,E-05	4,01,E-05
				Total	6,73,E-04	2,80,E-04	1,61,E-04

4.11.15 Component Failure Frequency

One of the causes of hazard event occurred which can cause the potential for fire is a failure of a component in the system that is not functioning as standard. Therefore, a frequency analysis must be carried out on all existing components to determine the failure of the function of the components in the system of each node. In determining the frequency of component failure in a component of each system, the OREDA reference and the Centre for Chemical Process Safety Generic Failure Data Base are used.

Table 4.80 Component Failure Frequency on Node 1

Component Failure Frequency						
Node 1: LNG Filling Station System Part 1						
			Equipment Size		Failure Mode	Failure/Year
No.	Description	Code	Value	unit		
1	Ball Valve	XV-100301D	80	mm	Fail to close on demand	6,48,E-10
2	Ball Valve	XV-100301C	80	mm	Fail to close on demand	6,48,E-10

(Continue to the next page)

(Continued from the previous page)

3	Flow Control Valve	FV-100301C	80	mm	Fail to open on demand	3,21,E-10
4	Flow Control Valve	FV-100301D	80	mm	Fail to open on demand	3,21,E-10
					Total	1,94,E-09

Table 4.81 Component Failure Frequency on Node 2

Component Failure Frequency						
Node 2: LNG Filling Station System Part 2						
No.	Description	Code	Equipment Size		Failure Mode	Failure/Year
			Value	unit		
1	Ball Valve	-	80	mm	Fail to close on demand	6,48,E-10
2	Ball Valve	-	80	mm	Fail to close on demand	6,48,E-10
3	Shutdown Valve	SDV-100301D	80	mm	Fail to close on demand	1,82,E-09
4	Shutdown Valve	SDV-100301D	80	mm	Fail to close on demand	1,82,E-09
					Total	4,93,E-09

Table 4.82 Component Failure Frequency on Node 3

Component Failure Frequency						
Node 3: LNG ISO Tank to AAV						
No.	Description	Code	Equipment Size		Failure Mode	Failure/Year
			Value	unit		
1	Gate Valve	XV-080101A	35,7	mm	Fail to close on demand	9,72,E-10
2	Gate Valve	XV-080101B	35,7	mm	Fail to close on demand	9,72,E-10
					Total	1,94,E-09

Table 4.83 Component Failure Frequency on Node 4

Component Failure Frequency						
Node 4: AAV to CNG Compressor						
No.	Description	Code	Equipment Size		Failure Mode	Failure/Year
			Value	unit		
1	Ball Valve	XV-080301	35,7	mm	Fail to close on demand	6,48,E-10
2	Ball Valve	XV-080302	35,7	mm	Fail to close on demand	6,48,E-10
					Total	1,30,E-09

4.11.16 Indicator and Safeguard Failure Frequency

Indicator and safeguard equipment have a function to monitor the system when the system is operating because if this equipment fail to monitor, it can cause a hazard event occurred. Therefore, a frequency analysis must be carried out on all existing components to determine the failure of the function of the components in the system of each node. In determining the frequency of component failure in a component of each system, the OREDA reference and the Centre for Chemical Process Safety Generic Failure Data Base are used.

Table 4.84 Indicator and Safeguard Failure Frequency on Node 1

Indicator and Safeguard Failure Frequency						
Node 1: LNG Filling Station System Part 1						
No.	Description	Code	Equipment Size		Failure Mode	Failure/Year
			Value	unit		
1	Pressure Gauge	PG-100301D	80	mm	Catastrophic	2,83,E-08
2	Pressure Gauge	PG-100301C	80	mm	Catastrophic	2,83,E-08
3	Temperature Indicator	TI-100301C	80	mm	Spurious Operation	2,54,E-10
4	Temperature Indicator	TI-100301D	80	mm	Spurious Operation	2,54,E-10

(Continue to the next page)

(Continued from the previous page)

5	Pressure Indicator	PI-100301C	80	mm	Fail to transmit data	1,04,E-08
6	Pressure Indicator	PI-100301D	80	mm	Fail to transmit data	1,04,E-08
7	Flow Transmitter	FT-100301C	80	mm	Fail to function on demand	3,02,E-10
8	Flow Transmitter	FT-100301D	80	mm	Fail to function on demand	3,02,E-10
					Total	7,85,E-08

Table 4.85 Indicator and Safeguard Failure Frequency on Node 2

Indicator and Safeguard Failure Frequency						
Node 2: LNG Filling Station System Part 2						
No.	Description	Code	Equipment Size		Failure Mode	Failure/Year
			Value	unit		
1	Temperature Indicator	TI-100302C	80	mm	Spurious Operation	2,54,E-10
2	Temperature Indicator	TI-100302D	80	mm	Spurious Operation	2,54,E-10
3	Pressure Indicator	PI-100302C	80	mm	Fail to transmit data	1,04,E-08
4	Pressure Indicator	PI-100302D	80	mm	Fail to transmit data	1,04,E-08
					Total	2,14,E-08

Table 4.86 Indicator and Safeguard Failure Frequency on Node 4

Indicator and Safeguard Failure Frequency						
Node 4: AAV to CNG Compressor						
No.	Description	Code	Equipment Size		Failure Mode	Failure/Year
			Value	unit		
1	Temperature Gauge	TG-080101	35,7	mm	Catastrophic	2,83,E-08

(Continue to the next page)

(Continued from the previous page)

2	Temperature Indicator	TIA-080101	35,7	mm	Catastrophic	2,83,E-08
3	Pressure Indicator	PI-080101	35,7	mm	Fail to transmit data	1,04,E-08
4	Pressure Gauge	PG-080101	35,7	mm	Fail to operate	2,10,E-10
					Total	6,72,E-08

4.11.17 Fault Tree Analysis (FTA)

Fault tree analysis is a method to determine the frequency of a top event which the top event of this system is gas release that might lead to fire. To do the fault tree analysis is using a “top-down” approach, which considering the causes of the top event. The fault tree structure starts from top event and works down towards the basic event. In fault tree analysis structure, there are logic gates to show how the basic event can cause the top event. Logic gates that will be use are AND logic gates and OR logic gates.

AND logic gates used if there are two or more events that must occur in combination. The mathematical equations of AND logic gates can be seen below.

$$P(A \cap B) = P(A) \times P(B) \tag{4.13}$$

OR logic gates used if one of several events occur that may cause the higher event. The mathematical equations of OR logic gates can be seen below.

$$P(A \cap B) = P(A) \times P(B) \tag{4.14}$$

To make the fault tree analysis structure and calculating the frequency of the top event in this Bachelor Thesis are using Relex Evaluation Software. The analysis is by input the frequency of leakage and the frequency of failure that obtained from previous sub-chapter on every node. As example, FTA structure on node 1 with bore scenario 5 mm can be seen on the figure below.

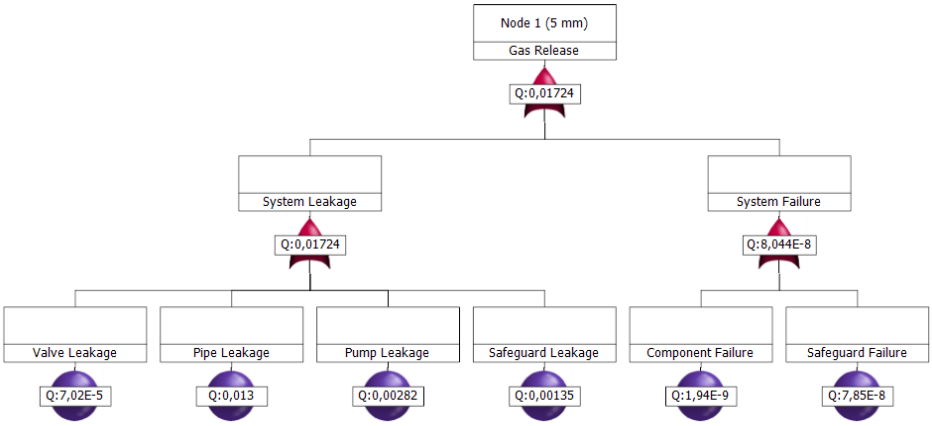


Figure 4.24 Fault Tree Analysis of Node 1 Scenario 5 mm

There are three bore scenario that used, which are 5 mm, 15 mm, and 30 mm. The recapitulation from FTA analysis on every node can be seen on the table below.

Table 4.87 Fault Tree Analysis Recapitulation

Fault Tree Analysis			
	The Frequency of Gas Release		
Node	5 mm	15 mm	30 mm
1	1,73,E-02	1,34,E-02	1,23,E-02
2	5,92,E-03	5,30,E-03	4,61,E-03
3	8,73,E-03	5,03,E-03	3,95,E-03
4	3,22,E-03	2,02,E-03	1,64,E-03

4.11.18 Event Tree Analysis (ETA)

Event tree analysis is a method to determine the frequency of a hazard that developed after initiating event (gas release) occurs on every node. Fire start from ignition after the initiating event occur with scenario in this bachelor thesis, which are jet fire, vapour cloud explosion, flash fire, and gas dispersion. To know the frequency on each scenario, the probability of each scenarios using secondary data from (The Center for Chemical Process Safety (CCPS), 2000). The probability on each scenario can be seen in the table below.

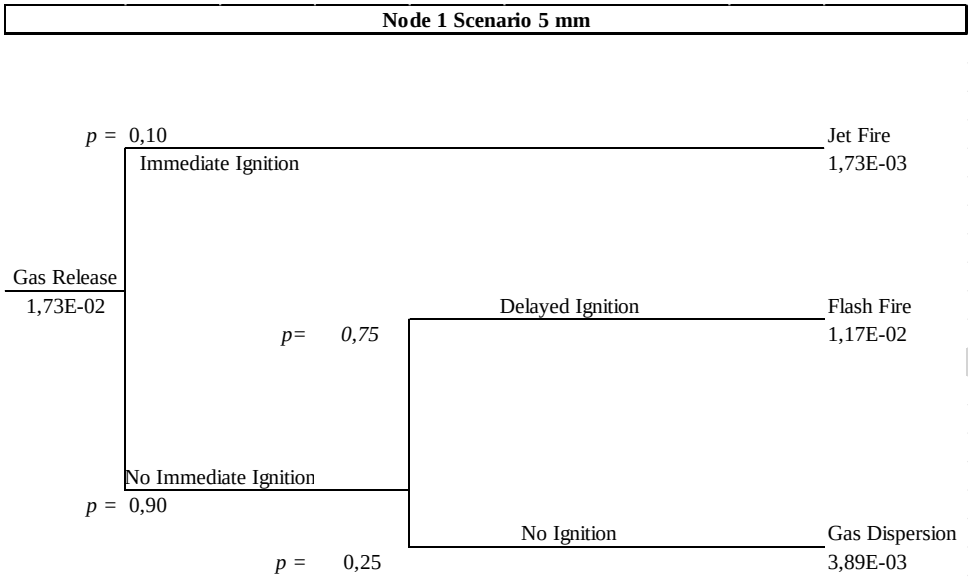
Table 4.88 Hazard Fire Probability

Hazard Fire Probability			
Hazard	Ignition	Probability	Description
Jet Fire	Immediate Ignition	0,1	Fire that ignited immediately after a flammable gas or liquid released from a pressurized system
Gas Dispersion	No Ignition	0,25	Gas that released from a system
Flash Fire	Delayed Ignition	0,75	Fire that ignited after a cloud of flammable gas released if there is no turbulence

(Source: (The Center for Chemical Process Safety (CCPS), 2000))

Event tree analysis is using 3 scenarios bore scenario, which are 5 mm, 15 mm, and 30 mm. As example, event tree analysis structure on node 1 with bore scenario 5 mm can be seen on the figure below.

Figure 4.25 Event Tree Analysis of Node 1 Scenario 5 mm



The recapitulation from ETA analysis on every node with every scenario can be seen on the table below.

Table 4.89 Event Tree Analysis Recapitulation

Event Tree Analysis			
Node	Frequency of Event / Bore Scenario		
	Jet Fire		
	5 mm	15 mm	30 mm
1	1,73E-03	1,34E-03	1,23E-03
2	5,92E-04	5,30E-04	4,61E-04
3	8,73E-04	5,03E-04	3,95E-04
4	3,22E-04	2,02E-04	1,64E-04
Node	Flash Fire		
1	1,17E-02	9,04E-03	8,28E-03
2	4,00E-03	3,58E-03	3,11E-03
3	5,89E-03	3,40E-03	2,67E-03
4	2,17E-03	1,36E-03	1,11E-03
Node	Gas Dispersion		
1	3,89E-03	3,01E-03	2,76E-03
2	1,33E-03	1,19E-03	1,04E-03
3	1,96E-03	1,13E-03	8,89E-04
4	7,25E-04	4,54E-04	3,69E-04

4.11.19 Consequences Analysis

After obtaining the frequency of the hazard on every node, the next step is determining the consequence of the hazard event. To do the consequences analysis is using ALOHA fire modelling software to do the hazard modelling. There are 3 scenarios that will be occurred, which are jet fire, vapour cloud explosion, and flash fire. Gas dispersion is not included because liquified natural gas is not a toxic gas and did not harm humans.

4.11.20 Jet Fire Consequences Analysis

Jet fire is a one of the hazard events after the initiating event occurred (gas release) in each system and nodes. To do the consequences analysis, it is using the ALOHA fire modelling software. Jet fire is a fire that ignited immediately after a flammable gas or liquid released from a system. The jet fire scenario will be plotted with three pipeline leakage with diameter 5 mm, 15 mm, and 30 mm. The scenario will be occurred on daylight time with wind velocity 6 knots from North North West (NNW), air temperature

34°C, relative humidity 80%, that referring to Table 4.55. The threat zone of jet fire can be seen on the table below.

Table 4.90 Threat Zone of Jet Fire

Threat Zone of Jet Fire			
Thermal Radiation			
Colour	Value	Unit	Description
Red	10	*kW/(sq.m)*	potentially lethal within 60 s
Orange	5	*kW/(sq.m)*	2nd degree burns within 60 s
Yellow	2	*kW/(sq.m)*	pain within 60 s

(Source: ALOHA Software,2021)

In the figure below, it is showing the result of jet fire modelling using ALOHA fire modelling software on node 3 with leakage scenario 15 mm.

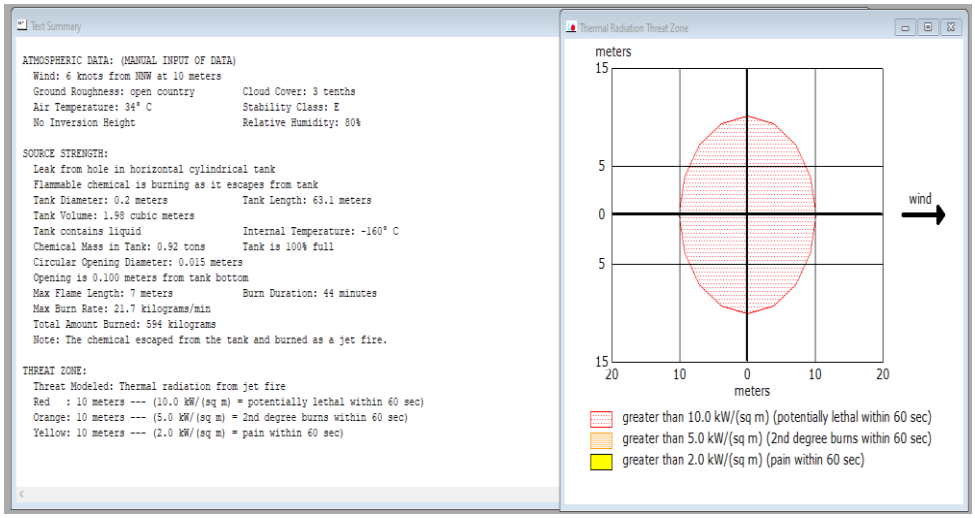


Figure 4.26 Fire Modelling of Jet Fire on Node 3 Scenario 15 mm

In the figure above there are three zone, which are, red, orange, and yellow. Red zones have thermal radiation value 10 kW/(sq.m) which can cause death to humans. Orange zones have thermal radiation value 5 kW/(sq.m) which can cause 2nd degree burns to humans. Yellow zones have thermal radiation value 2 kW/(sq.m) which can cause pain to humans. The jet fire of node 3 scenario 15 mm on layout of SSGS can be seen in the figure below.

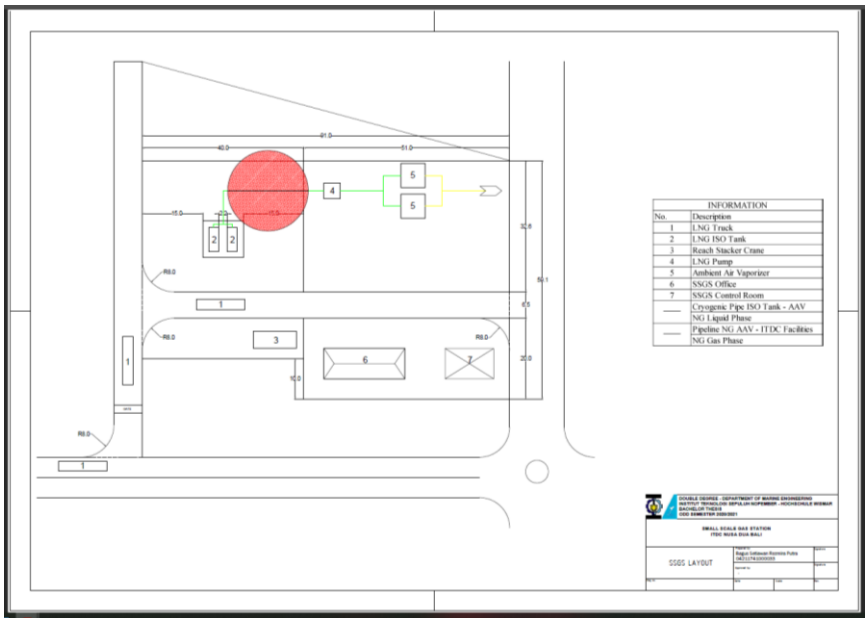


Figure 4.27 Jet Fire of Node 3 Scenario 15 mm

After obtaining the fire modelling using ALOHA software, on the table below showing the consequences analysis recapitulation of jet fire and the condition of the scenario is on daylight time (noon).

Table 4.91 Consequences Analysis of Jet Fire

Consequences Analysis			
Node	Bore Scenario (mm)	Jet Fire Frequency	Fatality
1	5	1,73E-03	4
	15	1,34E-03	4
	30	1,23E-03	6
2	5	5,92E-04	4
	15	5,30E-04	4
	30	4,61E-04	6
3	5	8,73E-04	3
	15	5,03E-04	4
	30	3,95E-04	8
4	5	3,22E-04	3
	15	2,02E-04	3
	30	1,64E-04	3

4.11.21 Flash Fire Consequences Analysis

Flash fire is a one of the hazard events after the initiating event occurred (gas release) in each system and nodes. To do the consequences analysis, it is using the ALOHA fire modelling software. Fire that ignited after a cloud of flammable gas released from a pressurized system. The flash fire scenario will be plotted with three pipeline leakage with diameter 5 mm, 15 mm, and 30 mm. The scenario will be occurred on daylight time with wind velocity 6 knots from North North West (NNW), air temperature 34°C, relative humidity 80%, that referring to Table 4.55. The threat zone of flash fire can be seen on the table below.

Table 4.92 Threat Zone of Flash Fire

Threat Zone of Flash Fire			
Flammable Area			
Color	Value	Unit	Description
Red	30000	*ppm*	60% LEL = flame pockets
Yellow	5000	*ppm*	10% LEL

(Source: ALOHA Software,2021)

In the figure below, it is showing the result of flash fire modelling using ALOHA fire modelling software on node 4 with leakage scenario 15 mm.

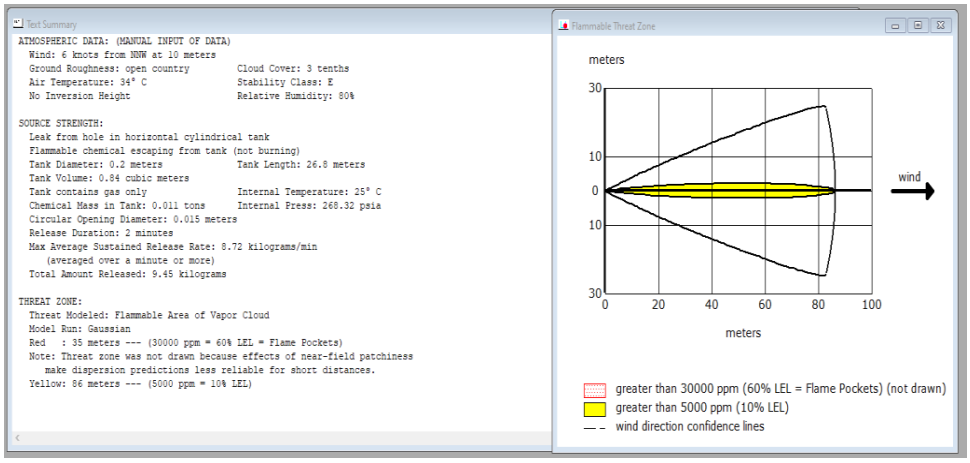


Figure 4.28 Fire Modelling of Flash Fire on Node 4 Scenario 15 mm

In the figure above there are two zone, which are, red and yellow. Red zones have flammable area value 30000 ppm which can cause death to humans. Yellow zones have flammable area value 5000 ppm which can cause pain to humans. The flash fire of node 4 scenario 15 mm on layout of SSGS can be seen in the figure below.

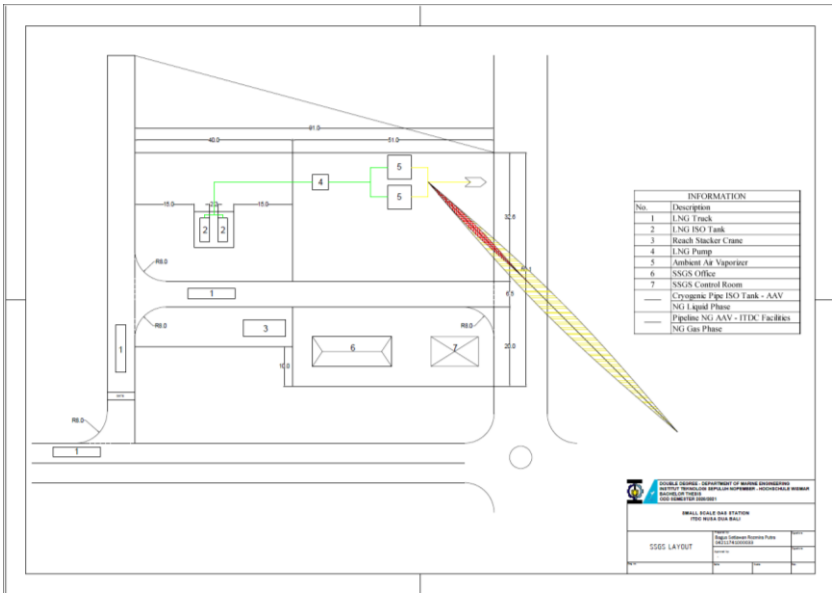


Figure 4.29 Flash Fire of Node 4 Scenario 15 mm

After obtaining the fire modelling using ALOHA software, on the table below showing the consequences analysis recapitulation of flash fire and the condition of the scenario is on daylight time (noon).

Table 4.93 Consequences Analysis of Flash Fire

Consequences Analysis			
Node	Bore Scenario (mm)	Flash Fire Frequency	Fatality
1	5	1,17E-02	7
	15	9,04E-03	8
	30	8,28E-03	9
2	5	4,00E-03	7
	15	3,58E-03	8
	30	3,11E-03	9
3	5	5,89E-03	9
	15	3,40E-03	12
	30	2,67E-03	14
4	5	2,17E-03	3
	15	1,36E-03	4
	30	1,11E-03	4

4.11.22 f/N Curve (UK-HSE)

After the analysis of frequency and consequence analysis on a system, the steps taken are to conduct risk mapping. The risk mapping conducted in this bachelor thesis adopted from f/N Curve UK -HSE. The consequences resulting from the f-N Curve risk mapping are the consequences of human life (societal risk). The f-N curve itself is the result of the relationship between the cumulative frequency per year (f) and the number of fatalities (N) or known as a societal risk which is the impact of an event.

The risk representation contained in the f-N curve can provide information on a scenario that is in an Acceptable, or ALARP, or Unacceptable area. No mitigation action is required if a scenario is in the ALARP area. However, prevention is important when a scenario is in an unacceptable position.

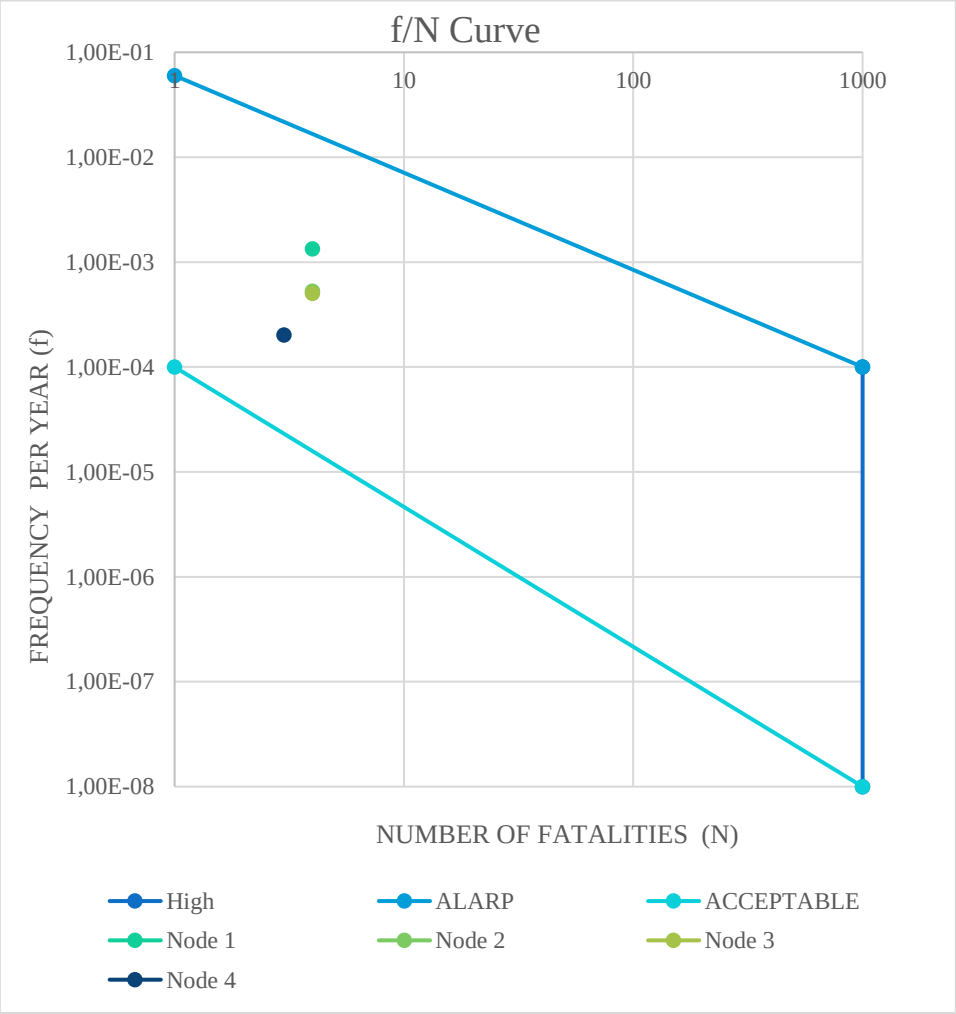


Figure 4.30 f/N Curve of Jet Fire Scenario 15 mm

The figure above is the result of the risk mapping of the jet fire scenario 15 mm. The results of the frequency per year (f) are represented on the y-axis and the results of the number of fatalities (N) or known as a societal risk which is the impact of an event represented on the x-axis.

In table below, is the recapitulation of the results of the risk mapping of jet fire scenario. According to figure above, Node 1, Node 2, Node 3, and Node 4 on jet fire scenario is in ALARP area.

Table 4.94 Risk Mapping of Jet Fire

Description	Jet Fire Frequency (5 mm)	Number of Fatalities	Risk Level		
			Acceptable	ALARP	Unacceptable
Node 1	1,73E-03	4		YES	
Node 2	5,92E-04	4		YES	
Node 3	8,73E-04	3		YES	
Node 4	3,22E-04	3		YES	
Description	Jet Fire Frequency (15 mm)	Number of Fatalities	Risk Level		
			Acceptable	ALARP	Unacceptable
Node 1	1,34E-03	4		YES	
Node 2	5,30E-04	4		YES	
Node 3	5,03E-04	4		YES	
Node 4	2,02E-04	3		YES	
Description	Jet Fire Frequency (30 mm)	Number of Fatalities	Risk Level		
			Acceptable	ALARP	Unacceptable
Node 1	1,23E-03	6		YES	
Node 2	4,61E-04	6		YES	
Node 3	3,95E-04	8		YES	
Node 4	1,64E-04	3		YES	

The figure below is the result of the risk mapping of the flash fire scenario 15 mm. The results of the frequency per year (f) are represented on the y-axis and the results of the number of fatalities (N) or known as a societal risk which is the impact of an event represented on the x-axis.

