Development of A Risk-based Acceptance Index to Support Design of Compressed Natural Gas Vehicle

By

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Finally, yet importantly, I wish I knew a better way to express my indebtedness to my family for their unconditional support, endless love, to my parents, who left us peacefully for their encouragement and inspiration throughout my life.

DEDICATION

I would like to dedicate this research project to my supervisors for their sincere guidance, constructive criticisms, and their moral support throughout this research. Furthermore, I would like to dedicate this research project to my family members and friends to share with our achievement in this research project as an appreciation for their encouragement and support.

Lastly, I would like to dedicate this research project to the public who have participated in this research project and have given me valuable and supportive information to complete this research project.

COVID-19 Impact Statement

Like most students, I have faced challenging situations during the pandemic. Father of four and living with family in St John's, it has added pressure on my work schedule and my ability to complete my research plan. Below is a list of the activities, which I planned to finish in the winter and spring semester. However, I could not complete it due to the closure of the lab and university.

1. Testing and validation of numerical COMSOL model with CFX and other commercially available industry-tested tools.
2. Detailed uncertainty and sensitivity analysis of the proposed Risk-based Acceptance Index
3. Two new applications of the risk-based acceptance index
4. Writing research papers based on the present work.

While I failed to complete the activity one as planned, I did try doing sensitivity analysis, which provides in relative terms a better understanding of the COMSOL results and practical application. I did attempt to undertake activity 2; partial results are presented in the thesis. I could not do rigorous work as planned due to the inaccessibility of tools and lab.

I did explore a new application (activity 3) for the risk-based acceptance index. I could not complete the study and, therefore, not presented in the thesis. I have revised the scope of the application and hope to finish it soon. This is briefly mentioned in the thesis.

I have devoted significant time to activity 4. I have written two papers, one is submitted and is likely to be accepted soon. Another manuscript is ready to be submitted.

In conclusion, the pandemic has severely impacted the last part of my research plan; however, I was able to mitigate some impact.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

FIGURES

TABLES

Abstract

The research aims to develop a risk-based acceptance index (RBAI) for the assessment of compressed natural gas (CNG) onboard vehicle and discover the reason why an accident occurred and alleviate the risk aversion towards high-pressure applications onboard such as CNG, H_2, and LPG. It is offering a proactive way to identify and resolve safety issues.

A good understanding of CNG properties requires an evaluation of the associated threat with CNG onboard is essential. Existing standards, specifications, regulations, and designing guidelines need to examine for safety purposes with consideration for the applicability to a specific design.

Safety professionals have attribute about (70-80%) to human faults. Human is an important factor in the cause of accidents. As the design of overpressure storage tanks becomes safe, the accidental causes are becoming more likely to be attributed to the human factor. Recent traffic accidents have left the public wondering how an overpressure system with the potential to harm the end-user and public could have operated onboard of vehicle. No hazard analysis can be used during the design phase of a CNG cylinder onboard to identify and evaluate hazardous scenarios involving human error.

Human cognitive characteristics guideword could stimulate safety professionals to consider the suitability of various system aspects for human use from a perception point of view. Professionals must consider the impact of the human perception factor on safety. It intended to be helpful and practical for teasing out the human and system design flaws that can lead to hazards. In the next chapters, the integration of human guideword into

RBAI will be used for the risk analysis.

As a case study, an introduction to the overpressure calculation and the consequences to the material damages presented. An unintentional rupture filled with CNG would generate a rapid energy release in the form of the pressure energy (blast) studied.

The procedures described are practical and attempt to give a perfect understanding of the subject and help to understand the meaning of all the variables by performing SPSS-Amos code. The research concluded with a discussion on the possible cause and effect that influence the end user's decision of choice.

Therefore, the research has divided into two parts; the first part includes developing an acceptance index to support the design of compressed natural gas (CNG). This part consists of three chapters; chapter one, including introduction, research goal, and the use of acceptance index for risk assessment. Chapter two provided the background related to the acceptance index and literature reviewed concerning the CNG cylinder. Chapter three illustrated the methodology of the experiment that focused on aspects associated with the experimental parameters. It includes design questionnaires, data collection methods, data processes, and data analysis. The second part of the research divided into three chapters. Chapter four described the ethical considerations and approval process, including all required letters of approval for the feasibility of the acceptance index with designing CNG onboard vehicles. Chapter five addresses the theoretical background and some fundamentals related to the risk assessment and proposed method. In contrast, chapter six considers the application of compressed natural gas and mechanical effect as a case study. Lastly, chapter seven is performing SPSS for data gathering and analysis.

Keywords: risk, index, assessment,pressure, natural gas, safety,effect,hazard.

CHAPTER 1: RESEARCH OVERVIEW

Humans play an essential role during the development of any safety system. Incentives to operate complex transport systems in a high-risk state are present. However, the safe design of the socio parts of the sophisticated vehicle system such as CNG onboard vehicle is challenging. Even if the system designed to be safe for anticipated system needs and operating environments, without consideration of pressures for increased performance and efficiency and shifting system goals, the system would turn to a high-risk operating regime. The individual competency has promoted transportation diversity, but also the importance of the end-users needs has tackled.

The development, demonstration, and verification of a methodological framework for the transport industry are required to close the gap between the simplistic method representation in today's models and the complexity of the actual risk process (i.e., trial and error, learning from others). It is thereby improving the specification of a model-based index (MBI) to demonstrate the feasibility of the method applied to hazard analysis that used today or in future to high-pressure systems such as CNG.

The proposed method addresses the development of a risk-based acceptance index to support design for compressed natural gas onboard (RBAI). A review of the literature on the proposed work presented with emphasis on compressed natural gas. Critical knowledge gaps, as they apply to compressed natural gas vehicles and potential areas for future studies, are also outlined.

The controversial debate associated with the risk of equipped overpressure cylinder inside a vehicle to people, property, and environment has stimulated the author to develop a tool to assess risk-based acceptance index (RBAI) to support the compressed natural gas onboard vehicle (CNGV). However, estimating the behavior of a CNG cylinder inside a vehicle is well-known as challenging tasks, and the presence of other physical factors (i.e., weather, seasons, car design, driver) makes it more complicated.

The research proposed method designed based on the selected index, including the survey sample, mathematical model, and computational code. The survey sample focussed on understanding end-users' responses towards CNGV. Understanding of end-users' needs, in particular, the social and cognitive aspects of practical and ethical decision making. Knowledge acquisition and inference process of individuals also examined in the experimental study of the research. As a result, the influence of the acceptance index (AI) investigated. A mathematical model for describing the relationship between independent (i.e., AI) and dependent (CNGV) variables designed. In the computational model, which is adapted to capture the across-subject variability observed in the experimental study and interviewed with structural equation modeling (SME). The SME conducted for its ability to attribute relationships among variables and to ensure that the model can create realistic data. Finally, the adopted model integrated into a risk assessment framework.

The principal value of the Ph.D research is the understanding and development of risk-based acceptance index to support complex-system (i.e., CNG) cylinder onboard. This information is essential for risk analysis that is policies for the transportation industry (i.e., operation, safety, cost, design).

After that, risk analysis performed to discover reasons for the occurrence of accidents (frequency and consequence) and to prevent such a future event. It has been noted by earlier literature[1] that safety professionals have attributed to a forty-eight percentage (48%) of transportation accidents to humans 'Figure 1.2'. It is considered high. Investigators have long known that the human aspects of systems are vital contributors to accidents, yet they lack a rigorous approach for analyzing their impacts. Many safety professionals and engineers strive for blaming free reports that would foster reflection and learning from the accident (trial and errors) but struggle with methods that require direct technical causality, do not consider systemic factors, and seem to leave individuals looking censurable. A developed risk analysis method is necessary to guide the work and aid in the analysis of the role of the human when an accident event happened.

Current hazard analysis methods, adapted from traditional accident models, are not comprehensively able to evaluate the potential for risk or identify scenarios involving humans in the case of CNG onboard. Thus, the ability to design systems that prevent loss events is weak.

The CNG systems should be analyzed with methods that identify all potential factors related-hazards during the design process so that this information used to change and optimize the design, and therefore, errors can be avoided. Thus, the requirement of a new type of risk analysis method that identifies hazardous scenarios involving humans is essential and highly recommended for both systems in conception and those already in the field.

The thesis contains a novel new approach to hazard analysis. The procedure is based on principles found in the Human Factors (HF), and Safety System(SS) literature, and hoped that the analysis method aid academic and professionals understanding how human actions and decisions are connected to the accident and help in the development of blaming free reports that encourage learning from accidents. Thus, the framework of the RBAI model created by combining the acceptance Index (AI) with system design. The methodology presented to facilitate the overpressure system state(i.e., CNG cylinder onboard vehicle-model) and make them accessible. A toolset assembled to identify and assess the hazard. For this purpose, a practical survey with state of the art methods has been conducted.

The research method is beneficial for several reasons: 1) designing systems to be safe; 2) diagnosing policies and identifying design flaws that contribute to high-risk operations; 3) identifying designs that increase the risk; 4) it enables the identification of technical and organizational factors to monitor states of increasing risk before an accident occurs, and 5) allowing systematic decision-makers to predict how current policies would affect safety.

1.0 INTRODUCTION

Natural gas is one of the promising potential energies carriers due to its unique properties. According to the world statistics summary [2], there are more than twenty million natural gas vehicles NGVs on the roads worldwide. Although the environmental and economic benefits associated with alternative fuels (i.e., CNG, LNG, H_2, etc.) attracted many industries to invest in it, alternatives utilized to perform in more challenging environments, with higher energy densities and power efficiencies over longer lifetimes. As a result of CNG operation, about 90% of emission reduction [3] also noted that the potential for water pollution occurred with fossil fuels is minimal [4]. Regardless of the benefits of CNG [5], the safety concern of overpressure cylinder CNG considered a problem. However, effectiveness modeling is becoming one of the necessary tools for developing and ensuring the quality and safety of alternative fuels, particularly for systems such as compressed natural gas (CNG) during Operation. Also, to account for societal acceptance criteria of the risk associated with the process of CNG, it is necessary to establish the acceptable level of reliability of the components of the CNG. Moreover, the study of compressible gas (CNG) onboard vehicles has not thoroughly examined with the applicability and possible failure of the CNG cylinder.

In this research, there would be an outline and discussion of best practices regarding risk-based acceptance index (RBAI) as an appropriate, cost-effective means as part of risk evaluation.

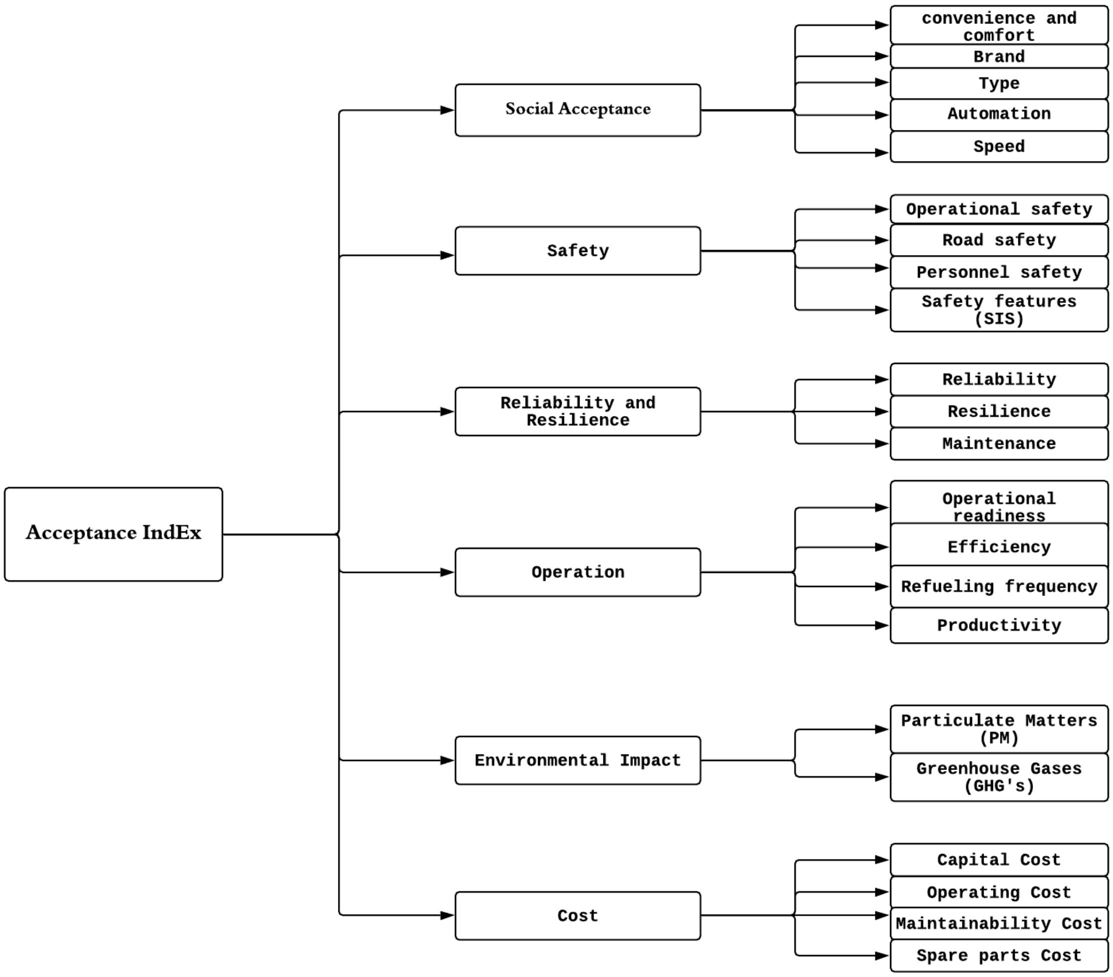


Figure 1.0: The framework of Acceptance Index calculation

Despite the engineering similarity with accident reports, there are struggling to learn regarding the design for new systems, which is most likely leading to more failures and accident continue to occur [6].

While alternative fuels such as CNG reduce pollution hazards, other potential hazards are initiated. Information is essential to cope with the impact of any circumstance (e.g., hazard). The evaluation of risk for CNG onboard required a good understanding of CNG chemical and physical properties under various operating conditions. To evaluate the risk of a proposed design, a risk-based acceptance index used to assist in managing risk, offering a proactive way to identify and resolve safety issues.

Furthermore, the applications of the generic risk assessment framework and the RBAI to decision making on target reliability indices for the structural design of components of CNG. A description of the concept of risk-based acceptance index (RBAI), which model critical aspects in CNG onboard introduced. Subsequently, alternative tools and methods (i.e., spss, survey) are supported to help decision-makers in managing a state of high risks.

The CNG could indeed become one of the promising technologies for transportation in the future if we could safely cope with the "threat" of the high-pressure system.

However, earlier researches noted that uncertainty attributed to ambiguity, likelihood approximation, and inconsistency in defining the variables, parameters, and performances [6]. Thus, it is most likely that any predictive assessment model is inherently uncertain [6,7]. Risk assessment is not an exception too. The question is not often whether or not uncertainty is involved in an evaluation; instead, it is how much change (uncertainty) included. In identifying the uncertainties in risk assessment, it is imperative to discuss the methods used to assess the risk. Therefore, improper uncertainty characterization could lead to a higher likelihood of an adverse event, as well as the estimated cost as a means of compensating for that risk increased [6,7,8]. An accidental scenario of the applicability of the RBAI for designing a CNG can be performed. To achieve this objective, it is necessary to understand and define the dynamic feedback in complex systems process that may cause the risk to increase over time—a detailed CNG risk assessment discussion provided in chapter five.

1.1 THE LIMITATIONS OF FAILURE ANALYSIS

A lack of a method for framing and connecting end-user factors to the technical system failure or loss event is one of the safety officer's concerns [6]. They are used to examine the safety of a deployed system after it has failed. Professionals have attributed human factors as a cause of accidents [7]. Recently, accident analysts have also begun to cite organizational factors as contributory causes of accidents. Although analysts have long known that the human factor is a critical contributor to accidents, there was a lack of defining an approach for analyzing the accidental impacts. It is difficult to understand or recognize which data was available or followed when an accident occurred. Therefore, accident investigators are unable to identify which people to interview or what questions to ask [9,10]. Thus, different risk investigation methods (i.e., survey, risk-related, and hazard) required as guidance for helping in the analysis of the role of end-users in accidents, Appendix A.

1.1.1 HAZARD ANALYSIS DESCRIPTION AND KNOWLEDGE GAPS

The hazard analytical method is the process by which a design analyzed for safety. It used to identify hazardous states in a system or scenario. If it integrated with a design process, Figure 1.3, this allows us to consider the RBAI for design aspects during system development. RBAI enables them to make an intelligent compromise between safety and other aspects of the design (e.g., performance, cost, reliability, etc.). As Hammer states that "The concept of the safety system predicated on the principle of the most effective means to avoid any accident during system operations is by cutting off or mitigating hazards and threats during design and development stage" [11]. The hazard analysis methods in use today do not call for safety engineers and managers to analyze and plan for the impact of end-users, social context, and community in which it operates. Although engineers devote considerable attention to technical processes, they pay a little attention to prospectively analyzing or planning the whole social levels of the design of a system for safety, particularly for the CNG system. Therefore, the results have appropriate technical specifications but contain flaws in the process design. Also, one of the limitations of the traditional hazard methods is that it cannot comprehensively identify hazardous scenarios involving humans (i.e., end-user). It is worthing to note that safety must be design into a system rather than added on to an otherwise complete design; however, engineers should intentionally create interactions with the system to be safe and also plan for safety into the individual human roles, including, end-user behavior, procedures. It is vital to set up an alternative hazard analysis method for a high-pressure system and consider the end-user role in potential losses in the process. Woods has reported that there is a trend to design humans out of the system, which squeezes the problem solver role and reduces the system resistance, eventually increase the likelihood of accidents [12]. Therefore, developing the human (i.e., end-user) into the system structure is essential and beneficial.

1.2 SAFETY CHALLENGES

A unique challenge to the evaluation of the safety of an overpressure cylinder, the design of safe systems, and the investigation of risks is the dynamic nature of complex alternative fuel systems (i.e., CNG, H_2, etc.). For instance, as the needs identified, new environmental requirements levied, and stakeholder expectations raised, the needs of organizations change, and the system pressured to change. Even if the system designed to be safe, without consideration of the system's evolving goals, risk propagation would occur. Reflection of humans and impacts on safety needs to be reviewed both in the development and Operation of alternative complex systems throughout the system lifecycle to prevent or mitigate any possible risks.

Leveson and Stringfellow noted that complex systems often operated in high-risk states, which can lead to unacceptable loss events [13][14]. Thus, end-users or operators may be unable to 1) recognize which designs, processes, and procedures would lead to high-risk operations; 2) understand the factors encourage high-risk operations, or 3) find solutions to promote safer operations. The challenges to safe operations are insurmountable without consideration of safety in the development of the system. Unsafely designed systems cannot be secured over a long period; thus, adopting a model to design flaws that would foster risky operations and guide designers to safe alternatives.

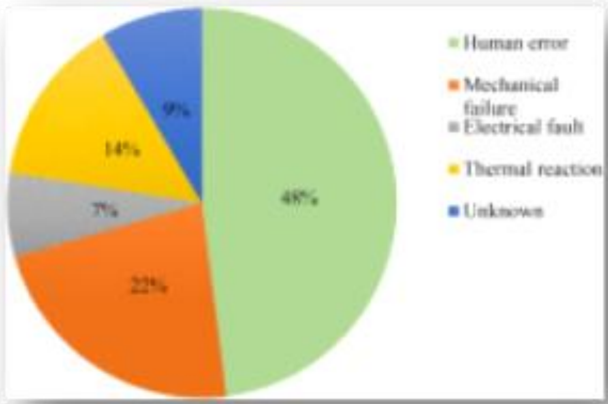


Figure 1.1: Causes of Accidents in transportation [17]

Therefore, a useful analysis technique must fulfill several goals:

- Safety Analysis Method

The safety analysis method must consider how systems pushed to high-risk states and the boundary of safe operations. Also, it can be useful in the following aspects;

a) exposure of hazardous systems that will be susceptible to risk migration;

b) identification of high-risk operations;

c) prediction of the impact on safety by proposed policies.

Also, it cant be used as guidance for industrial developers to consider measures against increasing risk and help in the design of resilient systems.

- A new Analysis Method Technique

It must be of use in the design of alternative systems as well as those already deployed. In modern systems, the risk analysis method will be integrated into the design process to ensure the creation of a safe design. In existing systems, it used to analyze and then propose changes to reengineer a system.

There is no Risk-based acceptance index analysis currently exists. This thesis presents the motivation, development, and demonstration of feasibility for such a new risk analysis based adopted index.

1.3 RESEARCH GOALS AND HYPOTHESIS

In the research, the purpose was to apply existing theories to a novel situation (alternative fuels (i.e., CNG) in Transportation Industry). As the literature review showed, a theoretical framework already exists that can be constructed and applied to the research situation, a detailed explanation of the framework given in the following chapter.

The goal of the research presented in this thesis is to create a methodology for the inclusion of human factors as social context into safety engineering processes by conducting one of the RBAI tools Figure 1.2. The goal implemented by developing a method that uses a rational framework, including human decisions and factors that contribute to control in the safety analysis. It enables the discovery and exposure of conditions leading to hazards; and help to find new solutions, policies, and design changes to improve system safety. To that end, I sought to develop a novel method for risk-based acceptance index (RBAI) analysis suitable for socio-technical complexes, such as CNG, systems.

PROPERTIES	GASOLINE	CNG
Vapour density	3.5	0.68
Ignition	430˚C	700˚C
Octane rating	96	130
Boiling point (Atm.Press)	27˚C	-162˚C
Air-Fuel Ratio (Weight)	14.5	17.24
Chemical Reaction With Rubber	Yes	No
Storage Pressure	Atm. Pressure	20.6Mpa
Fuel Air Mixture Quality	Poor	Good
Pollution CO-HC-Nox	High	Very Low
Flame Speed (m/ sec)	0.83	0.63
Combust. ability with air	1-16%	4-14%

Table 1.0: Characteristics of Gasoline and CNG [3].