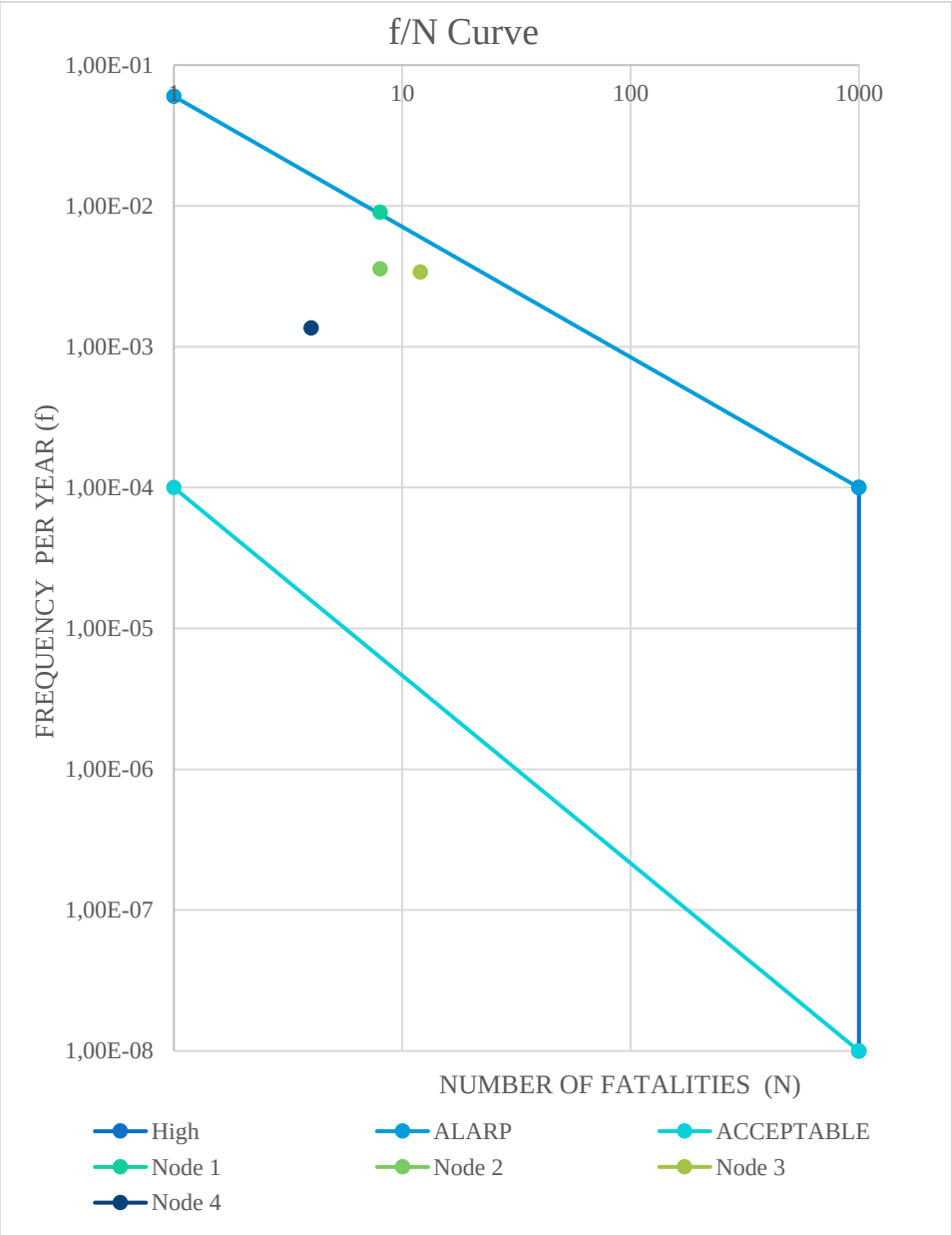


Figure 4.31 f/N Curve of Flash Fire Scenario 15 mm

In table below, is the recapitulation of the results of the risk mapping of flash fire scenario. According to figure above, Node 2, Node 3, and Node 4 on jet fire scenario are in ALARP area and Node 1 is in Unacceptable area, which mitigation is needed.

Table 4.95 Risk Mapping of Flash Fire

Description	Flash Fire Frequency (5 mm)	Number of Fatalities	Risk Level		
			Acceptable	ALARP	Unacceptable
Node 1	1,17E-02	7			YES
Node 2	4,00E-03	7		YES	
Node 3	5,89E-03	9		YES	
Node 4	2,17E-03	3		YES	
Description	Flash Fire Frequency (15 mm)	Number of Fatalities	Risk Level		
			Acceptable	ALARP	Unacceptable
Node 1	9,04E-03	8			YES
Node 2	3,58E-03	8		YES	
Node 3	3,40E-03	12		YES	
Node 4	1,36E-03	4		YES	
Description	Flash Fire Frequency (30 mm)	Number of Fatalities	Risk Level		
			Acceptable	ALARP	Unacceptable
Node 1	8,28E-03	9			YES
Node 2	3,11E-03	9		YES	
Node 3	2,67E-03	14		YES	
Node 4	1,11E-03	4		YES	

4.11.23 Mitigation

Mitigation is a process or a step to control, evaluate, and prevention to the risks that will occur in the future. Mitigation can reducing the risk level to the minimum to avoid consequences to environment, human, system or company property. The method to do the mitigation is using LOPA method by recommend to add safety equipment or Independent Protection Layers (IPL) with LOPA standards. Mitigation in this bachelor thesis to reducing the frequency not only for the unacceptable condition, but on ALARP condition too.

The Frequency of Unmittigated Consequences is the frequency of the initiating event (gas release) multiplied with conditional modifier which is the ignition probability. The ignition probability is using secondary data from (The Center for Chemical Process

Safety (CCPS), 2000). Then, the frequency value multiplied by the Probability Failure on Demand of Independent Protection Layer (IPL). PFD or Probability Failure on Demand is a probability if the IPL equipments fail to perform or operate its function when needed. The PFD of IPL value obtained from (Yun, 2007). In this Bachelor Thesis, the mitigation plan is the worst case scenario with the worst risk level so that it represents several scenarios that are considered safer. The scenario on every node that will be mitigated can be seen on the table below.

Table 4.96 Hazard Event for The Mitigation Plan

Hazard Event	
No.	Description
1	Jet Fire Node 1 Scenario 5 mm
2	Jet Fire Node 2 Scenario 5 mm
3	Jet Fire Node 3 Scenario 5 mm
4	Jet Fire Node 4 Scenario 5 mm
5	Flash Fire Node 1 Scenario 5 mm
6	Flash Fire Node 1 Scenario 15 mm
7	Flash Fire Node 1 Scenario 30 mm
8	Flash Fire Node 3 Scenario 5 mm

The mitigation plan will be done to 8 scenarios, according to the table above have shown. For node 1, node 2, node 3, and node 4 on bore scenario 5 mm in the event of jet fire, additional gas detectors, pressure alarms, and temperature alarms are added. For node 1 on bore scenario 5 mm, 15 mm, and 30 mm in the event of flash fire, additional gas detectors, pressure alarms, and temperature alarms are added. For node 3 bore scenario 5 mm, additional gas detectors, pressure alarms, and temperature alarms are added too. Overall mitigation in this Bachelor Thesis, the addition made is by adding safety equipment or Independent Protection Layer such as Gas Detector, Pressure Alarm, and Temperature Alarm. On the next page is the result of mitigation recommendation on each scenario.

Table 4.97 LOPA Worksheet Jet Fire Node 1 at 5 mm

Scenario Number: 1		**Scenario Title:** Gas Release for Jet Fire Node 1 at 5 mm	
		Risk Level: ALARP	
Date: 31-1-2021	**Description**	**Probability**	**Frequency (per Year)**
Consequence (Description)	Fire and explosion event category Jet Fire because of gas release incident		
Risk Tolerance Criteria (Frequency)	Tolerable risk of a hazard event		1,00E-04
Initiating Event (Frequency)	Gas Release		1,73E-02
Enabling Event	N/A	N/A	
Conditional Modifiers			
Ignition Probability	Immediate Ignition	1,00E-01	
Frequency of Unmitigated Consequence			1,73E-03
Independent Protection Layers (IPL) & Probability of Failure on Demand (PFD)			
IPL & PFD	Pressure Alarm	4,22E-02	
	Gas Detector	1,00E-01	
	Temperature Alarm	5,52E-02	
Total PFD for all IPLs		2,33E-04	
Frequency of Mitigated Consequence			4,03E-07
Risk Tolerance Criteria Met (Yes/No):		YES	
Action Required to Meet Risk Tolerance Criteria:	Install Pressure Alarm, Gas Detector, and Temperature Alarm around the node or the system		

Table 4.98 LOPA Worksheet Jet Fire Node 2 at 5 mm

Scenario Number: 2		**Scenario Title:** Gas Release for Jet Fire Node 2 at 5 mm	
		Risk Level: ALARP	
Date: 31-1-2021	**Description**	**Probability**	**Frequency (per Year)**
Consequence (Description)	Fire and explosion event category Jet Fire because of gas release incident		
Risk Tolerance Criteria (Frequency)	Tolerable risk of a hazard event		1,00E-04
Initiating Event (Frequency)	Gas Release		5,92E-03
Enabling Event	N/A	N/A	
Conditional Modifiers			
Ignition Probability	Immediate Ignition	1,00E-01	
Frequency of Unmitigated Consequence			5,92E-04
Independent Protection Layers (IPL) & Probability of Failure on Demand (PFD)			
IPL & PFD	Pressure Alarm	4,22E-02	
	Gas Detector	1,00E-01	
	Temperature Alarm	5,52E-02	
Total PFD for all IPLs		2,33E-04	
Frequency of Mitigated Consequence			1,38E-07
Risk Tolerance Criteria Met (Yes/No):		YES	
Action Required to Meet Risk Tolerance Criteria:	Install Pressure Alarm, Gas Detector, and Temperature Alarm around the node or the system		

Table 4.99 LOPA Worksheet Jet Fire Node 3 at 5 mm

Scenario Number: Jet Fire Node 3		**Scenario Title:** Gas Release for Jet Fire Node 3 at 5 mm	
		Risk Level: ALARP	
Date: 31-1-2021	**Description**	**Probability**	**Frequency (per Year)**
Consequence (Description)	Fire and explosion event category Jet Fire because of gas release incident		
Risk Tolerance Criteria (Frequency)	Tolerable risk of a hazard event		1,00E-04
Initiating Event (Frequency)	Gas Release		8,73E-03
Enabling Event	N/A	N/A	
Conditional Modifiers			
Ignition Probability	Immediate Ignition	1,00E-01	
Frequency of Unmitigated Consequence			8,73E-04
Independent Protection Layers (IPL) & Probability of Failure on Demand (PFD)			
IPL & PFD	Pressure Alarm	4,22E-02	
	Gas Detector	1,00E-01	
	Temperature Alarm	5,52E-02	
Total PFD for all IPLs		2,33E-04	
Frequency of Mitigated Consequence			2,03E-07
Risk Tolerance Criteria Met (Yes/No):		YES	
Action Required to Meet Risk Tolerance Criteria:	Install Pressure Alarm, Gas Detector, and Temperature Alarm around the node or the system		

Table 4.100 LOPA Worksheet Jet Fire Node 4 at 5 mm

Scenario Number: 4		**Scenario Title:** Gas Release for Jet Fire Node 4 at 5 mm	
		Risk Level: ALARP	
Date: 31-1-2021	**Description**	**Probability**	**Frequency (per Year)**
Consequence (Description)	Fire and explosion event category Jet Fire because of gas release incident		
Risk Tolerance Criteria (Frequency)	Tolerable risk of a hazard event		1,00E-04
Initiating Event (Frequency)	Gas Release		3,22E-03
Enabling Event	N/A	N/A	
Conditional Modifiers			
Ignition Probability	Immediate Ignition	1,00E-01	
Frequency of Unmitigated Consequence			3,22E-04
Independent Protection Layers (IPL) & Probability of Failure on Demand (PFD)			
IPL & PFD	Pressure Alarm	4,22E-02	
	Gas Detector	1,00E-01	
	Temperature Alarm	5,52E-02	
Total PFD for all IPLs		2,33E-04	
Frequency of Mitigated Consequence			7,50E-08
Risk Tolerance Criteria Met (Yes/No):		YES	
Action Required to Meet Risk Tolerance Criteria:	Install Pressure Alarm, Gas Detector, and Temperature Alarm around the node or the system		

Table 4.101 LOPA Worksheet Flash Fire Node 1 at 5 mm

Scenario Number: 5		**Scenario Title:** Gas Release for Flash Fire Node 1 at 5 mm	
		Risk Level: UNACCEPTABLE	
Date: 31-1-2021	**Description**	**Probability**	**Frequency (per Year)**
Consequence (Description)	Fire and explosion event category Flash Fire because of gas release incident		
Risk Tolerance Criteria (Frequency)	Tolerable risk of a hazard event		1,00E-04
Initiating Event (Frequency)	Gas Release		1,73E-02
Enabling Event	N/A	N/A	
Conditional Modifiers			
Ignition Probability	Delayed Ignition	6,75E-01	
Frequency of Unmitigated Consequence			1,17E-02
Independent Protection Layers (IPL) & Probability of Failure on Demand (PFD)			
IPL & PFD	Pressure Alarm	4,22E-02	
	Gas Detector	1,00E-01	
	Temperature Alarm	5,52E-02	
Total PFD for all IPLs		2,33E-04	
Frequency of Mitigated Consequence			2,72E-06
Risk Tolerance Criteria Met (Yes/No):		YES	
Action Required to Meet Risk Tolerance Criteria:	Install Pressure Alarm, Gas Detector, and Temperature Alarm around the node or the system		

Table 4.102 LOPA Worksheet Flash Fire Node 1 at 15 mm

Scenario Number: 6		**Scenario Title:** Gas Release for Flash Fire Node 1 at 15 mm	
		Risk Level: UNACCEPTABLE	
Date: 31-1-2021	**Description**	**Probability**	**Frequency (per Year)**
Consequence (Description)	Fire and explosion event category Flash Fire because of gas release incident		
Risk Tolerance Criteria (Frequency)	Tolerable risk of a hazard event		1,00E-04
Initiating Event (Frequency)	Gas Release		1,34E-02
Enabling Event	N/A	N/A	
Conditional Modifiers			
Ignition Probability	Delayed Ignition	6,75E-01	
Frequency of Unmitigated Consequence			9,04E-03
Independent Protection Layers (IPL) & Probability of Failure on Demand (PFD)			
IPL & PFD	Pressure Alarm	4,22E-02	
	Gas Detector	1,00E-01	
	Temperature Alarm	5,52E-02	
Total PFD for all IPLs		2,33E-04	
Frequency of Mitigated Consequence			2,11E-06
Risk Tolerance Criteria Met (Yes/No):		YES	
Action Required to Meet Risk Tolerance Criteria:	Install Pressure Alarm, Gas Detector, and Temperature Alarm around the node or the system		

Table 4.103 LOPA Worksheet Flash Fire Node 1 at 30 mm

Scenario Number: 7		**Scenario Title:** Gas Release for Flash Fire Node 1 at 30 mm	
		Risk Level: UNACCEPTABLE	
Date: 31-1-2021	**Description**	**Probability**	**Frequency (per Year)**
Consequence (Description)	Fire and explosion event category Flash Fire because of gas release incident		
Risk Tolerance Criteria (Frequency)	Tolerable risk of a hazard event		1,00E-04
Initiating Event (Frequency)	Gas Release		1,23E-02
Enabling Event	N/A	N/A	
Conditional Modifiers			
Ignition Probability	Delayed Ignition	6,75E-01	
Frequency of Unmitigated Consequence			8,28E-03
Independent Protection Layers (IPL) & Probability of Failure on Demand (PFD)			
IPL & PFD	Pressure Alarm	4,22E-02	
	Gas Detector	1,00E-01	
	Temperature Alarm	5,52E-02	
Total PFD for all IPLs		2,33E-04	
Frequency of Mitigated Consequence			1,93E-06
Risk Tolerance Criteria Met (Yes/No):		YES	
Action Required to Meet Risk Tolerance Criteria:	Install Pressure Alarm, Gas Detector, and Temperature Alarm around the node or the system		

Table 4.104 LOPA Worksheet Flash Fire Node 3 at 5 mm

Scenario Number: 8		**Scenario Title:** Gas Release for Flash Fire Node 3 at 5 mm	
		Risk Level: ALARP	
Date: 31-1-2021	**Description**	**Probability**	**Frequency (per Year)**
Consequence (Description)	Fire and explosion event category Flash Fire because of gas release incident		
Risk Tolerance Criteria (Frequency)	Tolerable risk of a hazard event		1,00E-04
Initiating Event (Frequency)	Gas Release		8,73E-03
Enabling Event	N/A	N/A	
Conditional Modifiers			
Ignition Probability	Delayed Ignition	6,75E-01	
Frequency of Unmittigated Consequence			5,89E-03
Independent Protection Layers (IPL) & Probability of Failure on Demand (PFD)			
IPL & PFD	Pressure Alarm	4,22E-02	
	Gas Detector	1,00E-01	
	Temperature Alarm	5,52E-02	
Total PFD for all IPLs		2,33E-04	
Frequency of Mitigated Consequence			1,37E-06
Risk Tolerance Criteria Met (Yes/No):		YES	
Action Required to Meet Risk Tolerance Criteria:	Install Pressure Alarm, Gas Detector, and Temperature Alarm around the node or the system		

CHAPTER 5

CONCLUSION AND SUGGESTION

5.1 Conclusion

According to the research that have been done in this Bachelor Thesis on planning of LNG distribution scheme for Indonesia Tourism Development Corporation (ITDC) in Nusa Dua, Bali, it is resulting the following conclusions:

1. There are 21 facilities in ITDC Nusa Dua, Bali, that will be using natural gas with gas consumption in Liquified Natural Gas unit, 81367.09 MMBTU, or 0.2132 MMSCFD, or 7.46 m^3/day
2. The LNG Distribution Scheme will be from LNG Terminal Benoa then transferred with LNG Filling Station to fill LNG ISO Tank that will be carried with Truck to Small-Scale Gas Station near ITDC area as the regasification unit to process the LNG back to the gas phase, then the gas will be distributed to each facility using pipeline natural gas
3. There are 2 truck routes for the LNG Distribution Scheme, which are:
    a. LNG Distribution Scheme A: after the truck fill the LNG ISO Tank in LNG Filling Station, the truck will pass through Raya Pelabuhan Benoa Road, then turn left to Mandara Toll Road, after that turn left to By Pass Ngurah Rai, and then turn left to Pratama Raya Road with a total road length 11.3 km
    b. LNG Distribution Scheme B: after the truck fill the LNG ISO Tank in LNG Filling Station, the truck will pass through Raya Pelabuhan Benoa Road, then turn left By Pass Ngurah Rai, and then turn left to Pratama Raya Road with a total road length 19.5 km
4. The hazard identification on road transport using the What-if Analysis method resulting there are several systems that potentially fail, it is because components in the system are failed and damaged. If the potential failure occurred, it could lead the truck to have a road accident by crashing another vehicle
5. The result from risk assessment analysis of the road transport, the chosen truck route is LNG Distribution Scheme A because the frequency of a collision on route A is less than the frequency of a collision on route B. The highest frequency on route A is on By Pass Ngurah Rai with a value 1,11801E-06 per year and the highest frequency on route B is on By Pass Ngurah Rai with a value 2,63E-05 per year. It is because on frequency calculation, the longer the truck passes through the road, the frequency of a collision on that road also increases

6. The result from consequences analysis, the fatalities number from road accident on route A much smaller than route B because there are fewer intersections or junctions on route A than on route B. The total consequences of road accident on route A are 54 humans, and the total consequences of road accident on route B are 105 humans
7. On risk mapping by the Netherlands F/N curve also still accepts route A where the roads on route A are in Tolerability region A (Mandara Toll Road & By Pass Ngurah Rai) and Tolerability Region B (Raya Pelabuhan Benoa Road & Pratama Raya Road). While route B, there are two roads in unacceptable areas (Raya Pelabuhan Benoa Road & By Pass Ngurah Rai Road) and only one road in Tolerability region B (Pratama Raya Road)
8. The summary of LNG Distribution Scheme A can be seen on the table below.

Summary LNG Distribution Scheme A		
Road Transport (Truck)		
Information	*Value*	*Unit*
Truck (ISO Tank Size)	20,00	*ft*
	20,37	*m³*
Road Length (LNG Filling Station - Small Scale Gas Station) A	11,30	*km*
Gas Demand	7,46	*m3/day*
Duration on the Road	20	*minutes*
Total Time Forward and Backward	160	*minutes*
Standby Time	2,4	*days*
Total Time / Round Trip	2,5	*days*
Round Trip / Year	145	*times/year*
Natural Gas Pipeline		
Information	*Value*	*Unit*
Pipeline Length (Small Scale Gas Station - Facilities in ITDC Nusa Dua)	8,42	*km*
Gas Flow Rate	154213,78	*ft³ Gas/day*
Pipe Standard	JIS G3452	-
Pipe Material	Carbon Steel	
Nominal Diameter (A)	32	-
Nominal Diameter (B)	1 1/4	-
Outside Diameter	42,7	*mm*
Wall Thickness	3,5	*mm*
Inside Diameter	35,7	*mm*

9. The hazard identification on LNG filling station system and Small-Scale Gas station system using Hazard and Operability Study (HAZOP) divided into 4 nodes to detail hazard identification so that nothing missed. The potential hazard on each node is fire
10. The frequency analysis is using Fault Tree Analysis (FTA) with 3 bore scenarios which are 5 mm, 15 mm, and 30 mm. The top event in FTA structure is gas release. The highest frequency of gas release is on Node 1 bore scenario 5 mm with a value 1,73,E-02 per year and the lowest frequency of gas release is on Node 4 scenario 30 mm with a value 1,64,E-03 per year
11. The result from frequency analysis using Event Tree Analysis (ETA) there are 3 hazard events, which are, jet fire, flash fire, and gas dispersion. The highest frequency of jet fire is on Node 1 bore scenario 5 mm with a value 1,73E-03. The highest frequency of flash fire is on Node 1 bore scenario 5 mm with a value 1,17E-02. The highest frequency of gas dispersion is on Node 1 bore scenario 5 mm with a value 3,89E-03
12. The consequences analysis is using fire modelling software to obtain the thermal flux range on each hazard event that occur which has a fatal impact on humans in LNG facility area. The highest fatalities number from every hazard event is on flash fire Node 3 bore scenario 30 mm with a value 14 people
13. On risk mapping using f/N Curve UK-HSE showing that jet fire event is in ALARP area. The flash fire event is in ALARP area and 3 scenarios in Unacceptable area, which are Node 1 with bore scenario 5 mm, 15 mm, and 30 mm.
14. Mitigation is using Layer of Protection Analysis (LOPA) by adding a gas detector, pressure alarm, and temperature alarm. Thus, the frequency value decreases.

5.2 Suggestion

According to the research that have been done in this Bachelor Thesis on planning of LNG distribution scheme for Indonesia Tourism Development Corporation (ITDC) in Nusa Dua, Bali, it is resulting the following suggestions:

1. The economic analysis needs to be conducted to see the distribution scheme that has been planned, whether it is economically feasible or not.

This page is intentionally left blank

REFERENCES

Akram, M., & Andrzej, P. (1 July, 2015). The Technical and Economical comparison between marine CNG and LNG Transportation. *Oil & Gas Journal "Young Petro"*(7).

ANTOR (HK). (2013). *Tourism and Hospitality Studies.* Wan Chai, Hong Kong: Government of the Hong Kong Special.

Artana, K., & Dinariyana, A. (2013). Teori Keandalan Sistem dan Aplikasinya. *Surabaya: Guna Widya*.

Artana, K., & Soegiono. (2006). *Transportasi LNG Indonesia.* Surabaya: Airlangga University Press.

Badan Lingkungan Hidup Provinsi Bali. (2011). *Peta Jalan (Road Map) Menuju Bali Green Province.* Bali: Badan Lingkungan Hidup Provinsi Bali.

Badan Pendapatan Provinsi Bali (Government Income Department of Bali Province). (2020). *Banyaknya Kendaraan Menurut Jenisnya dan Kabupaten/Kota di Provinsi Bali (Unit).* Retrieved 18 February, 2021, from Badan Pusat Statistik Provinsi Bali: https://bali.bps.go.id/indicator/17/250/1/banyaknya-kendaraan-menurut-jenisnya-dan-kabupaten-kota-di-provinsi-bali.html

Badan Pusat Statistik (BPS). (2019). *Rata-Rata Pertumbuhan Kunjungan Wisman ke Indonesia (2014-2018).* Jakarta: Badan Pusat Statistik (BPS). Retrieved 8 September, 2020, from https://databoks.katadata.co.id/datapublish/2019/07/17/5-tahun-terakhir-rerata-pertumbuhan-kunjungan-wisawatan-mancanegara-14#

Badan Pusat Statistik Provinsi Bali. (2019). *Jumlah Hotel Bintang.* Bali: BPS Provinsi Bali/BPS - Statistics of Bali Province. Retrieved 9 September, 2020, from https://bali.bps.go.id/indicator/16/222/1/jumlah-hotel-bintang.html

Badan Pusat Statistik Provinsi Bali. (2019). *Provinsi Bali Dalam Angka/Bali Province in Figures 2019.* Bali: BPS Provinsi Bali/BPS - Statistics of Bali Province. Retrieved 9 September, 2020, from https://bali.bps.go.id/publication/2019/08/16/99cd2c6d79aad1a0062dddfc/provinsi-bali-dalam-angka-2019.html

Baskoro, D. (2019). *PENILAIAN RISIKO POTENSI KEBAKARAN DAN LEDAKAN PADA FLOATING STORAGE REGASIFICATION UNIT.* Surabaya: INSTITUT TEKNOLOGI SEPULUH NOPEMBER.

Batarlienė, N. (2018). RISK AND DAMAGE ASSESSMENT FOR TRANSPORTATION OF DANGEROUS FREIGHT. *Transport and Telecommunication, 19*, 356–363.

Bengston, PhD, PE, H. (2016). CE-080 Natural Gas Pipeline Flow Calculations. *Natural Gas Pipeline Flow Calculations*.

Bhattacharya, R., & Kumar, V. (2015). Consequence analysis for simulation of hazardous chemicals release using ALOHA software. *International Journal of ChemTech Research*, 2038-2046.

Budiarta, K. (2020). *PENILAIAN RISIKO TERMINAL LNG TANJUNG EMAS SEMARANG.* Surabaya: INSTITUT TEKNOLOGI SEPULUH NOPEMBER.

Budiyanto, M., Riadi, A., Buana, I., & Kurnia, G. (2020). *Study on the LNG distribution to mobile power plants utilizing small-scale*.

BUPATI BADUNG. (2013). PERATURAN DAERAH KABUPATEN BADUNG NOMOR 26 TAHUN 2013 TENTANG RENCANA TATA RUANG WILAYAH KABUPATEN BADUNG TAHUN 2013-2033. BADUNG, BALI, INDONESIA.

Center, M. (18 March, 2019). *Hotel dan Resort Batam Mulai Beralih ke Natural Gas*. (MEDIACENTER, Editor) Retrieved 14 September, 2020, from Media Center: https://mediacenter.batam.go.id/2019/03/18/hotel-dan-resort-batam-mulai-beralih-ke-natural-gas/

Chart Industries. (2013). *LNG ISO INTERMODAL CONTAINERS ISO CRYOGENIC BULK LIQUIDS.* Retrieved 14 September, 2020, from Chart Industries: http://files.chartindustries.com/14732510_LNG_ISO.pdf

Construction Review Online. (28 January, 2020). *120-km natural gas pipeline to be constructed in Morocco*. Retrieved from Construction Review Online: https://constructionreviewonline.com/2020/01/120-km-natural-gas-pipeline-to-be-constructed-in-morocco/

Dewi, A. (2013). *APLIKASI FORMAL SAFETY ASSESSMENT (FSA) UNTUK PENILAIAN RISIKO KECELAKAAN DI PELABUHAN SEMAYANG BALIKPAPAN.* Surabaya: Institut Teknologi Sepuluh Nopember.

Direktorat Jenderal Minyak dan Gas Bumi Kementrian Energi dan Sumber Daya Mineral. (2020). *Laporan Tahunan Capaian Program dan Kegiatan 2019.* Jakarta: Direktorat Jenderal Minyak dan Gas Bumi Kementrian Energi dan Sumber Daya Mineral.

Erlangga, R. (2015). *ANALISA KEANDALAN SUBSEA GAS PIPELINE DALAM KONDISI TERBURUK: STUDI KASUS DARI PEMPING ONSHORE RECEIVING FACILITIES MENUJU BATAM ONSHORE RECEIVING FACILITIES.* SURABAYA: INSTITUT TEKNOLOGI SEPULUH NOPEMBER.

Fabiano, B., Curro, F., Palazzi, E., & Pastorino, R. (2002). A framework for risk assessment and decision-making strategies in dangerous good transportation. *Journal of Hazardous Materials 93*, 1–15.

Government of Canada. (6 August, 2020). *Liquefied Natural Gas*. Retrieved 13 September, 2020, from Government of Canada: https://www.nrcan.gc.ca/our-natural-resources/energy-sources-distribution/clean-fossil-fuels/natural-gas/liquefied-natural-gas/5679

Gucma, L. (2009). METHODS OF SHIP-BRIDGE COLLISION SAFETY EVALUATION. *R&RATA # 2(13) part 1 (Vol.2)*, 50-63.

Health and Safety Executive. (February, 2013). *Publications.* Retrieved 20 February, 2021, from Health and Safety Executive: https://www.hse.gov.uk/pubns/hse49.pdf

Health and Safety Executive. (2015). *The Control of Major Accident Hazards Regulations 2015.* Norwich, UK: Health and Safety Executive. Retrieved from https://www.hse.gov.uk/pubns/books/l111.htm

Health and Safety Executive. (2020). *LNG terminals - Consent and operational issues*. Retrieved 20 February, 2021, from Health and Safety Executive: https://www.hse.gov.uk/gas/supply/ingterminals.htm

Herdzik, J. (2011). LNG AS A MARINE FUEL – POSSIBILITIES AND PROBLEMS. *Journal of KONES Powertrain and Transport, 18*.

Indonesia Tourism Development Corporation (ITDC). (2018). *Laporan Tahunan 2018-Delivering Solid Progress-Mempersembahkan Kemajuan*

Nyata. DKI Jakarta: Indonesia Tourism Development Corporation (ITDC).

International Gas Union. (2012). *Natural Gas Conversion Guide.* Retrieved 17 September, 2020, from http://agnatural.pt/documentos/ver/natural-gas-conversion-guide_cb4f0ccd80ccaf88ca5ec336a38600867db5aaf1.pdf

Irsyad, M., & Negara, P. (2017). *LAPORAN KINERJA 13 SIMPANG YANG TERPANTAU OLEH ATCS DINAS PERHUBUNGAN PROVINSI BALI.* Bekasi: Sekolah Tinggi Transportasi Darat Program Studi Diploma III Lalu Lintas dan Angkutan Jalan .

Java Energy Semesta. (2015). *Future Development*. (Java Energy Semesta) Retrieved 16 September, 2020, from Java Energy Semesta: http://jes-green.co.id/en/future-development

Katili, A., Artana, K., & Dinariyana D.P., A. (2016). Kajian Teknis dan Ekonomis Distribusi Gas Alam dari FSRU Menuju Superblok. *JURNAL TEKNIK ITS*, 2337-3539.

Kementrian Energi dan Sumber Daya Mineral Direktorat Jenderal Minyak dan Gas Bumi. (August, 2018). Neraca Gas Bumi Indonesia. *2018 - 2027*.

Kepolisian Daerah Bali (State Police of Bali Province). (2020). *Banyaknya Kecelakaan Lalu Lintas Menurut Kabupaten/Kota di Provinsi Bali.* Retrieved 18 February, 2021, from Badan Pusat Statistik Provinsi Bali: https://bali.bps.go.id/subject/17/transportasi.html#subjekViewTab5

Kontovas, C. (2005). *Formal Safety Assessment Critical Review and Future Role.* Greece: NATIONAL TECHNICAL UNIVERSITY OF ATHENS School of Naval Architecture & Marine Engineering.

LI, Y., LI, W., YU, Y., & BAO, L. (2017). Planning of LNG Filling Stations for Road Freight: A Case Study of Shenzen. *Transportation Research Procedia 25*, 4580–4588.

Lisowski, E., & Czyzycki, W. (2011). TRANSPORT AND STORAGE OF LNG IN CONTAINER TANKS. *Journal of KONES Powertrain and Transport, 18*.

Mokhatab, S., A. Poe, W., & Y. Mak, J. (2015). *HANDBOOK OF NATURAL GAS TRANSMISSION AND PROCESSING.* Elsevier Inc.

National Fire Protection Association. (2019). *NFPA 59A, Standard for the Production, Storage, and Handling of Liquified Natural Gas (LNG).* Las Vegas, NV: National Fire Protection Association.

Pratama, R., Artana, K., & Baliwangi, L. (2010). Risk Assessment Tanker LNG dalam Studi Kasus Suplai LNG dari Ladang Tangguh ke Teluk Benoa Bali. *Undergraduate Thesis, Marine Engineering, RSSP 363.102 Pra r, 2010*.

PT. Melia Energi Nusantara & Melia Holdings PTE LTD. (2018). *OUR PRODUCTS & SERVICES*. Retrieved 13 September, 2020, from PT. Melia Energi Nusantara & Melia Holdings PTE LTD.: https://www.meliaenergi.com/products-services

PT. Pelindo Energi Logistik (PEL). (2019). *Company Profile Pelindo Energi Logistik.* Retrieved September 9, 2020, from PT. PELINDO ENERGI LOGISTIK: https://www.pel.co.id/download?lang=en

Purnomo, D. (2019). *FORMAL SAFETY ASSESSMENT FOR SHIP COLLISION IN BALI STRAIT.* Surabaya: Institut Teknologi Sepuluh Nopember.

Purwanto, W. W. (2016). THE NATURAL GAS INDUSTRY DEVELOPMENT IN INDONESIA. *DRAMATIC CHANGES - STREAMLINE POLICIES AND DOMESTIC GAS PRICING REFORM**, 1.

Pusat Pengkajian Industri Proses dan Energi (PPIPE), Badan Pengkajian dan Penerapan Teknologi (BPPT). (August, 2020). OUTLOOK ENERGI INDONESIA 2020. (Adiarso, E. H., & A. S., Eds.) *2020*.

Putra, H. (2019). *SOCIETAL RISK ASSESSMENT ON 60 MW BARGE MOUNTED POWER PLANT IN SOUTH EAST SULAWESI.* Surabaya: INSTITUT TEKNOLOGI SEPULUH NOPEMBER.

Santoso, N. B. (2014). Pemanfaatan LNG Sebagai Sumber Energi di Indonesia. *Jurnal Rekayasa Proses, 8*.

Styles, D., Schonberger, H., & Galvez Martos, J. (2017). *Best Environmental Management Practice in The Tourism Sector.* EUR 26022 EN: European Union.

The Center for Chemical Process Safety (CCPS). (2000). *Guidelines for Chemical Process Quantitative Risk Analysis.* New York: A John Wiley & Sons, Inc., Publication.

U.S. Department of Transportation. (26 November, 2020). *TPM Guidance.* Retrieved from Transportation Performance Management: https://www.fhwa.dot.gov/tpm/guidance/avo_factors.pdf

Yun, G. (2007). *BAYESIAN-LOPA METHODOLOGY FOR RISK ASSESSMENT OF AN LNG IMPORTATION TERMINAL*. Texas: Texas A&M University.

ATTACHMENT

ATTACHMENT I: ACCIDENT REPORT IN 2018

Accident Report 2018																	
January																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
1	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Depan Kantor Desa Sanur Kaje	1			1		1		1							2
2		Jl. By Pass Ngurah Rai Simpang 4 TL GBB	1			3		2			1						2
3		Jl. By Pass Ngurah Rai Simpang 4 TL Tirtanadi	1	1		1		2			1		1				1
4		Jl. By Pass Ngurah Rai Simpang 4 TL Tirtanadi	1			1		2			1				1		1
5		Jl. By Pass Ngurah Rai Golden Kris Tours	1	1		2		2		1							2

6		Jl. By Pass Ngurah Rai Grahadi Kuta Badung	1			1		2				1					2
7		Jl. By Pass Ngurah Rai Depan Midian Praja Raksaka	1		1	1		2				1					2
8	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
9	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
10	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			7	2	1	10	0	13	0	2	3	2	1	0	1	0	12
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (January)			7	2	1	10	0	13	0	2	3	2	1	0	1	0	12
February																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike

11	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Selatan Ptung Ngurah Rai	1	1		1		2	1								2
12		Jl. By Pass Ngurah Rai Median Tragia Nusa Dua Kutsel	1			3		3			1						3
13		Jl. By Pass Ngurah Rai Depan SLB Jimbaran Kuta Selatan	1			1		2				1				1	1
14		Jl. By Pass Ngurah Rai Selatan Ptung Tuban	1	1							1		1				1
15		Jl. By Pass Ngurah Rai Depan Kantor AJP Barat	1			1		1		1							2
16		Jl. By Pass Ngurah Rai Mercuri KM 15	1		1					1					1		1
17		Jl. By Pass Ngurah Rai Selatan Langsit Biru	1			1		2				1				1	1

18		Jl. By Pass Ngurah Rai Depan Stan Bunga Sari Tanjung Jaya	1		1	1		2		1			1				1
19		Jl. By Pass Ngurah Rai Sebelah Timur Simpang Jl. Danau	1			1		2				1	1				1
20		Jl. By Pass Ngurah Rai Depan Warung Belitar KM 8	1			3		3		1			1			1	1
21		Jl. By Pass Ngurah Rai Simpang TL Sakenan	1			1		2			1					1	1
22		Jl. By Pass Ngurah Rai Simpang 4 Jl Hangtuah TL GBB	1		1	1		1		1			1				1
23		Jl. By Pass Ngurah Rai Depan Kantor Otel	1			2		1		1		1	1				2

24	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	Jl. Raya Pelabuhan Benoa	Jl Raya Pelabuhan Benoa Pintu Masuk Flores Tiga Dibawah Plang Tol Bali	1			1		2				1		1			1
26	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			13	2	3	16	0	21	1	6	3	4	6	0	1	4	18
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			1	0	0	1	0	2	0	0	0	1	0	1	0	0	1
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (February)			14	2	3	17	0	23	1	6	3	5	6	1	1	4	19
March																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
27	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Simpang 4 TL Sanggaran	1	1								1	1				1

28		Jl. By Pass Ngurah Rai Median Pasiran Jembatan Panjang	1	1		1		2			1						2
29		Jl. By Pass Ngurah Rai Depan Galuh Spa KM 35	1			1		2				1				1	1
30		Jl. By Pass Ngurah Rai Depan Bengkel Tangkas Body Repair KM 10	1			1		1		1					1		1
31		Jl. By Pass Ngurah Rai Petasikan KM 9	1	1				1								1	
32		Jl. By Pass Ngurah Rai Simpang 4 TL GBB DENSEL	1			1		1		1							2

34		Jl. By Pass Ngurah Rai Keluar Depan Kurnia Dewata KM 7	1			1		2				1					2
35		Jl. By Pass Ngurah Rai TL Pratama	1			1		1			1				1		1
36		Jl. By Pass Ngurah Rai Depan Rumah No 280	1			1		2				1			1		1
37	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			9	3	0	7	0	12	0	2	2	4	1	0	3	2	11
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (March)			9	3	0	7	0	12	0	2	2	4	1	0	3	2	11
April																	

No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
40	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Depan Toko Bangunan Murah Makmur	1		1				1								1
41		Jl. By Pass Ngurah Rai Stone Carving Cili Bali KM 5	1	1						1						1	1
42		Jl. By Pass Ngurah Rai Dealer Suzuki KM 7	1	1				1		1				1			1
43		Jl. By Pass Ngurah Rai Simpang 3 Jl Pemogan	1			1		1		1							2
44		Jl. By Pass Ngurah Rai TL Taman Griya Warung Barokah	1			1		2				1			1		1

45		Jl. By Pass Ngurah Rai Depan Bale Bale Woodenhouse	1		1			2			1				1		1
46		Jl. By Pass Ngurah Rai Jl Padang Galak KM 7	1			2		2			1						2
47	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-
48	Jl. Raya Pelabuhan Benoa	Jl. Pelabuhan Benoa di Median Axame KM 12	1		2			2			1						3
49	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-
Total (Jl. By Pass Ngurah Rai)			7	2	2	4	0	8	1	3	2	1	0	1	2	1	9
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			1	0	2	0	0	2	0	0	1	0	0	0	0	0	3
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (April)			8	2	4	4	0	10	1	3	3	1	0	1	2	1	12
May																	
No.	Location	Crime Scene		Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				

			Number of Events	FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
50	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Depan Puri Stone KM 8	1	1				1		1							2
51		Jl. By Pass Ngurah Rai Sebelah Barat Pos Pantau KM 9	1	1		1		1				1					2
52		Jl. By Pass Ngurah Rai Dealer Daihatsu KM 7	1		1			1				1	1				1
53		Jl. By Pass Ngurah Rai SPBU Sakenan	1			1		1			1		1				1
54		Jl. By Pass Ngurah Rai Kuala Kampus Kelan KM 25	1	1				1				1					1

55		Jl. By Pass Ngurah Rai Utara Hotel Cristal Kuta KM 23	1			1		1				1	1				1
56		Jl. By Pass Ngurah Rai No 34 KM 12 Pesanggaran	1	1				2				1	1				1
57		Jl. By Pass Ngurah Rai Depan Mr Kuta	1			2		2	1						1		1
58	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
59	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			8	4	1	5	0	10	1	1	1	5	4	0	1	0	10
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (May)			8	4	1	5	0	10	1	1	1	5	4	0	1	0	10
June																	

No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
61	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Median Panjang Selat Bundaran Patung	1	1		1		2				1	1				1
62		Jl. By Pass Ngurah Rai Depan Rumah Masakan Padang	1	1				2			1				1		1
63		Jl. By Pass Ngurah Rai Depan Onasis Spa Kuta	1	2				1									1
64		Jl. By Pass Ngurah Rai Depan Puri Mumbul Permai	1	1													1
65		Jl. By Pass Ngurah Rai Simpang 4 Jl Padang Galak	1			1		1		1						1	1

66		Jl. By Pass Ngurah Rai Median Panjang Selatan Patung	1		1			2			1		1				1
67		Jl. By Pass Ngurah Rai TL Siligita	1		1			2	1						1		1
68	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
69	Jl. Raya Pelabuhan Benoa	Jl. Raya Pelabuhan Benoa Depan Kantor Pelindo III KM 10	1		1			1			1						1
70		Jl. Raya Pelabuhan Benoa Bawah Jl Toll Bali KM 12	1			2		2			1					1	1
71	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			7	5	2	2	0	10	1	1	2	1	2	0	2	1	7
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			2	0	1	2	0	3	0	0	2	0	0	0	0	1	2

Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (June)			9	5	3	4	0	13	1	1	4	1	2	0	2	2	9
July																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
72	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Ulunsui Jimbaran Kuta Selatan	1			1		2			1				1		1
73		Jl. By Pass Ngurah Rai Depan Mason Advantures	1			1		2			1				1		1
74		Jl. By Pass Ngurah Rai Depan Cosmic Diner	1			2		2				1					2
75		Jl. By Pass Ngurah Rai Ex Tragia Nusa Dua	1			2	1	1			1				1		1
76		Jl. By Pass Ngurah Rai Simpang TL Sakenan	1			2		2			1						2

77		Jl. By Pass Ngurah Rai Depan The Griya Sanur	1		1			2			1					1	
78		Jl. By Pass Ngurah Rai Depan Polaris	1		1	1		2			1		1				1
79		Jl. By Pass Ngurah Rai Depan RS Bali Mandara	1			2		2				1					1
80	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
81	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
82	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			8	0	2	11	1	15	0	0	6	2	1	0	3	1	9
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (July)			8	0	2	11	1	15	0	0	6	2	1	0	3	1	9
August																	
No.	Location	Crime Scene		Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				

			Number of Events	FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
83	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Depan Dealer Suzuki	1		1			1				1			1		
84		Jl. By Pass Ngurah Rai Barat Kantor Indonesia Power	1	1				2			1		1				2
85		Jl. By Pass Ngurah Rai Depan Hotel Sanur Agung	1			2		2			1						1
86		Jl. By Pass Ngurah Rai Under Pass Patung KM 25	1		1						1						1
87		Jl. By Pass Ngurah Rai Kaliuda Galery KM 13	1	1				1			1						1

88		Jl. By Pass Ngurah Rai Sebelah Barat Kantor Pemasaran Urban Oasis	1		1			1				1			1		1
89		Jl. By Pass Ngurah Rai Depan Toko Bokasi	1			1		1				1	1				1
90		Jl. By Pass Ngurah Rai Simpang 4 Pesanggaran	1		1			1				1			1		
91		Jl. By Pass Ngurah Rai Simpang Waribang	1			1		1		1							2
92		Jl. By Pass Ngurah Rai Depan Grahadi Kuta	1		2			1			1			1			1
93	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
94	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

95	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			10	2	6	4	0	11	0	1	5	4	2	1	3	0	10
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (August)			10	2	6	4	0	11	0	1	5	4	2	1	3	0	10
September																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
96	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Median Ulun Suwi Jimbaran	1		1	2		3			1						2
97		Jl. By Pass Ngurah Rai Simpang Taman Griya Jimbaran	1		1	1		1			1						1
98	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Depan Kantor Notaris KM 5	1		1			1			1						2

99		Jl. By Pass Ngurah Rai Depan Hotel The Griya Sanur	1		1	1		2			1						2
100		Jl. By Pass Ngurah Rai Depan Lab Bali Stone KM 7	1			1		1				1	1				1
101		Jl. By Pass Ngurah Rai TL Taman Griya	1			3		3		1							1
102		Jl. By Pass Ngurah Rai Banjar Mumbul Kuta Selatan	1			2		2				1					2
103		Jl. By Pass Ngurah Rai Simpang Trec Kedonganan	1			1		2				1	1				1
104	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Simpang 4 Jl Danau Buyan	1			2		2			1						2

105		Jl. By Pass Ngurah Rai TL GBB KM 7 Sanur	1			1		1			1						2
106	Jl. Pratama Raya	Jl. Pratama Depan Rumah makan Rindu Rasa	1			2		2			1						2
107	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
108	Jl. Toll Bali Mandara	Jl. Tol Bali Mandara KM B 2800 Nusa Dua	1		1	1		2				1					2
Total (Jl. By Pass Ngurah Rai)			10	0	4	14	0	18	0	1	6	3	2	0	0	0	16
Total (Jl. Pratama Raya)			1	0	0	2	0	2	0	0	1	0	0	0	0	0	2
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			1	0	1	1	0	2	0	0	0	1	0	0	0	0	2
Total (September)			12	0	5	17	0	22	0	1	7	4	2	0	0	0	20
October																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike

109	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Depan Dealer Suzuki	1	1		1		2		1					1		
110		Jl. By Pass Ngurah Rai Depan Stan Poetry 66	1			1		1				1			1		1
111		Jl. By Pass Ngurah Rai Depan Maxi Hotel	1	1		2		2			1						2
112		Jl. By Pass Ngurah Rai Depan Hotel Lavender	1		2			2				1			1		1
113		Jl. By Pass Ngurah Rai Barat Indonesia Power	1		1			2			1				1		1
114		Jl. By Pass Ngurah Rai Simpang 4 TL Pesanggaran	1		1			2			1				1		1

115		Jl. By Pass Ngurah Rai Depan Alfamart Kuta Timur	1			1		1		1						1	1
116		Jl. By Pass Ngurah Rai Timur Toll Bali	1			1		1		1						1	1
117		Jl. By Pass Ngurah Rai TL Sakenan	1	1				1		1							2
118		Jl. By Pass Ngurah Rai Depan Dealer Suzuki	1			3		1				1					1
119	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
120	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
121	Jl. Toll Bali Mandara	Jl Tol Bali Mandara KM 800	1		1	1		2			1						2
Total (Jl. By Pass Ngurah Rai)			10	3	4	9	0	15	0	4	3	3	0	0	5	2	11
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total (Jl. Toll Bali Mandara)			1	0	1	1	0	2	0	0	1	0	0	0	0	0	2
Total (October)			11	3	5	10	0	17	0	4	4	3	0	0	5	2	13
November																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
122	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Depan Artikue	1			1		2			1					1	1
123		Jl. By Pass Ngurah Rai MBG Kuta Badung	1	1		1		1				1					2
124		Jl. By Pass Ngurah Rai Clandys Kedonganan	1	1	1			2				1	1				1
125		Jl. By Pass Ngurah Rai Depan Pondok Makan Sari	1	1		1		2		1			1		1		1
126		Jl. By Pass Ngurah Rai Depan RS Bali Mandara	1		1			2		1				1			1

127		Jl. By Pass Ngurah Rai Depan Toko Roja Seluler	1		1			1		1					1		1
128		Jl. By Pass Ngurah Rai Bundaran TL Patung KM 20	1		1	1		2	1								2
129		Jl. By Pass Ngurah Rai Sebelah Barat Jembatan	1		1			1			1						1
130		Jl. By Pass Ngurah Rai Pos Zebra Jimbaran	1			2		2	1								2
131		Jl. By Pass Ngurah Rai Depan Mcdonalds	1			1		2				1	1				1
132	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
133	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
134	Jl. Toll Bali Mandara	Jl Toll Bali Mandara KM 4500 Kuta	1	1				2				1	1		1		

Total (Jl. By Pass Ngurah Rai)			10	3	5	7	0	17	2	3	2	3	3	1	2	1	13
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			1	1	0	0	0	2	0	0	0	1	1	0	1	0	0
Total (November)			11	4	5	7	0	19	2	3	2	4	4	1	3	1	13
December																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
135	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai TL Tohpati KM 6	1	1				1				1	1				1
136		Jl. By Pass Ngurah Rai Depan Hotel Grand Mega	1			1						1			1		
137		Jl. By Pass Ngurah Rai Suar Tour KM 6	1	1				1				1			1		1
138		Jl. By Pass Ngurah Rai Sekolah SMK Nusa Dua	1			1		1		1							2

139		Jl. By Pass Ngurah Rai Mekar Abadi Bangunan	1	1				3				1	1		1		1
140		Jl. By Pass Ngurah Rai Median Drupadi Café	1	1			2				1		1		1		1
141		Jl. By Pass Ngurah Rai Kantor Pembuangan Limbah	1	1				1				1	1				1
142	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
143	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
144	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			7	5	0	2	2	7	0	1	1	5	4	0	4	0	7
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (December)			7	5	0	2	2	7	0	1	1	5	4	0	4	0	7

Summary Accident Report In 2018																	
No	Description	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
			FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
1	Total Accident in 2018 (Jl. By Pass Ngurah Rai)	106	31	30	91	3	157	6	25	36	37	26	3	27	12	133
2	Total Accident in 2018 (Jl. Pratama Raya)	1	0	0	2	0	2	0	0	1	0	0	0	0	0	2
3	Total Accident in 2018 (Jl. Raya Pelabuhan Benoa)	4	0	3	3	0	7	0	0	3	1	0	1	0	1	6
4	Total Accident in 2018 (Jl. Toll Bali Mandara)	3	1	2	2	0	6	0	0	1	2	1	0	1	0	4
5	Total Accident in 2018	114	32	35	98	3	172	6	25	41	40	27	4	28	13	145

ATTACHMENT II: ACCIDENT REPORT IN 2019

Accident Report 2019																	
January																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
1	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Depan Kurnia Dewata POT KM 7	1		1			1		1							2
2		Jl. By Pass Ngurah Rai Depan Kantor Lurah Kedonganan KM 26	1	1				2				1	1		1		1
3		Jl. By Pass Ngurah Rai Median Kapuas Kelan	1	1	1	3		2			1						2

4		Jl. By Pass Ngurah Rai Depan Prambana Kencana KM 7 Padang Galak	1			1		2				1				1	1
5		Jl. By Pass Ngurah Rai Depan Toko mahkota Bali KM 7	1			2		1			1					1	1
6		Jl. By Pass Ngurah Rai Depan Klinik Spesialis Kulit	1		1	2		2				1					2
7		Jl. By Pass Ngurah Rai Depan Mideian Depan Bali Fantasi	1		1	1		2			1				1		1
8		Jl. By Pass Ngurah Rai Depan Warung Laota Jimbaran	1		1			1				1			1		1

9	Jl. Pratama Raya	Jl. Pratama Raya Nusa Dua Depan Hotel Conrad KM 33 Kuta Selatan	1	1	1			2	1								2
10		Jl. Pratama Raya Nusa Dua Depan Warung Soto Cuplik	1	1	1	1		2	1						2		1
11	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
12	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			8	2	5	9	0	13	0	1	3	4	1	0	3	2	11
Total (Jl. Pratama Raya)			2	2	2	1	0	4	2	0	0	0	0	0	2	0	3
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (January)			10	4	7	10	0	17	2	1	3	4	1	0	5	2	14
February																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike

14	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Selatan Ptung Titibanda	1	1		1		2				1					2
15		Jl. By Pass Ngurah Rai Dekat Median Fantasi	1	2				2				1			1		1
16		Jl. By Pass Ngurah Rai Timur Lapangan Kapten Japa	1		1	3		3				1					3
17	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			3	3	1	4	0	7	0	0	0	3	0	0	1	0	6
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (February)			3	3	1	4	0	7	0	0	0	3	0	0	1	0	6
March																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
20	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai KM 25	1			1		1				1			1		2
21		Jl. By Pass Ngurah Rai Keluar Under Pass	1			1		1		1					1		1
22	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			2	0	0	2	0	2	0	1	0	1	0	0	2	0	3
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total (March)			2	0	0	2	0	2	0	1	0	1	0	0	2	0	3
April																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
25	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Grapari Telkomsel	1	1		1		1		1							2
26		Jl. By Pass Ngurah Rai Pom Bensin Sakenan	1		1	1		2			1			1			1
27		Jl. By Pass Ngurah Rai Simpang 3 Jl. IB Mantra	1			1		1				1					2
28		Jl. By Pass Ngurah Rai Depan Diamond Cold	1	1				2				1	1				1
29	Jl. Pratama Raya	Jl. Pratama Raya Nusa Dua Depan Siobak Singaraja	1		1	1		2			1						2

30	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-		-	-		-	-	-
31	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-		-	-		-	-	-
Total (Jl. By Pass Ngurah Rai)			4	2	1	3	0	6	0	1	1	2	1	1	0	0	6
Total (Jl. Pratama Raya)			1	0	1	1	0	2	0	0	1	0	0	0	0	0	2
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (April)			5	2	2	4	0	8	0	1	2	2	1	1	0	0	8
May																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
32	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Depan Bali Poam KM 10 Densel	1	1				1				1			1		1
33		Jl. By Pass Ngurah Rai Depan Rumah 52 Kedonganan KM 27	1	1				1				1				1	1

34		Jl. By Pass Ngurah Rai KM 7 Dentim	1			1		1		1						1	1
35		Jl. By Pass Ngurah Rai Median Ulunsui Jimbaran Kuta	1			2		2			1				1		1
36		Jl. By Pass Ngurah Rai Jimbaran Selatan Mekar Abadi Bangunan	1			2		2				1	1				1
37	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			5	2	0	5	0	7	0	1	1	3	1	0	2	2	5
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (May)			5	2	0	5	0	7	0	1	1	3	1	0	2	2	5
June																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
40	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Simpang Jl. Raya Pelabuhan Benoa	1	1				1			1		1				1
41		Jl. By Pass Ngurah Rai Jembatan Panjang Jimbaran KM 28	1			1		2				1	1				1
42		Jl. By Pass Ngurah Rai Depan PT Tunas Jaya	1			1		2		1					1		1
43		Jl. By Pass Ngurah Rai Depan Alfa Mart KM 30	1	1				2				1	1				1

44		Jl. By Pass Ngurah Rai Depan Lapangan Golf Sanur	1	1				2				1			1		1
45		Jl. By Pass Ngurah Rai Depan Toko Aneh Aneh	1		1			2	1								2
46	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
47	Jl. Raya Pelabuhan Benoa	Jl. Raya Pelabuhan Benoa Keluar Toll Flores III KM 9	1			1		2		1						1	1
48	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			6	3	1	2	0	11	1	1	1	3	3	0	2	0	7
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			1	0	0	1	0	2	0	1	0	0	0	0	0	1	1
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (June)			7	3	1	3	0	13	1	2	1	3	3	0	2	1	8
July																	

No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
49	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai TL Taman Griya Jimbaran	1	1				2				1			1		1
50		Jl. By Pass Ngurah Rai Median Depan Golden Gete KM 20	1		1			2			1		1				1
51		Jl. By Pass Ngurah Rai Simpang Empat Jl Danau Buyan TL Taman Ari	1	1				2			1				1		1
52		Jl. By Pass Ngurah Rai Desa Budaya Kertalangu KM 7	1		1			2		1					1		1

53		Jl. By Pass Ngurah Rai Simpang Empat Jl. Pesanggaran	1		1			2			1				1		1
54		Jl. By Pass Ngurah Rai Depan IM'BE'U KM 10 Pesanggaran	1	1				1		1				1			1
55	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
56	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
57	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			6	3	3	0	0	11	0	2	3	1	1	1	4	0	6
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (July)			6	3	3	0	0	11	0	2	3	1	1	1	4	0	6
August																	

No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
58	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Median Timur TL Sakenan	1			1		1		1					1		1
59		Jl. By Pass Ngurah Rai Median Depan Br. Bumbul KM 27	1	1				2				1			1		1
60		Jl. By Pass Ngurah Rai Depan Kantor PT Sakidin LPG	1		1	1					1		1				1
61	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
62	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
63	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Total (Jl. By Pass Ngurah Rai)			3	1	1	2	0	3	0	1	1	1	1	0	2	0	3
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (August)			3	1	1	2	0	3	0	1	1	1	1	0	2	0	3
September																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
64	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Depan Stand Kerajinan KM 7	1			1		2				1	1				1
65		Jl. By Pass Ngurah Rai Simpang 4 TL Sakenan	1			1		1		1						1	1
66		Jl. By Pass Ngurah Rai Depan Travel Sandaholiday Kuta	1			1		1			1						2