1.4 RESEARCH APPROACH

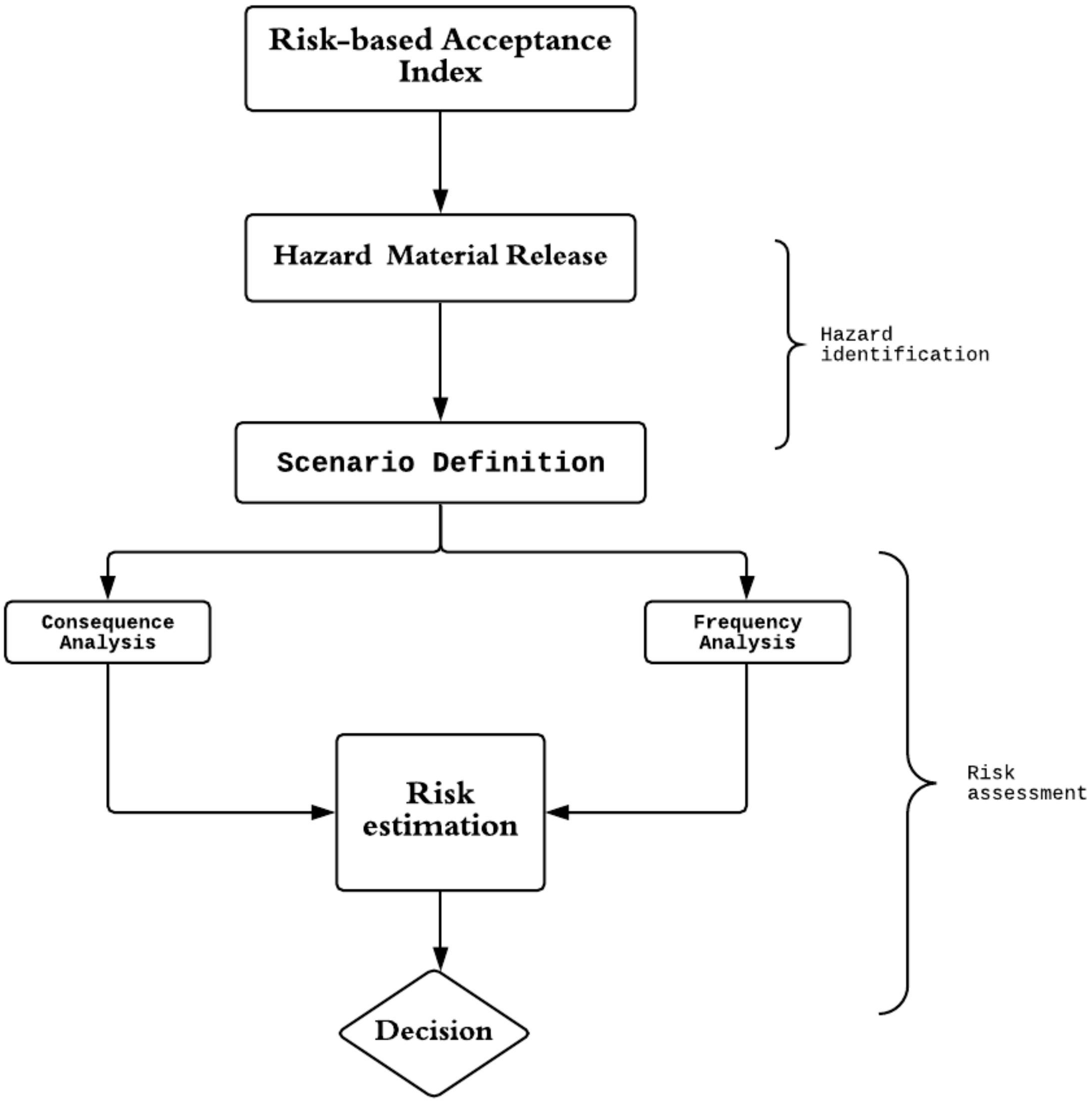


Figure 1.2: Risk-based Acceptance Index (RBAI)

Figure 1.2 illustrated the integration of acceptance index into the hazard identification to give a complete risk-based acceptance index. The RBAI is supporting overpressure storage tanks in the automobile industry divided into two parts. The first part describes the risk of the system, while the second part is selecting the acceptance index defined as the determinants. As Figure 1.0 showed, the process started with a definition of elemental requirements that used as the foundation in the designing process. Some of these requirements can be classified as functional and technical requirements. These requirements are also can be good candidates for the evaluation process. It assists in understanding what and how alternatives supposed to works.

1.4.1 CNG ONBOARD SYSTEM USING RBAI

The evaluation of the risk of CNG onboard vehicle requires a good understanding of CNG chemical and physical properties under various operating conditions. Existing standards, specifications, regulations, and designing guidelines should be examined for safety purposes with consideration for the applicability to a specific design. This information assists in conducting a system risk analysis. To consistently evaluate the risk of a proposed CNG onboard vehicle designing, a risk-based acceptance index may be used to help manage the risk. They are offering a proactive way to identify and resolve safety issues.

Risk-based acceptance index (RBAI) is a scientific method and process used to manage the risk of a component or system such as CNG onboard. RBAI methodology could be classified into several risk analysis methods such as risk assessment, risk control, risk, management, and risk perception.

Risk assessment consists of hazard identification, event-probability, and consequence assessment. Risk control provides design and operating features to reduce risk. Risk management requires the definition of acceptable risk and comparative evaluation of options or alternatives through a decision analysis method. Risk management provides decision techniques with consideration of risk assessment results and risk control measures. Risk communication involves perceptions of risk, which vary depending on the particular audience.

The proposed framework divided into several steps. The first step is defining the system through a system breakdown model. This model identifies the functional relationship among the system components and categorized as factors (i.e., determinants). Hazard identification is used to identify hazards associated with CNG system design. A hazard is an act or phenomenon posing harm to people and surrounding(s).

Risk assessment combines the probability and consequence of various possible scenarios to determine risk. Risk management determines the acceptable design, considering the results of the risk assessment in the decision process. The design may need to improve or changed to meet the tolerable risk levels. Therefore, defining a systematic method to develop an alternative risk-based analysis method for designing CNG onboard vehicles is a complex task. To simplify it, we sought to understand the CNG factors that contribute to failures. Then, I tried to know how to identify social factors and CNG design that contribute to high-risk operations before an accident has occurred. In so doing, the following research approaches considered:

1. Performing a grounded theory qualitative research approach using risk reports and analyses for data. Reviewed related reports and risk-based studies from the fields of

industry, energy, manufacturing, and medicine and then identified inadequate control actions.

2. Identified the context (the system design) that permitted or encouraged insufficient control.

3. Identified improper control actions (Hazard Identification)

4. The next step was to set-up the foundation of the method (Acceptance Index). Using concepts from recent studies.

5. The identified requirements help to bridge the gap between identifying the causes of failure and applying principles from control systems when thinking to design safe systems, particularly the CNG system. After that, I attempt to classify the factors using an engineering framework. (Risk Assessment)

a. The requirements used to create indicators that describe and classify sources of inadequate control for CNG system

6. Using the guidewords, a structured approach to risk-based acceptance index analysis created.

a. An application of the risk-based analysis method to a well-known accident to demonstrate its feasibility achieved.

7. Application of the analysis method from several industries.

More detailed information about the research methodology provided in the following chapters, Figures 1.3. Generally, the first layer covers the investigation and classification of information related to the vehicle, transportation environment, infrastructure, and end user's needs. Typically, data is carried out at this stage to derive relevant information. The information obtained by this layer used by the decision layer, where CNG onboard situation and condition are analyzed to identify the end-users concern and estimate risk-based (risk assessment). Based on this analysis and the risk-based estimation, a decision on an appropriate action can be made. It is a complex process due to the complicated relationship between the end-user and the variables. In other words, for example, if the end-user indicates a concerning behavior towards safety as it is the most significant factor affect the decision of choice. However, it might be different with the cost as it changes with time. Identifying and estimating risk in such a situation is a challenge. To resolve that, therefore, distinguishing and characterizing between an independent variable and dependent variable important and may be used as an indication.

Furthermore, a characterization of the sequence events results in failure described as determinants (social acceptance, safety, reliability, cost, environment, and Operation). This characterization of the index provides information on the causation mechanism and the relationships between these factors, i.e., CNG and safety. To develop an effective method for the development of safe CNG onboard, acceptance index (AI) developed based on real issues that the end-users encounter in daily life. It requires a thorough understanding of why and how critical traffic situation such as accidents occurrence and how the end-user behave towards it. In this stage of the framework, the development of risk-based acceptance index (RBAI) assists to derive the required information is the goal. The RBAI should help the end-user to observe the ability of CNG onboard to fulfill their demands. It includes enhancing the end-users' ability to explain and interpret the development of system design. The research framework provides a combination of social and industrial in making a decision.

- Providing additional support in the form of information about the end-users; needs and preference
- Define the end-users' needs, based on the value end-users' needs and the risk of choice.
- Risk can be predicted by the end-users' needs over time and the value

In particular, the model concept presented here is intended to provide support to CNGV design, where the risk of accidents with CNG is high. As illustrated earlier in Figure 1.0, the basic idea of the concept is to use separate adopted acceptance index in the infrastructure for observation of risk to support CNGV designing. Risk estimation can be obtained. If the risk exceeds the selected threshold criteria, a necessary improvement is essential. This model approach including:

1- The requirements of observation of CNG onboard vehicle and estimation of the end-users' needs based on the adopted risk-based acceptance index.
2- Designing a questionnaire sample or study instrument for data collection
3- Accident risk assessment
4- Using appropriate software-SPSS

The process of the framework methodology based on various scenarios in a sample (questionnaires sample). This sample divided into four sections (socio-economics, perception, behavioral, and attitudinal); see Appendix I. Each one implies the sequence of events leading to various situations. In the first section, a general description of the end-user provided. The second section, risk as to the end-user, behaves towards CNG, defined that it is well-known as a perception of risk. In the third section, CNG and end-user behavior are included. It clarifies the circumstances in traffic that how the essential factor affects the end-user's behavior. For example, a general description for a CNG onboard could provide feedback to the end-user in a more safely driving situation. Besides, a description of the interaction of the selected index with end-user obtained.

Consequently, a detailed description of the failure causation mechanisms of each scenario (questionnaire) obtained. Traditionally, accident data investigated to accommodate this description, i.e., to explain why and how an accident occurred.

In this study, however, it is difficult to obtain a large sample, especially if the data collection is limited to a certain region. This application of quantitative judgmental assessment to procedural detail of CJG onboard vehicle suggested in favor of verbal quantifier (i.e., likely, unlikely, etc.) for probability analysis achieved. It includes six factors of acceptance index. The quantitative response mode used typically label (1=strongly low; 2=low; 3=somewhat low; 4=neutral; 5=somewhat high; 6= high; 7=strongly high). Misinformation of inference can bias probability estimation. SEM is used for data analysis, and it is a statistical method for the estimation of frequency and rate. SEM is an ideal tool for identifying and confirming full models of relationships between variables [15].

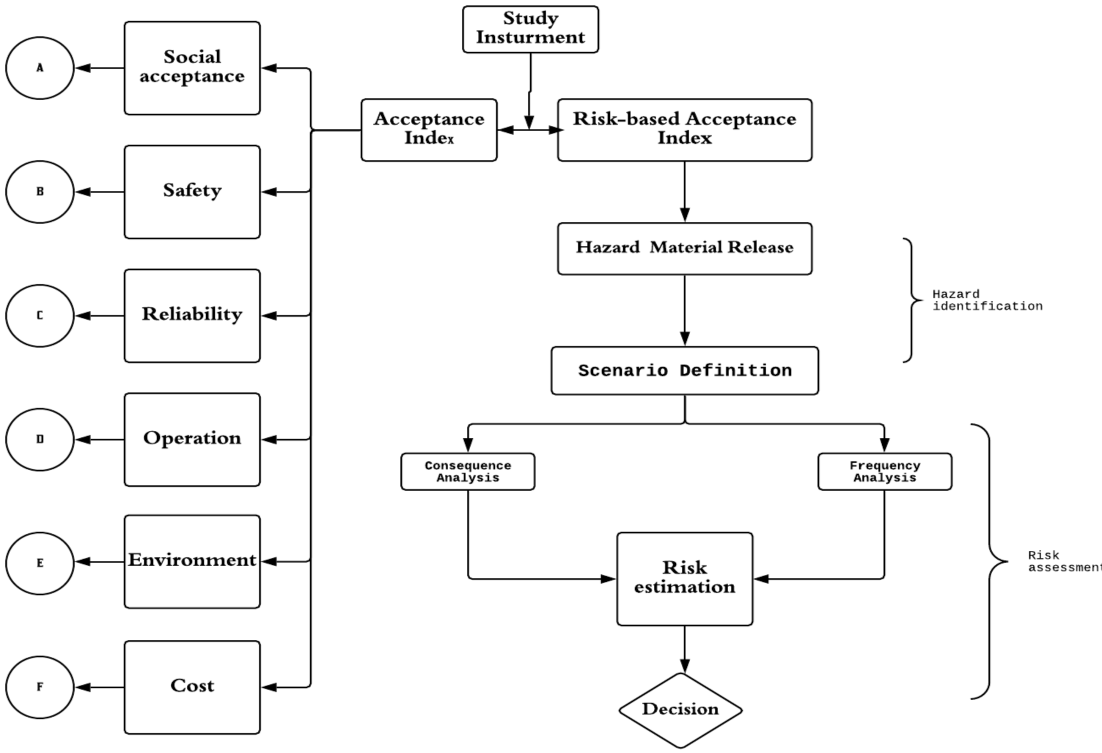


Figure 1.3: The Research procedures framework

A detailed description of the integration of social context and industrial by assigned items. These assigned items on the left side are the basis of the acceptance index, while the assigned items on the right side are mainly the hazard identification and risk analysis. The integration of those items generated the Risk-based Acceptance Index (RBAI).

CHAPTER 2: LITERATURE REVIEW

In the current millennium, the improvement of transportation patterns has become essential since it is one of the largest sources of energy-related CO_2 and contributing to environmental damage (i.e., GHG's, CH_4, CO_2, SO_2,etc.), and causing fire and explosion threat. International Traffic Safety Data and Analysis Group (IRTAD) reported that 1.25 million people killed on the world's roads every year, and tens of millions are injured [18].

There are many kinds of literature searching and defining variables controlling human factor selection. Secondly, the chapter proposed the theoretical research model followed by a research framework to improve the reliability of the model.

The topic of the study introduced and background information on the individual decision of selections along with a discussion of the significant contribution of the academia, researchers, engineers, and industries provided. Secondly, the chapter discusses the literature gap and gives a simple conceptual framework of the research. The paper offers an integrated framework for risk assessment that can be useful to regulators of the CNG industry for code development and to operators to support compliance with some code requirements. The proposed framework is a systematic procedure that also helps the decision-making process on the evaluation of risks associated with alternatives activities and for cost-benefit assessment of measures to reduce risks. The integrated framework here provides an improved methodology for quantitative risk assessments that fully support approaches applied for decision-making regarding the structural design of CNG systems components. It optimized the reliability in financial terms and helped support the decision-making process for selecting target effective design. It can be expected to be useful as a tool for code development

Research methods frequently applied in domestic and foreign studies on the safety of designing optimization are mainly fuzzy evaluation, optimization model of minimal safety cost, an optimal model of safety benefits. Fuzzy evaluation relies primarily on surveys conducted by experts. Safety benefits, the fundamental aim of using the adopted acceptance index is to lower safety risks, which may reduce safety risks.

The safety-driven design in a new concept in safety engineering and current state-of-the-art solutions for examining the impact of humans on safety are mostly limited to analyses performed after a system has developed. These methods tend to focus their recommendations for safety improvements on end-user selections. For complex systems (i.e., CNG), it must be designed to be safe from the beginning to support a safe individual decision.

2.1 GENERAL BACKGROUND

The theory underlying analysis procedures derives from the research in settings outside the oil and gas industries. Such as in medicine, education, aviation, and psychology industries. There are many investigations led to understand causes events focussed on the individual and complexity of technology events, which may result in an adverse consequence, such as how people interact with technologies daily. Earlier Kerm mentioned that the importance of human factors in the designing process, system, devices for safe and productive for human use, and how it could lead to confusing and disrupting if not taking into account [16]. The causes of adverse alternative technological events may lie in factors such as Human factors. It also has been noted that human behaviors factor has a potential impact on the design of tools, i.e., machines, systems, tasks, jobs, and environments [16]. Furthermore, Baalisampang mentioned that the human factor is an integral part of the system and organization [17]. According to Preventing Motor Vehicle Occupant Injuries (PMVCI), human factor affects the risk of accidents.

In 2018, Baalisampang focused on the influence risk factors and observed that most of the fire and explosion accidents caused by end-users [17]. On the other hand, Chiu and Tzeng analyzed the factor influencing rational decision and satisfaction when choosing a vehicle [19]. In their investigation, the cost and safety carefully considered as the prime concerns driving people to invest in a private car.

However, Xiu and Zhang [20] noted that the fluctuation in fuel price has made the end-users more cautious about the traditional transportation mode. Historically, the average rate of the regular vehicle price gradually increased as well as the fuel due to the fluctuations in oil prices. Therefore, the end-users decision made upon the comparison and the sustainability of costs and expenses. The initial investigation of the study defined that potential factors of the experimental research, including safety, and cost, are valid. The following part of this chapter reviews the cause and effect of the possible accidents in the transportation sector.

Although the number of accidents in the transportation industry fluctuated, the causes of those accidents remain the same in Figure 1.1. The figure shows a significant influence on the human factor. For instance, human errors (i.e., faulty decision, skills, and misunderstanding, etc.) are the causes of transportation accidents followed by 22% mechanical failures and 14% thermal reaction, but electrical faults cause only 3%. However, about 9% of the total accidental is still unrecognized.

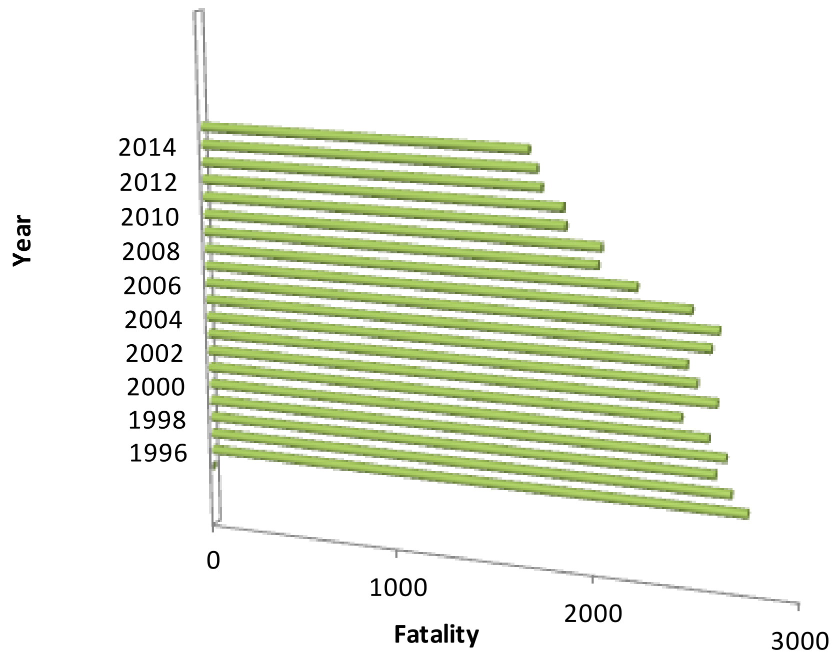


Figure 2.0: The number of fatal accidents in Canada [21]

However, although other researchers demonstrated that CNGV required complex operational units and also required new installations. One of the research targets is to show the essential role of safety when the participants decide on CNGV. It has been done by adopting an experimental survey study and randomly distributed. First, it showed that the safety and risk associated with the high-pressure state the primary concern of the response when CNG cylinder installed onboard vehicle. Therefore, the threat related to an overpressure CNG cylinder could lower the chance of vehicle preference. It is worthy of mentioning that the CNG cylinder is a critical risk for CNGV technology. It is a challenge. In this regard, a scenario profoundly analyzed in more detail in the thesis. The studies presented different factors that influence an individual decision. Table 2.1 summarizes the results of the previous studies of the controlled factors on the decision-making process on alternatives.

Author (s)	Factor (s)
Cheron and Zins	Reliability, comfort, durability, power, safety, economy, price of parts, perceived risk, having an accident, mechanical breakdown, and readiness
Diamond	high occupancy vehicle, gas, the annual cost of fuel, income
Chiu and Tzeng	Purchasing price, reliability, speed, emission level, operating cost, style, agility, cruise distance, and acceleration
Lipman and Delucchi	Manufacturing cost, lifecycle cost, and retail prices
Sallee	Tax credits
West	Gasoline price
Chandra	Tax rebates
Li &Berensteanu	Gasoline price, government support
Kang and Park	Experience, policy, change in gasoline price, values, and needs
Zhang et al.	Performance, policy, environmental requirements, opinions, price, fuel availability and price, maintenance costs, and safety
Tarigan et al.	Knowledge, personal benefits, and environmental attitude
Klockner et al.	Needs, social norm, consequences, and attitude, knowledge
Skippon	Dynamic performance and cruising performance

Table 2.1: Summaries of previous studies of controlling factors on decision

2.2 CONCEPTUAL AND THEORETICAL FRAMEWORK OF SURVEY

Qualitative survey methods started to gain prominence in development projects during the decade of the eighties(1980s), primarily in response to the drawbacks of questionnaire type surveys, which considered as time-consuming, expensive, and not suitable for providing an in-depth understanding of an issue. It led to a polarization in the collection and analysis of information with quantitative and qualitative methods. The limitation of this approach based on the quality of data of this polarization. In the meantime, it recognized that there are areas/interfaces where the two types of approach can benefit from each other, leading in improving the quality of information required for intelligent decision-making at the various stages. During the '90s, attempts made to highlight the complementarity of the approach. For example, in the field of renewable natural resources research, it was realized that while some researchers were combining methods as a matter of course while conducting field research. Moreover, several avenues of potential remained untapped due to the complexity of defining risk, which requires a practical method for constructing the risk of CNG cylinder onboard vehicles. Therefore, adopting a hierarchy model for making an alternative decision is needed. The decision hierarchy model is a tool to evaluate the complicated decision by measuring the rating scale, which reflects the preference level of the end-user towards the survey sample. The model designs the problem in a network structure to create a relationship between independent variables and dependent variables.

2.3 PRESENTATION OF THE MODEL

Among the decision-making models, the multi-regression model is the most widespread and used in many fields. It seeks to study the decision of choice or the perception of the value of an event among a set of mutually independent variables.

The consideration of the individual decision of choice as a selection process between several mutually exclusive contingencies that belong to a set of eventualities was studied. Those eventualities chosen by the individuals (i.e., end-users) would be the ones that optimize their objective function. The decision is taken, therefore, result from an optimization process reflecting the rational behavior of the individual.

As long as the choice of the individual established randomly, the modeling would remain probabilistic. Thus, the choice of individual may not be precisely predicted, but an estimation of the probability of the choice possible according to the circumstance of choice and the socio-demographic characteristics of the individual as well as the method of choice/ technique.

2.3.1 THE RESEARCH MODEL

The following multi regression model allows us to estimate the probability that an individual (e.g., i) choose an alternative (e.g., j) in given circumstances characterizing the environment of choice. The individual decision of choice behavior (perception) of the value of an event considered as a selection process between several mutually exclusive choices that belong to a set of eventualities. These eventualities decided by an individual are the one that optimizes its objective function. The objective function of each individual depends on the sociodemographic and technical characteristics of individual and alternative, respectively. Therefore, the choice is taken result from an optimization process reflecting a rational behavior of the individual. We, in this case, can call it probabilistic modeling since the individual decision of choice is established randomly, which never occurs in an identical circumstance. The probability estimation can then obtain according to the choice circumstance and the socio-demographic factor. Therefore, the following mathematical model is used to assess the proposed risk-based acceptance index to develop and support a solid compressed natural gas vehicle design. It also helps to identify the risk that occurs due to the failure of the dependent variable. The dependent variable is a result of a failure of one or multiple independent variables. Thus, the estimation of risk probability can be defined regarding the weighting. Identifying the relationship between the alternative compressed natural gas vehicle (dependent variable) and the risk-based index could help to develop a promising vehicular design that copes with the social and industrial demands. The correlation between variables illustrated as the determinants of transportation selection, including; SO, SA, RR, OP, EI, and C (i.e., independent factors). The following model (1) defines the risk by multiplying weighting factor (probability) by consequence,

$$R = P * C \qquad (1)$$

$$TC = ß0 + ß1SOT + ß2SAT + ß3\ RRT + ß4OPT + ß5EIT + ß6COT \qquad (2)$$

R = Risk

P = Probability

C = Consequence

TC = Transportation Choice

SOT = Social Acceptance

SAT = Safety

RRT = Reliability and Resilience

OPT = Operation

EIT = Environmental Impact

COT= Cost

Suppose the outcome of the process is denoted by variable (TC), and known as the dependent variable, depending on the dependent variables (e.g., SAT, RRT, OPT, EIT, COT are independent variables), $ß_0$ is the intercept and the characterization of each variable defined by ($ß_1$, $ß_2$, $ß_3$, $ß_4$, $ß_5$, $ß_6$) respectively which used to estimate the average rate of change. These parameters are unknown that we seek to estimate, respectively, reflecting weighting coefficients of variables in the determination of the probability. The deterministic function (TC) reflects the perception of an average individual of the satisfaction provided by choice of an alternative. It takes many forms, but the study adopted this form to estimate the weighting coefficients of variables that reflect the importance of each variable relating to individual characteristics, and the attributes of variables in the description of the objective function. For instance, if they are positive, then they affect the probability positively and vice versa.