67		Jl. By Pass Ngurah Rai Depan Hotel Mumbul Kuta Selatan	1		1			1		1			1				1
68		Jl. By Pass Ngurah Rai Simpang Empat TL Tirta Nadi KM 10	1		2	1		2		1							2
69		Jl. By Pass Ngurah Rai Depan PT Oceana Biru	1		2	1		1				1					2
70		Jl. By Pass Ngurah Rai Simpang 4 TL Waribang KM 6	1		1	1		2			1						2
71		Jl. By Pass Ngurah Rai Simpang Traffic Light Pintu Toll	1		1							1					2
72		Jl. By Pass Ngurah Rai Depan Pura Penghulu Carik	1			2		1			1						2

73		Jl. By Pass Ngurah Rai Pintu Keluar Toll Pertigaan	1			1		2			1		1				1
74	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
75	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
76	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			10	0	7	9	0	13	0	3	4	3	3	0	0	1	16
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (September)			10	0	7	9	0	13	0	3	4	3	3	0	0	1	16
October																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike

77	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Depan Citra Bali Salon	1			1		2		1			1				1
78		Jl. By Pass Ngurah Rai Utara Kafe KM 9	1		1			1				1	1				1
79		Jl. By Pass Ngurah Rai Depan Toko Wisata Belanja Dewata	1		1	1		2			1						2
80		Jl. By Pass Ngurah Rai Depan Median Stand Air Mancur	1			2		2			1						2
81		Jl. By Pass Ngurah Rai Depan Hardys Hotel dan Spa	1		1			1		1							2
82		Jl. By Pass Ngurah Rai Timur Dewa Ruci	1			2		1		1							2

83		Jl. By Pass Ngurah Rai Sebelah Barat Pura Candi Narmada	1		1			2				1	1				1
84	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
85	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
86	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			7	0	4	6	0	11	0	3	2	2	3	0	0	0	11
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (October)			7	0	4	6	0	11	0	3	2	2	3	0	0	0	11
November																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike

87	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai TL GBB KM 7 Sanur	1			3		2				1					2
88		Jl. By Pass Ngurah Rai Depan Warung Bu Yanto KM 8	1			1		1		1					1		1
89		Jl. By Pass Ngurah Rai Depan Pos Pantau PJR Suwung	1			1		2				1			1		1
90		Jl. By Pass Ngurah Rai TL Depan Toko Wisata	1		2			2			1						2
91		Jl. By Pass Ngurah Rai Depan Dealer Nissan Kedonganan	1		1			2				1			1		1
92		Jl. By Pass Ngurah Rai Depan Simpang TL Sanggaran	1			1		1	1								2

93		Jl. By Pass Ngurah Rai Depan Rumah Makan Kedaton	1		1			2		1					1		1
94		Jl. By Pass Ngurah Rai Simpang Traffic Light WR Supratman	1			2		1			1						2
95		Jl. By Pass Ngurah Rai BR. Wates Jimbaran	1	1		1		3				1			1	1	
96	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
97	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
98	Jl. Toll Bali Mandara	Jl Toll Bali Mandara KM 5,6	1	1				1									1
Total (Jl. By Pass Ngurah Rai)			9	1	4	9	0	16	1	2	2	4	0	0	5	1	12
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total (Jl. Toll Bali Mandara)			1	1	0	0	0	1	0	0	0	0	0	0	0	0	1
Total (November)			10	2	4	9	0	17	1	2	2	4	0	0	5	1	13
December																	
No.	Location	Crime Scene	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
				FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
99	Jl. By Pass Ngurah Rai	Jl. By Pass Ngurah Rai Timur Perum Kerta Lestari	1	2		1		2				1			1		1
100		Jl. By Pass Ngurah Rai Depan Kantor CV Menara KM 20	1	1				2				1	1				1
101		Jl. By Pass Ngurah Rai Depan Orenge KM 10	1	1				1		1							2
102		Jl. By Pass Ngurah Rai Timur Jembatan Tanah Kilap	1		1			1				1			1		1

103		Jl. By Pass Ngurah Rai Depan Stand Kerajinan Ukiran Junita Jaya	1	1				1		1							2
104		Jl. By Pass Ngurah Rai Depan Simpang TL GBB KM 7 Simpang 4	1			2		2		1					1		1
105		Jl. By Pass Ngurah Rai Depan Papan Iton Supermarket	1		1			1			1						2
106		Jl. By Pass Ngurah Rai Depan Klinik Pratama Remdium Care	1			1		2			1						2
107		Jl. By Pass Ngurah Rai Depan Petshop Bahagia	1			2		2				1			1		1

108		Jl. By Pass Ngurah Rai Depan Stand Bali Tirta	1		1	2		3				1			1		1
109		Jl. By Pass Ngurah Rai Depan Proyek DSDP KM 10	1			1		1		1			1				1
110		Jl. By Pass Ngurah Rai Depan Coco De Haeven	1	1		1		2				1			1		1
111	Jl. Pratama Raya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
112	Jl. Raya Pelabuhan Benoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
113	Jl. Toll Bali Mandara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total (Jl. By Pass Ngurah Rai)			12	6	3	10	0	20	0	4	2	6	2	0	6	0	16
Total (Jl. Pratama Raya)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Raya Pelabuhan Benoa)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Jl. Toll Bali Mandara)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (December)			12	6	3	10	0	20	0	4	2	6	2	0	6	0	16

Summary Accident Report In 2019																
No	Description	Number of Events	Consequences			Damage to Vehicle		Type of Accident				Involved Vehicle				
			FA	MAI	MII	MAD	MID	FF	SS	FS	FB	Truck	Bus	Car	Pick-Up	Motorbike
1	Total Accident in 2019 (Jl. By Pass Ngurah Rai)	75	23	30	61	0	120	2	20	20	33	16	2	27	6	102
2	Total Accident in 2019 (Jl. Pratama Raya)	3	2	3	2	0	6	2	0	1	0	0	0	2	0	5
3	Total Accident in 2019 (Jl. Raya Pelabuhan Benoa)	1	0	0	1	0	2	0	1	0	0	0	0	0	1	1

4	Total Accident in 2019 (Jl. Toll Bali Mandara)	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1
5	Total Accident in 2019	80	26	33	64	0	129	4	21	21	33	16	2	29	7	109

ATTACHMENT III: LOCAL ENHANCING PARAMETERS *(hj)*

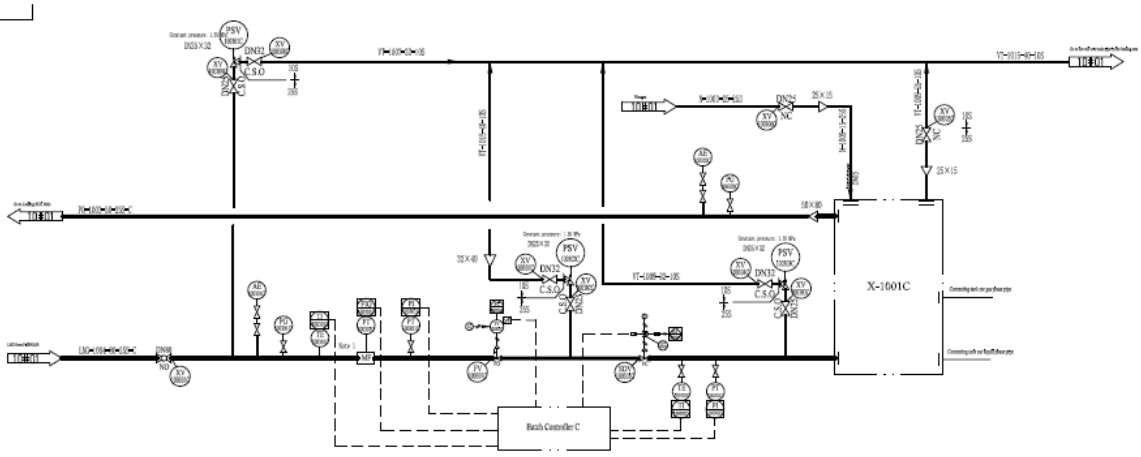
Raya Pelabuhan Benoa Road			Value
Intrinsic Characteristics	*h1*	Straight road	1
		Road bend (radius>200 m)	-
		Road bend (radius<200 m)	-
	h2	Plane road	1
		Slope road (gradient<5%)	-
Intrinsic Characteristics	*h2*	Steep slope road (gradient>5%)	-
		Downhill road (gradient<5%)	-
		Steep downhill road (gradient<5%)	-
	h3	Two lanes for each carriageway	-
		Two lanes and emergency lane for each carriageway	-
		Three lanes and emergency lane for each carriageway	0,8
	h6	Tunnel	-
		Bridge	-
Meteorological Conditions	*h4*	Fine Weather	1
		Rain	1,5
		Snow/ice	-
Traffic Characteristics	*h5*	Low intensity < 500 vehicle/h	-
		Medium intensity < 1250 vehicle per hour with heavy traffic < 125 truck per day	-
		High intensity > 1250 vehicle per hour	-
		High intensity > 1250 vehicle per hour with heavy traffic > 250 truck per day	2,4
		Total	7,7

Mandara Toll Road			Value
Intrinsic Characteristics	*h1*	Straight road	1
		Road bend (radius>200 m)	1,3
		Road bend (radius<200 m)	-
	h2	Plane road	1
		Slope road (gradient<5%)	1,1
		Steep slope road (gradient>5%)	-
		Downhill road (gradient<5%)	-
		Steep downhill road (gradient<5%)	-
	h3	Two lanes for each carriageway	-
		Two lanes and emergency lane for each carriageway	1,2
		Three lanes and emergency lane for each carriageway	-
	h6	Tunnel	-
		Bridge	-
Meteorological Conditions	*h4*	Fine Weather	1
		Rain	1,5
		Snow/ice	-
Traffic Characteristics	*h5*	Low intensity < 500 vehicle/h	-
		Medium intensity < 1250 vehicle per hour with heavy traffic < 125 truck per day	-
		High intensity > 1250 vehicle per hour	-
		High intensity > 1250 vehicle per hour with heavy traffic > 250 truck per day	2,4
		Total	10,5

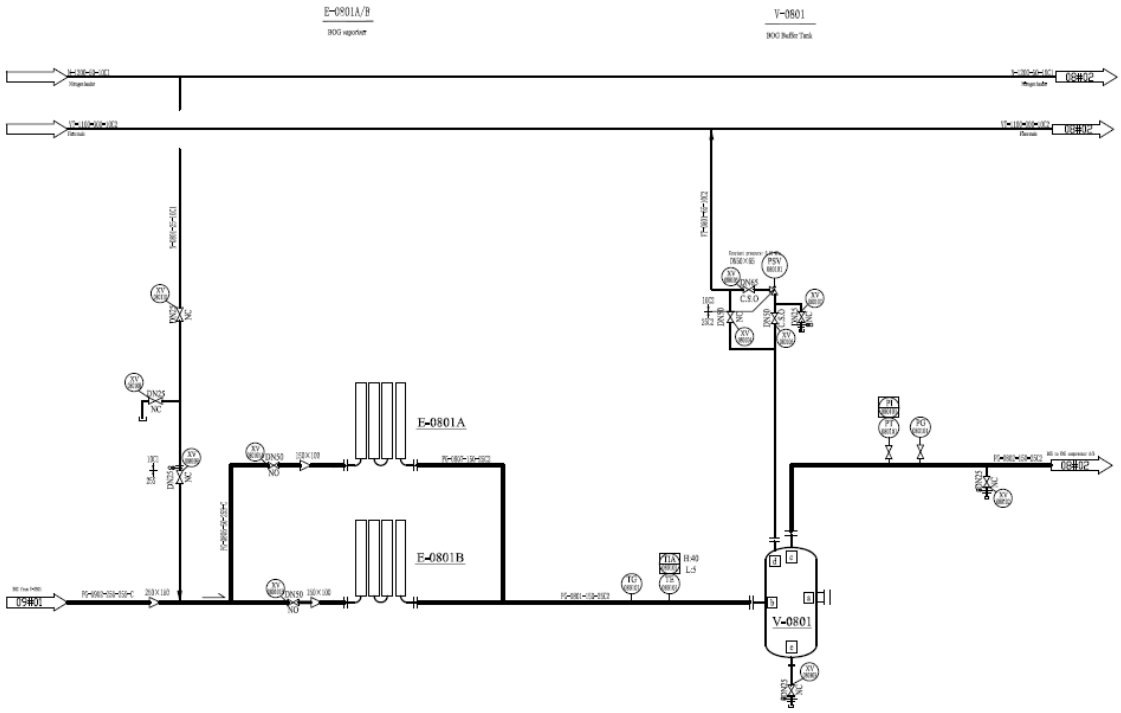
By Pass Ngurah Rai Road			Value
Intrinsic Characteristics	*h1*	Straight road	1
		Road bend (radius>200 m)	1,3
		Road bend (radius<200 m)	-
	h2	Plane road	1
		Slope road (gradient<5%)	-
		Steep slope road (gradient>5%)	-
		Downhill road (gradient<5%)	-
		Steep downhill road (gradient<5%)	-
	h3	Two lanes for each carriageway	1,8
		Two lanes and emergency lane for each carriageway	-
		Three lanes and emergency lane for each carriageway	-
	h6	Tunnel	-
		Bridge	-
Meteorological Conditions	*h4*	Fine Weather	1
		Rain	1,5
		Snow/ice	-
Traffic Characteristics	*h5*	Low intensity < 500 vehicle/h	-
		Medium intensity < 1250 vehicle per hour with heavy traffic < 125 truck per day	-
		High intensity > 1250 vehicle per hour	-
		High intensity > 1250 vehicle per hour with heavy traffic > 250 truck per day	2,4
		Total	10

Pratama Raya Road			Value
Intrinsic Characteristics	*h1*	Straight road	1
		Road bend (radius>200 m)	1,3
		Road bend (radius<200 m)	-
	h2	Plane road	1
		Slope road (gradient<5%)	-
		Steep slope road (gradient>5%)	-
		Downhill road (gradient<5%)	-
		Steep downhill road (gradient<5%)	-
	h3	Two lanes for each carriageway	1,8
		Two lanes and emergency lane for each carriageway	-
		Three lanes and emergency lane for each carriageway	-
	h6	Tunnel	-
		Bridge	-
Meteorological Conditions	*h4*	Fine Weather	1
		Rain	1,5
		Snow/ice	-
Traffic Characteristics	*h5*	Low intensity < 500 vehicle/h	-
		Medium intensity < 1250 vehicle per hour with heavy traffic < 125 truck per day	1
		High intensity > 1250 vehicle per hour	-
		High intensity > 1250 vehicle per hour with heavy traffic > 250 truck per day	-
		Total	8,6

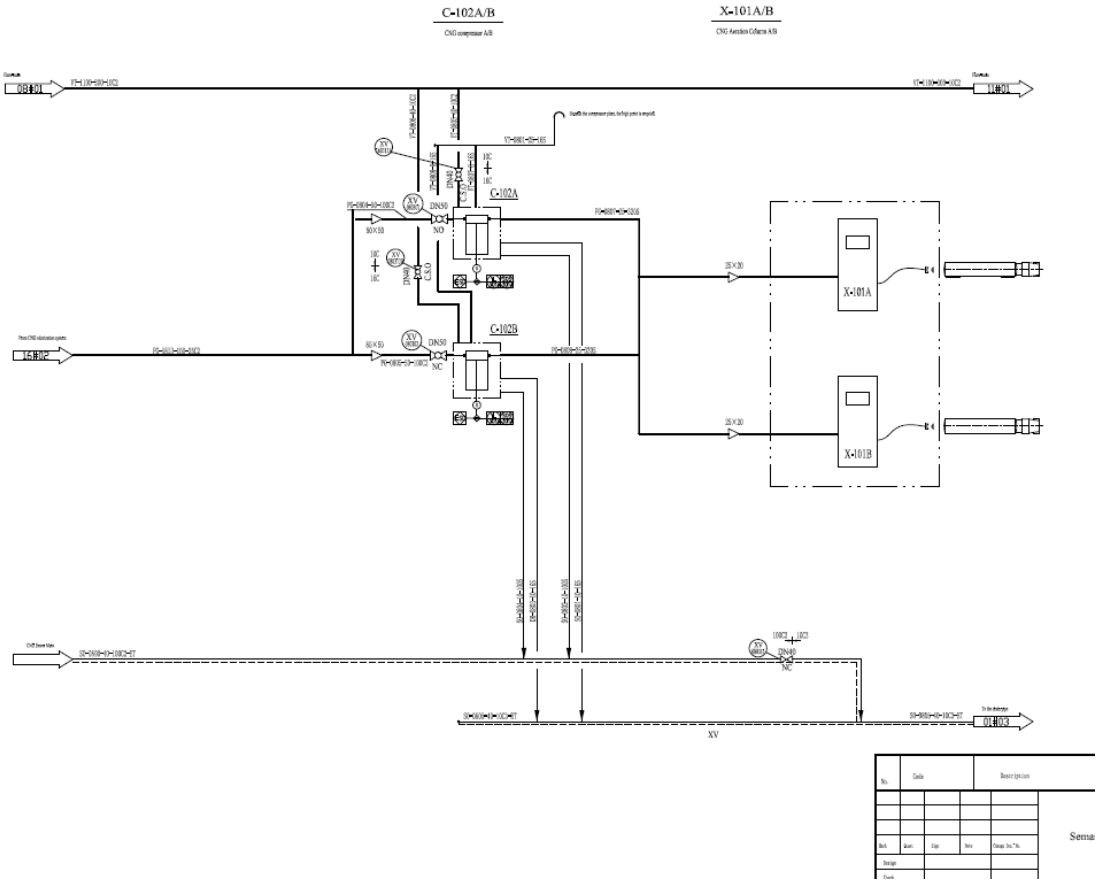
ATTACHMENT IV: PIPING AND INSTRUMENTATION DIAGRAM



LNG Filling Station P&ID

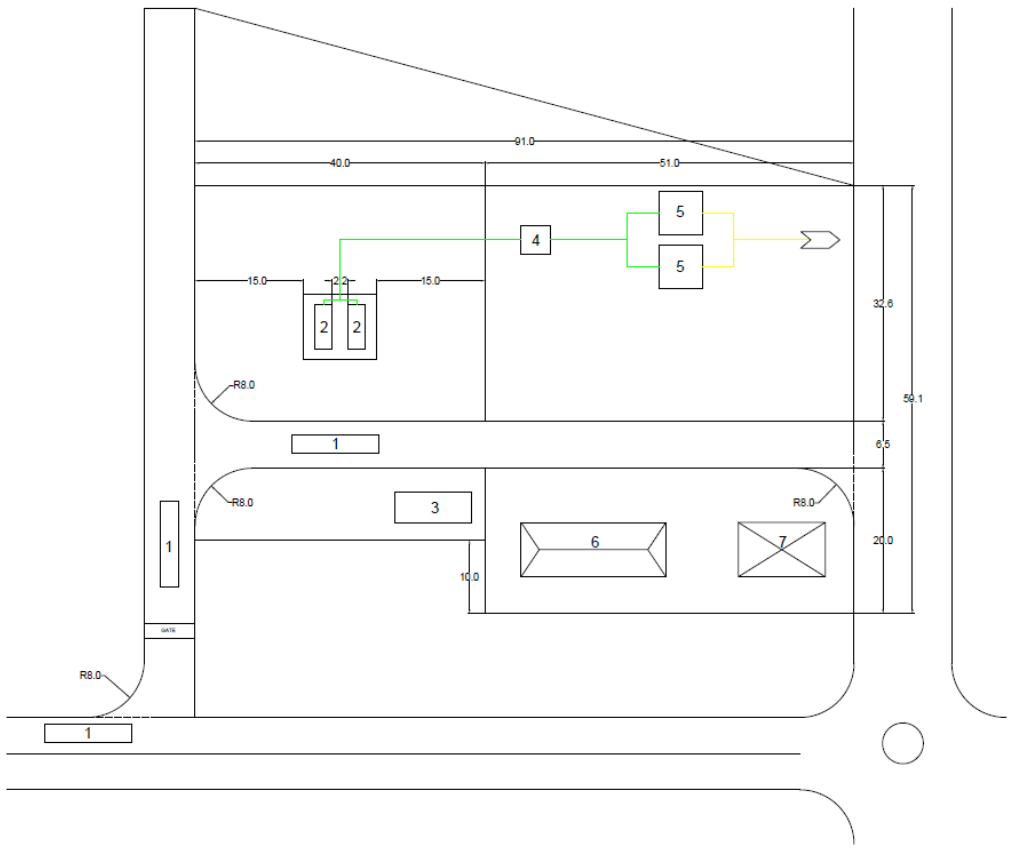


SSGS P&ID LNG ISO Tank to AAV



SSGS P&ID AAV to CNG Compressor

ATTACHMENT V: SMALL-SCALE GAS STATION LAYOUT



INFORMATION	
No.	Description
1	LNG Truck
2	LNG ISO Tank
3	Reach Stacker Crane
4	LNG Pump
5	Ambient Air Vaporizer
6	SSGS Office
7	SSGS Control Room
___	Cryogenic Pipe ISO Tank - AAV
	NG Liquid Phase
___	Pipeline NG AAV - ITDC Facilities
	NG Gas Phase

DOUBLE DEGREE - DEPARTMENT OF MARINE ENGINEERING
INSTITUT TEKNOLOGI SEPULUH NOPEMBER - HOCHSCHULE WISMAR
BACHELOR THESIS
ODD SEMESTER 2020/2021

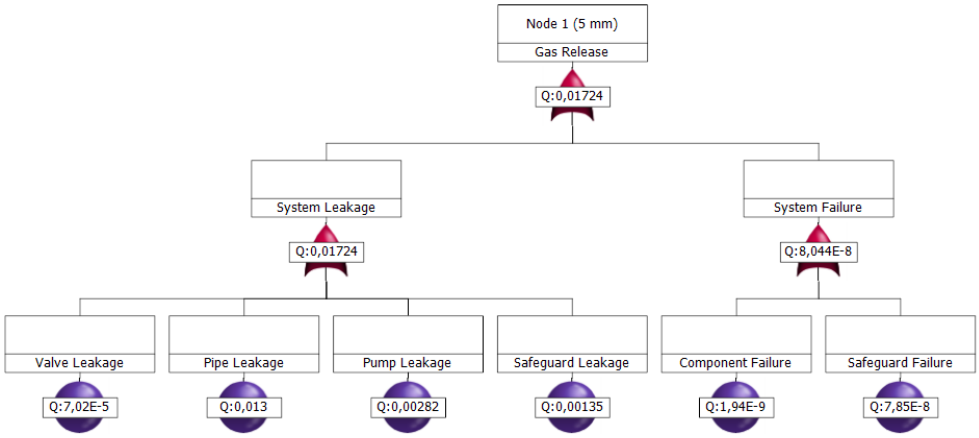
SMALL SCALE GAS STATION
ITDC NUSA DUA BALI

SSGS LAYOUT

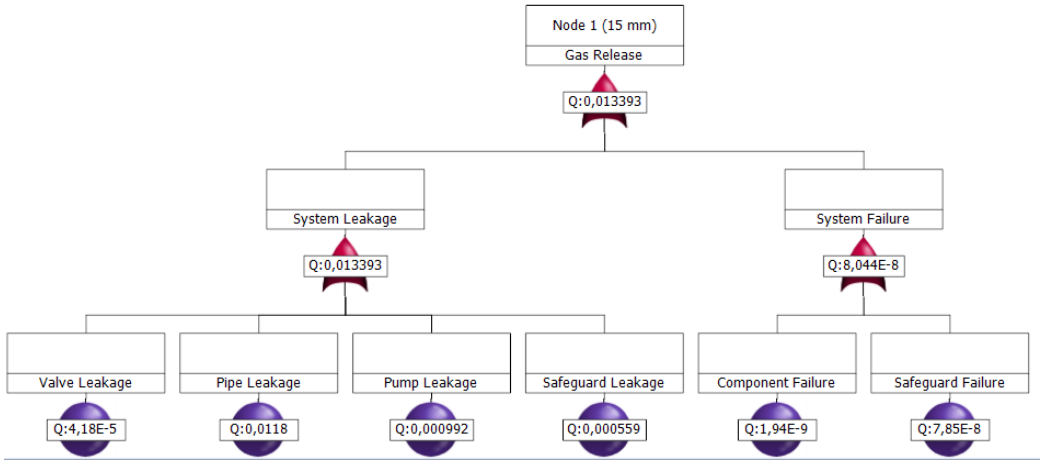
Prepared by: Bagus Setiawan Rozmira Putra 04211174 1000033 — Signature

Approved by: - — Signature

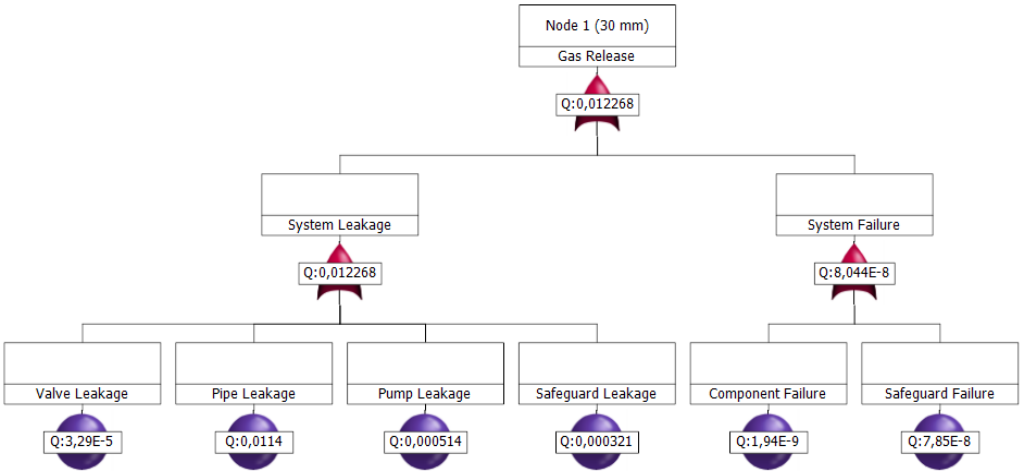
ATTACHMENT VI: FAULT TREE ANALYSIS (FTA)



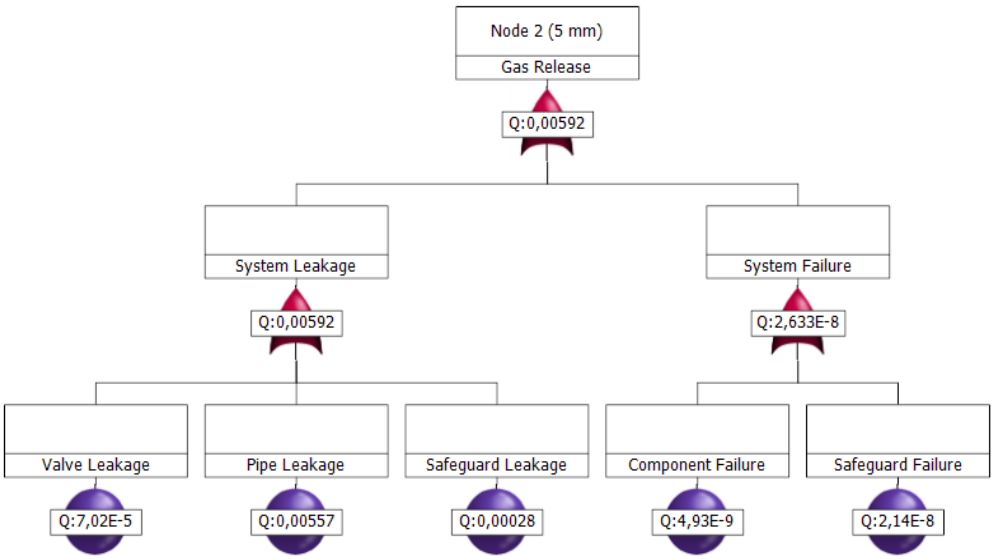
FTA NODE 1 SCENARIO 5 MM



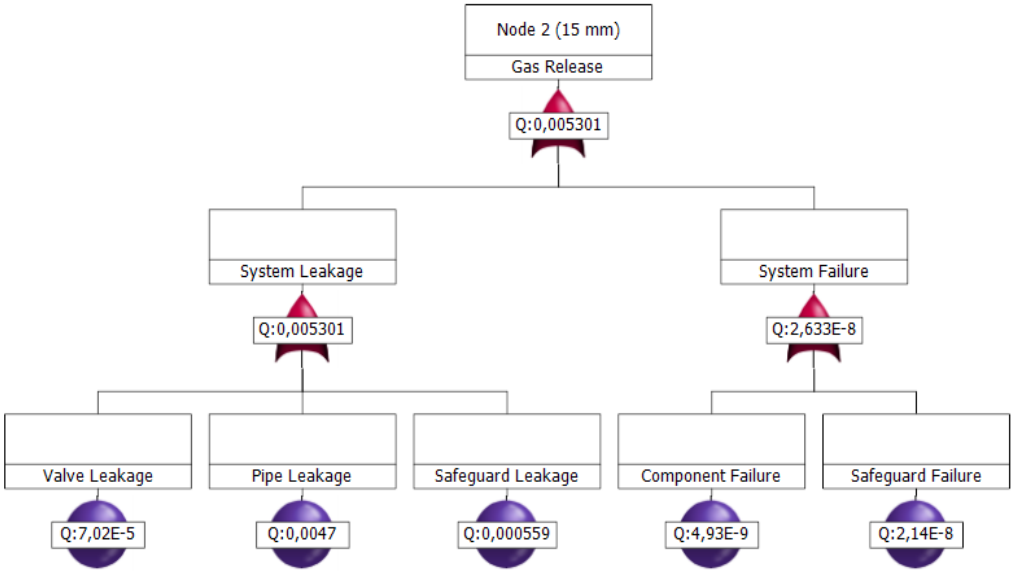
FTA NODE 1 SCENARIO 15 MM



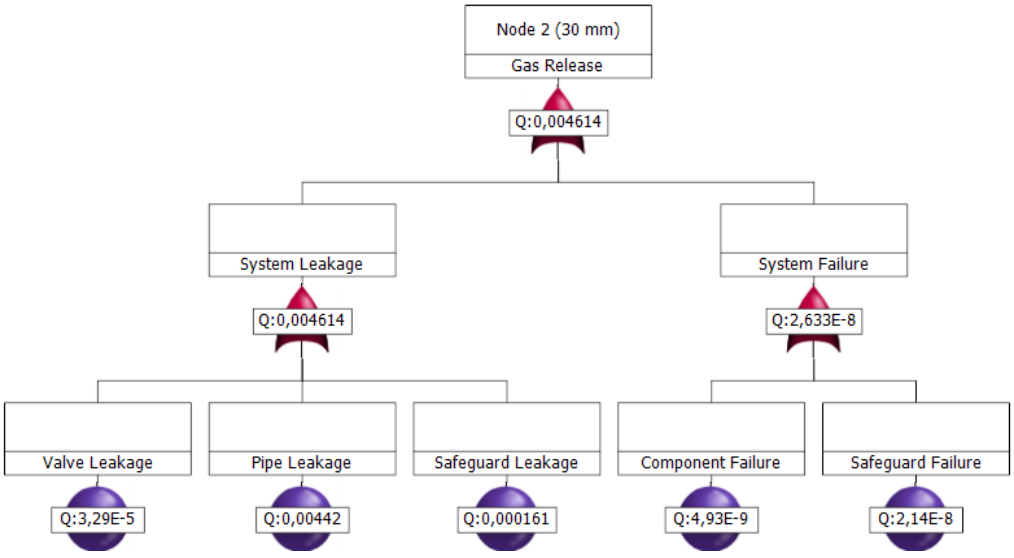
FTA NODE 1 SCENARIO 30 MM



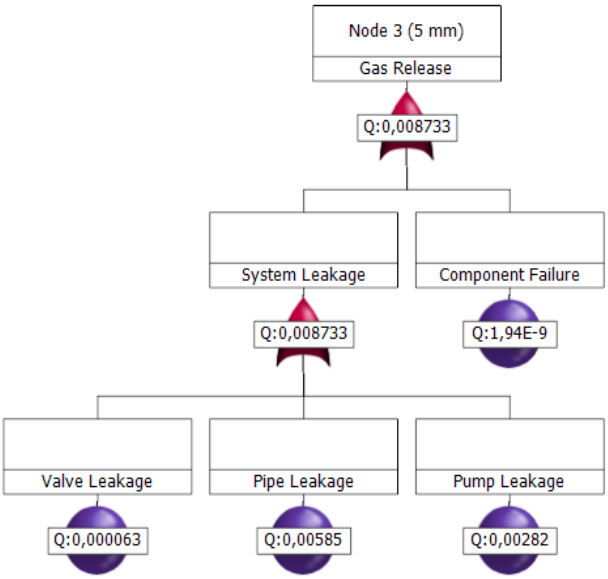
FTA NODE 2 SCENARIO 5 MM



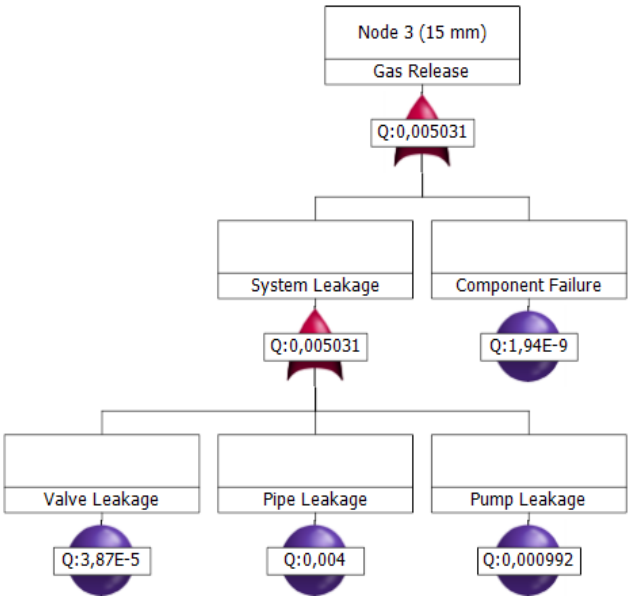
FTA NODE 2 SCENARIO 15 MM



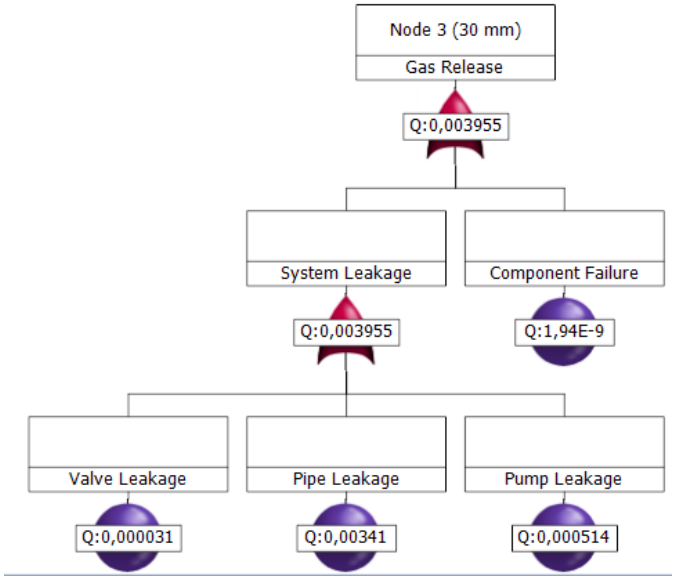
FTA NODE 2 SCENARIO 30 MM



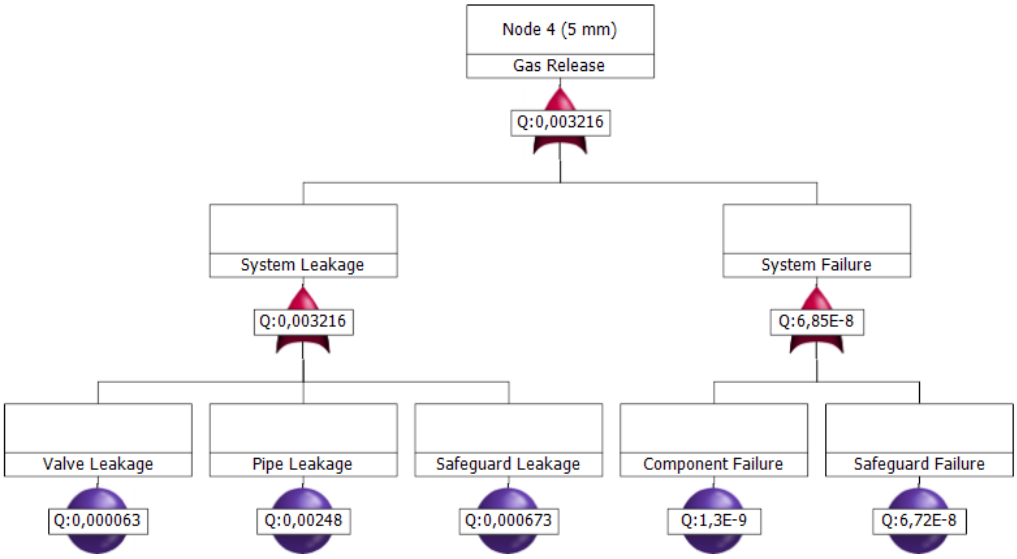
FTA NODE 3 SCENARIO 5 MM



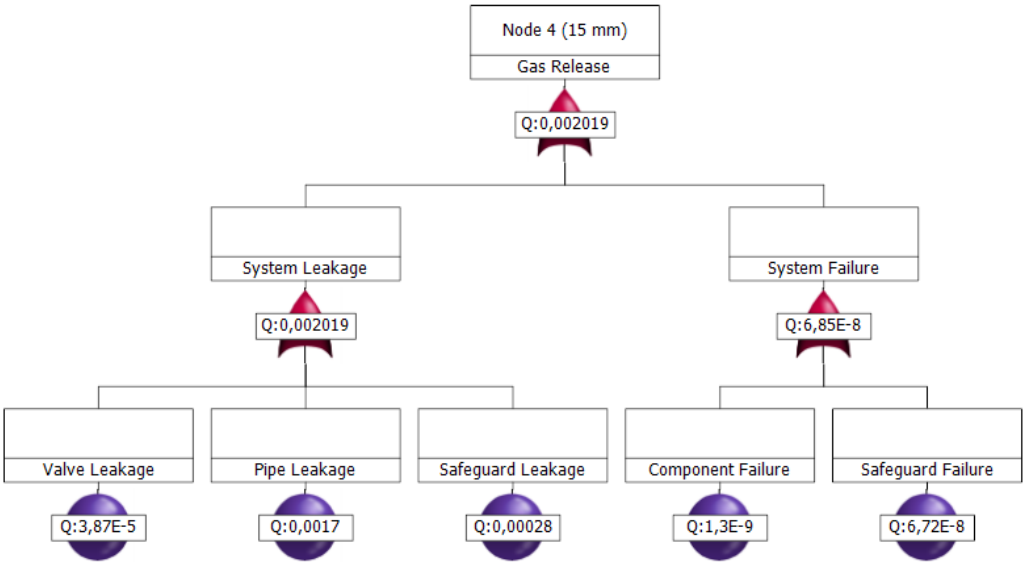
FTA NODE 3 SCENARIO 15 MM



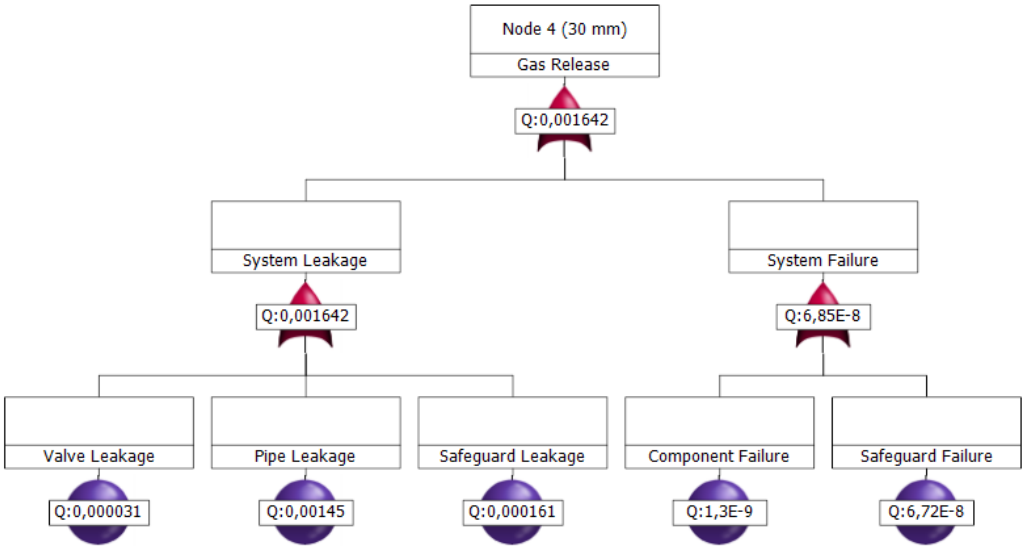
FTA NODE 3 SCENARIO 30 MM



FTA NODE 4 SCENARIO 5 MM



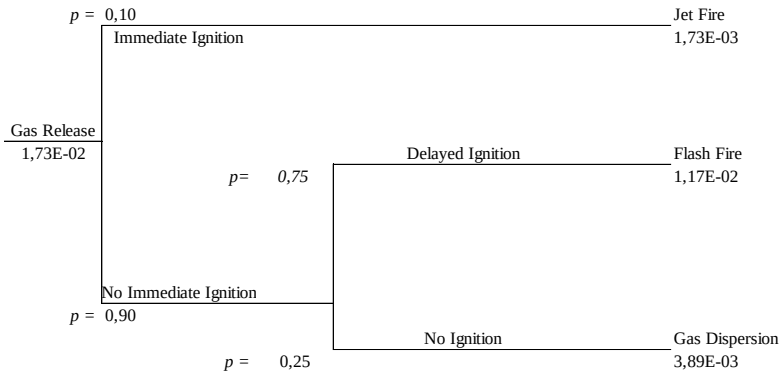
FTA NODE 4 SCENARIO 15 MM



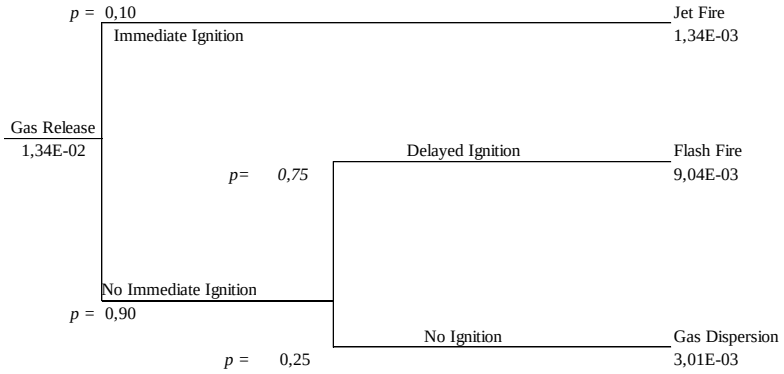
FTA NODE 4 SCENARIO 30 MM

ATTACHMENT VII: EVENT TREE ANALYSIS (ETA)