Thus, it particularly in this study, allows us firstly to assess the degree of influence of selected independent variables on the alternative technology, CNGV.

Secondly, it enables us to find out some judgments about the fact and the relative strengths of different independent variables. A case study provided in the later chapter. More details for the model applications given in chapter seven.

2.4 RELATIONSHIP DEVELOPMENT BETWEEN VARIABLES AND ALTERNATIVE TECHNOLOGY (CNGV)

The effect of the end-user analysis process on the alternative compressed natural gas vehicle (CNGV) and uncertainty associated with the proposed index thoroughly evaluated. The experimental study has been focused on two issues: (1) how the end-user behaviors evolved into the future and changes in the assumptions that lead to different predictions of choices. (2) How the result interpreted and analyzed in the engineering perspectives. Finally, an integration of social responses reflected as decisions and engineering analysis on the design of alternative technology CNGV using appropriate analysis tools achieved.

The Factor analysis is a unique method to test the correlation between observed variables and factors that affect the value of the observed variables, i.e., indicators. Applications of factor model to analyze industrial-related decisions are uncommon. The fundamental mathematical analysis first described by Charles Spearman in 1904. Recent studies noted that decision-makers are susceptible to two factors: (1) process and (2) state of the affair [22]. Others presented the awareness of the second choice that may cause by experience, lifestyle, and values, and economy-society factors. McFadden empirically demonstrated how human behaviors influence decision-making due to the way information stored and processed [23]. Therefore, an individual derives the utilities by making a decision. Then cumulative probabilities of individual selection help to produce estimation for the population.

Figure 1.2 described the adopted acceptance index (AI) given in the previous chapter. It divided into six factors. In this thesis, analysis and discussion of the relationship between alternatives and variables were performed. The proposed study instrument illustrates the impact of those indicators, including (1) social acceptance, (2) safety, (3) reliability, (4) operation, (5) environmental impact, (6) cost on the compressed natural gas vehicle design.

Many researchers emphasize that the quality of the technology and how it becomes essential when a comparison made. Earlier [23,26] MacFadden has empirically demonstrated that human behaviors influenced decision making; he has surveyed by using large samples to analyze factors that influenced rational decisions. Other researchers mentioned quality considered one of the most important influential factors that affect human decisions. It is shaping the arrangement of transportation mode. Also, the instrument of study has shown that the impact of social factors on the decision-makers, i.e., convenience, brand, type, automation, and speed, has positively identified and statistically discussed.

Cheron and Zins studied determinants factors such as comfort and its impact on the consumer's choices [24]. Their study concluded that the most critical selection criteria, i.e., quality, reliability, and cost.

In addition, it has been found that the impact of the reliability and resilience on the participant's decisions were minimal [24].

There has been an increased awareness of improving traffic safety while developing safety programs [25]. Despite the remarkable effort performed at a different level to achieve a fast transportation system, the number of accidents and incidents on the road is still high. Thus, the transport system considers as riskier than air transportation. Change in technology is not as easy as we might expect; the safety of adopted technology such as

CNGV can affect decision-making regarding purchasing choices. Also, it may lead to developing alternative and new safety measures. The participants' responses and opinions towards safety define the safety role and determine how this information could help decision-makers. For instance, there is a hidden extra cost that may affect the decision-making process, i.e., the effect of indirect cost (incremental insurance cost). It becomes essential and hardly measured when an accident happened [27].

The reliability of an alternative can be an ideal way to demonstrate and present alternative CNGV into the market. Recent studies mentioned that a mixed relationship between transport choice and reliability found. There were some researchers supported the argument that the reliability affected and controlled the end user's decision. Chiu found that more than 35% of the respondents consider the safety is a factor when they decide to buy a car while Zhang pointed out that reliability as an essential factor. Based on those studies, younger ages have high expectations of the reliability of the car than the older generations.

Although CNG recognized for its environmental advantages, a minimal effect on the decision process reported by the questionnaire survey, it may be due to recent development technologies that offer a variety of options regarding emission reduction associated with each form of transport.

Others noted that giving off new technologies created a situation where users are more aware of marketing conditions and cause more sensitivity towards the price. The uncertainty of alternative marketing costs for CNG may be a challenge in the future.

However, the initial response of the questionnaire sample showed that respondents were more sensitive towards safety at the most.

Also, Gaerfe's research mentioned that the introduction of risk into industrial decisions has the potential to change the process of decision-making when personal safety is a concern. Recently, Fuchs [28] discussed how events affect the safety and also analyzed the impact of hypothetical accidents on individuals' decision, but Rittichainuwat assessed the human behaviors of safety measures. Thus, natural and social are the most inducers that affect the management decision to deal with any events. In 2013, the author noted that the correlation between human behaviors and natural disasters (i.e., wildfire), while others found that the characteristics are essential regarding the perception of the type of risk. It demonstrated the fact that human behaviors towards natural catastrophes and pointing out how individuals define and understand risk and how they control their future decision.

Furthermore, Azim concluded that gender might play a significant role in the perception of physical risk. He mentioned that the likelihood of alerting decisions in a risky event influenced by gender. It also supported by Zhang and Gibson, who were distinguishing between female and men and mentioned that men are more concerned about it than a woman [29]. Although there some scientists who believe that there was a social influence on the decision, George suggested that there is no relationship between gender and the perception of related risk [30].

How the end-users' needs recognized and achieved is the purpose of the previous part of this section. It is socially defined to evaluate the social response and measure their understanding of the compressed natural gas vehicle. It enables us to determine the participants' needs by asking multiple questions regarding the research title. Furthermore, to achieve this purpose, a specific group of people randomly chosen from MUN community, which reflected a multidisciplinary institute dedicated to innovation and creativity in education and public engagement, to respond.

Secondly, the body of the experimental study focuses on the relationship between social response and industrial observation towards compressed natural gas vehicle CNGV. The research proposed a mathematical equation to define the relationship amongst variables. Consequently, it demonstrates that if there is a significant relationship between the independent and dependent variables. Also, it presents how the respondents persuaded to decide when they tempted into CNGV's.

Several studies have modeled the outcomes involved in accident modeling. An illustration of the risk-based acceptance index for supporting the design of the compressed natural gas vehicle provided Chapter 1.

Although CNG considered environmentally clean, the limitation of compressed natural gas vehicles and uncertainty associated with the outcome of the failure of overpressure container still unclear regarding the magnitude and risk degree if an accident occurred, and the transportation safety measure. Also, the uncertainty of technical and operational of CNGV.

Furthermore, the fluctuation of the fuel price may become a key factor even though the current fuel price showed that it is cheaper than fossil fuel's price. The fuel characteristic of CNG may be attractive factors. However, requirements for new infrastructure and installations (i.e., gas pipelines) may cause problems.

However, the study considers a question of safety to be discussed based on the result of the experimental research (survey) of the selected index.

Is it possible that CNGV drove safely? (Yes / No)Whether the answer yes or no, the study explains the form of scenario presentation to determine the impact of CNG installation in the driven vehicle.

The framework of the study illustrated the determinants of alternative compressed natural gas onboard vehicle CNGV decision, which involved the social acceptance index of safety, reliability, Operation, environmental impact, and cost as independent factors. The quantification of each fundamental parameter performed for the proposed process or product. An analytical method used to compute the weights for each essential parameter and sub-indices. For this purpose, SSPS is implemented as a composite process to determine the final overall value. Several indices widely published in literature such as ECO-INDEX and LINX index. Those procedures valid to explain the methodology for the computation of the new indexing system and displaying with an application [31]. The development of the study experiment involved an examination of the frequency distribution of items and the correlation matrix — those used to improve the internal consistency of items using SSPS.

No.	Section	Number of Question
1	Socio-Demographic	5
2	Perception	6
3	Facts	9
4	Opinion	24

Table 2.2: Classification of the questionnaire survey

The acceptance index (AI) divided into six factors, including:

- Social Acceptance factors: Influential factors that are controlling people behaviors
- Safety: Being safe and protected from risk or injury
- Reliability and Resilience: Imply a constant excellent performance
- Operation: Implies the transformation of input (raw material) to output which can be identified as the level of the participant's satisfaction
- Environmental Impact: The environmental effect of the alternative CNGV on the decision-making
- Cost: Implies the influence of alternative CNGV costs on the decision.

2.4.1 TRANSPORTATION MODE SELECTION AND SOCIAL FACTORS

Many researchers emphasize that the quality of technology is an essential factor when a comparison made. MacFadden [23] has empirically demonstrated that human behaviors influenced decision making by performing a survey using more than 350 samples to analyze the influential factors. An agreement of other literature that quality is one of the prominent factors and plays a vital role in end-user's decision. Cheron and Zins studied determinants factors such as comfort and its impact on the consumer's selections [24]. The study focused on the essential selection criteria (i.e., quality, reliability, and cost).

Thus, quality considered one of the influential factors when a decision made. It indirectly influences transportation mode choice. Furthermore, based on our thesis, the impact of the quality of the transportation (i.e., social acceptance factors including convenience, brand, type, automation, and speed) has positively identified by conducting an experimental study.

2.4.2 TRANSPORTATION MODE AND SAFETY

Natural gas does have several safety benefits over conventional vehicles (i.e., gasoline). Since it is gas instead of a liquid, it has high dispersal rates. It is lighter than air, so it tends to rise and disperse into the atmosphere rather than spreading on the floor as gasoline. Also, non-toxic to people or animals. The only respiratory risk of natural gas is that it may displace the oxygen needed for breathing if a leak occurs in a confined space.

However, change in technology is not as easy as we might expect; the safety may affect the perception of CNGV. Thus, alternatives CNGV may require alternative safety measures. Therefore, increased awareness of improving traffic safety while developing safety programs needed [30].

Some researchers emphasize that trust is vital in the relationship. To have end-users a strong sense of feeling towards the CNGV(s), the CNGV developers ensured to build up a trust relationship with end-users. Only 18 % of a questionnaire survey sees the CNG as a threat to their lives and considered it dangerous, while 42% of the participants think CNG is not attractive[31]. However, when an alternative technology safety is secured, it would gain the confidence and trust from the end-users. Other than that, end-users would promote it through the satisfaction and positive relationship and spread attention towards others. When there are right images and feedback from the public, it improves the decision and confidence for the end-user towards an alternative.

Furthermore, the relationships between the safety of a system and the decision of choice made by end-users attracted some literature attention. Thus, the end-users opinions towards safety help to define the role of the safety program and determine how the information can relate to other aspects. For example, the cost of injury is one of the critical aspects which may increase the total insurance cost. However, these direct costs might be measured easily, but other indirect costs (damages) hardly estimated when an accident [27]. Besides, other literature demonstrated that CNG onboard vehicles required complex operational units. Thus, the safety measures might do so. It is worth mentioning that when the degree of protection of alternatives (I,e, CNG) is higher, the probability of achieving the goal of production of technology and getting the end-users satisfaction would be higher.

2.4.3 TRANSPORTATION MODE SELECTION AND RELIABILITY & RESILIENCE

The reliability of the alternative car CNG must be at least comparable to the current transport modes (gasoline and diesel) to be accepted. Recent studies discussed the relationship between transport selection and reliability, while others supported the influence of the reliability and reported that the importance of the end user's decision. Furthermore, more than 35% of the respondents consider reliability as a factor when a decision made [18]. A master's research reported that younger ages have high expectation on the reliability of the car while the older generations influence have the least.

Although reliability and resilience considered to be responsible for affecting the participant's choice, another study has analyzed the impact of the reliability and resistance on the participants' choice were minimal [24].

Now CNG vehicles are approximately 8.0 % less efficient than conventional vehicles. The reliability is a function of the system resist and lifetime.

To sum up, much research has shown that both reliability and resilience highly influenced the transportation choice made by end-users.

2.4.4 TRANSPORTATION MODE AND OPERATION

Most gasoline-vehicles sold today have gasoline storage tank capacities of 12-30 gallons. The capacity was applicable to deliver a range between 300 and 500 miles. For a CNG fueled-vehicles to replace a gasoline version, it must operate for a range of approximately 300 miles. Therefore, a pressure of about 3600 psi is essential. At this compression level,the average distance traveled per unit of energy consumed is one gasoline gallon equivalent (GGE) used by National Institute of Standards and Technology (NIST) to compare energy consumption of alternative equals about 900 BTU of usable gasoline equivalent energy,the equivalent of one GGE at 3600 psi requires 0.51 cubic feet of space in a CNG cylinder.Therefore, to achieve a range of 300 miles, a CNG fueled-vehicle needs to have a fuel storage capacity of 6-10 cubic feet. It is about three times the volume of a comparable gasoline tank. However, it may affect the size and the volume of the passenger and cargo.

An experimental study performed, and the participants asked multiple questions regarding the operational issues of CNGV. It provides perspective and a view of each response. In the next step, a comparison of responses to Operation. For each comparison, the study results indicate which response is more robust by giving a weight.

Various methods can make it. It is making a decision based on given criteria about the importance of alternative CNGV concerning operational matters possible.

2.4.5 TRANSPORTATION MODE AND ENVIRONMENTAL IMPACT

There are many studies attempted to quantify the amount of greenhouse gases (GHG's) emissions produced by transportation modes as a function of how efficient the car is. Each study has its own set of assumptions, which results in occasionally contradictory conclusions. Survey results showed that an approximation of 72% of the respondents agreed on the environmental benefits of CNG, and 60% agreed on the cost savings. A consensus of studied on transports industries release is given in the following Table 2.3. They are showing the emission production of current CNG vehicles, which is lower than that released by conventional vehicles (i.e., gasoline). However, the requirements of high energy for producing CNG and holding out the internal pressure need to be considered. For example, a certain weight and energy are required (3.8 kg CNG, 10.25 GJ). Also, CNG storage tank requirements need to be able to hold out about 3600 psi.

Emission	CNG	Gasoline
Production & Distribution	50 g/mile equivalent	100 g/mile equivalent
Operation	250 g/mile	325 g/mile

Table 2.3: Vehicle Well to Wheel Emission

2.4.6 TRANSPORTATION MODE AND COST

The cost of CNG cylinder design and production needs to be taken into consideration since there is about a one third of the total cost of CNG cylinder required for direct material (cost of raw material or parts that goes directly into cylinder production) which is a prime cost. Thus, the initial cost of purchasing a CNG vehicle is a challenge. It may influence the end-user’s decision. Other's findings showed a mixed relationship between product selection and cost. A comparison of the cost versus types of cars given in Table 2.4.

Type	CNG Vehicle	Gasoline Vehicle
Honda	$26,500	$18,500
Ford	$55,000	$42,500
GMC	$53,000	$43,000

Table 2.4: Purchasing Price Comparison of CNG and conventional vehicles

The experimental study showed that one-third of respondents consider price a factor when selecting a car. Differences emerge when comparing consumer responses based on the type of company they chose. [23] analyzing the selection decisions of two businesses, and the study has found that both end-users consider product pricing as the most critical factor in the decision-making. Other research on the determination of selection on undergraduate studies in Singapore has concluded that young generations have high expectations on pricing and product diversity. In contrast, others or third party influence have the least votes [27].

Therefore, the cost is responsible for affecting end-users decisions. It is an essential factor, but there are a few pieces of literature that show a negative correlation exists between product or system cost and choice. Although many studies have shown that both cost and alternative system services selection highly correlated with each other, a few remarks that mentioned there is a negative relationship exists between them. Roman and Anca discussed the heterogeneity of pricing. The result showed that there is heterogeneity in pricing in the short-run, however, not in the long run. Thus product pricing correlation with technology process choice may produce a difference correlation depends on the time, see Figure 2.1.

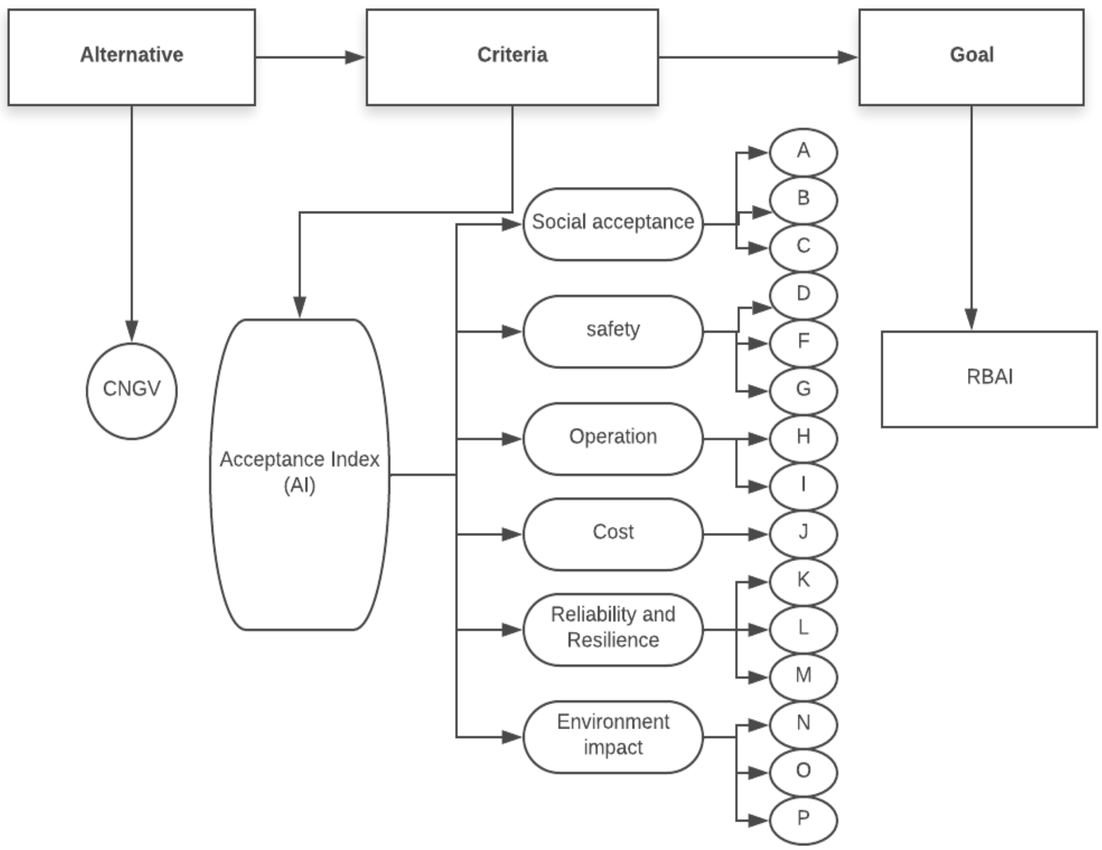


Figure 2.1: Study Process Analysis

CHAPTER 3: RESEARCH METHODOLOGY

The methodology chapter explained how the research carried out to understand by the reader. The proposed study is critical because currently, no adopted modeling for compressed natural gas vehicle CNGV in the vehicular sector established. The alternative CNG may affect the transportation sector due to the uncertainty of the behavior of CNG that is not yet understood. A sudden explosion is more likely to occur due to extreme pressure. The reach methodology divided into two sections; (1) Experimental analysis, (2) Risk assessment.

The first part of the study methodology provided a questionnaire survey sample that describes the characteristics of respondents. The method of the research consists of research design, data collection method, sampling design, measurement scales, and data analysis method.

3.1 RESEARCH DESIGN

A coherent collection of tasks was designed in which; essential risk variables would be analyzed differently but related tasks; direct responses of explicit risk aspects could be compared with implicit risk dimensions to be inferred from multi-dimensional scaling analyses. It means that the behavior influence factor as risk may affect the individual choice and inversely interpret the actual risk of alternative or product. The response format in most tasks was as simple as possible, with an alternating written response. Qualitative tasks as answering a set of questions regarding perceived CNG risks were added to supplement the results of the more strictly defined quantitative analysis tasks. Figure 3.0 illustrates the development of a systematic decision process for estimation that analyzing the functions of the various components (i.e., performance, reliability, quality, safety, operationality, and usability) is also a vital way for marketing a product. It can be utilized by interpreting the end-users' needs or requirements into product functions or components for engineering purposes. A quality function deployment matrix relates information about end-user requirements (i.e., features to satisfy end-user needs) to a system's functions. The model may also include a competitive evaluation. Therefore, the relationship between competitive end-user needs and the system's design parameters highlighted. It can be applied to compute functional (component) rankings of how vital each component is to the end-users, and these rankings used to compute a value index (ratio) for each component. If the value index is somehow less than the target level, the cause exceeds the effect, and the component is a likely candidate for a reduction in efforts to achieve the target value.

The given set of risky activities analyzed, which represents a subset of the relevant aspects of the decision. Response methods used were: constrained categorical, ranking order, scaling rating, answering questions (i.e., technical, personal, and attitudinal)—appendix C.

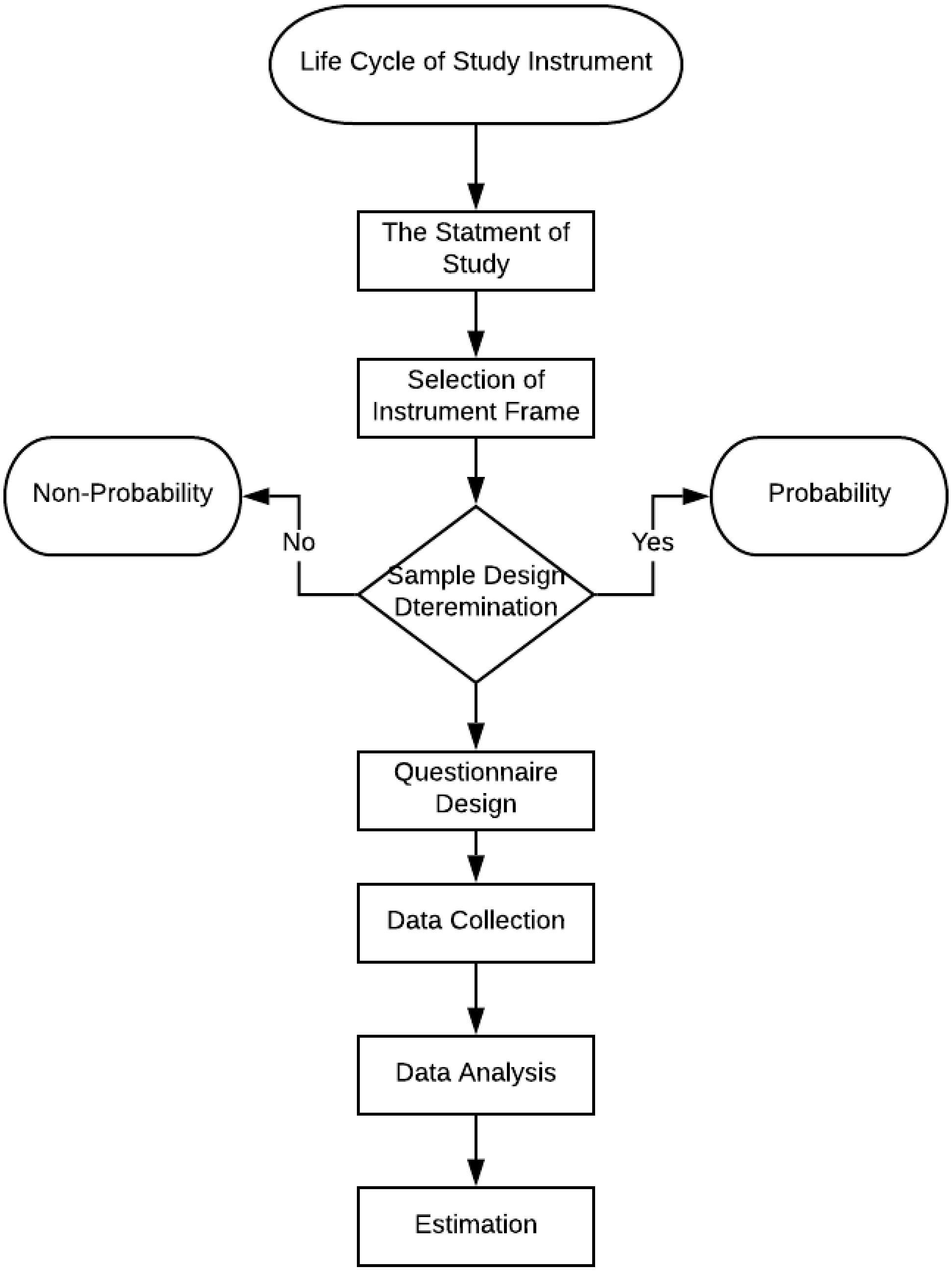


Figure 3.0: The life cycle of the study instrument

A related behavior decision processes through the statistical model describing the relationship between transportation characteristics and the end-user choice for CNGV designed by a conceptual framework in the previous chapter. In order to determine the influence of the acceptance index of alternative CNGV, theoretical framework research quantitatively intended for eliciting preferences used in the absence of revealed preference data. A suitable method constructed for the examination through reference to other similar studies and the literature on research design. For example, in our data, the author might have asked participants to complete a sample of a questionnaire measuring their levels of satisfaction towards CNGV. Also, a discussion of the research philosophy and approach, the research strategy, and specifics of the research, including participants and sampling procedures, data collection, and data analysis included. Ethical concerns of the study. A comprehensive discussion of the reasons for specific methodological choices.