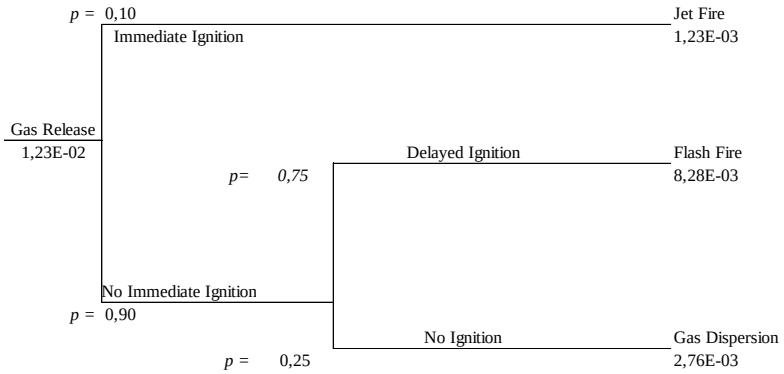
Node 1 Scenario 5 mm



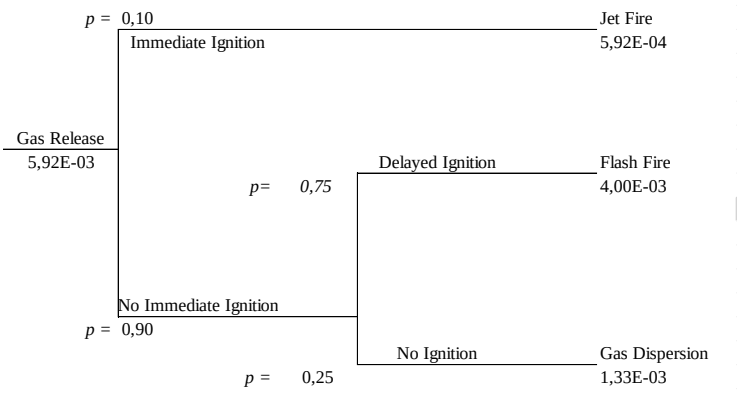
Node 1 Scenario 15 mm



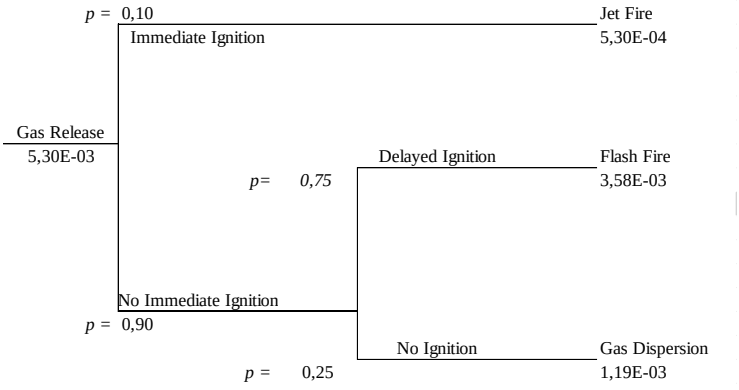
Node 1 Scenario 30 mm



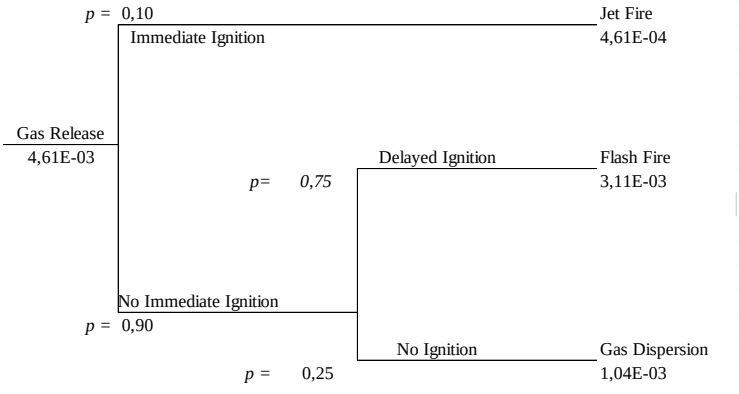
Node 2 Scenario 5 mm



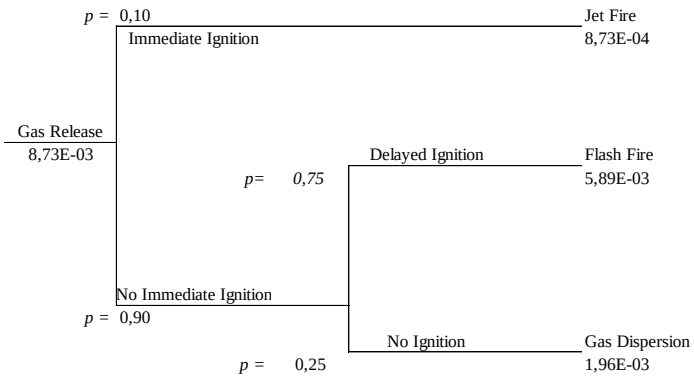
Node 2 Scenario 15 mm



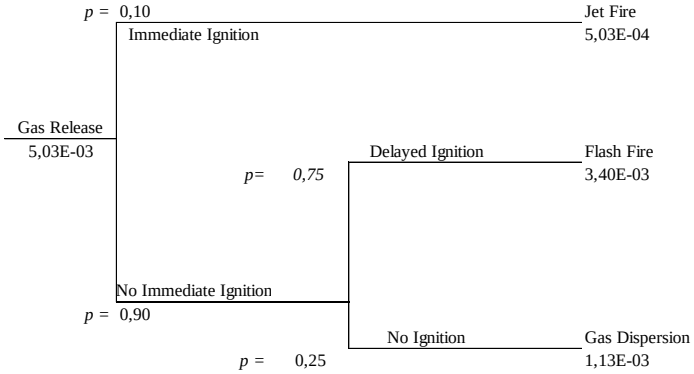
Node 2 Scenario 30 mm



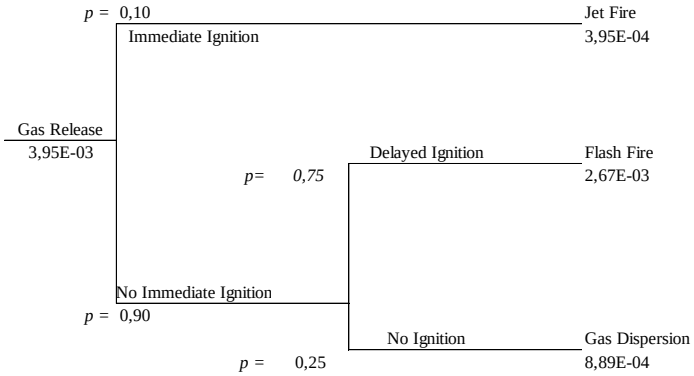
Node 3 Scenario 5 mm



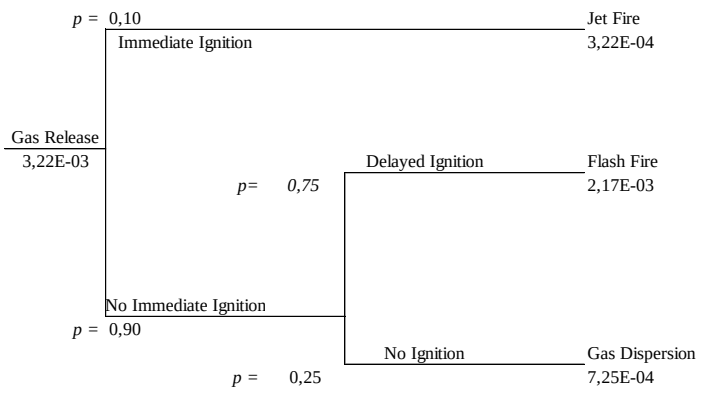
Node 3 Scenario 15 mm



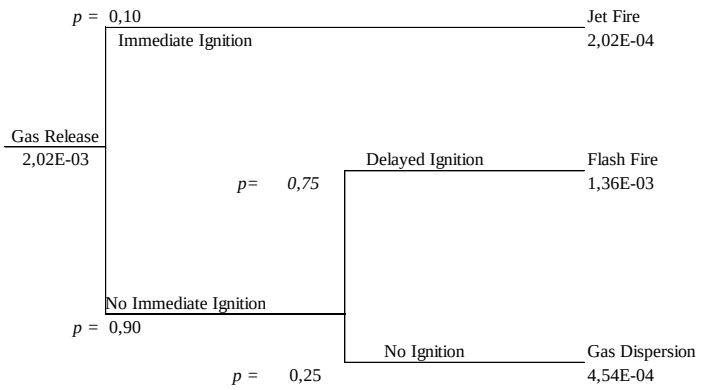
Node 3 Scenario 30 mm



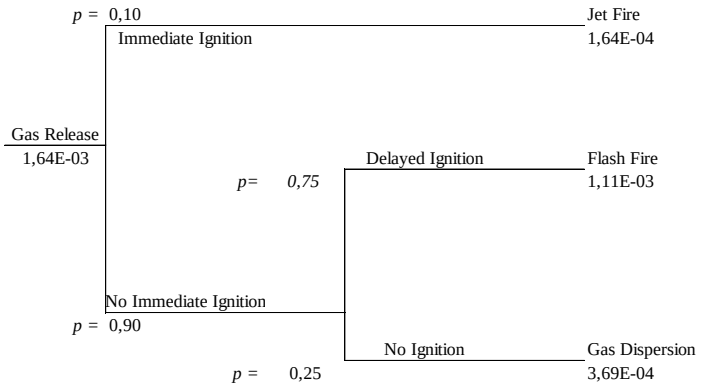
Node 4 Scenario 5 mm



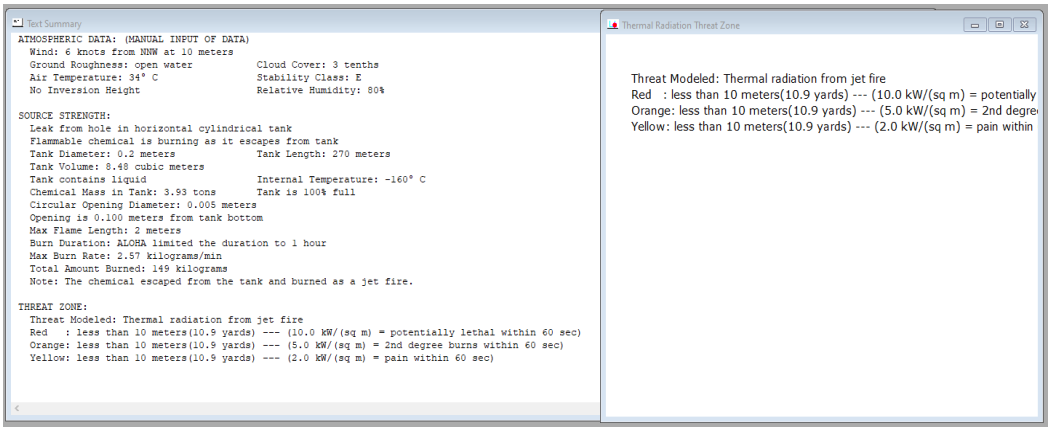
Node 4 Scenario 15 mm



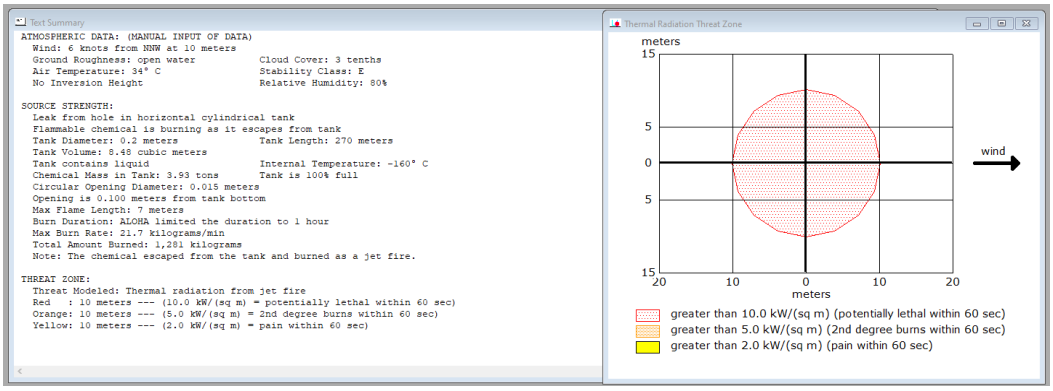
Node 4 Scenario 30 mm



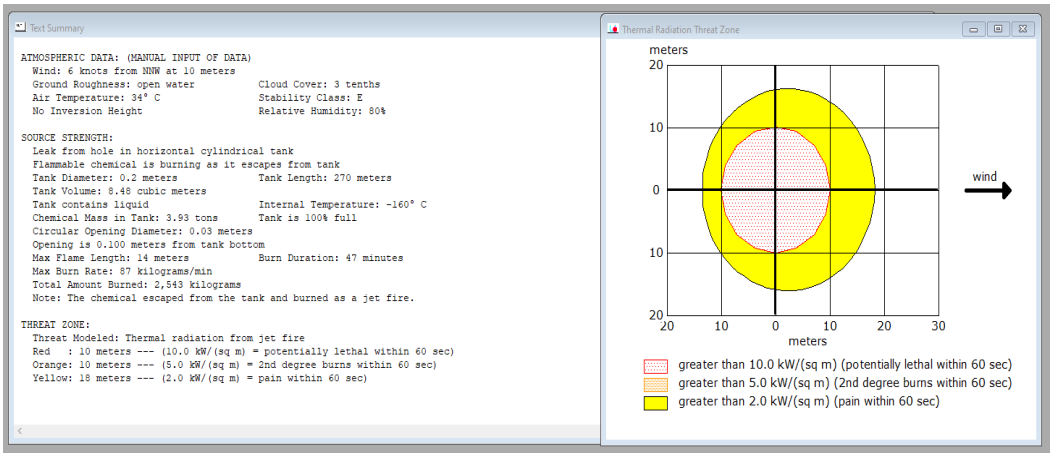
ATTACHMENT VIII: FIRE MODELLING ALOHA



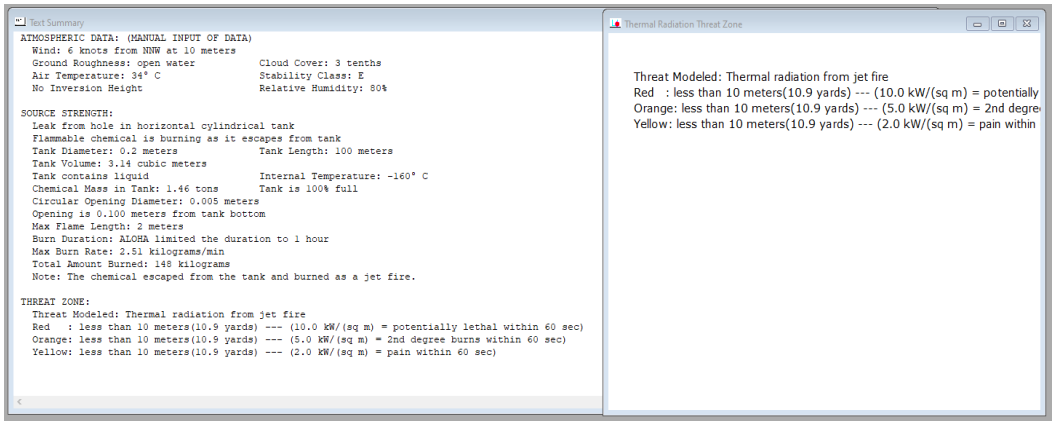
JET FIRE NODE 1 SCENARIO 5 MM



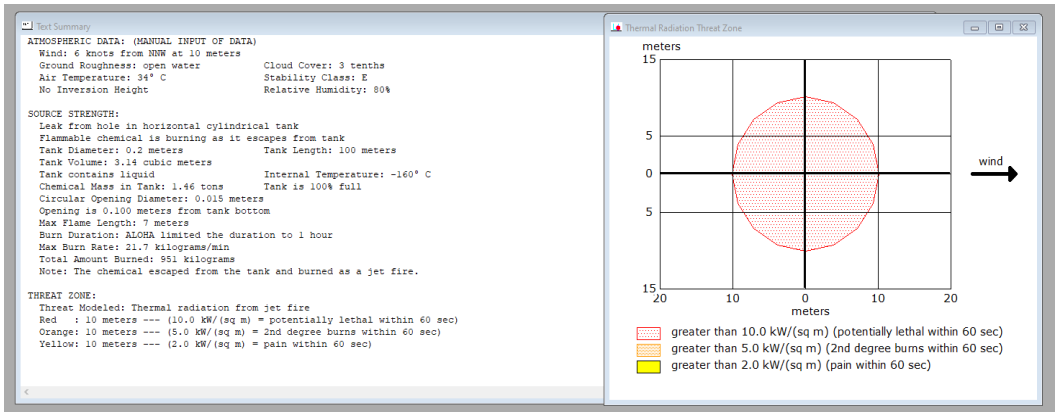
JET FIRE NODE 1 SCENARIO 15 MM



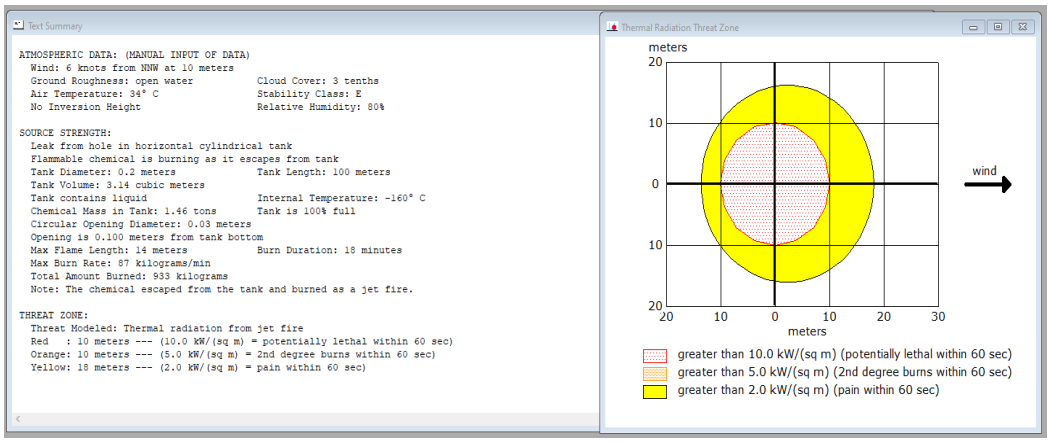
JET FIRE NODE 1 SCENARIO 30 MM



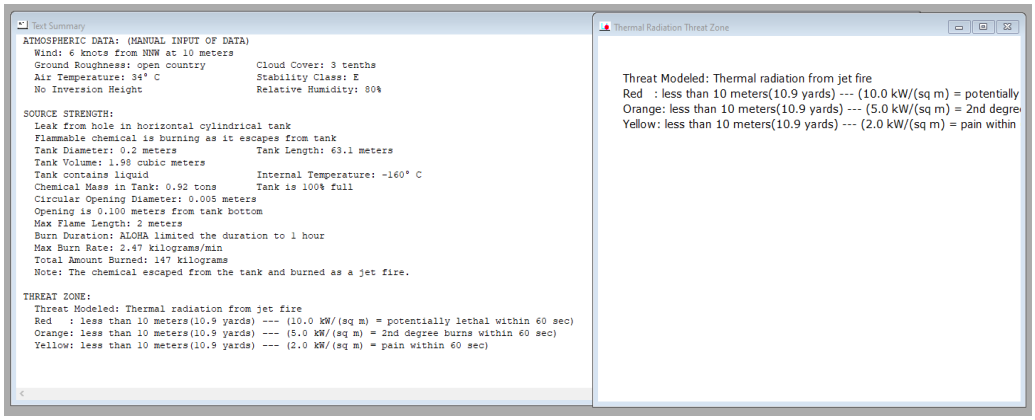
JET FIRE NODE 2 SCENARIO 5 MM



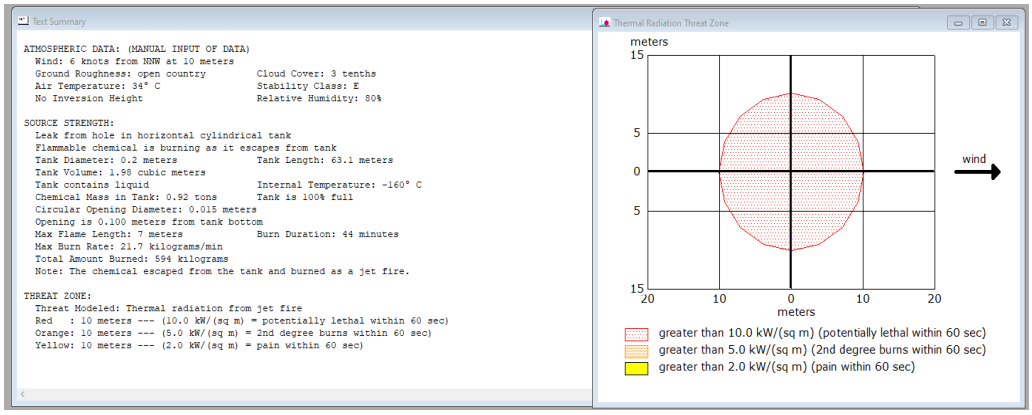
JET FIRE NODE 2 SCENARIO 15 MM



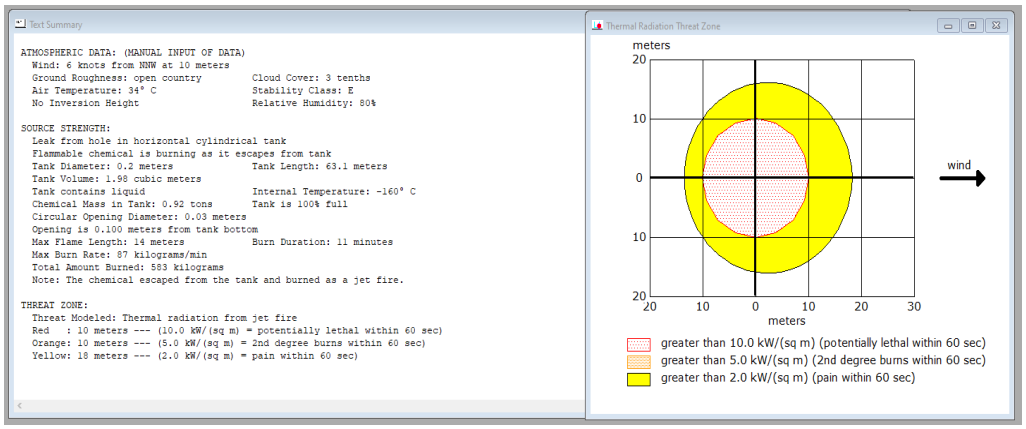
JET FIRE NODE 2 SCENARIO 30 MM



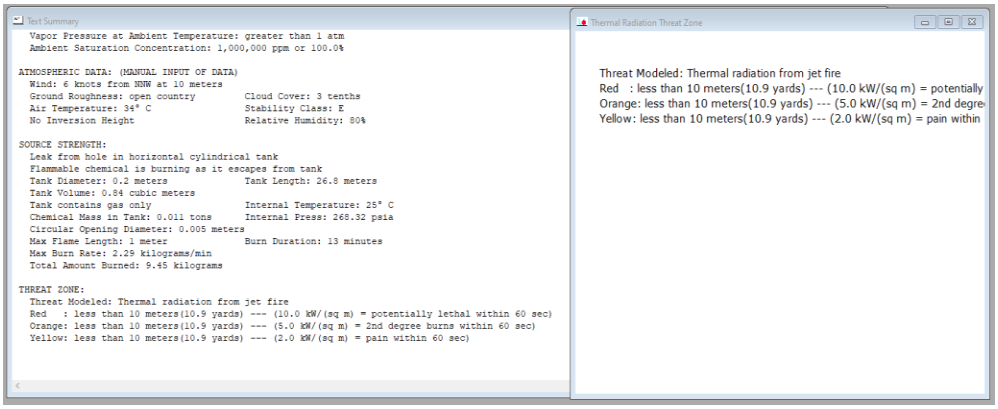
JET FIRE NODE 3 SCENARIO 5 MM



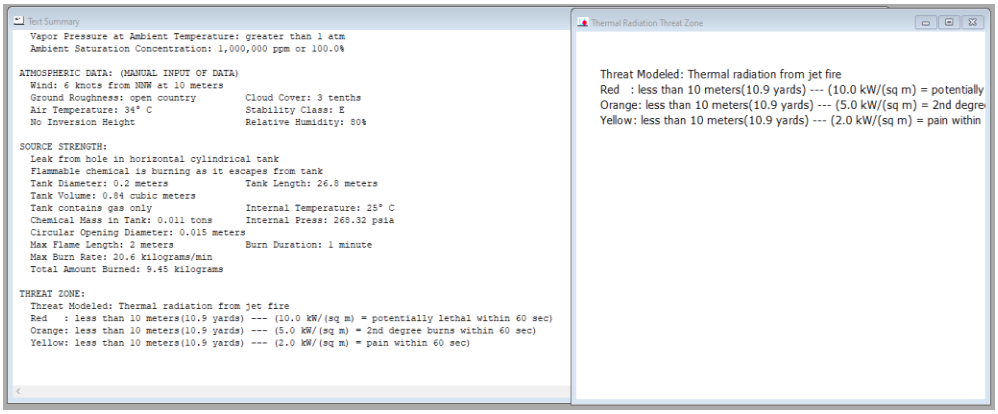
JET FIRE NODE 3 SCENARIO 15 MM



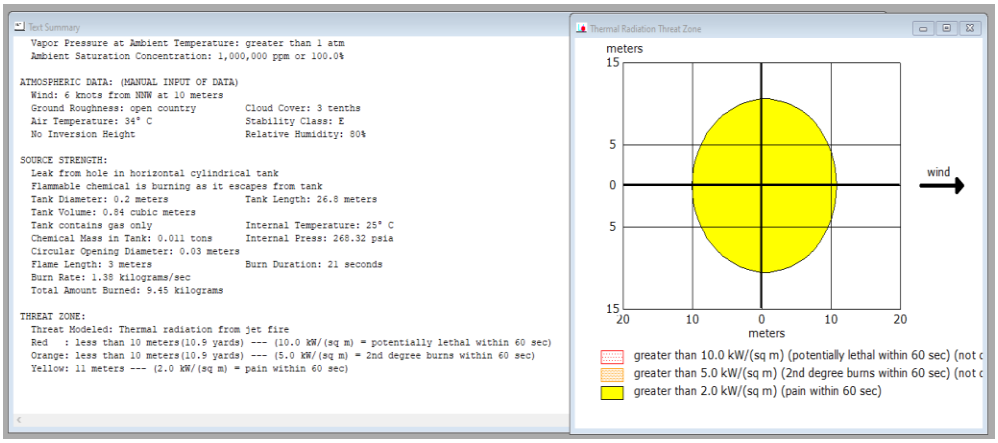
JET FIRE NODE 3 SCENARIO 30 MM



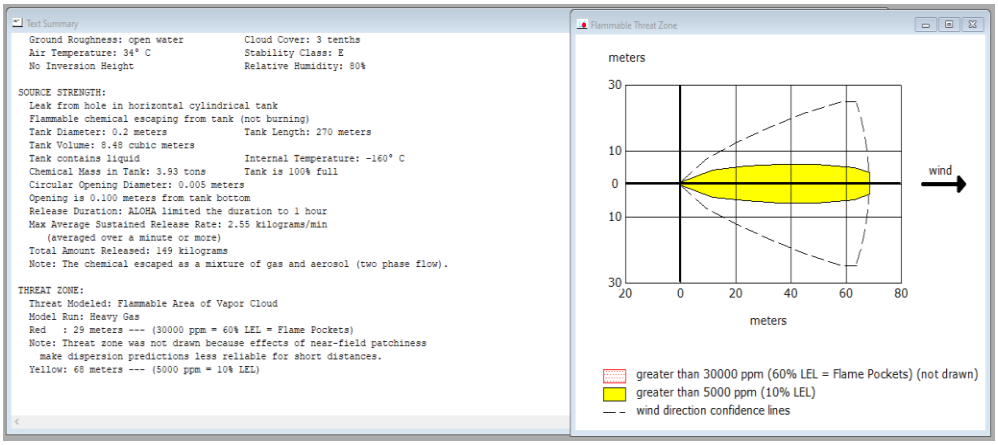
JET FIRE NODE 4 SCENARIO 5 MM



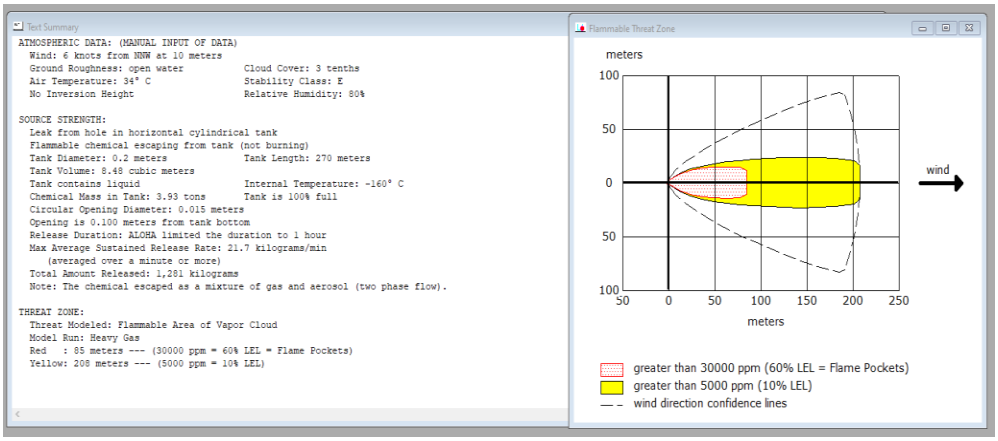
JET FIRE NODE 4 SCENARIO 15 MM



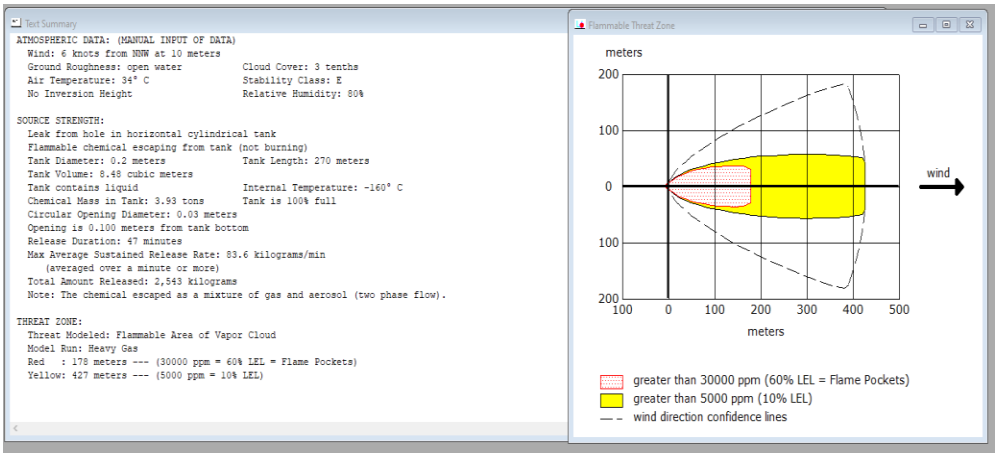
JET FIRE NODE 4 SCENARIO 30 MM



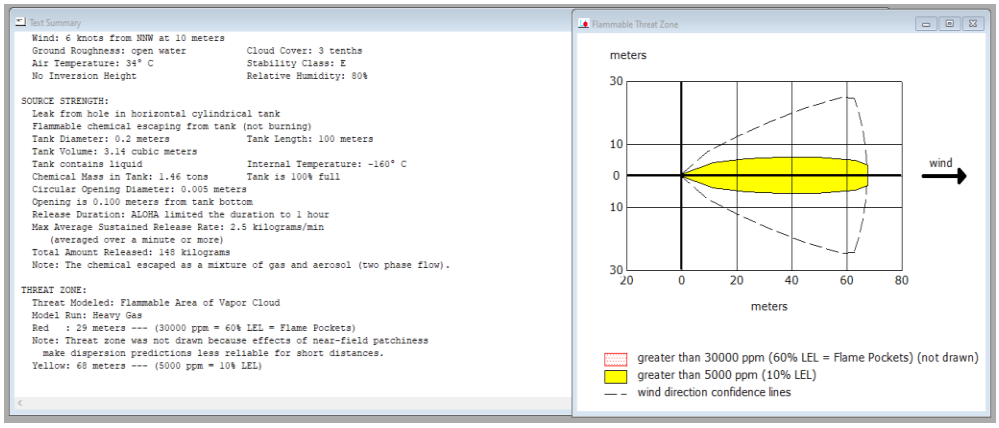