3.1.1 RESEARCH APPROACH

In this research, the purpose is to apply current theories to a novel situation (CNGV choice) and scientifically defined. As the literature review showed, a theoretical framework already exists that can be constructed and referred to the research situation; this framework explained in detail in Chapter 2. A deductive approach was selected since it is the most appropriate choice for this research. Also, a statistical analysis technique used to identify Structural Equation Modeling (SEM). The SEM is ideal for designing the models which can determine the relationships between independent and dependent variables [32]. SEM is a set of techniques (including factor analysis, path analysis, and other approaches) that based on the general linear model [33]. The SEM was also determined to be appropriate because it helps to identify latent variables and eliminate irrelevant and unnecessary variables from the proposed research model [32]. The extraction of latent variables from observed variables means that SEM can determine the underlying structure of the research phenomenon [33].

One approach is to include indicators (such as response to the survey questions regarding individuals' perception) directly in the utility function, as depicted in Figure 5.0. Another approach is to perform factor analysis on the indicators, and then use the fitted variables in the utility. It describes the information incorporates data as indicator the variables by a simultaneous estimation method for integrated variables and decision model, which result in consistent and efficient estimates of the model parameters. The resulting methodology is an integrating of latent variables, which aim to quantify unobservable concepts. The method incorporates indicators of variables provided by responses to survey questions to aid in estimating the model. A statistical approach provided a more comprehensive analysis than the more straightforward analysis techniques by considering all the factors in combination.

3.1.2 SCOPE

The aim is to develop a methodological framework to identify the gap between the conventional transport system and the complexity of the modern transport system. The research begins with a brief explanation of the risk-related decision in recent literature. Then, the fundamentals of the study instrument (SI) and the uncertainty of compressed natural gas CNGV discussed. Thus, the study developed a methodological framework of risk-based acceptance index. On establishing the risk-based acceptance index for the CNGV system, reliable instrument and software programming used and relevant information of risk-based behavior also investigated. Besides, to ensure a successful risk-based acceptance index, a complete questionnaire survey sample performed. The research concept must be formulated in an accurate framework. Therefore, it based on the following aspects:

1. Define the considerable segment in the research instrument (End-users).
2. The geographical region that contains all events and specific location
3. The risk that linked to events which may lead to injuries or damages (scenarios expression to describe the uncertainty of CNG)

Therefore, gathering all of the aspects to capture the effect of risk results from the decision-analysis process related-index methodology and must follow the risk assessment framework. Also, there are hundreds of books and articles on decision analysis that convey the steps presented below Figure 3.1.

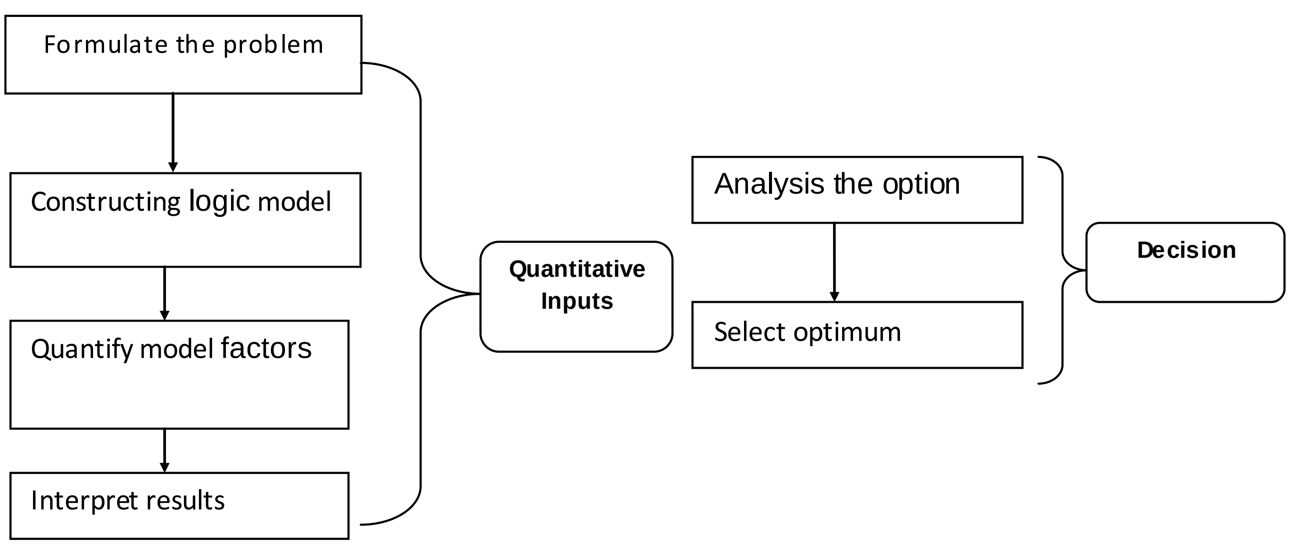


Figure 3.1: General Decision Analysis Steps (GDAS)

3.2 RESEARCH STRATEGY

The experimental research strategy designed quantitatively based on two pillars: data collection and analysis. It is a better research design option to identify the relationship between variables, and it is hypothetically stronger than other approaches. The quantitative technique used data collection methods and established statistical analysis tools to enable us to create knowledge and draw conclusions. Trochim confirmed that it is the only approach where findings can be generalized to some extent across populations [34]. Although the quantitative approach has some issues, it could be simplified and helped to ensure the research can be integrated on time. Thus, the study aims to use this approach, which consists of two sampling designs. The survey is the first and primary research design which effectively based on the collected data from participants using brief answers. The main criteria of a valid study depend on the response rate adequacy. A standard instrument is another vital element used for data collection. This experimental design is essential, where the influence of each factor would be measured. A survey research design performed, both for practical reasons and because there was no reasonable way to design an experiment for the research question. The author also wanted a broader and more generalized view of the factors involved in CNGV choice, which required a larger sample than could be collected using an experimental tool.

3.2.1 DATA SAMPLING

A sampling frame placed to reduce the complexity of data collection. The data collection was limited to include only St. Johns (Memorial University, which serves students primarily). This limitation on the sample placed for useful reasons since Memorial University (MUN) considers the major point in St. John's estimation of the sample size based on estimation techniques for SEM. The minimum sample size can be determined based on a relationship between minimum effect size, statistical power, and statistical significance, as a ratio of observed to latent variables [35]. In 2011, Gravetter and Forzaqno [36] presented the calculation of the minimum sample size in SEM. The results in a larger sample size than estimated using standard sampling techniques. The lack of knowledge about the demographics of the participants made it the best choice of a sampling method for this research.

Furthermore, the selected participants have been randomly chosen from the campus of MUN to increase the randomness of the sample. Demographic characteristics were also collected for a clear description of the sample. For gathering data from the respondents, the survey monkey performed. A valid survey sample sent via a secured email for individual participation. It helped reduce researcher bias since a questionnaire sample was distributed randomly to respondents with different background levels, income, age, and gender who belong to Memorial University of Newfoundland (MUN), St. John's. It helps to define a relationship between six independent variables, including; social acceptance, safety, reliability, operation, environment, and cost. These variables utilized as factors to affect the decision of respondents toward alternative CNGV.

3.2.2 SAMPLING TECHNIQUE

The sampling technique conducted randomly. It is relatively method allows us to easily choose and assemble the sample since all the respondents provided an equal chance of being selected. This technique reduces biased choice and enables us to have a clear outcome. Furthermore, many questions, including six dimensions of assessment, would be asked to the participants to rate the acceptance index. The rating scale evaluated from

1 to 7, indicating the range from “strongly Low” to “strongly High.” It helps to assess the participant's preference level towards each variable.

3.2.3 SAMPLE SIZE

The sample is a part of the population that allows us to draw inferences about the population. It is not possible to collect complete information about the population, and it is time-consuming. It is also expensive. Therefore, an appropriate sampling size characterized by the population is helpful. In the research, it utilized to estimate size of the sample by the following formula:

$$S = X^2NP\ (1-P)\ /\ d^2\ (N-1) + X^2P(1-P) \qquad (3)$$

S: the sample size

X^2: the Chi-Square value

N: the population size (approximately 10,000)

P: the population portion (0.5)

d: the degree of accuracy expressed as a proportion (0.05)

According to the given equation [36] for estimation of sample size, the study instrument was electronically distributed to faculties and students at Memorial University to collect results accurately. It conducted via the secured vocal point. More (n=63) samples were received.

The recommended sample size for given population size (n=63) (i.e., level of confidence 99.0%).

3.2.4 DATA COLLECTION

There are several types of methods for collecting data for a survey, including online questionnaires, telephone surveys, self-administered questionnaires, and structured interviews [37]. It is a vital part of the data collection methodology, which ultimately facilitates the analysis, where the participant fills out the questionnaire. The questionnaire can also be filled in as part of a structured interview where the author reads the questions and, if necessary, defines terms [37]. This approach is helpful and applicable to different fields of study, such as medical and health questionnaires. In the current research, a questionnaire choice electronically sent for data collection, and therefore no significant barriers with understanding found. The survey printed in English in an easy-to-read format, and the respondents asked to answer multiple questions classified into four sections namely; socio-demographic, perception, facts, and opinion, Table 2.2. In the case of the incomplete sample, if the respondent did not complete the survey, the sample discarded and was not counted in the sample. The survey study sample distributed electronically via emails. Every respondent was given a detailed questionnaire sample with the right to participate or not, he or she was contacted online and had their full freedom to respond to the survey sample questionnaire or not by explaining the objective of this research. If Participants do not feel willing to answer or complete the survey, discard it, which taken as an indication he or she did not wish to participate. When the team member received the questionnaire, he or she detached the information letter and sent it to our primary email, and then thanked them for his or her time in participating. No significant problems were reported in the data collection process from any of the volunteers. As a result of the data collection process, there was a total of More than 100 questionnaires were collected. Thus, the response rate was approximately 90.4%. After normality and elimination of incomplete questionnaires, the sample reduced. It is about 5.7% higher than the target sample size and was considered appropriate for the study.

The research instrument was a questionnaire. It was developed based on the variables presented in Figure 3.0. The items used for each variable shown in the Appendix.

3.3 DATA ANALYSIS

Data analysis was conducted in SPSS using three techniques. Firstly, a statistic technique was used as a descriptive profile of respondents and compared to a general population. A descriptive statistic is a statistic of a single variable meant to describe characteristics of the sample. The descriptive statistics calculated based on the data type and intended features. These included mean and standard deviation (for numerical and Likert scale variables) and frequency and percent (for categorical variables). These were presented using charts, graphs, and tables as appropriate.

Although the descriptive statistic technique is useful for understanding conditions in the sample, it does not give any insight into causal mechanisms or relationships. As a result, confirmatory factor analysis (CFA) used as an additional technique. It is available via SPSS using the AMOS plug-in. In CFA, the author identifies the items that are measuring the same underlying construct to determine factor loadings (indicating the extent of internal correlation) [38]. Based on Brown, convergent, and discriminant validity should be tested[38]. Convergent validity can be tested using Composite Reliability (CR), while divergent validity tested using Average Variance Extracted (AVE) and Square Correlation Coefficient. In the initial CFA run, the model was not fitted properly with acceptable CR value, indicating that convergent validity was appropriate. Still, AVE and Square

Correlation Coefficient (SCC) were too low for some factors (Social acceptance, Environmental Impact, and Cost).

Several attempts initially made and an adjustment to the model applied resulted in a properly fitted model with an appropriate Modification Index (MI). Thus, using the SEM process, as a final stage of analysis, the analytical model was valid and similar to the theoretical proposed framework. The SEM was performed in SPSS using the AMOS plug-in, which designed for Exploratory Factor Analysis (EFA), CFA, and SEM, more details of SEM Chapter 4. It is a statistical tool that is designed to test a qualitative model of causal assumptions based on the statistical relationships shown in the research data. The applicability of SEM used in two ways. (1) it can be used in multi-exploratory fashion to identify statistical relationships within the data and identify potential causal relationships and causal chains. (2) it used in an affirmative way to test a causal model specified by the author. In this research, the confirmatory SEM is used. The process of confirmatory SEM requires the author to define and operationalize variables (it performed using factor analysis and Cronbach's alpha, as described previously). The author then enters a hypothetical model to be tested against the data. Then the SEM model identified how well this model fits the outcomes of the data.

SEM offered some advantages. It allows us to test a full hypothetical model rather than a single hypothesis, which is an advantage over a regression model. The method also allows us to determine the strength of relationships, modify relationships and assumptions, and use hidden variables. It is better than other techniques (i.e., regression, which tests only bivariate correlations).

Analysis of the assumptions of SEM is one of the strengths of this technique. One of these assumptions is the directionality of the relationship, which is defined by the measurement model. The nature of the relationship, including that: The cause and effect and determine the covariation between cause and effect. They are controlling other factors that could cause the relationship (isolation of the covariation. These assumptions tested within the analysis process, and the model was adjusted based on the findings of the analysis. Therefore, the outcomes of the SEM process identified the strength of the relationships and factors associated with them.

3.3.1 RESEARCH INSTRUMENT

The instrument was developed for use in the CNGV study. The first instrument is an attitude questionnaire designed to measure attitude toward CNG technology. It was developed based on the variables presented in Figure 1.6 as a theoretical framework. Items include both affective and behavioral components of attitude mentioned in the preceding section. There are seven Likert-type scales, each indicating one dimension, ranging from strongly agree to disagree strongly. It has been validated through pilot studies. Six sub-scales are;

1. Interest: comprised of several items asking how well respondents participate in or are willing to participate/use a CNGV.

2. Role pattern: consists of several things asking how participants think that CNGV is appropriate for both as transport cars.

3. Consequences: comprised of some items asking questions on what participants think about the effects of CNG on society.

4. Difficulty: consist of several items exploring participants' perceptions regarding the pressure of the CNG system as a main or one of the transports.

5. Usage: comprised of questions that asking if participants would be pleased to have a CNGV in the future.

3.3.2 QUESTIONNAIRE DESIGN

A concept questionnaire designed to measure participants' concepts of the CNG system. It represents a cognitive component of attitude. Items were developed based on the characteristics of CNG technology identified by previous literature. This instrument designed first to illustrate people's perceptions regarding the risk associated with the CNG cylinder onboard. We addressed questions to illustrate the end-users action toward each question. It is composed of questions regarding CNG controlled by humans and their influence on society. It has a true and false format. The second scale consists of items and used to assess the difference between the CNG system and other conventional fuelled-vehicle (i.e., Gasoline, Diesel, etc.). The third scale, named technology and skill, included items and was used for evaluation of the relationship between CNG technology and particular skills. The fourth scale, called technology and pillars, has items that were used for measuring knowledge of CNG technology.

The aim of designing a questionnaire instrument is to yield more information regarding the concept of and attitudes toward alternative CNGV.

3.3.3 PILOT TEST

Because the research instrument designed for a specific reason, it had to be tested for reliability and validity before use. The reliability and validity tests conducted using built-in SPSS tools. First, face validity and content validity examined using expert review and pilot testing. The expert review process involved asking the professionals, i.e., the author's supervisors, as well as other subject matter experts, to review the instrument to make sure it reflected the intended constructs/factors. It resulted in some suggested changes, which incorporated into the questionnaire before the survey was conducted for a pilot test. A group of participants in the pilot test asked to fill out a brief online survey and identify any problems with the content, information, or wording. Thus, It led us to make some modifications to the language, which incorporated into the final survey. Next, the reliability of the instrument tested using Cronbach's alpha (CA) on a random sample of the investigation sample. Cronbach's alpha measures the internal consistency of a scale; it means that Cronbach's alpha measures the extent to which the items in a scale measure the same construct. However, there is no fixed alpha value for acceptance of a scale, a range of 0.6 - 0.8 demonstrated by most of the literature reviews [37].

The study used a necessary threshold of 0.7 for acceptance of scales; if scales did not meet this requirement, they would be adjusted as needed. Also, the construct validity of the instrument tested using factor analysis via SPSS. Factor analysis is a statistical approach for the determination of construct validity [38]. The construct validity means that the scale or measurement is measuring what it designed to measure. The Factor analysis determines the extent of internal correlation between measured variables; a high degree of correlation between multiple measured variables means that they are all measuring the same underlying latent variable [38]. There is no fixed threshold for acceptance, but any items out of place removed.

Therefore, The resulting factor loadings of the experimental study indicate there are no questions require to be eliminated, and the questionnaire sample can be used to collect actual data.

3.4 CONSTRUCTS MEASUREMENT

According to recent researches, the set of categories makes up the scale of measurement while the relationship between categories determines types of scale [37]. There several measurement scales used in various researches, such as Nominal scale, Ordinal scale, Interval scale, and Likert scale.

3.4.1 NOMINAL SCALE

The nominal scale contains a set of the group which has various terms. It allows us to categorize the observation [39]—also, questions one to five designed based on the nominal scale. For example, the education variable categorizes the respondents into four groups, including; School Certificate, Diploma, Bachelor’s degree, Postgraduate degree.

3.4.2 ORDINAL SCALE

This scale arranged in the sequence order in terms of size and magnitude.

3.4.3 LIKERT SCALE

It is a type of measurement scale used to assess the participants’ responses from a high degree to a low degree or strongly low level to strongly high level. The research used the Likert scale in section four to measure the respondent's opinion toward the questionnaire.

A practice data set example (PDS) includes X cases (n = x) and Y (y) variables. A unit of measurement chosen in the study. In this case, our unit of measurement is people (n).

PRACTICE DATA SET (PDS)

For Variables: (A), (B) , (C) , and (D)

(n = j)

Variable Name: (a,b,c, and d)

Case	A	B	C	D
1	2	1	2	3
2	1	1	1	3
3	1	2	1	2
4	1	3	1	1
5	2	4	4	1
6	2	3	3	1
7	3	4	2	4
8	4	4	3	3
9	5	3	4	5
n_j	3	2	5	2

Table 3.0: Example of practice data set (PDS)

Data set can be simplified qualitatively, as the four variables (A, B, C, and D) are vital for one participant. It is an illustration of the applicable SPSS processing. In the context, it is intended to get inside the logic of doing a quantitative study by going through the steps of entering data. Also, the design helps to enforce our understanding of the measurement level, practical use of the logic variable, and how data coding applies. The data set comes in three basic categories, as indicated previously. The testing method depends on its level of measurement. Sometimes category level (i.e., interval data) distinguished from other data for logical, mathematical reasons; however, SPSS lumps them together as one specific category such as scale data. For example, nominal data characterized as gender. Thus, the statistical test type used for each data can be illustrated and explained by how to deal with nominal, ordinal, and interval/ratio (scale) Figure(s)- 3.2,3.3, and 3.4

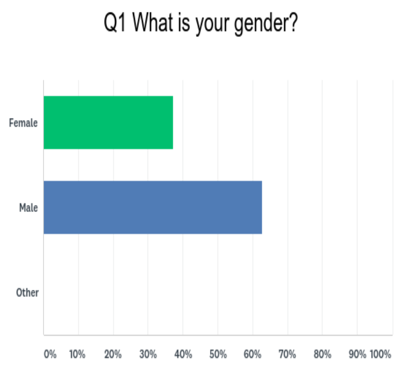


Figure 3.2: Gender of the respondent(s)

The age distribution illustrated in figure 3.2 points out that the mean age largest group of respondents was 29.5 years (47.46%), followed by 39.5 years (38.98%). However, the lowest number of respondents 45-54 years (1.69%) and (11.86%) of respondents was aged 18-24 years.

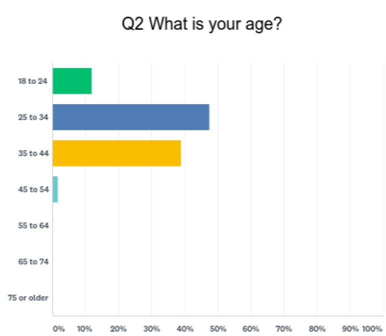


Figure 3.3: Age of respondent(s)

The education level of the survey sample illustrated in figure 3.3 showed that 71.9% of the total respondents having a high degree and 27.12% having a Bachelor's degree. It attributed to the geographical location of the survey.

Q3 What is the highest level of education you have completed?

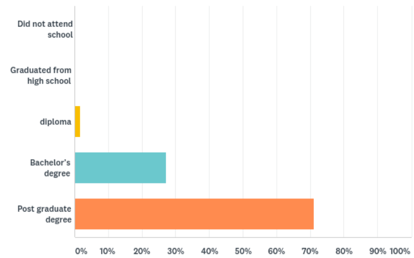


Figure 3.4: Education level

Figure 3.4 illustrated the average income of the respondents. The income classified as student income (76.27%) and average employee income (23.73%). Approximately of $30,000-69,000 (38.98%) was the highest income amongst all respondents followed by average of $29,000 (30.51%) then $70,000-99,000 (23.73%). However, 6.78% of the respondents had more than $100,000 of average income.

Q4 What is your approximate average household income?

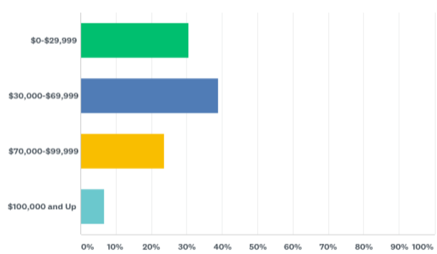


Figure 3.5: The average income of respondent(s)

		Age	Education	Gender	Incomes	Occupation
Age	Pearson Correlation	1	-.412	.162	.487	.709*
	Sig. (2-tailed)		.311	.702	.221	.049
	N	62	62	62	62	62
Education	Pearson Correlation	.412	1	.417	-.032	.339
	Sig. (2-tailed)	.311		.304	.940	.411
	N	62	62	62	62	62
Gender	Pearson Correlation	.162	.417	1	.325	.293
	Sig. (2-tailed)	.702	.304		.433	.482
	N	62	62	62	62	62
Incomes	Pearson Correlation	.487	.032	-.325	1	.747*
	Sig. (2-tailed)	.221	.940	.433		.033
	N	62	62	62	62	62
Occupation	Pearson Correlation	.709*	.339	.293	.747*	1
	Sig. (2-tailed)	.049	.411	.482	.033	
	N	62	62	62	62	62

Table 3.1: Correlation Coefficients

The outputs of the Pearson Correlation varied. So we have different correlations for some variables. The information in the row labeled Sig. (2-tailed) tells us that the significant level. It is, therefore, unlikely to occur by chance (A detailed discussion of the concept of statistical analysis attached to Chapter 7).