FLASH FIRE NODE 1 SCENARIO 5 MM



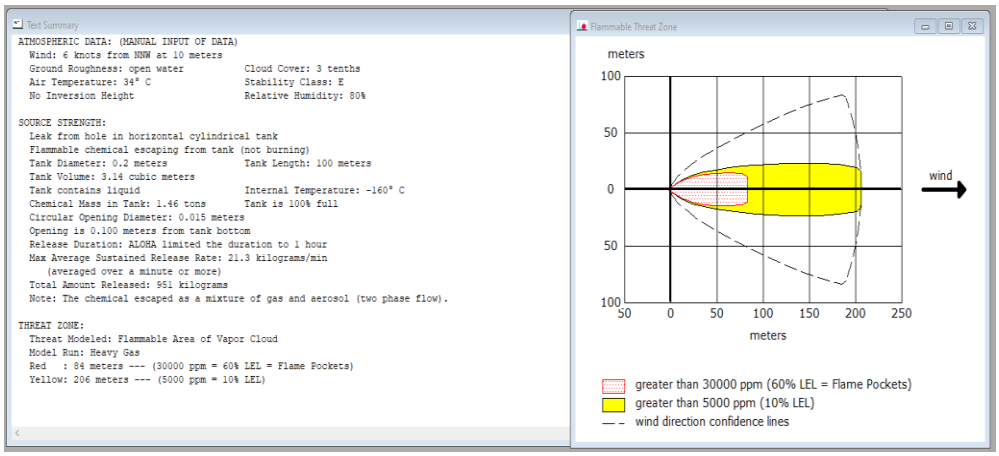
FLASH FIRE NODE 1 SCENARIO 15 MM



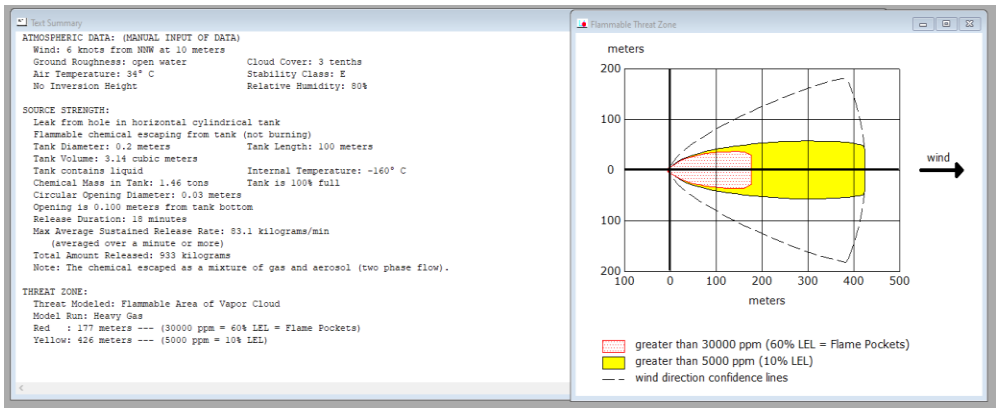
FLASH FIRE NODE 1 SCENARIO 30 MM



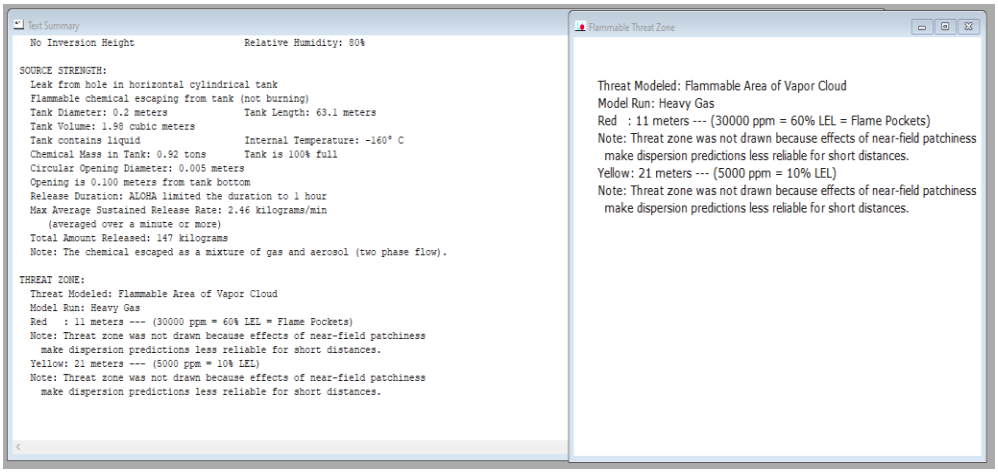
FLASH FIRE NODE 2 SCENARIO 5 MM



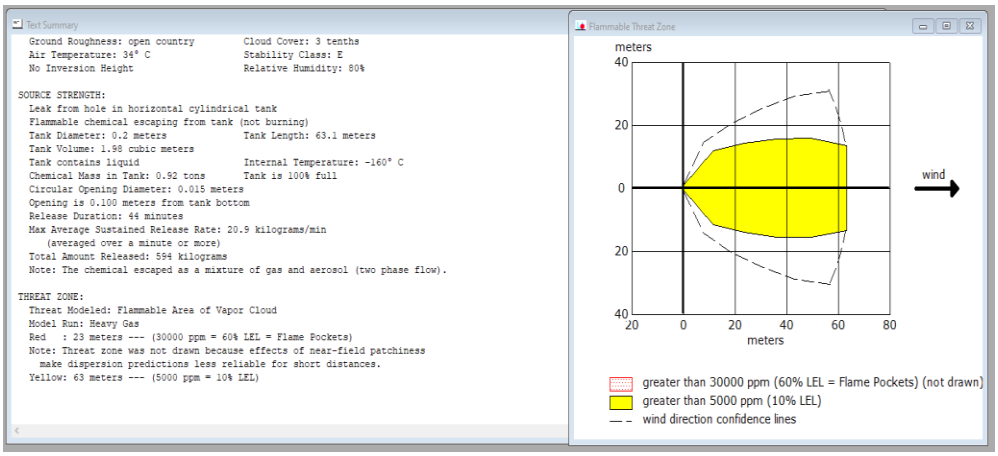
FLASH FIRE NODE 2 SCENARIO 15 MM



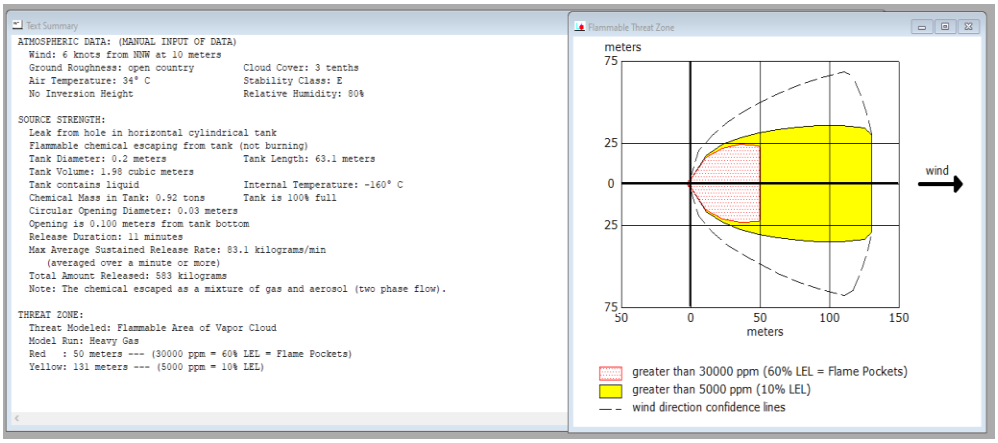
FLASH FIRE NODE 2 SCENARIO 30 MM



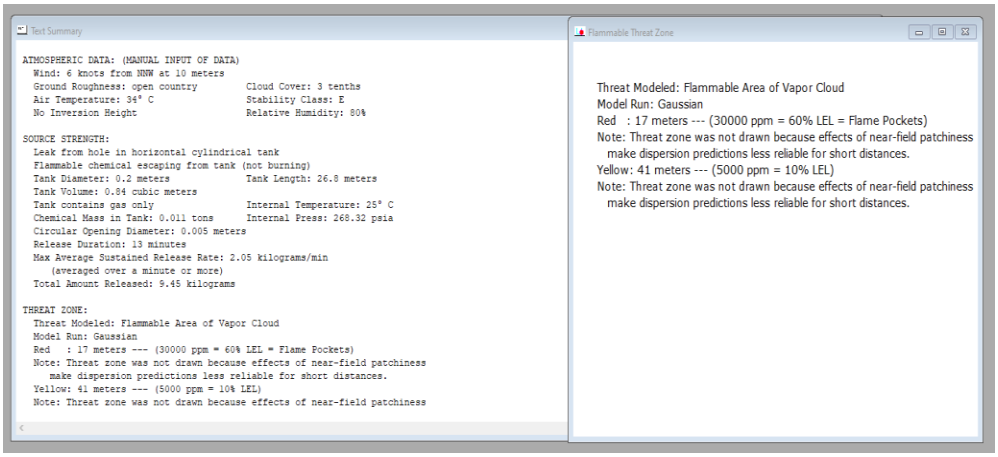
FLASH FIRE NODE 3 SCENARIO 5 MM



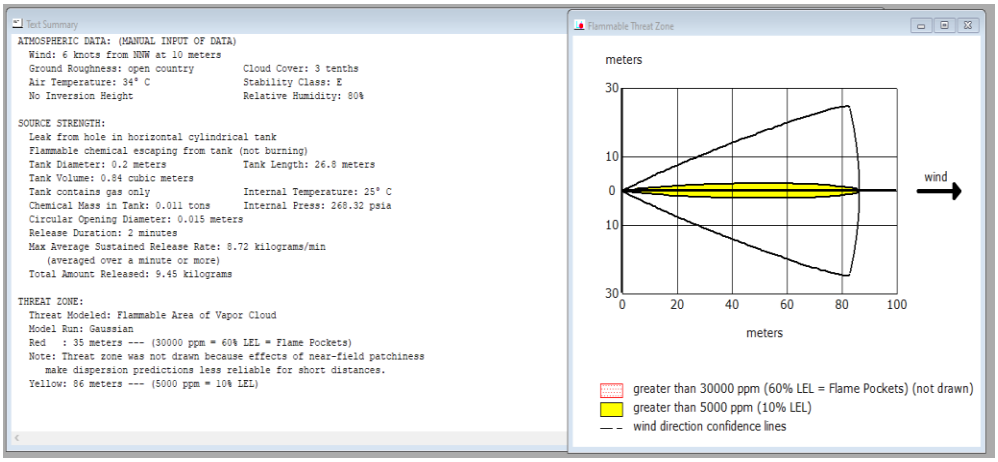
FLASH FIRE NODE 3 SCENARIO 15 MM



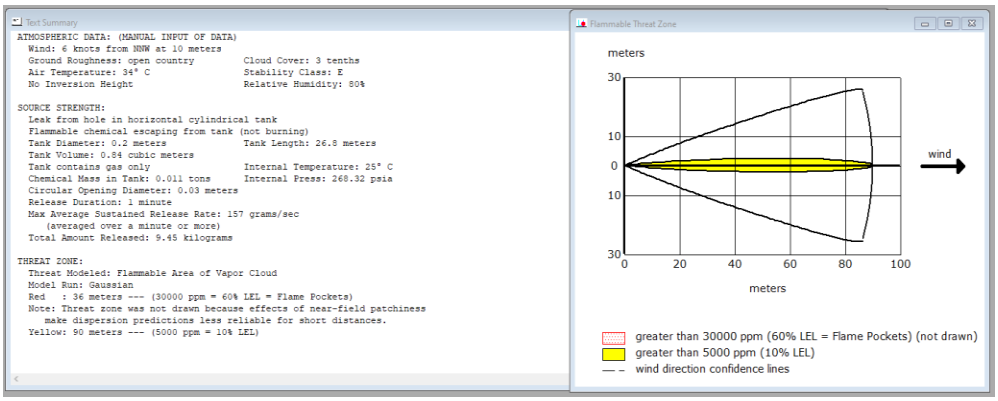
FLASH FIRE NODE 3 SCENARIO 30 MM



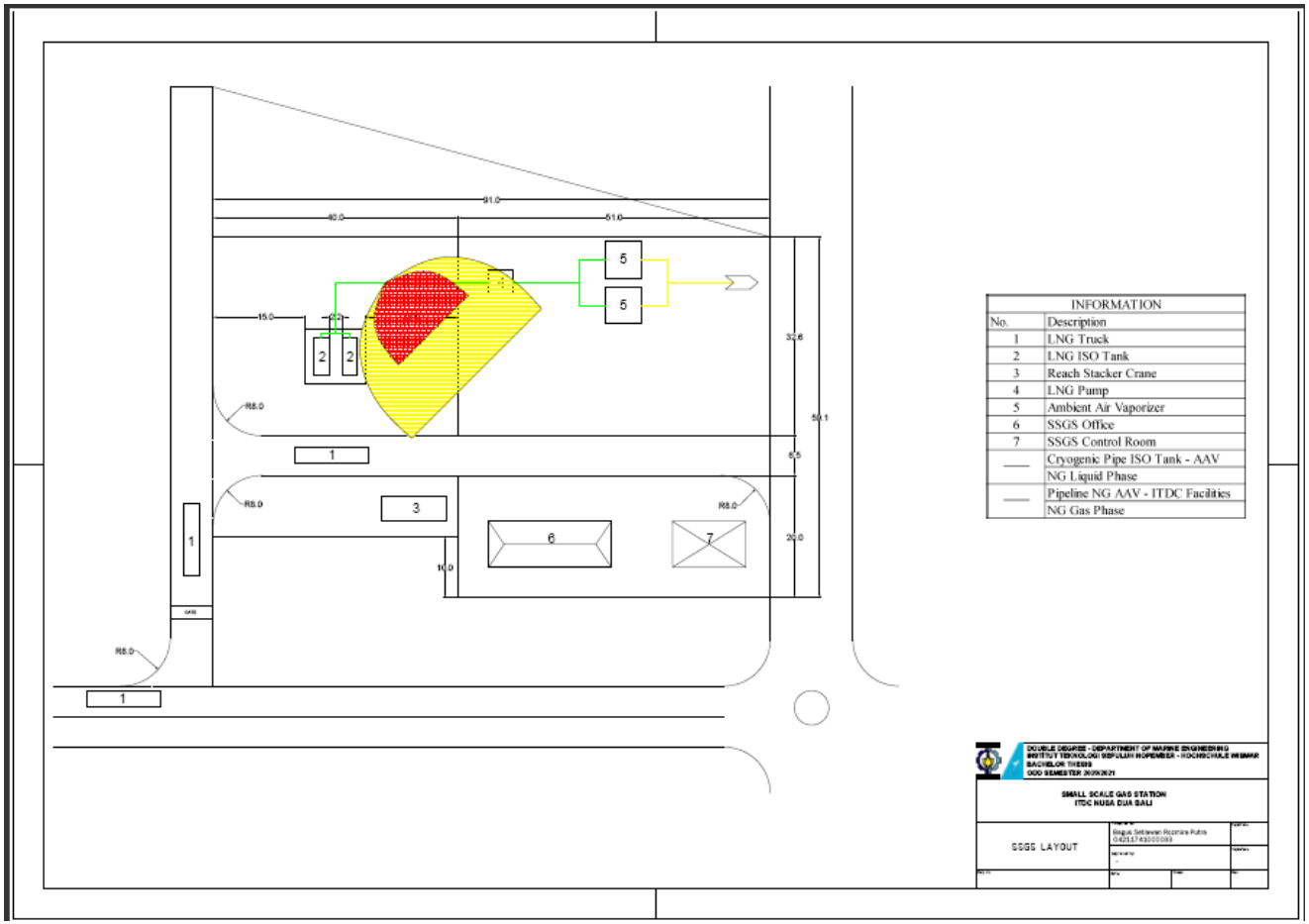
FLASH FIRE NODE 4 SCENARIO 5 MM



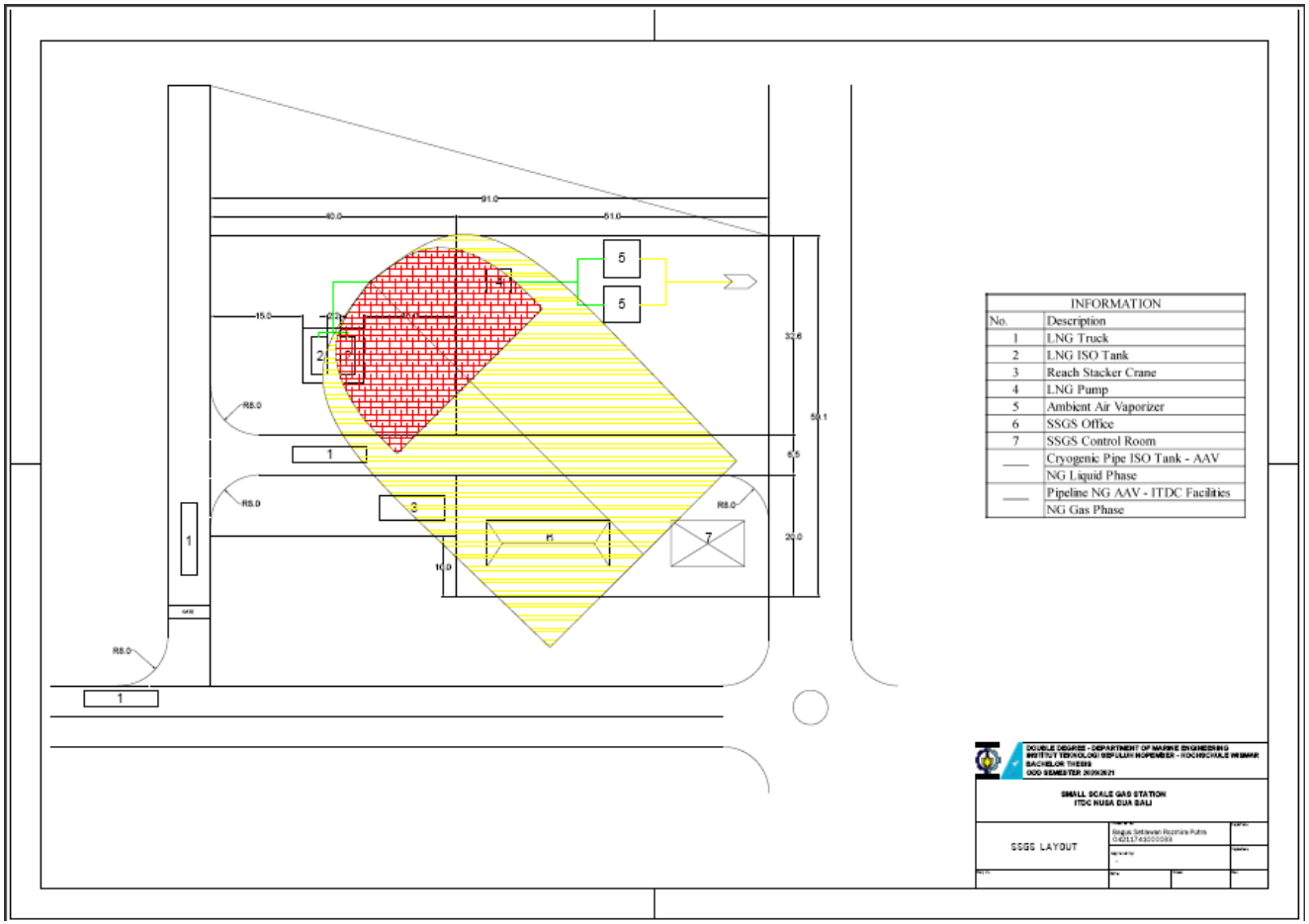
FLASH FIRE NODE 4 SCENARIO 15 MM



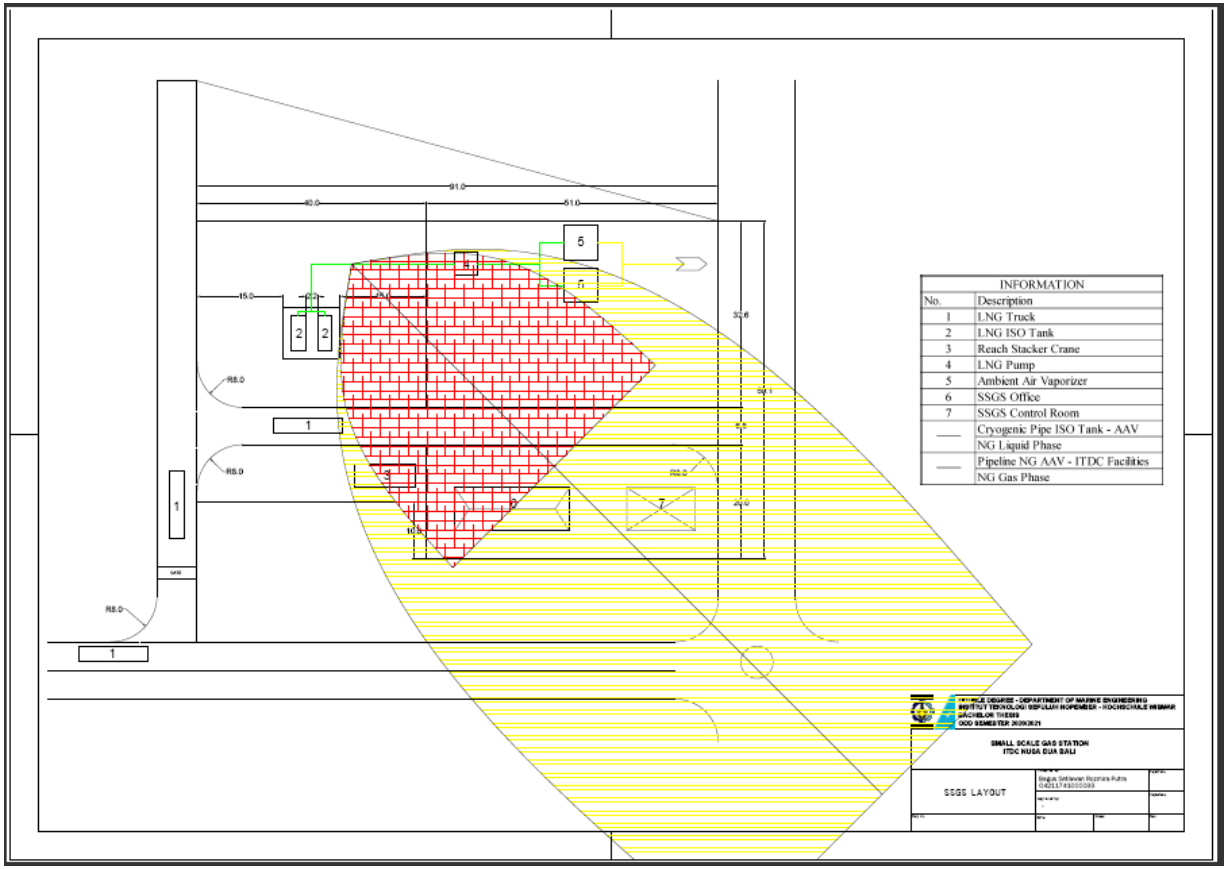
FLASH FIRE NODE 4 SCENARIO 30 MM



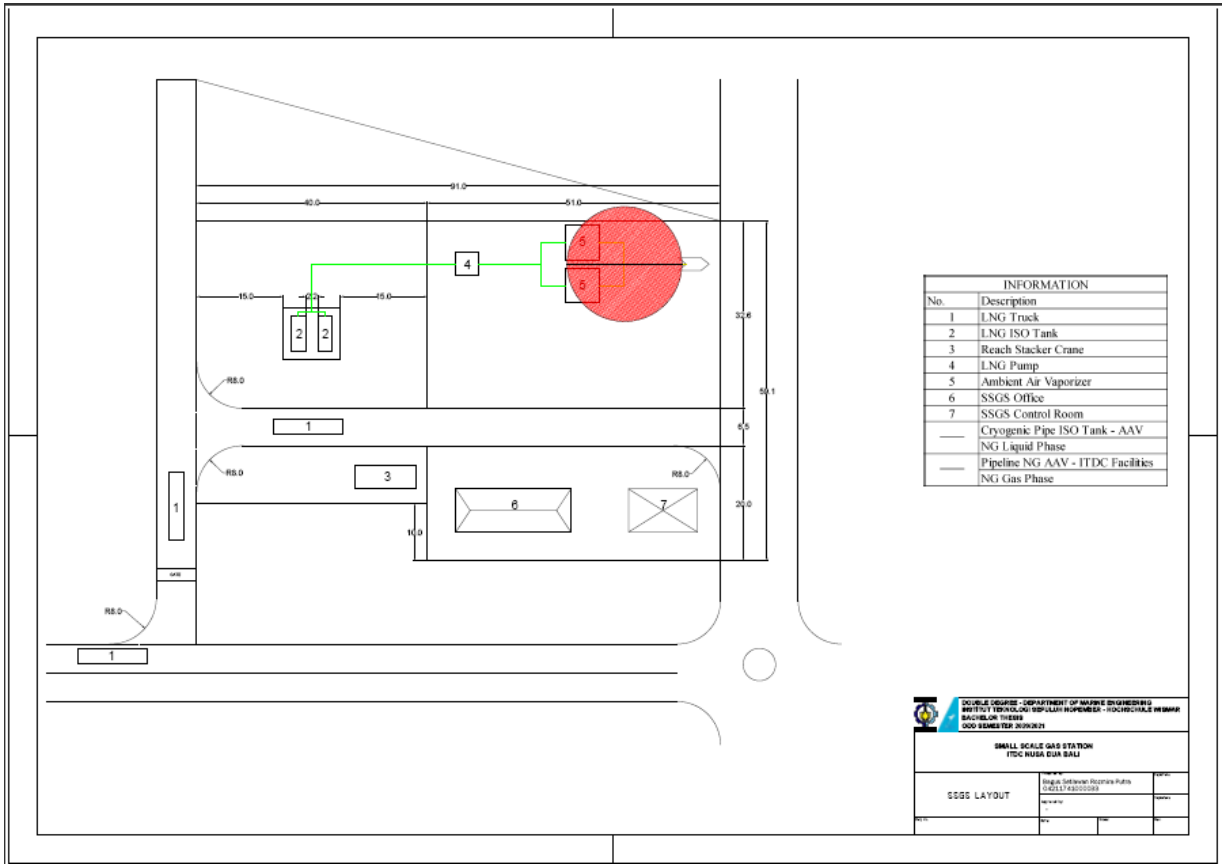
JET FIRE NODE 3 SCENARIO 5 MM



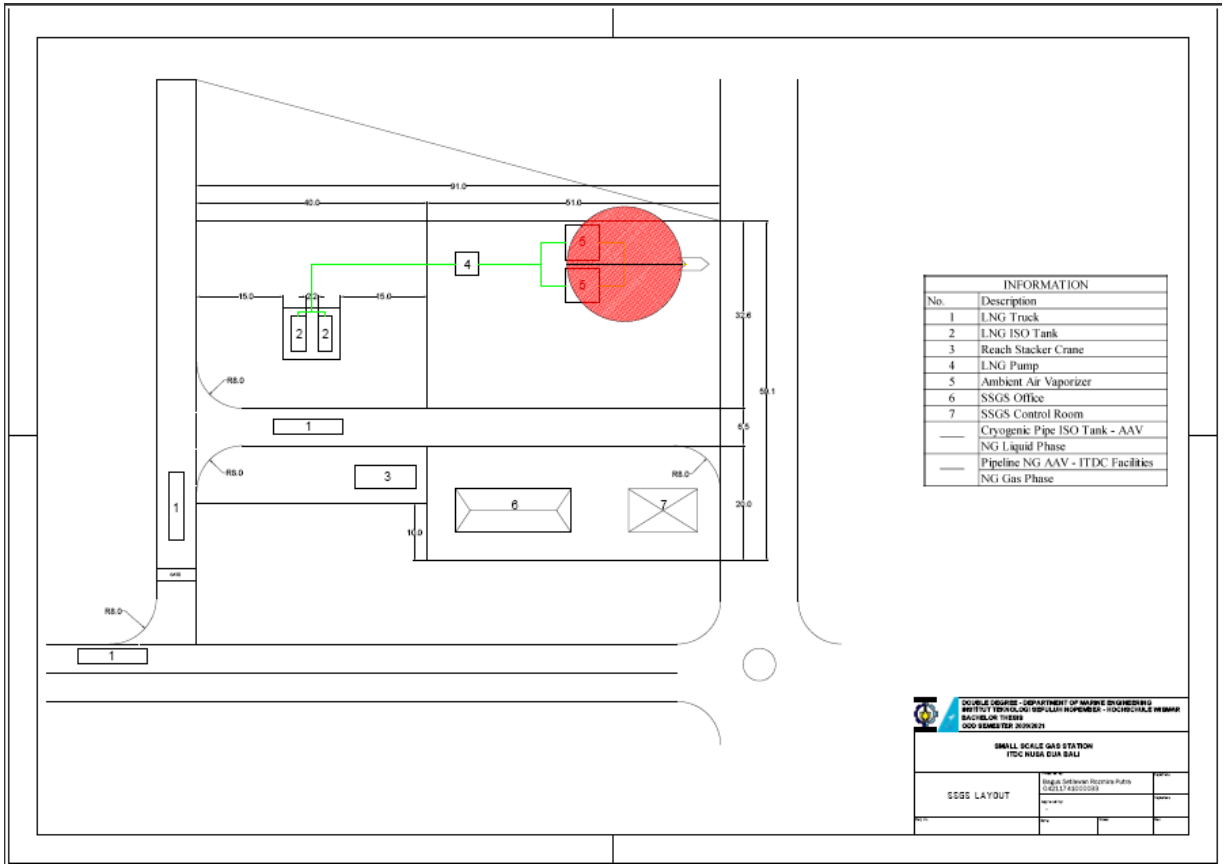
JET FIRE NODE 3 SCENARIO 15 MM



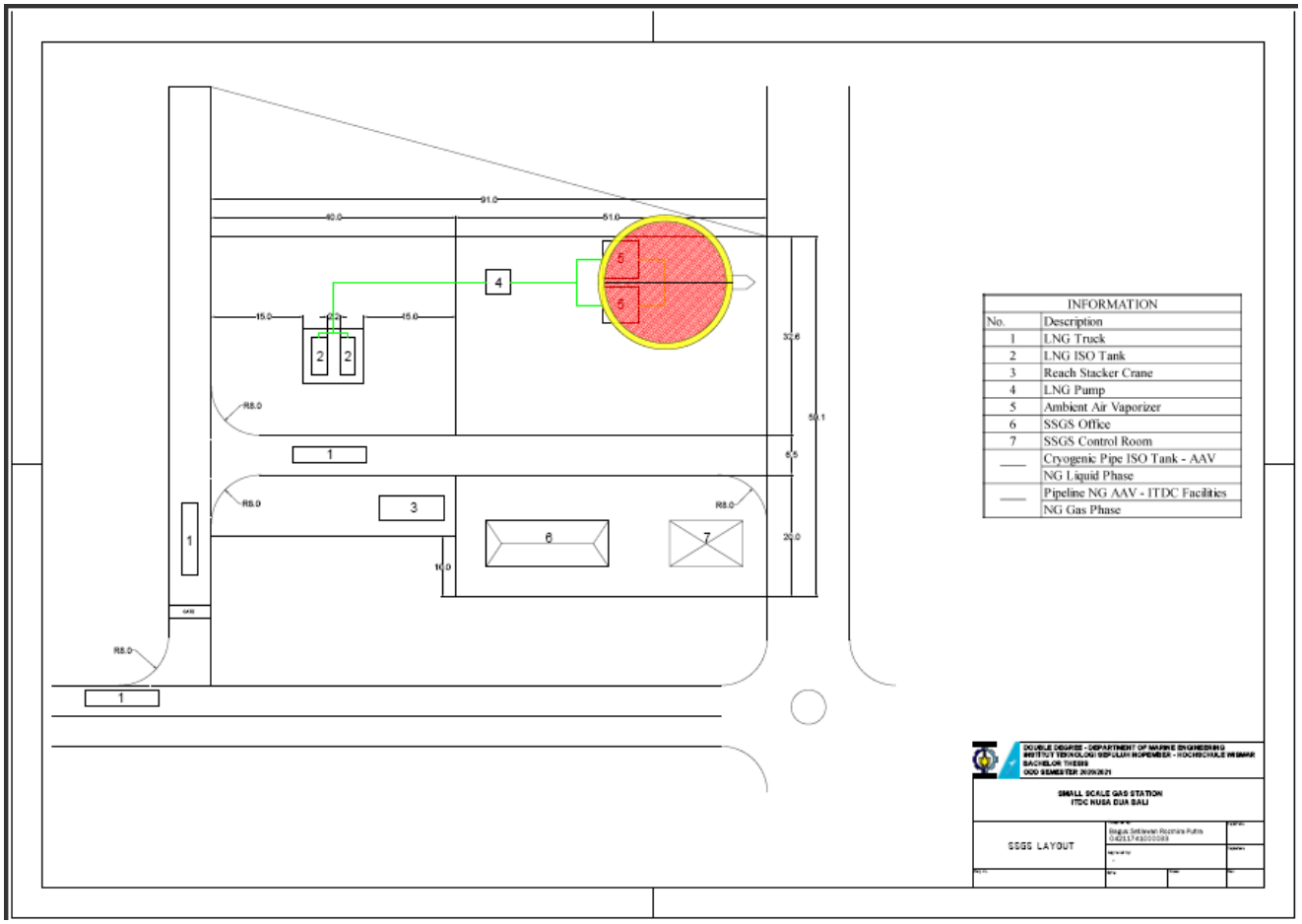
JET FIRE NODE 3 SCENARIO 30 MM



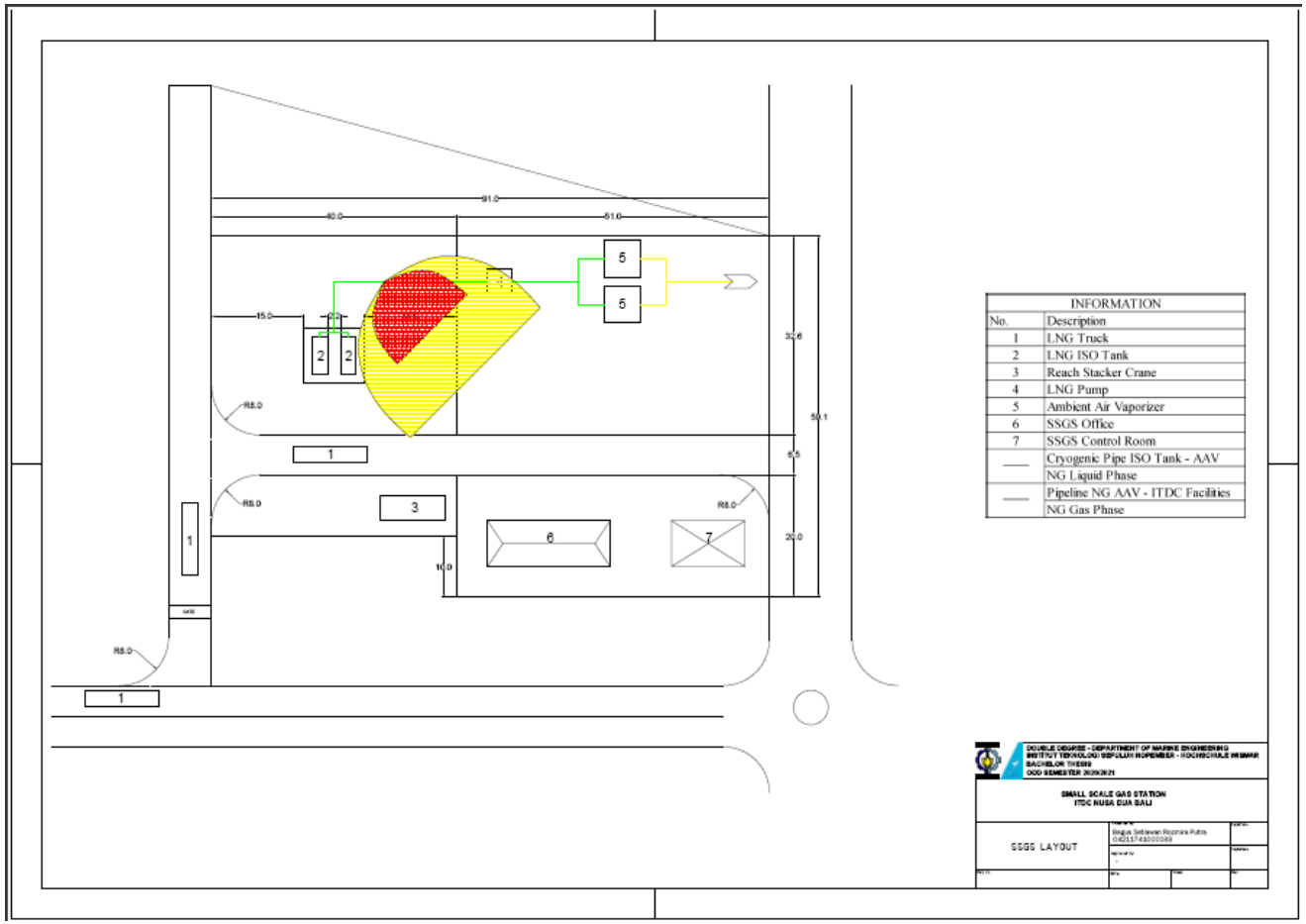
JET FIRE NODE 4 SCENARIO 5 MM



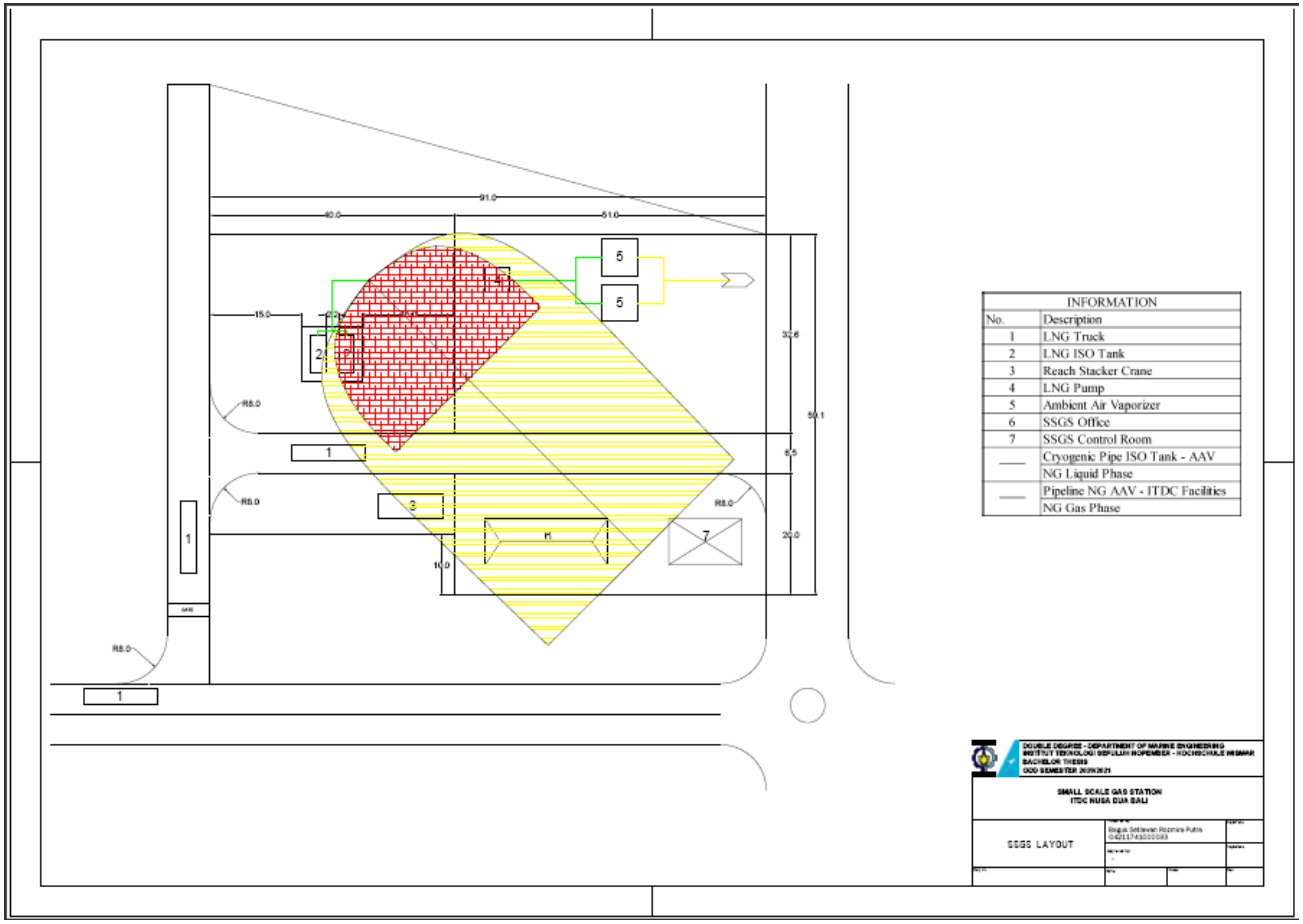
JET FIRE NODE 4 SCENARIO 15 MM



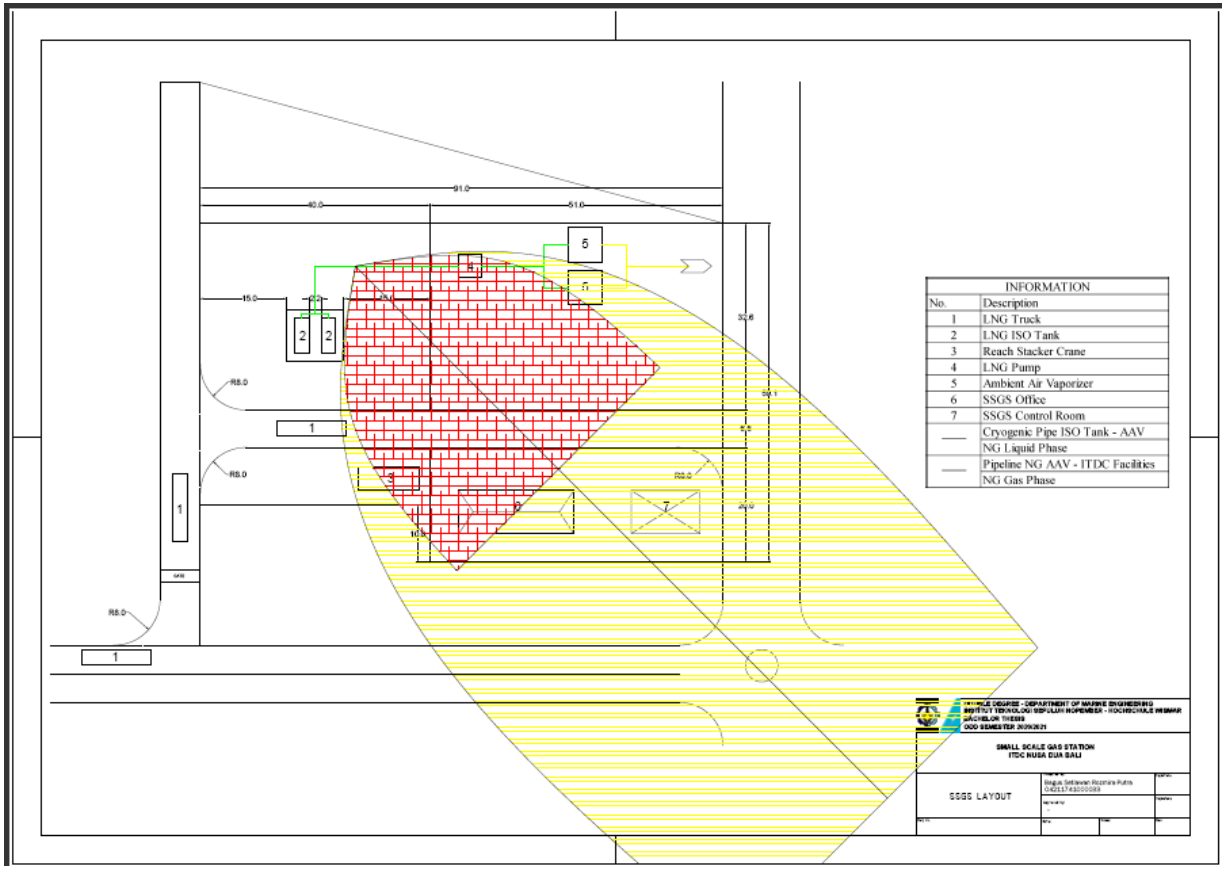
JET FIRE NODE 4 SCENARIO 30 MM



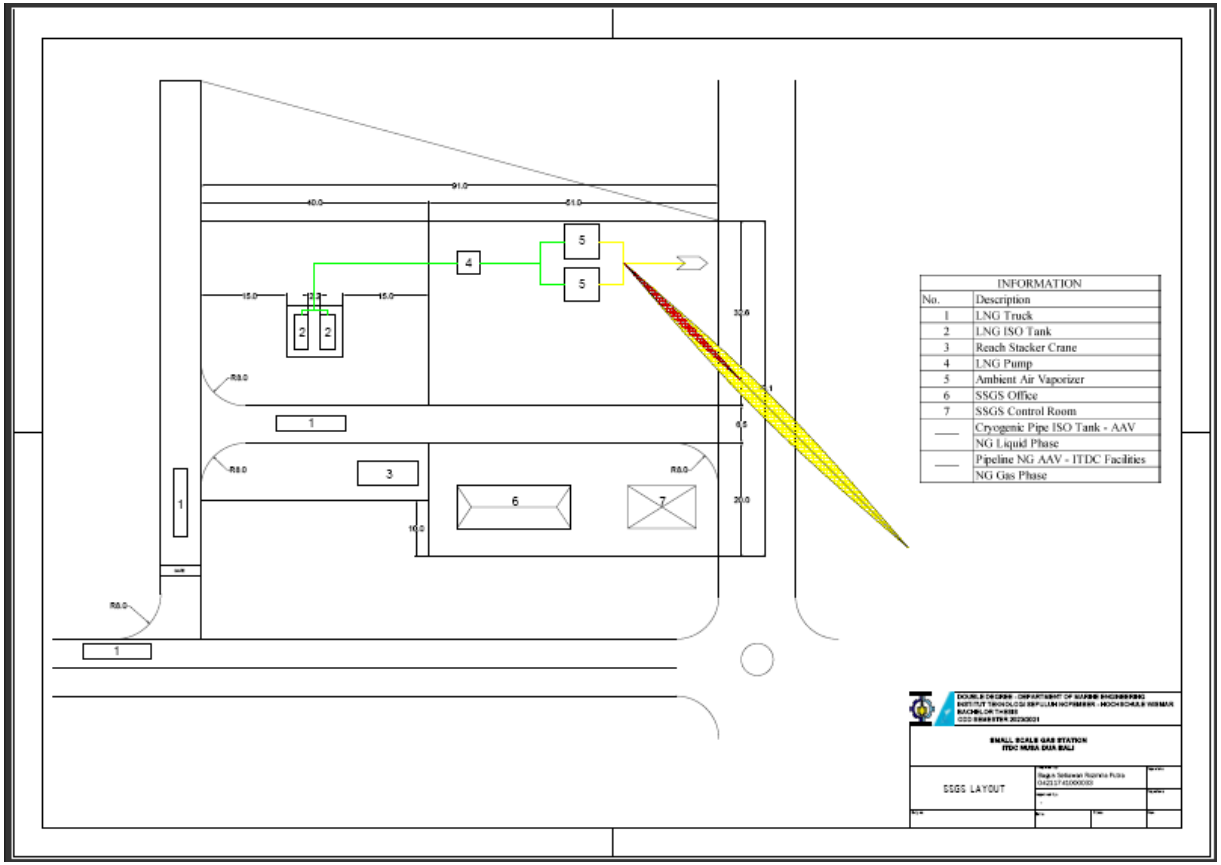
FLASH FIRE NODE 3 SCENARIO 5 MM



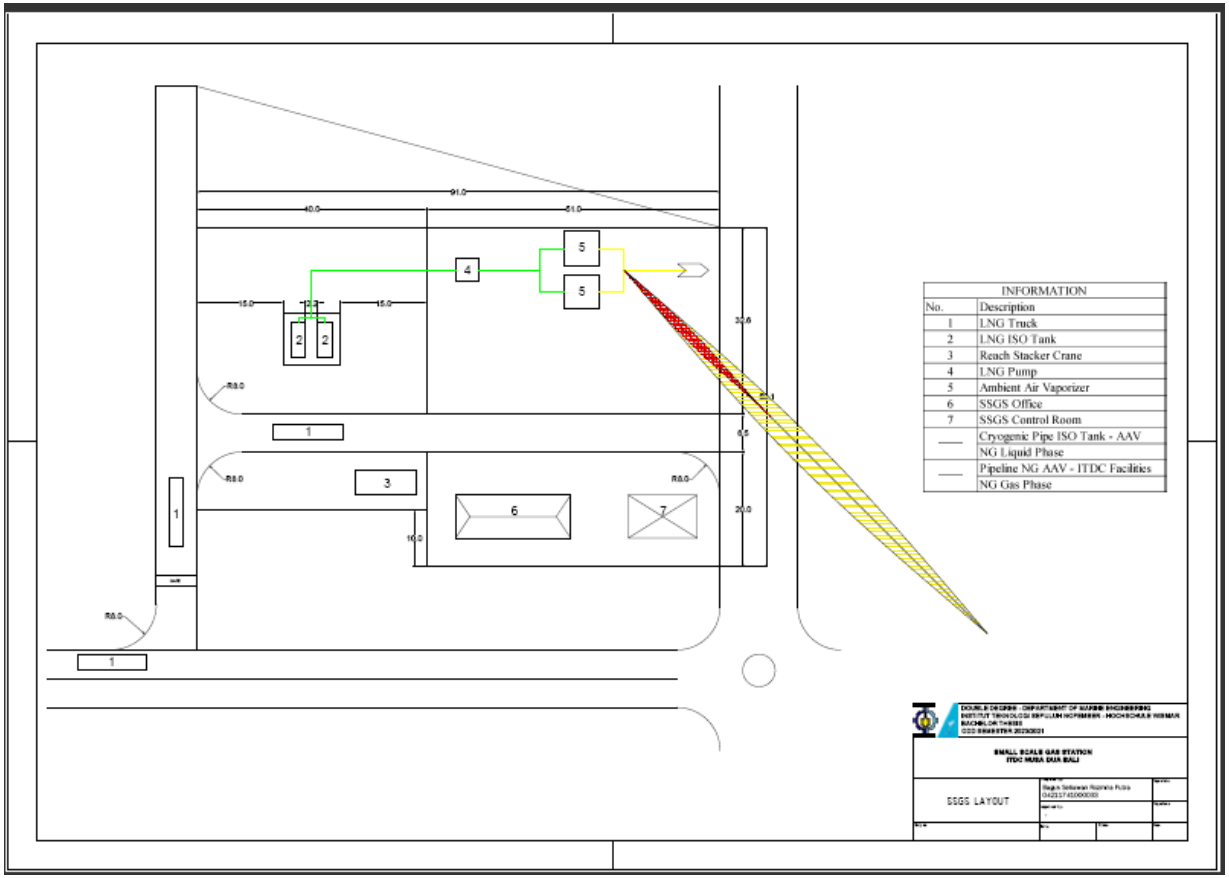
FLASH FIRE NODE 3 SCENARIO 15 MM



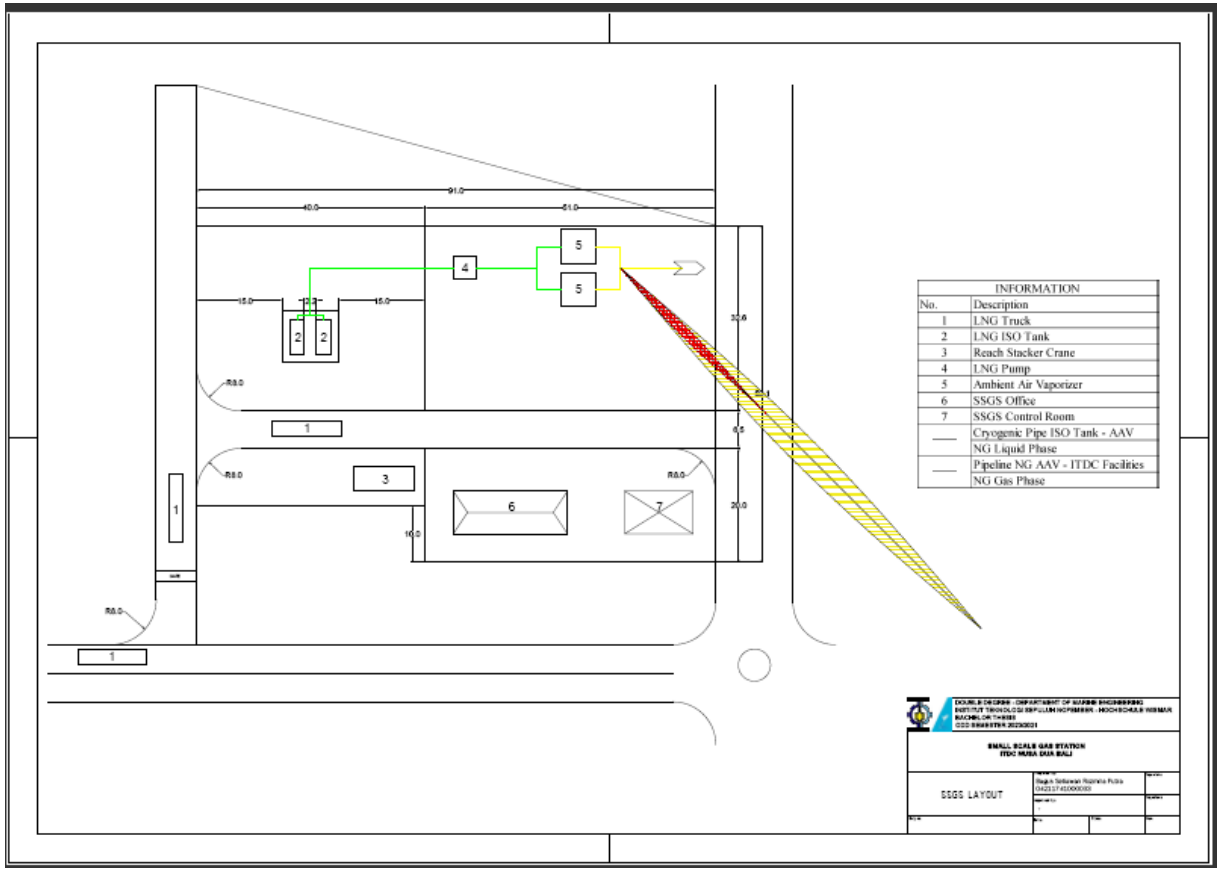
FLASH FIRE NODE 3 SCENARIO 30 MM



FLASH FIRE NODE 4 SCENARIO 5 MM

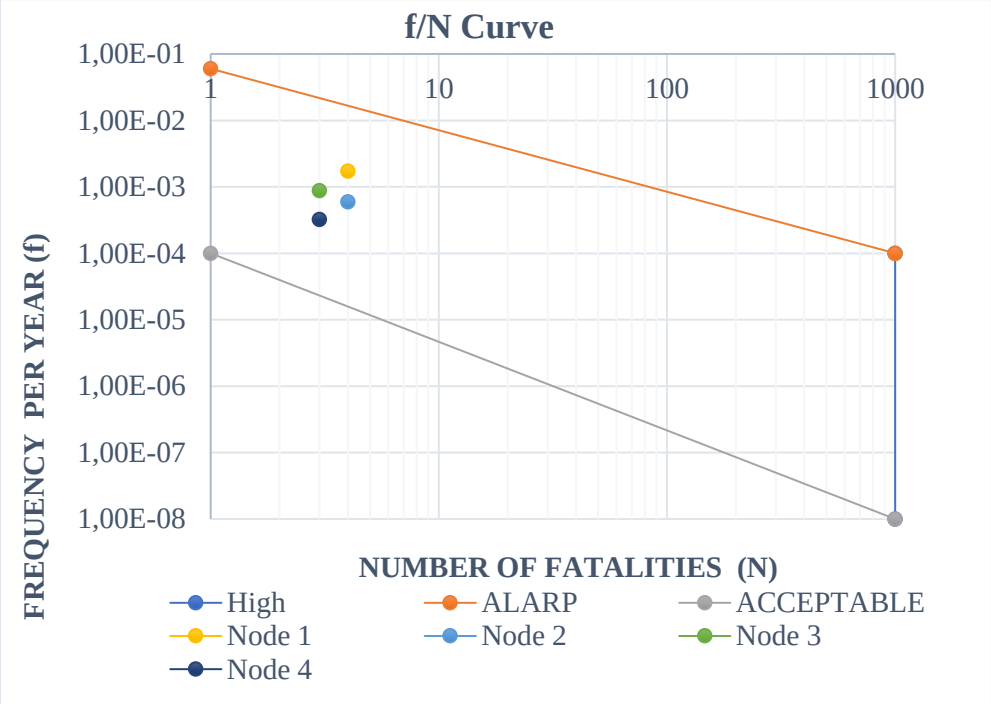


FLASH FIRE NODE 4 SCENARIO 15 MM

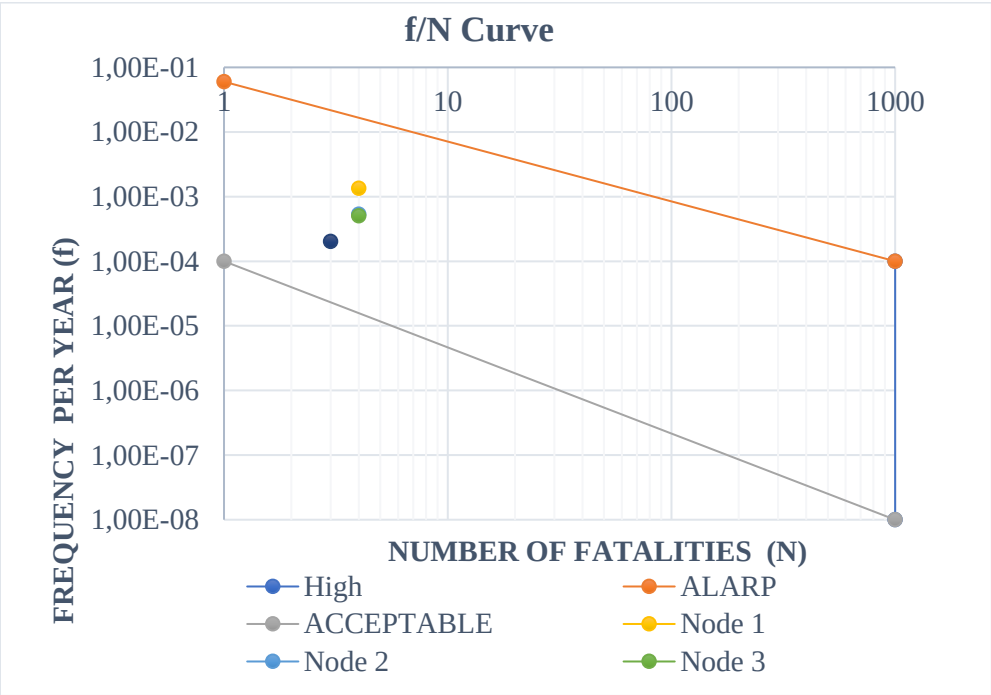


FLASH FIRE NODE 4 SCENARIO 30 MM

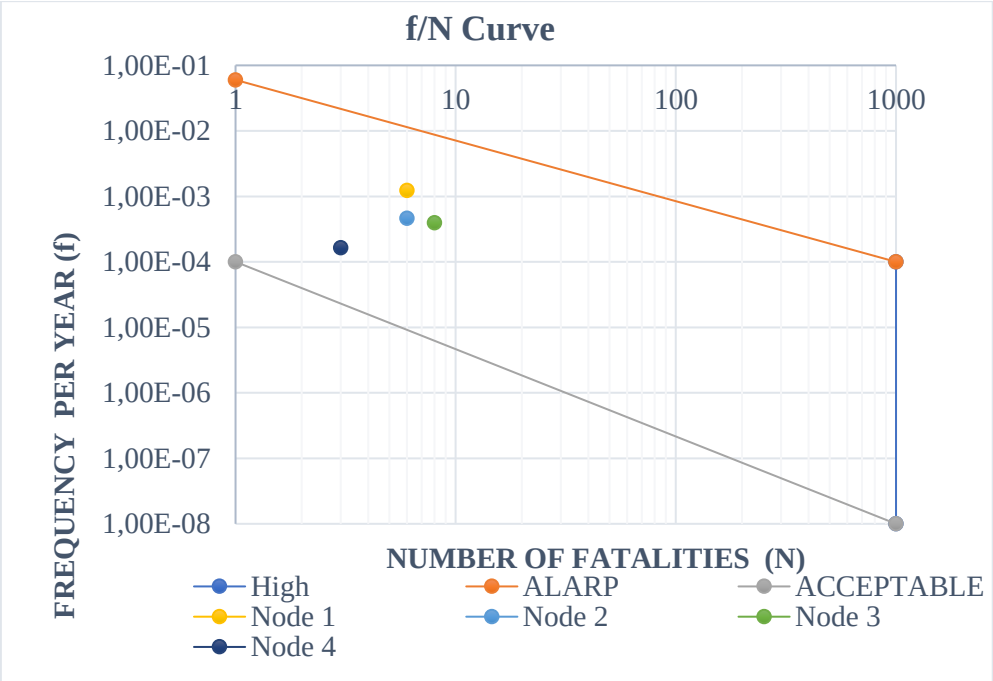
ATTACHMENT IX: F/N CURVE (UK-HSE)



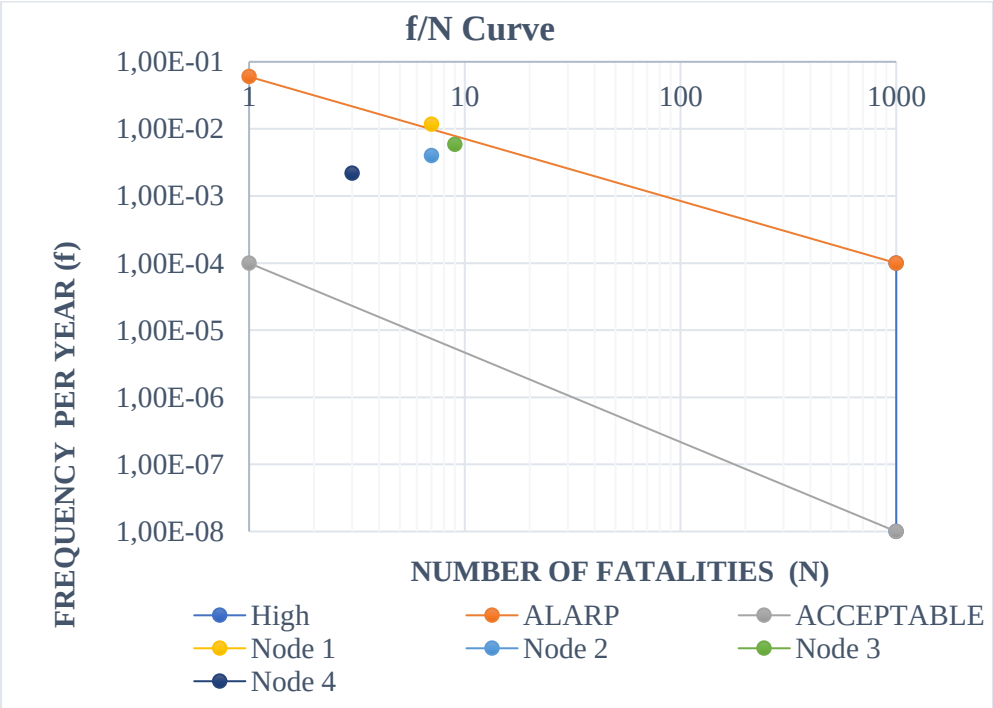
JET FIRE SCENARIO 5 MM



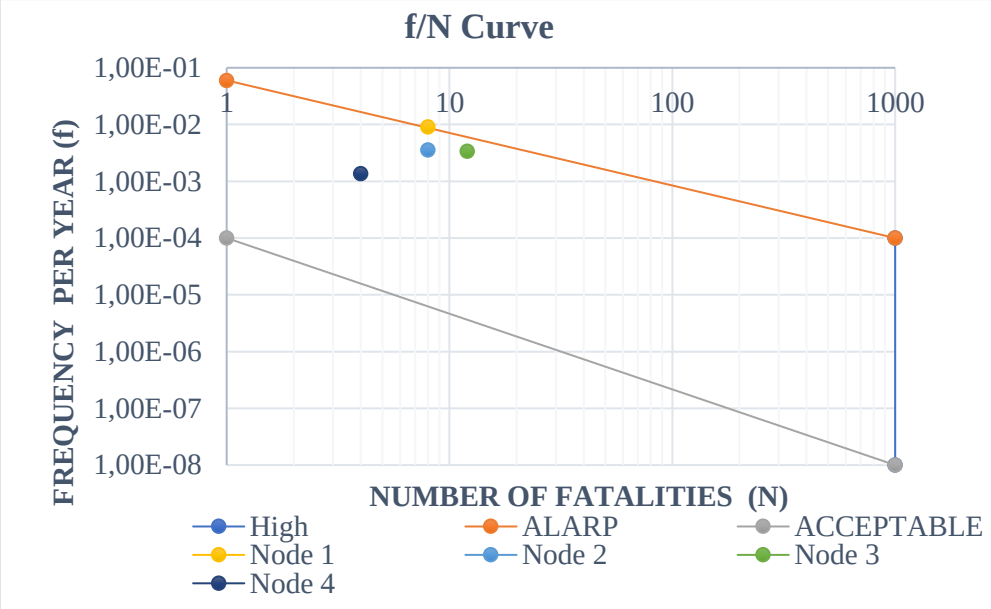
JET FIRE SCENARIO 15 MM



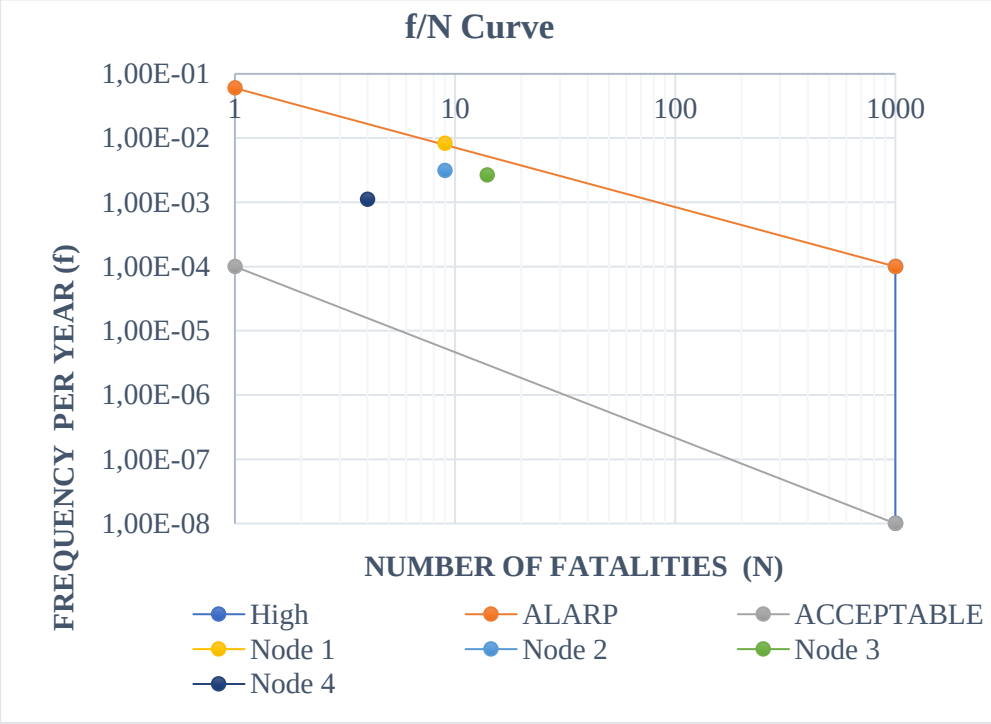
JET FIRE SCENARIO 30 MM



FLASH FIRE SCENARIO 5 MM



FLASH FIRE SCENARIO 15 MM



FLASH FIRE SCENARIO 30 MM

BIOGRAPHY

Bagus Setiawan Rozmira Putra (born August 29th, 1999) is the first son ever from Herros Herryawan and A.A. Ayu Mirah Permatasari. Born and raised in Bali, Bagus completed his high school from SMAN 1 Denpasar (2014-2017). Author then continue his education to Double Degree Program of Marine Engineering Department, Institut Teknologi Sepuluh Nopember, Surabaya with Hoschule Wismar, Germany. During the study, author has been actively involved in some organization. *Unit Kegiatan Mahasiswa Fotografi* (UKAFO) is a photography organization in ITS has become one of the main highlights of author journey during college. Involved since the first year of college, author accomplished to become the Head of UKAFO Exhibition Event during his 3rd year of his study, leading an organization to lead and develop event for UKAFO ITS. During the milestone, author has accomplished various organization such as being Coordinator Section ITS EXPO 2019, Coordinator Design & Documentation FOX 2018, Staff of Publication Documentation Marine Icon 2018 & 2019, and Staff of UKAFO from 2017 until 2020. The Job on Training experience that has been taken by the author are at PT Dok & Perkapalan Kodja Bahari Shipyard Jakarta and PT Pelindo Energi Logistik, LNG Terminal Benoa. In the fourth year of college, the author took the concentration of Final Projects in the field of Reliability Availibility Management and Safety (RAMS).

Bagus Setiawan Rozmira Putra
Departemen Teknik Sistem Perkapalan, FTK, ITS, Surabaya
bagussetiawanrp@gmail.com