CHAPTER 4 THE ETHICS CONSIDERATION

4.1 ETHICS APPROVAL

The ethical concern of this research was preventing harm from participation. This study was anonymous consumer research and, as a result, did not pose any potential harm to the reputation or emotional state of its participants. Identities were not collected, and the research instrument was designed not to include items that might be considered private or sensitive. Demographics were only received as general categories to prevent individual participants from being identified through these characteristics. Results were only reported in the aggregate, and no information about individuals was used. The questionnaire was kept as short as possible, and participants were given an online survey with free time that would be required to complete the study at their convenience time (20-30 minutes, based on the initial testing) Appendix (A, B, C, D, E, and F). Furthermore, data received electronically avoided complexity and bias collection without disturbing or approaching participants during the survey. Another ethical concern was provided in the attached Appendix, for example, informed consent. Although there was no particular harm that might result, it was still important for participants to be informed about the purpose of the study. The purpose of the research was explained to the participants that including a brief description of the study, contact information of the author and supervisor. It, therefore, allowed them to decide whether they are willing to participate or not.

CHAPTER 5: SAFETY RISK ASSESSMENT

The chapter covers the second part of the research associated with the risk of equipped overpressure cylinder onboard vehicles to people, property, and environment. As with any novel concept, the particular technical challenge needs to be initially identified to determine how feasible it is. The chapter aims to present and develop a tool to assess risk-based acceptance index (RBAI) to support the compressed natural gas onboard vehicle (CNGV). Furthermore, the research approach designed based on the selected index, including the survey sample, which helps for the estimation of the probability of the individual (models which were discussed in previous chapters).

In this chapter, hazard analysis performed and evaluates the potential for hazard identification involving humans in the case of CNG onboard. The identification focuses on hazards that result in loss of life, loss of property, and the environment. Since hazards are the source of events that may lead to damages, analyses define risk exposures must begin with knowledge of hazards present. Hazard identification rarely provided with the required information for making a decision, Figure 1.3.

It is defining the degree of severity as a function of the end-user and conditions of the vehicle. It also affected by the behavior of a CNG cylinder. It is a challenge. For this purpose, a scenario of CNG onboard as a function of system control failure given in the following section.

On the other hand, the estimation and analysis of the influence of selected factors on the decision of choice. The structure of the estimation is based on disaggregated data collection, and then we present and interpret the main outcomes of the study, chapter seven.

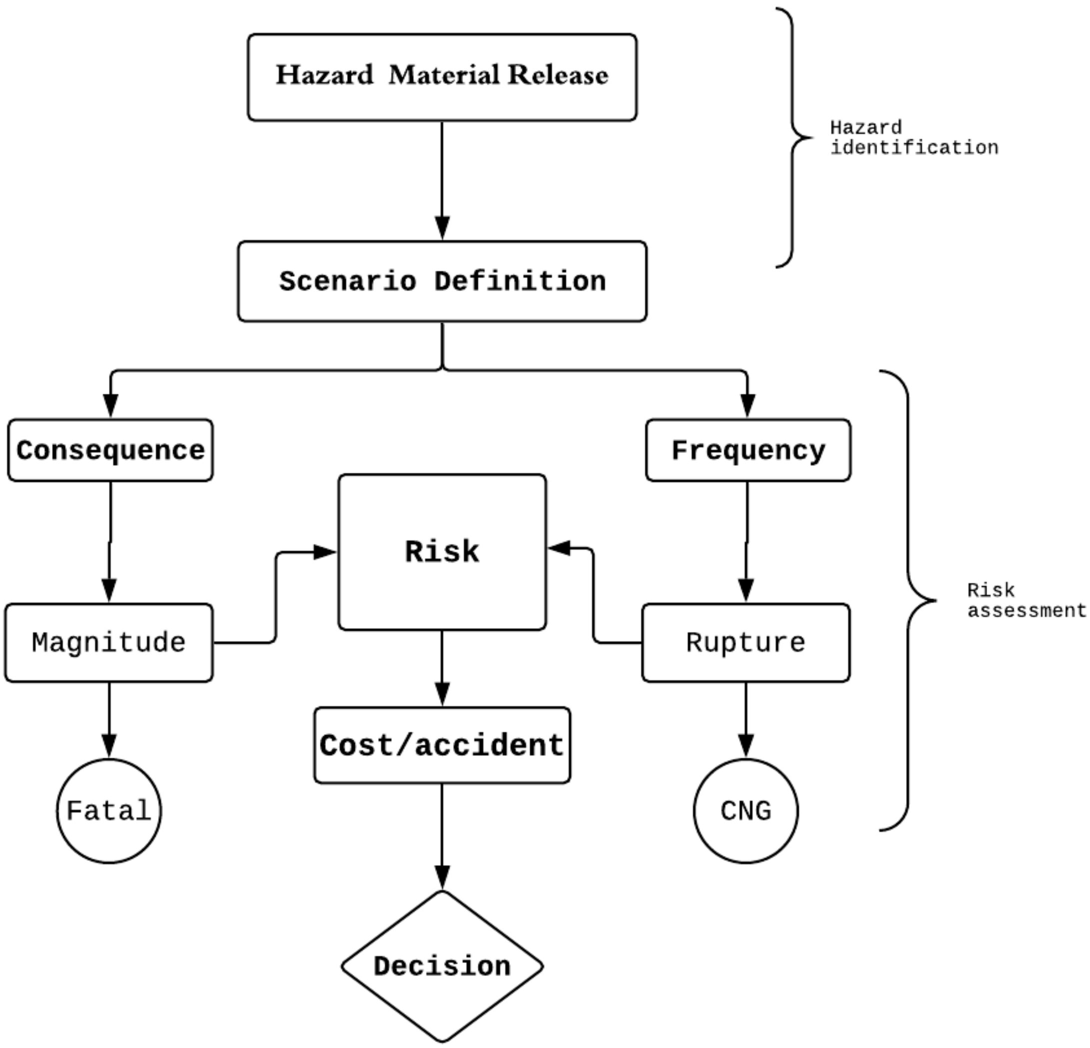


Figure 5.0: General Steps of Hazard Assessment

Generally, hazard identification focuses on risk analysis on key hazards of interest and the type of mishaps that a particular hazard may generate. A developed analysis method is necessary to guide the work and aid in the analysis of the role of the human when an accident event happened.

Although hazard analysis is used to determine the risk level of the CNG systems to ensure that the design applicability achieved at an acceptable safety level, there are no specific rules for the construction of the CNG cylinder that exists at present. The risk-based method is increasingly conducted for the evaluation of industrial design, which challenges the existing regulatory framework. The research approach developed a hazard modeling scenario by considering the CNG cylinder onboard accident type, such as fire and explosion, due to cylinder failure onboard vehicles. The identification hazard scenario proposed in this study, including effect model, number of fatalities, and risk in terms of monetary value. More detail provided in the following sections.

5.1 COMPRESSED GASES

Compressed gases can present chemical and physical hazards. It can be toxic, flammable, oxidizing, corrosive, or inert, causing environmental, operational, financial, and adverse health effects—compressed gas types, including cryogenic, liquefied, and non-liquified gases discussed in the following sections.

5.1.1 TYPES OF COMPRESSED GAS

5.1.1.1 LIQUEFIED GASES

Any gas that fills the space above the liquid at the vapor pressure of the substance at that temperature. As gas removed from the cylinder, the liquid evaporates to replace it, keeping the pressure in the cylinder constant, so long as the fluid is present. Common examples include ammonia, chlorine, propane, nitrous oxide, and carbon dioxide[56].

5.1.1.2 NON-LIQUEFIED GASES

Also known as compressed, or permanent gases. These gases do not become liquid when they are compressed at room temperature, even at very high pressures. Such as oxygen, nitrogen, and helium. Dissolved gases: Gases that are dissolved in a liquid solvent at pressures of 29 psi gauge or higher. Acetylene is commonly liquid gas. It is chemically, very unstable [40]. Acetylene cylinder is fully packed with inert, porous filler.

The filler is saturated with acetone or other suitable solvents, and it dissolved when added to the tank, dissolved into the acetone[40].

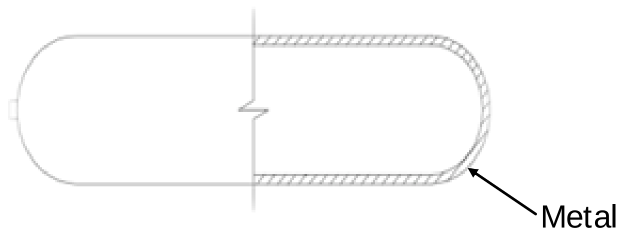


Figure 5.1: Cross-section of CNG (Metal) cylinder

5.1.1.3 CRYOGENIC GASES

Gases that have been cooled to a liquid state below 150 Kelvin (-123°C). They are extremely cold and can produce intense burns. They can be non-flammable, flammable, or oxidizing. Common examples include liquid nitrogen, liquid helium, and liquid argon[41].

5.2 COMPRESSED NATURAL GAS (CNG)

According to the administration of the Workplace Hazardous Materials Information System WHMIS [42], compressed gas is a substance that is a gas at average room temperature and pressure and is contained under pressure, usually in a cylinder. Some compressed gases (e.g., methane) are stabilized in the cylinder by dissolving the gas in a liquid or solid matrix Table 5.0. The handling of compressed gases must be considered more hazardous than the processing of liquid and solid materials because of the following properties unique to compressed natural gas: pressure, low flashpoints for flammable vapors, low boiling points, and no visual or odor detection of many hazardous gases. Compressed and liquefied gases are routinely used in different operations such as cooking, heating our home, and fueling our vehicles. Also, it can be found in the laboratories and various other activities. They have the potential to create hazardous working environments. Guidelines concerning the use and storage of compressed gas can be found within the regulations of the National Fire Code of Canada [43], Transport Canada – Transportation of Dangerous Goods Regulations (TGDR), selection and use of cylinders, spheres, tubes and other containers for the TGDR Class 2, CSA B340 [44].

CNG contents	Chemical formula	% CNG content
Methane	CH_4	70-90%
Ethane	C_2H_6	0-20%
Propane	C_3H_8	0-20%
Butane	C_4H_{10}	0-20%
Carbon Dioxide	CO_2	0-8%
Oxygen	O_2	0-0.2%
Nitrogen	N_2	0-5%
Hydrogen Sulphide	H_2S	0-5%
Rare Gas	A, He, Ne, Xe	Trace

Table 5.0: Typical Composition of Natural Gas [45]

5.3 HAZARDS ASSOCIATED WITH COMPRESSED GASES

In the hazard identification stage, the criteria used for defining the hazards. For this purpose, it divided into several steps. Furthermore, identified hazards classified into significant and non-significant hazards. The purpose of the HAZID procedure is to identify substantial hazards to achieve a tolerable residual risk. Since gases are invisible, their presence is not readily identifiable, and they have the potential to asphyxiate, burn, or harm users. In the case of high-compression gas, a severe consequence may create.

5.3.1 PRESSURE

Compressed gases are hazardous due to the high pressure inside the cylinder and the effect of temperature. Typical internal cylinder pressure between 3,000 to 3,600 psi, but it may go up to 6,000 lbs per square inch (psi) [46]. In addition, thermal explosion also may resulted as a consequence of a sudden increase in temperature. Alternatively, compression may result in temperature rise. To better understand how high the pressure of compressed gases is, for example, a car tire pressure is usually between 30-45 psi. Damage to the cylinder valve can result in a rapid release of the high-pressure gas propelling the cylinder as a rocket, causing injury and damage to people and property.

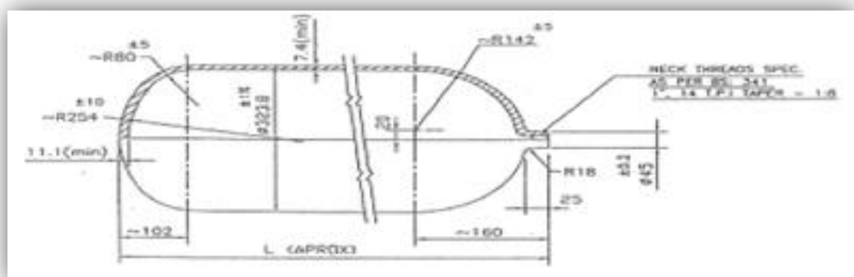


Figure 5.2: The CNG steel tube pressure vessel [47].

This type of pressure vessel was weighty. Thus, a limitation of weight and volume concern of CNG cylinders are obvious, heavy, and hard to handle. CNG cylinder is usually made of steel, aluminum, or a type of composite. Improper handling, or not appropriately securing cylinders while in use, can cause damages to the automobile.

5.3.2 FIRE AND EXPLOSION

Compressed natural gas CNG consists of several hydrocarbons, mainly CH_4, which can burn or explode under certain conditions. Although a significant development in natural gas observed and therefore brought some benefits to the automotive field[64], increasing the number of accidents is a significant threat. If CNG allowed to accumulate until their concentration is between their defined Lower Explosion Limit (LEL) and Upper Explosion Limit (UEL), an explosion may occur in case of if there is an ignition source present. Figure 5.3 shows the flammability range of some typical gases.

5.3.2.1 CAUSES

The NGV's accidents categorized into two parts: (1) Fire (2) explosion. Therefore, the following factors attribute to the fire explosion of the CNG vehicle.

5.3.2.2 GAS LEAKAGE

In most cases, gas leakage can be initiated from the high-pressure pipe due to:

1. Failure of the high-pressure pipe;
2. Damaging of high-pressure pipe without collision due to impact (i.e., mechanical wear, tear, and constant vibration);
    - Dislodging of high-pressure fitting;
    - Improper installation of pipe fittings which leads to damage of high-pressure pipe fittings;
    - Bursting of an unapproved valve;
    - Leakage of gas from the cylinder valve;
    - Malfunctioning of the valve leads to gas leakage

5.3.2.3 SPARKING

Sparking of air/fuel(A/F) mixture can be initiated by human faults (i.e., passengers) due to misuse of :

1. Cigarettes
2. Lighter and matchbox

3. Electrical instruments

4. Faulty wiring components.

Also, the ignition may result from:

5. Short-circuiting of battery and electrical wiring;

6. Contact of hot surfaces, i.e., engine, exhaust manifold, radiator, etc.;

7. Energy conversion, generate sparking during the conversion of the kinetic energy of motion into heat energy.

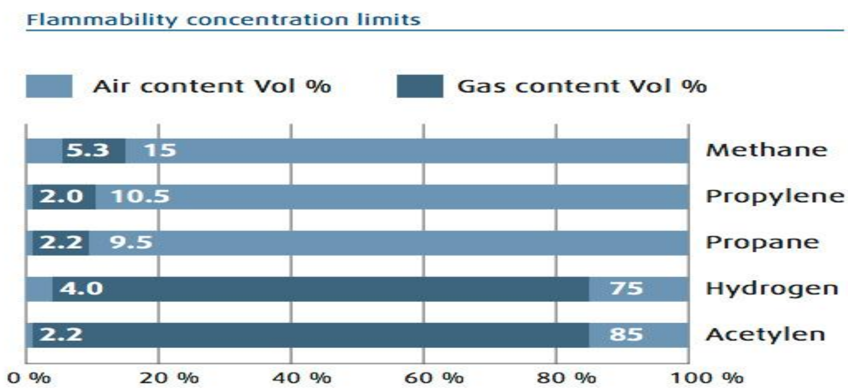


Figure 5.3: Flammability ranges of common gases. The concentration range where fire risk exists is shown in red. (ref: www.aga.se) , Refer to the list of Common Flammable Gases. Appendix.

The general benefits of the risk-based index as applied to fire and explosion scenario exposure, including:

1. Evaluation of several different risk reduction strategies effectively.
2. Increasing management control over the risk reduction strategies
3. A consistent decision can be made
4. Ability to assist in establishing an optimum balance between fire and explosion prevention, protection, and emergency response on cost/benefit analysis.

To rank the identified hazards, the probability of occurrence and the degree of severity estimated on the basis of the risk index (RI) as described.

5.3.3 CYLINDER DAMAGE

A consensus view on a typical size of CNG cylinder of 5 ft in height [17,19,20,21,62]. However, it still may destroy in several ways such as 1) fire and heat: which can cause the cylinder to expand and contract with pressure changes. Cylinders are designed, to some degree, to handle such pressure changes; however, cylinders made of aluminum are affected by heat can rupture. 2) arc damage: from welding operations can result in a heat rise sufficient enough to cause arc damage to the cylinder creating a pressure explosion or the pressure relief device to activate. Arc burns easily recognized by a spot, or series of spots, of freshly burned paint, exposing bare metal 3) Dents: occur from impact or mishandling, which can weaken the walls of the cylinder making it more susceptible to rupture.5) Corrosion impact: lead to cylinder rupture.

Several accidents were recorded between [48] (1976-2010) due to the failure of CNG (All vehicles included: 51% LDV/Trucks; 38% buses; 11% other commercial vehicles) distributed as 56% U.S.; 44% Europe, Asia, South America. Most of the problems were with an individual vehicle, but some systemic problems identified, especially with Pressure Relief Devices (PRDs) involving 12% fire [48].

An Accident Scenario: Risk Assessment of CNG Cylinder Onboard

In this study, it is using a scenario as a part of risk analysis for CNG onboard to identify the spectrum of possible fire accident scenarios that should be studied in more detail in a quantitative measure of the frequency of occurrence and likely consequences. A typical

CNGV considered for the risk assessment of CNG cylinder onboard vehicles. Risk is defined as the cost of human life per vehicle. In the study, the fire-resisting rate (FRR), i.e., time from the starting of fire to an explosion of tank rupture (in conditions of thermally activated pressure relief device (TPRD) failure to operate), of current thermally unprotected tanks is about 6-12 minutes.

Type of Incident	Percentage of Incident (%)
Cylinder rupture	37
PRD release (no fire)	10
Vehicle fire (no cylinder rupture)	13
Accident w/another vehicle	9
Single vehicle accident	4
Cylinder or fuel tank leak	10
Others and Unknown cause	16

Table 5.1: CNG incidents characterization [48]

This scenario aims to achieve a breakdown FRR beyond potential car fire duration. In other words, the longer fire resistance would allow slower CNG release from TPRD, shorter CNG jet fire, safe evacuation. There are several probability models such as probit function for calculating the time to failure or (FRR), the vessel volume, and the amount of heat radiation received by the target vessel. To estimate the FRR of CNG onboard vehicle exposed to fire. A well-known simplified model proposed by [49].

$$Y = a + b \ln (FRR) \quad (4)$$

$$\ln (FRR) = -0.947 \ln (I) + 8.835(V^{0.032}) \quad t \geq 10 \text{ min} \quad (5)$$

It is based on the probit approach. The authors proposed damage probability models that take into account the categories of industrial types of equipment. The physical effects of CNG (explosion) would be determined as an escalation factor that generated after a unit rupture (explosion). The following model used to quantify the probability

$$P = \frac{1}{2}\left[1 + erf\left(\frac{Y-5}{\sqrt{2}}\right)\right] \quad , \qquad (6)$$

Where probit coefficient a, and b were estimated, respectively, 6.28 and 3.72. The study assumed the response time of (6-25) minutes, the time for the fire-fighting department to the response. Thus, applicable constants were used as a=-2.13 and b=10.09

$Y = 10.09 – 2.13 \ln (FRR)$, therefore,

The impact of the failure of resistant rating (FRR) of onboard storage on a level of risk. It can be as a key pressure hazard of the CNG onboard accident scenario due to a blastwave from a cylinder rupture. It is found that most incidents with CNG onboard vehicles were not caused by the CNG tank or fuel storage systems (only one in 17 accidents); instead, they were started by an electric short, brakes, or leaking fuel, or exhaust system [48][50]. From Table 5.1, it is obvious that the tank rupture is the most likely consequence, followed by vehicle fires, PRD release failure, and tank leaks. Thus, it can be concluded that rupture is a very common consequence of onboard storage incident. It results in a gas explosion following a rupture. Therefore, the distance for fatality can be calculated by conducting a proposed equation by Kashkarov. The method suggested calculating the fatality hazard distance. This technique is widely used for explosions as followed;

$$D_f = 7.93.\ W^{1/3} \qquad (7)$$

D_f represents the diameter of the explosion; W (kg) is the mass of CNG (3.8 kg), $D_{f\,=}$ 31 m, the diameter calculated by the proposed method of 31(m); therefore, the fireball area is, A= πr^2, thus, A=754 m^2. When we compared our results with other data [86]. The fatality fireball area is 754 m^2 compared to 942 m^2, which means that by the distance of the fatality of the fireball, which is bigger than the fatality area of the blastwave, more danger expected. Furthermore, the number of potential fatalities obtained by the following equation

$$N^{\alpha} = N_0 . A_{eff}, \quad \alpha = \begin{cases} \alpha = 1 \text{ for neutral risk} \\ \alpha > 1 \text{ for perception risk} \end{cases}$$

N_0 is the population density in the accident area; A_{eff} is the area within hazard distance. Live lost in a single accident a function of N^{α}, $\alpha = 1$. The value of α has become a controversial topic in social risk assessment. Observation of society's apparent acceptance of major hazards, in contrast with its seemingly greater concern for potential hazards, has led some to conclude that society is risk-averse:

"The public appears to accept more readily a much greater social impact from many small accidents than it does from the more severe, less frequent occurrences that have a smaller social impact." [U.S. NRC 1975, p.12]

Two models were considered in this study for $\alpha = 1$ and $\alpha = 2$. In case of calculating the fatality per vehicle, estimation of frequency, and calculating the probability of emergency operations to put off fire leading to a tank rupture in a fire. We assume the initiated event has started. Then risk can be determined in terms of fatality rate (fatality/vehicle)

The following relations conducted;

$$N_0 = \frac{1}{n}\sum_{i=1}^{n} xi, \qquad (8)$$

$$\sigma = \sqrt{1/n}\sum_{i=1}^{n}(xi - \mathrm{N0})^2 \qquad (9)$$

Where σ (person/m^2) is the standard deviation, n is the total number of available population density data for various location proposed location was used with an average density population of 0.008 (person/m^2) in 662 locations and 1.5 persons in the car. Thus, this gives the number of fatalities for catastrophic rupture of a tank was determined as;

N = 9.2 fatality/accidents.

It is important to mention that the effect of safety barriers, i.e., thermal protection of onboard storage, on the reduction of the risk associated with a rupture CNG cylinder onboard storage was not within the recommended scope.

The probability for 8 min reported by Kashkarov [50], thus, probit model design as follows:

Y = 10.09 – 2.13 ln (8) = 5.66, result in

$P = \frac{1}{2}\left[1 + erf\left(\frac{Y-5}{\sqrt{2}}\right)\right]$ = 7.46E-01, A reported TPRD = 6.04E-03, used as recommended for compressed gas tank storage onboard by database NPRD [51], Therefore the cost can be calculated by multiplying the cost of fatality by probability,

Tank rupture frequency = (Initial frequency). (TPRD frequency)

The initial frequency was obtained as 3.41E-04, and therefore, For an engulfing fire, public database NPRD (reliability Analysis Center 1996) gives a value of the TPRD as 6.04E-03. Then, the risk based on the impact of fire-resisting time (FRR), Tank rupture defined as (rupture/vehicle/year) = 3.41E-04 * 6.01E-03 * 7.46E-01 = 1.53E-06, However, the risk without the impact of fire-resisting time(FRR) = 2.54E-04 (rupture/vehicle/year). It is to demonstrate the importance of TPRD as a safety measure, which could contribute to risk reduction. The risk of fatality determine as follows;

1. (Risk / Vehicle) = Rupture tank * N (10)

   = 1.41E-05 (fatality/vehicle)

2. (Risk/Vehicle) = 2.34E-03 (fatality/vehicle)

	W/ TPRD	W/O TPRD
Risk (fatality/vehicle)	1.41E-05	2.34E-03
	1.29E-04	2.15E-02

Table 5.2: The risk-based fire resist time (FRR), w/o TPRD

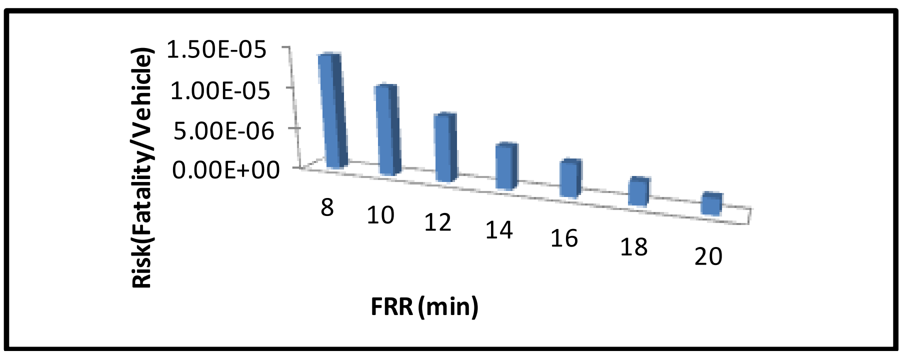


Figure 5.4: The risk as a function of fire resist time (FRR).

According to [51][52][53],the acceptable risk level is 1E-05 (fatality/vehicle/year). For selected conditions within made assumptions, therefore, the risk for the CNG cylinder onboard vehicle is about two or three times more than acceptable risk level. It is an important finding in terms of supporting CNG cylinder onboard vehicle safety design. Based on the acceptable risk level of 1E-05, the risk reduction possible if fire-resisting time (FRR) increased to 11 minutes or more. This result of FRR is proportionate with experimental observation [54] for FRR, which ranged (8-12) minutes. Furthermore, we may be able to interpret these results as that a reduction in the fatality rate may be achieved from 1/10000 to 1/1000000 if TPRD installed with CNG onboard vehicles.

The risk assessed in terms of cost per accident defined as monetary value. Approximately $13,358,696 per accident as a cost associated with loss of life in such as accident

Cost = $13,358,696 * 7.46E-01 * 6.04E-03 = $ 60,192.147 / accident.

The first and most important conclusion we can address from these results is that, based on our findings, safety should not be an obstacle to the development or demonstration of a CNG cylinder onboard. As we move from technology to real-world demonstration installation, data from the field is essential and can be confident that the risk levels of CNG onboard can adequately be managed. Consequently, systematic engineering solutions required such that of developing additional protection barrier of detection that increase fire-resisting rating (FRR) or optimizing technical and chemical specifications of CNG cylinder to respond thermally in a safe manner.

5.3.4 HEALTH HAZARDS

Toxic gases cause serious health problems dependent upon the specific gas and its concentration, length of exposure, and route of entry. Health symptoms of exposure to gases can be immediate or delayed. Refer to the attached Appendix for a list of Common or Highly Toxic Gases (HTX), the majority of CNG consists of methane. It is toxic. Therefore, a gas detection system is required as per the manufacturer's operating instructions. The adopted model discussed the effect of the type of technology or system such as CNG as "clean technology" on the end-user decision of choice. Furthermore, based on the study, the results do not show any relation between health hazards and people's choice.

5.4 RISK ANALYSIS

The risk analysis of CNG onboard vehicle determine in terms of frequency and severity should then predict the probability that individual with specific socioeconomic characteristics and during operation (driving) in a given traffic environment is involved in a road. The CNG system process consists of several pieces of equipment and unit operations, tens of control loops, and exhibit dynamic behavior. These process facilities have to deal with different hazards and several types of risks. Failure to manage or minimize hazards can result in serious incidents. For example, the CNG system involves several compressors, separators, complex piping systems, and storage tanks, etc. A small mistake by an or a problem in the CNG process system may escalate into a disastrous event. It is subjected to different types of risks, which include process risks due to compressibility, reactivity, and mechanical hazards, fire, and explosion risks. Therefore, it is essential to identify hazards, perform risk assessments, and take proper initiatives to mitigate or eliminate risks; else, a catastrophic accident may result.

5.4.1 RISK DEFINITION

Risk traditionally [55] defined as a combination of the probability (or likelihood) and the consequence of a negative outcome or loss. Combining these components leads to the expected value of risk.

Risk = Probability(P) x Consequence(C) (11)

This simple formula allows the calculation of expected losses associated with an event.

Risk assessment is a technical and scientific process by which the risks of a given situation for a system are modeled and quantified. It requires to provide qualitative and/or quantitative data to decision-makers for use in risk management and can be categorized as follows:

5.5.1 RISK CATEGORY

Risk can be categorized in several ways. Different disciplines often categorize risk differently, using terms such as hazards or risk exposures. The categorization can be done on the basis of the causes of risk or the nature of loss (consequences) or both. The appropriate way of risk categorization is a RISK-BASED INDEX. Significant risk-based index (i.e., safety, cost, and environment, operation, etc.) are identified.

5.5.1.1 SAFETY RISK

Estimate potential harms of overpressure systems such as the CNG cylinder caused by accidents occurring due to natural events (i.e., climatic conditions, earthquakes, brush fire, etc.) or human-made technology(i.e., crashes, explosions, accidents, or failure). Terrorism, riot, crime (vandalism, theft, etc.), and misappropriation of information (national security information, intellectual property, etc.). Risk-based index (safety), including road safety, operational safety, SIS, and personal safety, are significant. The cost of each category is high. Thus, the results showed that participants are much more concerned about the safety of the CNG cylinder when deciding to have a CNG onboard vehicle.

5.5.1.2 FINANCIAL RISK

Determine potential individual, institutional, and societal monetary losses such as currency fluctuations, interest rates, share market, project losses, bankruptcy, market loss, misappropriation of funds, and property damage.

5.5.1.3 ENVIRONMENTAL RISK

Determine losses due to contamination, and pollution in the ecosystem (water, land, air, and atmosphere) may not influence the end-users choice. However, a controversial debate on greenhouse gases (GHG's) may take into consideration.

Furthermore, based on the results of the study, the environmental influence on the people's decision is minimal.

5.5.1.4 OPERATIONAL RISK

Determine losses due to operational failures. As risk assessment focuses on identifying, quantifying, and characterizing uncertainties with losses, risk management essentially turns into an effort to manage such uncertainties.

Risk management is a practice involving coordinated activities to prevent, control, and minimizes losses incurred due to risk exposure, weighing alternatives, and selecting appropriate actions by taking into account risk values, economic and technology constraints, legal and political issues. The primary focusing risk management throughout the life cycle of a complex system involves proactive decision making to:

- Assess what could go wrong
- The decision of which risks are significant to deal with
- Control risk by employ strategies to minimize risks

- Monitoring by assessing the effectiveness of the strategy and revise them, if needed

5.5.2 RISK MEASURE

Risk is measured in two ways:

- Individual risk
- Group or societal risk

5.5.2.1 INDIVIDUAL RISK

Individual risk is defined formally based on chemical engineering prespective (CHEM) as the frequency at which an individual may be expected to sustain a given level of harm from the realization of specified hazards. It is usually taken to be the risk of death and often expressed as a risk per year. Individual risk can also be expressed fatal accident rate

$$\text{Average individual risk} = \frac{\text{Number of fatalities}}{\text{Number of people at risk}} \qquad (12)$$

5.6 THE STUDY OF RISK ASSESSMENT

Hazard studies require the use of analytical methods at the system level that takes into consideration subsystems and components when assessing their failure probabilities and consequences. Systematic approaches for assessing failure probabilities and consequences of engineering systems required.

5.6.1THE RISK-BASED METHODOLOGY (RBM)

A risk-based method (RBM) is a method used to assess and manage the risks of a system. RBM processes classified into risk management, which includes risk assessment and risk control using failure prevention and consequence mitigation, see Figure 1.4. Risk assessment consists of hazard identification, event- probability assessment, and consequence assessment. Risk control requires the definition of acceptable risk and comparative evaluation of options and/or alternatives through monitoring and decision analysis; risk control also includes failure prevention and consequence mitigation. Risk management involves perceptions of risk and depends on the audience targeted; hence it is classified into risk management to risk acceptance, risk analysis: decision making and monitoring.

Also, the study conducted for all items in the research framework model that related relevantly in designing and developing a CNG cylinder onboard and considered by experts, scientists, and developers. Risk acceptance is a method which is used by governmental agencies to assess the risk such as;

1.5.1.1 The Environmental Protection Agency (EPA) uses guidelines regarding acceptable risk (i.e., a lifetime cancer risk of less than 10^{-4} for the most exposed person and a lifetime cancer risk of less than 10^{-6} for the average person).

1.5.1.2 United Kingdom Health and Safety Executive (HSE) uses the ALARP system (as low as reasonably practicable) in the risk management approach.

The level of risk separating the unacceptable from the tolerable region is 10^{-3} for workers and 10^{-4} for the general public. The level of risk separating the tolerable from the broadly acceptable region is 10^{-6}. However, the acceptance criteria do not depend on the risk value; it depends upon society's perceptions, yet there are no guidance criteria for acceptable and unacceptable overpressure onboard cylinder to be applied to the transportation industries.

The study approach seeks to study the behavior of end-users regarding the decision of choice of risk based on high-pressure natural gas cylinder onboard vehicle for supporting its designing.

Furthermore, SPSS-Amos models were developed and applied of which is specified either by the nature of explanatory variables selected and in which characterize the alternative and individuals or by the statistical distribution law that follows the error terms or its ability to overcome the constraint of independence from irrelevant variables.

5.6.2 RISK-BASED ACCEPTANCE INDEX (RBAI)

While the risk takes many forms, the RBAI is an analysis technique associated with selected factors for a particular system or product (i.e., CNG) such as cost and performance. Thus, it can be scientifically classified into risk assessment, risk control, or risk management. The objectives are to help identify instances of inadequate design that could result in harm. It is suitable for the development of countermeasures that aim to prevent or reduce similar accidents from occurring. For example, it provided useful tools to prevent or reduce the uncertainty associated with the CNG cylinder onboard vehicles. Underlying the RBAI process is the notion that hazard is controlled through the system design. Knowledge used to determine when the design is safe. However, in most instances, safety cannot be extracted and treated in isolation from other utility concerns such as cost, operational, and performance risks; therefore, their risks have an impact on the safety of the CNG safety.

Thus, the general framework for RBAI represents a methodology to reduce the probability of undesirable events occurrence of hazards. It also allows us to define the causal factors that lead to inadequate action (i.e., flaws) and can quantify the risk to life posed by those factors. Once these factors identified, we can use that information to control all hazards affecting the system.

The potential process components of integrity threats can be identified as technical and functional factors (i.e., operational, safety, etc.). These factors that developed CNG system are the primary aim of RBAI that help the end-user to observe the ability of CNG vehicle to fulfill their needs. This includes enhancing the end-user ability to share the development of system design. This is a combination model of social and industrial in making-decision. For example, the study revealed the significant factors based on the socio-demographic prediction. An experimental instrument performed (i.e., survey sample) randomly. Also, possible interaction effects were investigated, which create some relationship associated with risk (i.e., age, level of education, etc.) as can be noted that the interaction was significant: (cost*environment), and (safety*reliability).

In the RBAI, the qualitative judgments described as a verbal quantifier (i.e., likely, unlikely, etc.) offers probability typically labels (1-7)

Consequence analysis focused on estimation because of failure occurrence. Failures include loss of breakdown, loss due to environmental damage, and loss due to reliability. Hence, there is a need for an optimal policy that aims at minimizing total cost. This paper presents an attempt to obtain an optimal replacement decision based on reducing the risk associated with CNGv's cylinder onboard vehicles.

A comprehensive case study to simplify the application of the model achieved as follow:

5.6.2.1 AN APPLICATION OF STUDY APPROACH

In this section, a case study adopted as an application for RBAI. It allows us to analyze alternative transportation demand and to identify important information about direct and indirect effects of transport demand concerning attributes of the variables (i.e., cost, reliability, operation, etc.). The end-user would choose the variable that increases its utility. However, this utility is unobserved. What we perceive as the end-user decision of choice. In this context, the variable to be explained would be the choice established by the end-user but not its utility. The variables are qualitative, which takes a limited number of integer values, whose each value illustrates a particular choice. It is the foundation of the model.

We assume that the model set is composed of six factors (i.e., j=1, 2, 3, 4, 5, 6). The variable expressed by the following relationship:If end-user (i) prefer SOT (Social Acceptance)

This is a model set of variables. We defined it as (Uij). The end-user i that prefer safety, for example, implies for more satisfaction that van be gained by end-user if safety measures perfectly performed. This satisfaction can be systematized by a linear indict utility function. The indirect utility function depends on a certain number of variables relating to the attributes of the chosen item and the end user's socio-demographic characteristics. Therefore, many variables can be integrated and tested, which characterized the end-user as the attributes of an alternative. In the study, five variables are characterizing the end-users, including Age, Gender, Income, etc. All of them considered as continuous variables, but gender is not. It is a binary variable coded as 1 if the end-user is female or 2 otherwise. However, other variables, such as price, brand, and speed) do not varied accordingly.

The general model described previously in section, 2.3.1 gives the following model:

$$U_{ij} = ß_0 + ß_{1j}Gender + ß_{2j}Age + ß_{3j}Income + ß_{4j}Education + ß_{5j}Occupation \quad (13)$$

U_{ij} depends on a certain number of variables relating to attributes of the chosen alternative CNG option. First, $ß_{ij}$ are the coefficients to estimate the weighting coefficients relating to the socio-demographic characteristics of the end-users—Respectively, gender, age, income, education level, and occupation. The weighting coefficients of these variables, β, reflect the relative importance of each of the variables relating to the socioeconomic. Thus an estimate of this model requires data. The data collected through a questionnaire sample presented previously. The results of our estimation described the values of coefficients associated with variables; the standard errors; the degree of significance; and exponential function, based on SPSS software, For example, the model description of each factor adopted in this study can be defined as follows:

1. Safety = $ß_0$ +$ß_{1j}$gender +$ß_{2j}$Age+$ß_{3j}$Income +$ß_{4j}$Education+ $ß_{5j}$Occupation
2. Cost = $ß_0$ +$ß_{1j}$gender +$ß_{2j}$Age+$ß_{3j}$Income +$ß_{4j}$Education + $ß_{5j}$Occupation
3. Social = $ß_0$ +$ß_{1j}$gender +$ß_{2j}$Age+ß3_{jI}ncome +$ß_{4j}$Education+ $ß_{5j}$Occupation
4. Environment=$ß_0$+$ß_{1j}$gender+$ß_{2j}$Age+ß3_{jI}ncome+$ß_{4j}$Education+ $ß_{5j}$Occupation
5. Reliability = $ß_0$ +$ß_{1j}$gender +$ß_{2j}$Age+ß3_{jI}ncome +$ß_{4j}$Education$_{+}$ $ß_{5j}$Occupation
6. Operation= $ß_0$ +$ß_{1j}$gender +$ß_{2j}$Age+ß3_{jI}ncome +$ß_{4j}$Education+ $ß_{5j}$Occupation

The constant parameter presents the heterogeneity in the representativeness of the end-user choices in our sample. The coefficients for those variables are statistically estimated by SPSS 0.004, 0.034,0.088,-0.003,0.285, and 0.054. It implies that if the cost of the safety of CNG onboard increased, the probability of choosing the CNG onboard vehicle compared to traditional ones decreased. This coefficient is significantly higher for safety than other variables, which reflect, therefore, the high proportion of safety. Also, the estimation of negative variables implied that if the chosen variable estimation increases, the probability of the chosen alternative decreased. It is, therefore, possible to investigate the influential factors on the alternative. More discussion attached to chapter seven.

The accident scenario described as a function of an individual's characteristics of end-user who considered a victim of the accident. Normally, the more of the risk perception, the lower the accident severity would be. The lower of risk perception, the higher the probability. Therefore, the risk perception influence both the occurrence of the accident and the severity level. It is useful for estimation of the probability as discussed thoroughly in previous sections. The consequence then can be defined as the severity of an accident sustained by an individual that influenced by other factors, including vehicle characteristics, design of the road, and driver or end-user behavior. The impact of these factors on accident severity is required. Finally, the crash characteristics included a crash with a stationary object or other vehicles and the manner of collision.

The relation between risk and perception or knowledge and behavior among different people is a complex process and has not yet entirely defined.

The data analysis used for investigation of end-user behavior classified by gender, age, income, education level. Also, investigating the relationship between selected predicted variables and the threat of CNG onboard vehicle, which may imply to accident severity, using P-value < .05 as significant level. The results of the survey showed that age and gender controlling factors that have a higher percentage of awareness among female and young users demonstrate the safety concern. As a result of the threat of high-pressure cylinder onboard vehicles. A former study noticed that the carelessness caused the most car accidents, contributing to 36.5% of total causes and fatalities recorded in the Road Traffic Accident (RTA). It implies one of the end-user behavior, indicating that road users acquire many dangerous and harmful driving habits and not compliance with traffic regulation properly. In such a study, the information is valuable.

Furthermore, speeding, for instance, is much more likely to be another factor in a fatal accident when the age of end-user under 30 years old reported by several studies. An Australian study mentioned those young people aged between 17-30 years have double the risk of being involved in a fatal accident. It referred to safety issues that match our study findings for people age between 20-30 years old, see Table 7.5. It is common among age and gender factors to control people's decisions of choice. Female and older people have more concerned about safety; in contrast, young aged people behave lesser towards safety. It may be explained by the increased frequency that more commonly by gender and age. Although the threat of CNG onboard vehicle acknowledges and control, lack of skills and experience in recognizing potential damages putting the end-users at an increased risk of a crash. Based on other studies, their several models suggested for the estimation of the risk of a road accident. Others used to calculate the probabilities of occurrence of the accident and predict the correlation between the user behavior, characteristics of the traffic system, and the severity of the accident. Other models tried to model the accident risk perception according to a set of factors, and some risk factors are applying to the general population that associated with age such as speed, safety measures as seat belts, drinking. Thus, manage and control these risky behaviors would contribute to the reduction of car accidents.

The results of the study also show that certain aspects of end-user behaviors and perceptions are significantly associated with their choice. The final set of independent variables, Appendix F-1, used to predict the Risk-based acceptance index to support CNG onboard. Information regarding six variables was included; social acceptance, safety, reliability, operation environment, and cost. Also, all respondents asked to indicate their frequency of use CNGV for each source. Our findings reveal that safety followed by reliability has statistically positive and significant influences on the end-user choice if decided to have a car. Approximately 40% of the respondents have a safety concern compared to how much does it cost. It is reflecting the greater concern of the safety of end-user compared to cost. On the other hand, cost and environmental impact have statistically lower effects in the model.

The questionnaire represents a heterogeneity in the representativeness of individual choices in our sample may due to a lack of knowledge about the threat of CNG onboard vehicles. Also, our findings indicate that the percentage of age and gender gap in alternative CNG-policy knowledge between men and women appears to be wide. In contrast, the gap appears to be narrower based on income.

Accident and Individual Risk Factors:

Generally, the majority of car accidents are associated with human beings' factor. Individual characteristics are important contributors to car accidents, as explained previously (i.e., age, gender). However, it seems that there are other factors associate with car accidents. Factors related to the traffic circumstances and the vehicle in question. On the other hand, there are factors related to human being factor. According to the weight coefficient of each index attached to Appendix I, we applied a proposed model by other literature to determine risk:

$$X = \sum_{i=1}^{m} \sum_{j=1}^{n} \beta ij Xij \qquad (14)$$

X is end user's risk

βij is weight coefficients

Xij is the mean

Firstly, we calculate the mean of all the attributes of indices, and then we found the sum of the mean multiplied by their respective weight coefficients to get the value of the first indices. For example,

Risk behaviour= β_1* “social (attribute)”+ β_2 * “safety (attribute) + $\sum_i \beta i X j$, (15)

After getting the value of all indices, the total risk can be determined,

Weight Coeff.	Attribute	Weight Coeff.	Risk Type
0.004	Social acceptance		
0.284	Safety		
0.088	Reliability and Resilience		
-0.003	Operation	**0.432**	**Risk Attitude**
0.034	Environmental Impact		
0.054	Cost		
0.125	Frequent driving habit		
0.277	Demand and need	**0.382**	**Risk Behavior**
0.113	Concern		
0.531	Consideration of Using CNG		
0.361	Awareness of safe driving	**0.215**	**Risk Perception**
0.119	Responsibility and Accident		

Table 5.3: The coefficient weight of each index

Based on our findings, the study suggested having a better understanding of the contributing factors affecting user behaviors. We, according to the risk model, the risk of CNG assessed, and the mean values for all item samples attached to the Appendix. The average risk value was ranged from (1-5); one represents a poor performance in the corresponding aspect and unsafe, while five represents being safe in the corresponding aspect. Following Tables 5.3 and 5.4, and risk modeling equation, our mean values of end user’s risk is 4.22. The statistical analysis revealed that our survey sample on the

CNG cylinder represents a high risk of about 81.51% of the end-users' concern regarding the CNG onboard, thus, prevent or alleviate life-threatening consequences due to the consumer's risk perception towards CNG cylinder onboard is important.

However, it can be a promising technology if we can cope with it since the significant correlations associated with the perception of CNG risk and related to risky driving patterns behavior, age, gender, and carelessness with all types of transports without exception.

Questionnaires	Number of Items	Mean (range 0-5)	S.D.
Risk Attitude Scale	32	**4.52**	
Social acceptance	5	5.23	0.013
Safety	5	5.64	0.048
Reliability and Resilience	5	3.78	0.139
Operation	9	4.82	0.011
Environmental Impact	4	3.89	0.102
Cost	4	3.81	0.042
Risk Behavior Scale	8	**4.00**	
Frequent driving habit	4	4.97	0.125
Demand and need	2	5.26	0.277
Concern	2	5.78	0.113
Risk Perception Scale	5	**4.15**	
Consideration of CNG	2	3.38	0.531
Awareness of safe driving	2	5.58	0.361
Responsibility	1	3.5	0.119

Table 5.4: Number and Mean of items

While safety concerns due to the driving behaviors defined, a comparison of our findings to other studies obtained. However, our study covers more safety factors than others, includes safety, operation, cost, environment, and reliability; see Appendix I-1.

CHAPTER 6:

SAFETY ANALYSIS OF INSTANTANEOUS RELEASE OF COMPRESSED NATURAL GAS CYLINDER

6.1 CASE STUDY

This study presents a numerical model to analyze the sudden failure of compressed natural gas (CNG) cylinder onboard. The model is developed using COMSOL. It accounts for the real gas effects, physical energy, and combustion of the flammable gas. The model is tested using experimental data.

The study highlight compression energy as one of the serious concern. An unintentional rupture of a compressed cylinder filled with natural gas would generate a rapid energy release in the form of the pressure energy (blast). The release of energy and gas would cause rapid mixing and create overpressure and may also cause flash fire. A detailed failure frequency analysis is also done to analyze the effectiveness of barriers. This study identifies critical points for the safe operation of the CNG system onboard a vehicle. Regardless of the benefits of using CNG (i.e., 90% emission reduction), the CNG has a serious safety. There are several factors attributed to the failure of CNG cylinders and may be listed as:

1. Use of unapproved cylinders that are not permitted for CNG use (i.e., oxygen cylinder, acetylene cylinder).
2. Maintainance and operation, cylinder failure may occur due to misfunction and inappropriate operating of fueling stations.
3. Use of wear out cylinder (i.e., expired cylinder).
4. PRDs failure during the occurrence of fire and explosion accidents.

5 Exceeding maximum allowable pressure of 20-25 MPa (200-250 bars).

However, the study addressed some key aspects:

- Propose a method to predict accidents using appropriate modeling techniques.
- Propose an approach to evaluate the effects of resultant blast wave pressure versus the magnitude of the accident (consequence criteria).
- Propose an alternative model for blast wave analysis.

Considering the increased overpressure risk discussed earlier, it is vital to develop a strategy to prevent or mitigate accidents in CNG vehicles.

6.2 METHODOLOGY

The methodology illustrates the research framework Figure 1.0. The first step, it aims to identify the hazard related to the system for fire-related or non-fire related to the internal pressure elevated inside a CNG cylinder. The identification of hazards relevant to the accident scenario with overpressure vessel in a fire. Those were identified based on prior studies as physical and thermal effects. The second step is to determine the consequence of CNG cylinder failure or rupture by presenting the research method compared with experimental and theoretical modeling schemes. In the consequence analysis, an alternative model presented for non-related fire [26]. It is designed based on a baker method and provided the estimation of hazard distances in which the pressure and thermal effects cause death, serious and slight injuries from fire and explosion calculated by the best fitted-model. These earlier models were tested for estimation of initiating event (overpressure) frequency, and calculation of the probability failure resulting in tank rupture. However, the limitation of physical parameters could be a source of error in many of those models. In this study, an appropriate technical method used (i.e., event tree). The estimation of the effect of pressure on the surface of the CNG cylinder using cost-effective model COMSOL. The analyses take into account the correlations amongst parameters at high-pressure when the system is a single-phase thermodynamically closed. Finally, therefore, risk can be obtained as a function of the tank rupture probability. In the study, we attempt to adopt a reliable methodology leading to predict the physical explosion of the CNG cylinder onboard. Therefore, a model application, in this study, to determine the overpressure storage CNG in blast wave ($\overline{r_P}$) used, as shown in the following equation.

$$\overline{rp} = \sqrt[3]{r\left(\frac{Ps}{\alpha E1+\beta E2}\right)} \qquad (16)$$

where E1and E2 are mechanical energy and chemical energy, Ps is the surrounding pressure, β and α are coefficients.

For comparison, the mechanical energy coefficient α added to the heat energy and used to determine the blast wave overpressures at different ranges,

Date	Description	Type	Death	Injury	Causes of Accident
30-03-2008	Explosion of CNG Cylinder	Pick-Up	2	3	during refilling at CNG station due to substandard cylinder
06-10-2008	Explosion of CNG Cylinder	Car	2	4	during refilling at CNG station due to substandard cylinder
07-06-2009	Explosion of CNG Cylinder	Car	2	4	during refilling at CNG station due to substandard cylinder
14-12-2009	Explosion of CNG Cylinder	Car	4	4	during refilling at CNG station due to substandard cylinder
18-02-2010	Explosion of CNG Cylinder	Van	6	15	Cylinder had crossed the standard age and not checked
21-10-2010	Explosion of CNG Cylinder	Car	2	2	during refilling at CNG station due to substandard cylinder
05-01-2011	Explosion of CNG Cylinder	Car	NO	4	during refilling at CNG station due to substandard cylinder
13-02-2011	Explosion of CNG Cylinder	Van	3	12	during refilling at CNG station due to substandard cylinder
12-07-2011	Fire explosion in CNG bus	Mini-bus	9	3	Gas leakage from CNG piping system and caught fire
03-09-2011	Fire explosion in CNG Van	Van	4	21	Gas leakage from CNG piping system and caught fire
01-11-2011	Fire explosion in CNG Van	Van	4	8	Gas leaked from the CNG cylinder, followed by a blast
29-11-2011	Fire explosion in CNG Van	Van	12	7	The vehicle hit the median on the GT Road and caught fire
03-12-2011	Explosion of CNG Cylinder	Car	2	1	during refilling at CNG station due to substandard cylinder
10-12-2011	Fire explosion in CNG bus	Van	17	10	the driver lost control and hit a tractor trolley laden with large oil cans
13-12-2011	Explosion of CNG Cylinder	Mini-bus	1	4	Explosion took place during refilling at CNG station
17-12-2011	Explosion of CNG Cylinder	Car	NO	6	during refilling at CNG station due to substandard cylinder
18-12-2011	Explosion of CNG Cylinder	Van	5	14	Sparking produced by Van Faulty wiring looms conduce to fire Explosion
21-12-2011	Explosion of CNG Cylinder	Van	6	15	The van rammed into a road's demarcation wall and caught fire due to CNG leakage
23-12-2011	Explosion of CNG Cylinder	Pick-Up	1	3	Explosion took place during refilling at CNG station due to substandard cylinder
24-12-2011	Explosion of CNG Cylinder	Mini-Van	NO	NO	Unknown

Table 6.0: Summary of some major CNG vehicles accidents [1][15][22][45][46]

6.2.1 NUMERICAL STUDY OF CNG ONBOARD

The numerical study of CNG onboard is a path to broaden knowledge of compressible gas flow in non-uniform regions with emphasis on the development of shock waves. Thus, we plan to use the COMSOL code to develop CNG cylinder rupture.

A numerical simulation approach performed as a result of a fully wrapped aluminum [solid, bulk] composite cylinder. The cylinder filled with CH_4 with a single-phase fluid in 3D Cartesian coordinates. The CNG cylinder assembly, as specified in global technical regulation (GTR) on fuel vehicles, consists of the compressed storage system and material specification.

The description of the designed mesh with the geometric of cylinder maximum and minimum element sizes 7.95E-02, and 4.5E-04 respectively, and maximum element rate is given in the following Figures 6.0 and 6.1.

Description	**Value**
Maximum element size	7.95E-02
Minimum element size	4.50E-04
Curvature factor	3.00E-01
Predefined size	Fine
Minimum element quality	8.66E-01
Average elements	9.64E-01
Triangular elements	2.64E+02
Width (m)	1.5E0.0
Height (m)	4.00E-01

Table 6.1: Geometry statistics of CNG cylinder

Also, the simulation of maximum flow with an increase in velocity occurring near the wall presented.

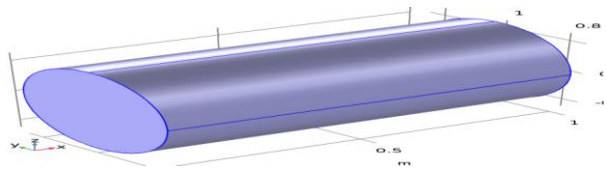


Figure 6.0: The 3-D CNG cylinder

Therefore, the first simulation result showed an effect on the CNG cylinder.

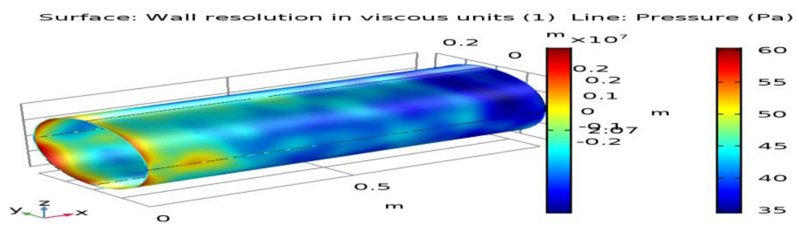


Figure 6.1: The result of the simulation study for CNG Cylinder

A CNG simulation performed as a result of a fully wrapped aluminum [solid, bulk] composite cylinder. The analysis takes into account the correlations among parameters at high-pressure with a single-phase system and thermodynamically closed. The cylinder filled with CH_4 with a single-phase fluid in 3D Cartesian coordinates Figure 6.0. The CNG cylinder assembly, as specified in global technical regulation (GTR) on fuel vehicles, consists of the compressed storage and material specification. In addition, the geometry and domain of the cylinder illustrated and a description of the mesh designed on the cylinder along with the geometric of the cylinder and maximum element rate Table 6.1.

It describes the characterization of the impact of the mechanical energy as a function of internal pressure provided.

Observation of some changes in the behaviors of the CNG was noticed. A growing boundary layer observed in the inlet of the cylinder, which gives an explanation of the stream acceleration as the displacement thickness of the boundary layer grows, but it loses its identity as the boundary layer thickness. It demonstrates the fluctuation of the pressure at the wall from a high value near the inlet to its low value for fully developed flow downstream. It is an indication of the momentum exchange between the high and low gas particles and causes a pressure increase. Therefore, it is worthy of mentioning that, a hot spotty may generated near the inlet of cylinder (i.e., red spots) by compression, which affects the temperature gradient.

6.3 ANALYSIS OF ACCIDENT FINDINGS

The study has assessed the risk analysis results of a proposed CNG onboard vehicle. For the sake of ensuring the enhanced safety of the system, a risk analysis was conducted. As a result of analyzing the identified hazards, the following perspectives on the safety of the CNG onboard were deduced:

(1) The majority of hazards to the CNG fall in the acceptable risk region.

(2) Critical hazards had an unacceptable risk level with a small number.

(3) Hazards, due to both the external factors associated with the environmental conditions and the internal factors related to the process operation, are the main concerns for the CNG onboard.

(4) Regarding the external hazards associated with, for example, environmental influence, relevant safety actions (i.e., alternative safety measures) for risk reduction must be provided in the system design.

(5) Regarding the internal hazards associated with the CNG process operations, it is recommended that additional safety actions for risk reduction should be investigated.

(6) Harmful effects of the CNG on the natural environment and residential areas (third parties) are expected not to exist or to be of a similar level as those of conventional automobile or transport, including fossil-fueled automobiles.

(7) Security hazards, such as attacks, strikes, and pirates, the CNG are similar to those of existing powered-fueled vehicles, and current practices being used are considered appropriate.

(8) Health hazards to the passengers onboard are insignificant.

6.4 LEARNING AND IMPLICATION

list of dangers for CNG on board would be a. Loss of cargo tank,b. Gas release into enclosed spaces, c. Fire and explosion, d. Collisions and impacts e. Structural and foundation failures, g. Drop objects, i. Stability failure. However, there are some learning and remedies gained from such an accident and can be listed as follows:

1. To avoid CNG cylinder explosion

Improper installation of cylinders has led to cylinder failures:

(a) Only approved CNG cylinder comply with prevailing international standards (i.e., approval seal stamp and marking standard number labeled.

(b) The CNG cylinder should be equipped as per ISO-14159 in the event of fire or explosion accidents.

(c) Appropriate and safe installation of CNG cylinders to avoid unpleasant fire accident

(d) Protection against over pressurization required,

- Additional pressure relief valve installation required for CNG refueling dispenser to protect the CNG cylinder against over pressurization from the station,

(e) The stability of CNG vehicle against any environmental barriers (i.e., wind)

- The weight of a CNG cylinder needs to be taken into consideration and carefully maintained

(f) It is highly recommended to install CNG cylinders in a proper spot safely

- However, avoid installing it beneath the passenger seats as after the accident the breaking and dislodging of high-pressure pipe, and fitting are the leading causes of fire in the passenger compartment of the CNG onboard
- Also, avoid gas accumulation inside the passenger cabin by installing a cylinder valve with air-tight cover and vented out of CNGV.
- CNG cylinders must be adequately mounted and fastened in the commercial vehicles, such that in the case of an accident, the cylinders are not detached from the fastening. Separating of the CNG cylinder may cause leakage of gas, breaking of pipes/fitting, and injury to the passengers. The mounting brackets used for cylinder mounting must be securely fastened to the vehicle at a location that provides sufficient strength to retain the cylinder in the event of a collision. Brackets must meet the minimum specification defined in the at least updates of the following standards: (1) ANSI/NFPA 52 vehicular fuel systems code; (2) ISO 15501-2 Road vehicles—CNG fuel systems—part 1: safety requirements (3) CGA B149.4 M1991 NGV installation code ; (4) FMVSS 304 CNG fuel container integrity ; (5) CSA B109 natural gas for vehicles installation code; (6) ANSI/AGA NGV3.1/CGA 12.3, fuel system components for natural gas-powered vehicles.

(g) External collision protection requires a portion reduction of the CNG cylinder or cylinder accessory. It should be located at the front axle or behind the point attached to the rear bumper to the vehicle.

- Each CNG cylinder of the vehicle should be mounted in a location that would minimize damage from a collision to avoid external accidents/collisions.

(h) Strict regulations should be enforced for cylinder removal after their useful life.

- The inspection for CNG cylinders conducted through a qualified pressure vessel inspector to avoid or remove affected CNG cylinders applied Periodically (i.e., corrosion) either by using proper painting (coating) or replacement.
- The corrugated pipe should be used to protect the high-pressure pipe from mechanical damage. Plastic fitting should be provided on holes made on the vehicle body so that the high-pressure piping remains stable. It would protect the pipe from vibration and metal to metal contact with the body of the vehicle.
- A manual shutoff valve should be provided in the high-pressure line in the vehicle where multiple CNG cylinders used.
- A Non-Return Valve (NRV) must be installed between the cylinder and the filling valve. It prevents leakage of gas due to the malfunctioning of the filling valve.
- The cylinder's valves should be protected from physical damage using the vehicle structure, valve protectors, or a suitable metal shield.

For public transportation, required training for the drivers and some road education, before they are given a permit to drive. The licenses issued to the drivers of public transport should be different from the conventional transport system. Such as, applying for a standard training program regarding the safety issue of CNGVs included as a mandatory requirement for availing CNG vehicle driving license.

CHAPTER 7: RESULTS, DISCUSSION, AND CONCLUSION

This chapter aims to present the following models while focusing on the multi-regression model that is most used in empirical studies. The chapter presents the specification of the models while reviewing its main tools for estimating and testing statistical validation and interpretation of its coefficients. In the experimental sample research, it has been found that the most significant factor that is controlling the end-user decision of choice is safety. CNGV industry requires a productive action towards the CNG onboard safety measures to increase the end-user satisfaction and attract them based on the Pearson correlation analysis. Generally, the diversity in the transportation industries gives the end-users extra options that bring them secure, reliable, and comfortable vehicles. The CNG onboard vehicle industry should devote to more development of the CNG system and adopt better safety and operational measures. The second significant factor is the reliability of CNGv as one of the priorities to give their customers a strong sense of security and reputations towards CNGV. Operation is the third significant factor that brings the importance of the technical part of CNGv, which may affect the end-users daily life if a technical problem occurred. However, social acceptance should not be neglected as it would impact the decision of end-user choices when the CNGV is strategically better than its competitors, which includes expanding braches and infrastructures of CNG as automobiles for end-users convenience. The outcomes of the study instrument created chances to understand the end-users characteristic of different categories on what they prefer and define the direct and indirect factors that induce the end-users decision of choice.

Although the study showed that different influences between factors, some factors have less impact on the decision of the end-users, it is an essential factor. It may be due to the lack of knowledge of CNG; technically, it creates a situation where end-users are more aware of the market conditions and conscious in their financial services choices because they would compare cost and benefits at the lowest cost given to their preference. It is one of a reason for industries to consider the cost as a priority as people would also willing to pay for better products and services.

Therefore, to test the significance of the results, the reliability test, Pearson correlation coefficient analysis, multiple linear regression analysis, path model, and bayesian test were used. For this chapter, researches are discussing the results of the statistical test. The author typically uses the following criteria in judging the statistical significance and theoretical meaning of a theoretical model:

1. The first criterion is the statistical significance of the Pearson correlation coefficient test and the sig. (2-tailed) values, which are global fit measures. It indicates that the sample matrix and the reproduced model implied pattern are similar.

2. The second criterion is the Cross-tabulation is one of the most frequently used methods of analysis for questionnaire data. It enables us to examine the relationship between categorical variables in greater detail than simple frequencies for individual variables. In this chapter, we see how to do this in SPSS and also apply a statistical analysis associated with cross-tabulation

3. The third criterion is the magnitude and direction of the parameter estimates, paying particular attention to whether a positive or negative coefficient makes sense for the parameter estimate.

So, in our hypothesis (prediction), there would be a difference in satisfaction ratings. It is '2-tailed' because we are not specifying whether the ratings are high or low just that there would be a difference. In general, the 2-tailed significance level is cited since we can rarely be certain of the outcome, despite any predictions.

7.1 SUMMARY OF STATISTICAL ANALYSIS

A descriptive analysis is used to obtain data through a questionnaire that describes the characteristics of the population. The survey questionnaires had been collected from the respondents with different gender, age, income, qualifications, and after receiving all questionnaires, transformed into the primary data via statistic software to conduct results.

The results of the experimental instrument of the research determine the factors that influence the end-user on their CNGV selection. Therefore, the inferential analysis provided to assess the relationship of consumers on CNG onboard vehicle selections among acceptance index factors such as cost, safety, environment, operation, reliability, and social acceptance technology (quality service). A total of sixty-three questionnaires were distributed electronically and successfully collected for logical analysis. For this research, SPSS-Amos analysis statistical tools performed for measurements to both descriptive and inferential analysis.

From this study, CNG safety, including reliability, environment, operation, and cost, were assigned, see Appendix F-1. Based on the research sampling data, it shows that safety and reliability considered as priorities to end-users on choosing the type of transport through the survey. Most of the respondents feel that CNG onboard vehicle industry should provide service that matches the end-user demands. They preferred the car with fewer expenses, flexibility, and availability. Besides, the requirements of CNG system services should be accessible and straightforward. Therefore, safety plays an essential role in the decision of the choice process of end-users. It also affects the demand of the CNG. A description of the likelihood estimation of observing the data sample that given distribution parameters given in Appendix F-1.

The purpose of the chapter is to interpret the findings from the data collected. From the data, which received earlier, the suggested test analysis, Statistical Package for Social Science (SPSS)-Amos, performed as the reliability test. Furthermore, the T-test and The Correlation Coefficient (CC) also used to calculate the correlation coefficient between the variables.

7.1.1 DESCRIPTIVE STATISTICS

The first findings discussed are the descriptive statistics. Descriptive statistics were calculated for all constructs, such as social acceptance, operation, CNG safety, etc.). Demographic factors were collected during the survey, including gender, age, education level, income, and occupation. These demographics compared in some cases. The primary demographic characteristics data collected were age, gender, education level, income, occupation of the sample, with 62% of respondents were male, and about 38% were female. The education level of 71.9% and 27.1% were bachelors and graduated degrees while there was approximately 53% income divided into 30% and 23% for student and employment incomes, respectively. The percent and cumulative percent were calculated and presented for all individual items in the variable scales (for each question item in the experimental research).

In general, the descriptive statistical outcomes showed different responses among items. For the age variable of the end-users of cost, A detailed analysis of the results was attached to the Appendix A, B, C, and D.

7.2 RELIABILITY TEST

The reliability test performance of the research described thoroughly in this chapter. In the initial run of the analysis, the model was not appropriately fitted for some factors such as environmental impact (EI) and social acceptance (SA) factors. However, adjusting the model within the scales was statistically made by removing the low correlation scales. Consequently, the analytical model was similar to the proposed theoretical framework. A qualitative method was used to test and identify the statistical relationship within the data and identified potential factors.

Furthermore, the research carried out a statistical model known as the Structural Equation Model(SEM), which offers some advantages. It examines the hypothetical model and requires specifying variables as previously described using multivariate analysis, including factor analysis and Cronbach's alpha [66][69].

Cronbach's Alpha Coefficient, α	Level of Reliability
$\alpha \geq 0.80$	Excellent Reliability
$0.70 \leq \alpha < 0.80$	Good Reliability
$0.60 \leq \alpha < 0.70$	Fair Reliability
$\alpha < 0.60$	Poor Reliability

Table 7.0: Rules of Thumb for Internal Reliability Test [66][67][68]

Then the SEM model was identified how well the model fits the outcomes of the data. It helps to determine the relationships amongst variables and modify or eliminate factors that not related. The theoretical model interest is to predict the satisfaction level of participants based on given variables as age, education level, and income. In this case, the dependent variable (satisfaction level), therefore, predicted by given independent variables.

Furthermore, the demographic profile illustrates you make up a statistically significant set of predictors of a participant's satisfaction level. Also, the initial result indicates the negative value of coefficients, which states as participant's age, education level, and income increased, participant's satisfaction decreased.

The basic profile description collected was gender and age. The study pointed out that females are more likely to participate than males. 37% of respondents were female, while the male respondents were about 63%.

7.2.1 MODEL SPECIFICATION

Model specification involves using all of the available relevant theory, research, and information to develop a theoretical model. Therefore, the model specification required to confirm before data collection and decide which variables are included, and which variables are not to be included, how those variables are related. Model specification involves determining every relationship and parameter in the model that is of interest to the researcher. It is the hardest part of structural equation modeling.

Once a specified SEM model obtains the parameter estimates, then how well the data fit the model determined. In other words, to what extent is the theoretical model supported by the collected sample data. We consider the individual parameters of the model. The main features of the individual parameters considered. One highlight is whether a free parameter is significantly different from zero. Once parameter estimates are obtained, standard errors for each estimate are also computed. A ratio of the parameter estimate to the estimated standard error can be formed as a critical value, which is assumed to be normally distributed, that is, the significant value equals the parameter estimate divided by the standard error of the parameter estimate. If the critical value exceeds the expected value at a specified level, for example, a = .05, 2-tailed test, tabled t = 1.96, then that parameter is significantly different from zero.

7.2.2 MODEL FIT

We considered, In the model approach, a hypothesis of a specific theoretical model, gathers data, and then tests whether the data fit the model achieved. In this approach, the theoretical model is confirmed based on a Pearson correlation coefficient statistical test of significance and meeting acceptable model-fit criteria. In the second approach using alternative models, the researcher creates a limited number of theoretically different models to determine which model the data fit best. When these models use the same data set, they are referred to as nested models.

The purpose of generating such a model is to find a statistical model that fits the data well, as illustrated in the following Tables 7.1 and 7.2. In the case of a best-fitting model that does not fit the data, the model, therefore, modified to improve the fit. Thus, finding a statistically significant theoretical model that also has practical and theoretical meaning is obtained using SEM-Amos structural equation modeling to :

1. Describe characteristics and patterns of use

2. Identify trends in user characteristics and patterns via comparisons with previous surveys.

3. Identify and profile managerially relevant market segments

4. Evaluate participant satisfaction and measure their preferences for new facilities and programs.

The study has also suggested that a SEM with a model-fit value of .90 - .95 is performed. For the significance or probability associated with the test. The T and Chi-square are the actual "test statistics," but the SIG's are what you need to complete the test. If a small probability (<.05), you reject the assumption of no relationship (null hypothesis). The rejecting of the Null Hypothesis means the data suggest that there is a relationship. To show the influence more clearly, a diagram was produced; see Figure I-2, Appendix I. The figure reflects the causal relationship between the variable and indicators. Arrows were used to illustrate the causal relationship, from the cause (independent variable) to the effect (dependent variable), while path model coefficients are standardized regression

Item(s)	Estimate	S.E.	C.R.	P
Social	.004	.013	.280	.779
Environmental	.034	.102	.709	.479
Reliability	.088	.139	.638	.523
Operational	-.003	.011	-.286	.775
Safety	.284	.048	2.791	.005
Cost	.054	.042	1.286	.198

Table 7.1: Variance of uncorrelated factor

Coefficient (Beta value) discovered from the regression equation. Therefore a comparison of six acceptance correlated and uncorrelated factors illustrated in the following tables provided a detailed outcome in terms of variance and covariance between the six factors. These results represented the probability of getting a critical ratio;

Social factor:

An estimate of variances for the variables provided. Critical (CR) is the parameter estimate divided by an estimate of its standard error. If the appropriate distribution assumptions are met, this statistic has a standard normal distribution under the null hypothesis that the parameter has a population value of zero. For an estimate of a CR higher than two, the estimate is significantly different from zero at the 0.05 level.

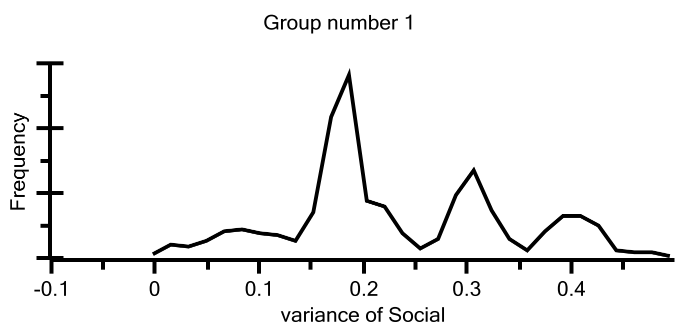


Figure 7.1.1: Variance of social acceptance

For social acceptance factor tabulated in the following table gives an estimation of variance, standard error, critical ratio, and probability. The variance estimation,.004, has a standard error of about .013. Also, critical ratio CR determined by dividing the variance estimate by the estimate of its standard error, z=.004/.013 = .280. In other words, the variance estimate is .280 standard errors above zero. Therefore, the probability of getting a critical ratio as large as .280 is .779. In other words, the variance estimate for the social acceptance factor is not significantly different from zero at the 0.05 level (two-tailed).

Safety:

The variance of safety is estimated to be .034 and has a standard error of about .048. It gives z=.034/.048 = .709. In other words, the variance estimate is .709 standard errors above zero. Therefore, the probability of getting a critical ratio as large as .709 is .479. In other words, the variance estimate for safety is not significantly different from zero at the 0.05 level.

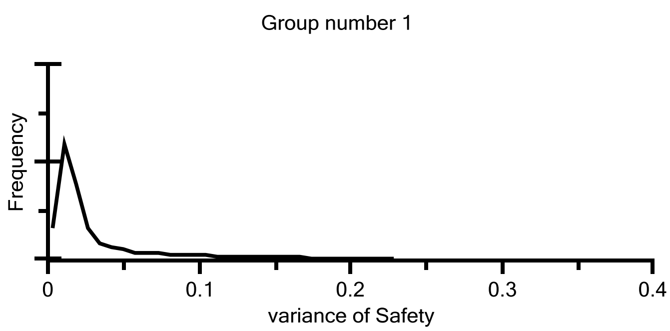


Figure 7.1.2: Variance of safety

Reliability:

The variance of reliability is estimated to be .088 and has a standard error of .139 given a z –value of .638. In other words, the variance estimate is .638 standard errors above zero. Therefore, the probability of getting a CR as large as.638 is .523. In other words, the variance estimate for reliability is not significantly different from zero at the 0.05 level.

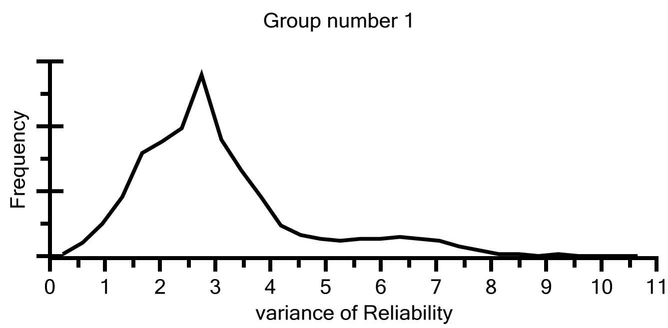


Figure 7.1.3: Variance of reliability

Operational:

The variance of operational is estimated to be .003, which has a standard error of about .011, and z=.286. In other words, the variance estimate is .286 standard error below zero. Therefore, the probability of getting a CRas large as .286 is .775. In other words, the variance estimate of operational is not significantly different from zero at the 0.05 level.

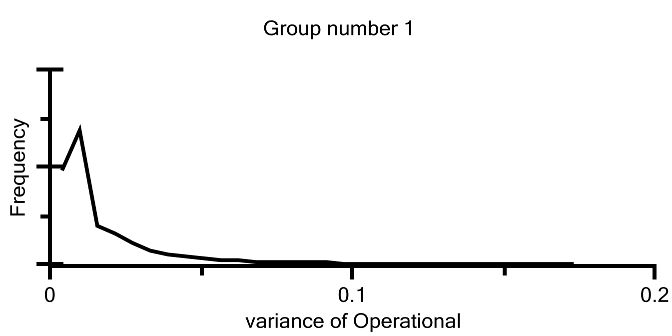


Figure 7.1.4: variance of operation

Environmental Impact:

The variance of environmental impact is estimated to be .284. The standard error of .102 gives that z= .791. In other words, the variance estimate is 2.791 standard errors above zero. Thus, the probability of getting a critical ratio (CR) as large as 2.791 is .005. In other words, the variance estimate for the environmental impact factor is significantly different from zero at the 0.01 level.

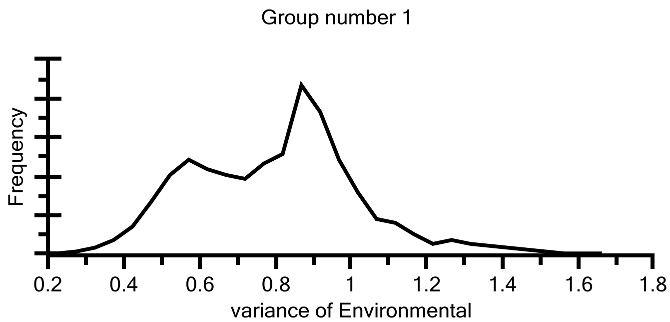


Figure 7.1.5: Variance of environmental impact

Cost:

The variance of the cost estimate to be .054 that has a standard error of .042 and z=1.286, which means that the variance estimate is 1.286 standard error above zero. Therefore, the probability of getting a CR as large as 1.286 is .198. In other words, the variance estimate for the cost is not significantly different from zero at the 0.05 level.

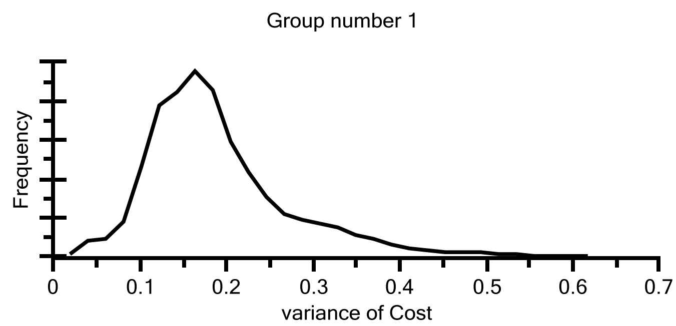


Figure 7.1.6: Variance of cost

Covariances between correlated factors presented in the following section given more accurate modeling results compared to uncorrelated factors. The estimate of covariances variables provided. It includes:

Social – Safety:

The covariance between social factors and the safety factor is estimated to be negative -.087 and has a standard error of .049. It gives z=1.776. In other words, the covariance estimate is 1.776 standard error below zero. Therefore, the probability of getting a critical ratio (CR) as large as 1.776 is .076. In other words, the covariance between the social acceptance factor and safety factor is not significantly different from zero at the 0.05 level.

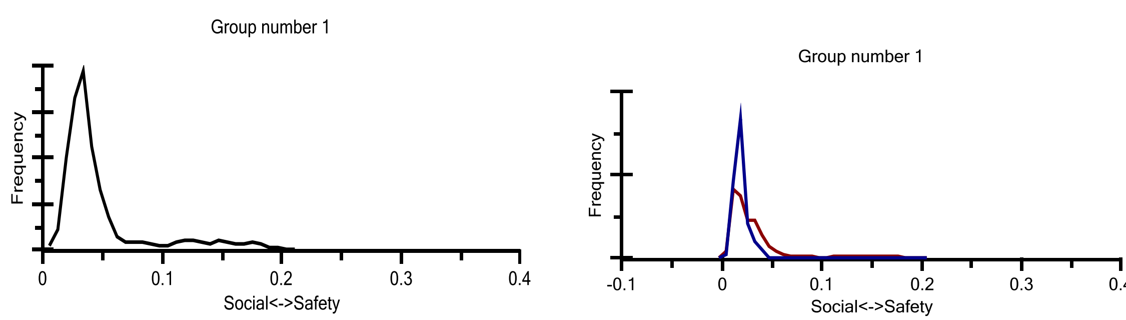


Figure 7.1.7: Covariance of social acceptance and safety

Social – Reliability:

The covariance between the social factor and reliability factor is estimated to be negative -.035 and has a standard error of .036. It gives z=.995. In other words, the covariance estimate is .996 standard error below zero. Therefore, the probability of getting a critical ratio (CR) as large as .995 is .320. In other words, the covariance between the social acceptance factor and reliability factor is not significantly different from zero at the 0.05 level.

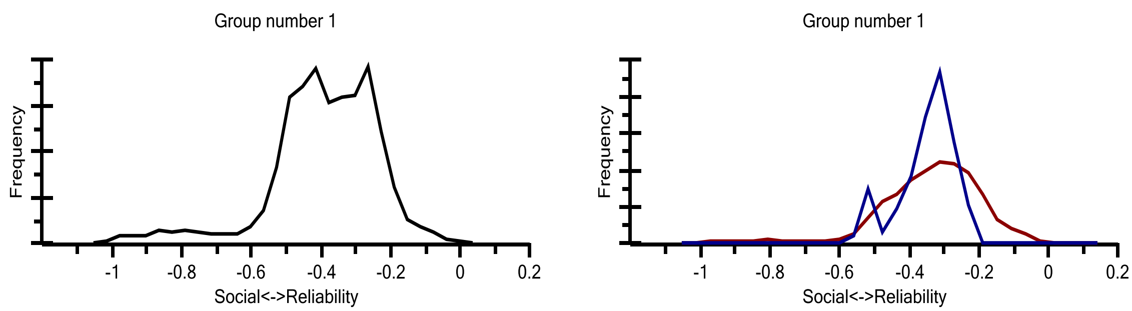


Figure 7.1.8: Covariance of social acceptance and reliability

Social – Operational:

The covariance between social acceptance and operational factors is estimated to be .009 and has a standard error of .026. Dividing the covariance estimate by the estimate of its standard error gives its z = .354. In other words, the covariance estimates .354 standard errors above zero. Therefore, the probability of getting CR as large as .354 is .723. In other words, the covariance between social acceptance and operational is not significantly different from zero at the 0.05 level.

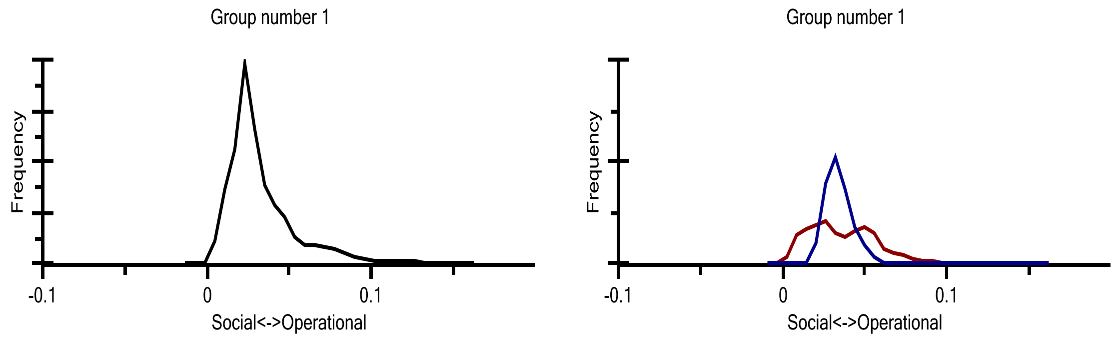


Figure 7.1.9: Covariance of social acceptance and operation

Social – Environmental:

The covariance between social acceptance and environmental impact factors is estimated to be .117 and has a standard error of .055. It gives a critical rate (CR) of 2.135. In other words, the covariance estimate is 2.135 standard errors above zero. Thus, the probability of getting a CR as large as 2.135 is .033. In other words, the covariance between social factor and environmental impact factor is significantly different from zero at the 0.05 level.

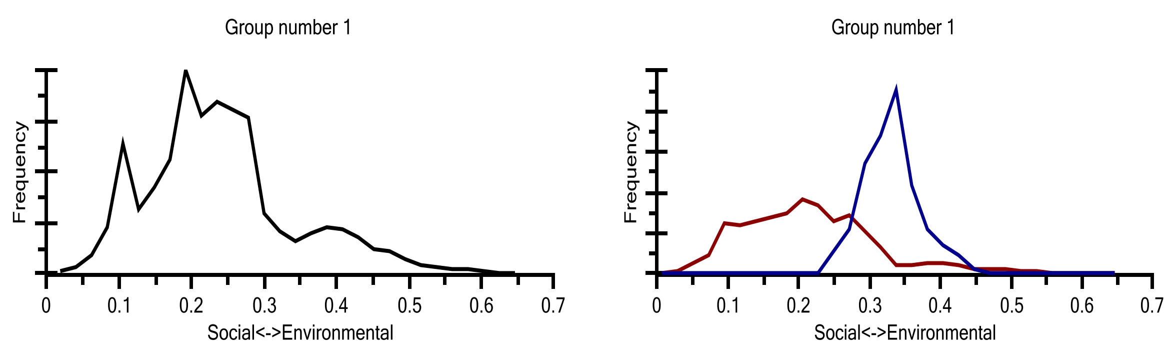


Figure 7.2.1: Covariance of social acceptance and environmental impact

Cost – Social:

The covariance between cost and social acceptance factors is estimated to be .065 and has a SE of .034. It gives a CR of 1.913. In other words, the covariance estimate is 1.913 standard errors above zero. We may say, the probability of getting a CR as large as 1.913 is .056. In other words, the covariance between cost and social acceptance is not significantly different from zero at the 0.05 level.

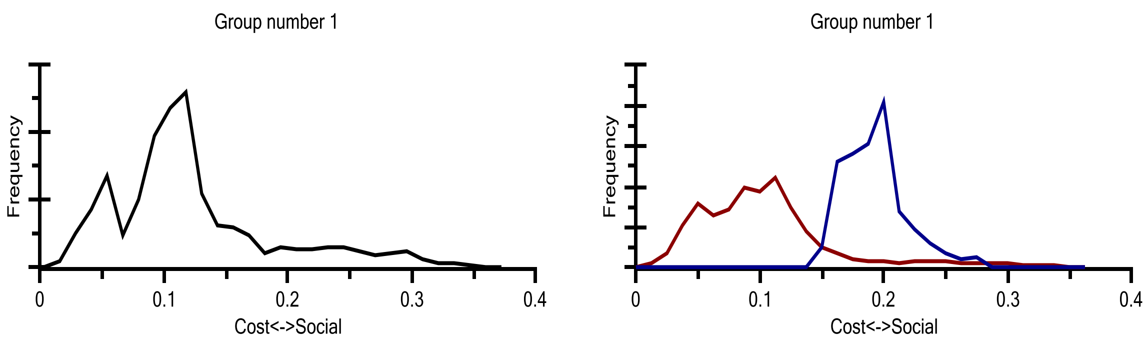


Figure 7.2.2: Covariance of cost and social acceptance

Safety – Reliability:

The covariance between safety and reliability factors is estimated to be .004 and has a SE of .043. It gives a CR of 1.017. In other words, the covariance estimate is 1.017 standard errors above zero. It may worthy to mention that the probability of getting a CR as large as 1.017 is .309. In other words, the covariance between safety and reliability is not significantly different from zero at the 0.05 level.

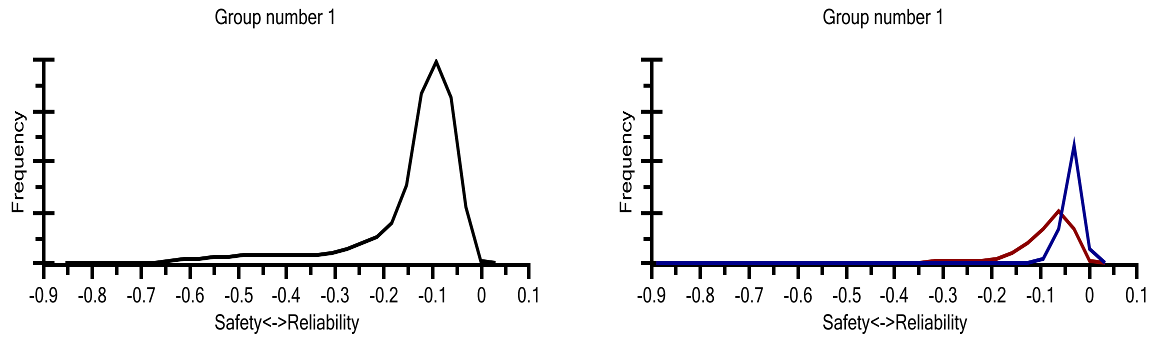


Figure 7.2.3: Covariance of safety and reliability

Safety – Operational:

The covariance between safety and operational is estimated to be .009 and has a SE of .026. It results in an estimation of a z-value of .354. In other words, the covariance estimate is .354 standard errors (SE) below zero. Therefore, the probability of getting a CR as large as .354 is .723. In other words, the covariance between safety and operational is not significantly different from zero at the 0.05 level (two-tailed).

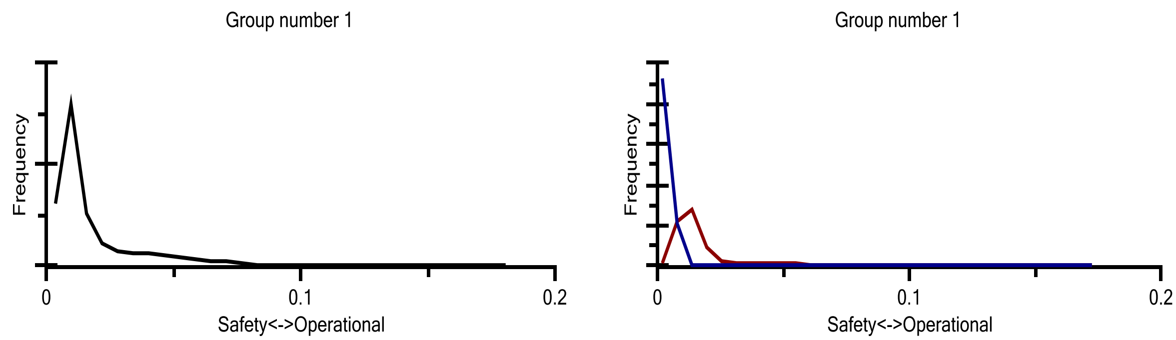


Figure 7.2.4: Covariance of safety and operation

Safety - Environmental :

The covariance between safety and environmental impact factors is estimated to be negative .120, and it has a SE of .056. It gives a z-value of 2.146 and tells us the covariance estimate of 2.146 standard error below zero. Therefore, the probability of getting CR as large as 2.146 is .032. In other words, the covariance between safety and environment is significantly different from zero at the 0.05 level.

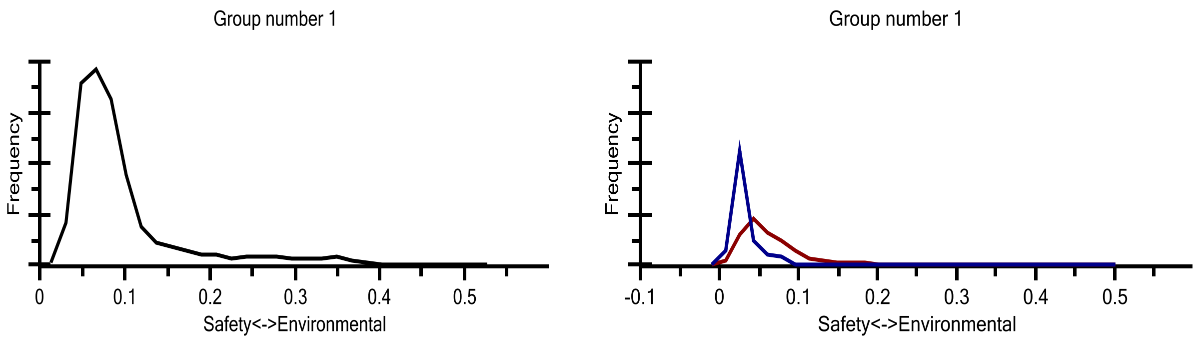


Figure 7.2.5: Covariance of safety and environmental impact

Cost – Safety:

The covariance between cost and safety factors is estimated to be negative .053, and it has a SE of .029. It gives a z-value of 1.829 and tells us the covariance estimate of 1.829 standard error below zero. Therefore, the probability of getting CR as large as 1.829 is .069. In other words, the covariance between safety and cost is not significantly different from zero at the 0.05 level.

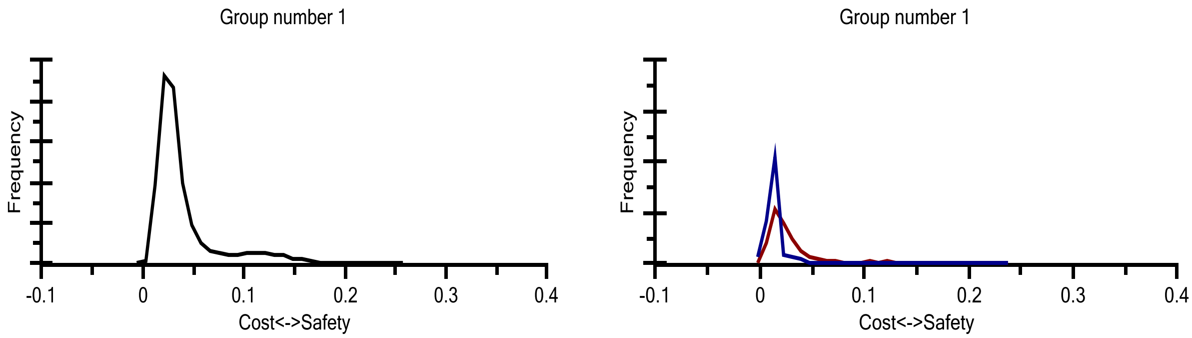


Figure 7.2.6: Covariance of cost and safety

Reliability – Operational:

The covariance between the reliability factor and operational factor is estimated to be negative -.006 and has a standard error of .019. It has a z-value of .331. In other words, the covariance estimate is .331 standard error below zero. Therefore, the probability of getting a critical ratio (CR) as large as .331 is .741. In other words, the covariance between the reliability factor and operational factor is not significantly different from zero at the 0.05 level.

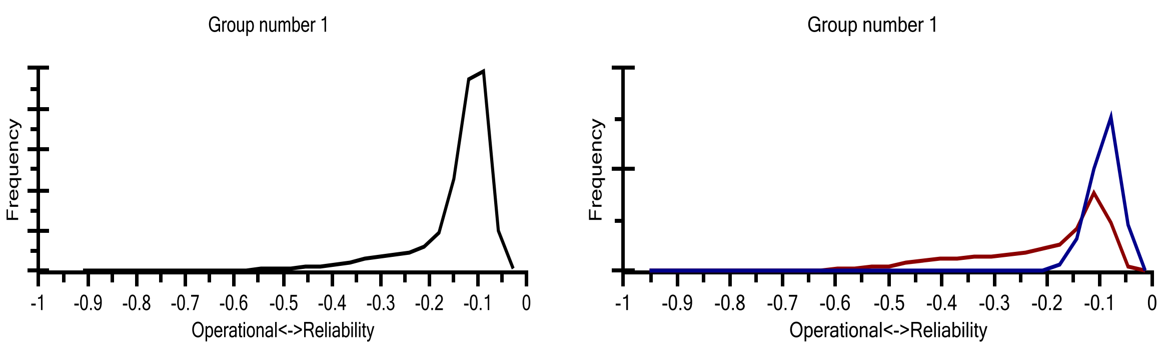


Figure 7.2.7: Covariance of operation and reliability

Reliability – Environmental :

The covariance between environmental impact factor and reliability factor is estimated to be negative -.117 and has a standard error of .105. It gives z=1.122. In other words, the covariance estimate is 1.122 standard error below zero. Therefore, the probability of getting a critical ratio (CR) as large as 1.122 is .262. In other words, the covariance between environmental impact factor and reliability factor is not significantly different from zero at the 0.05 level.

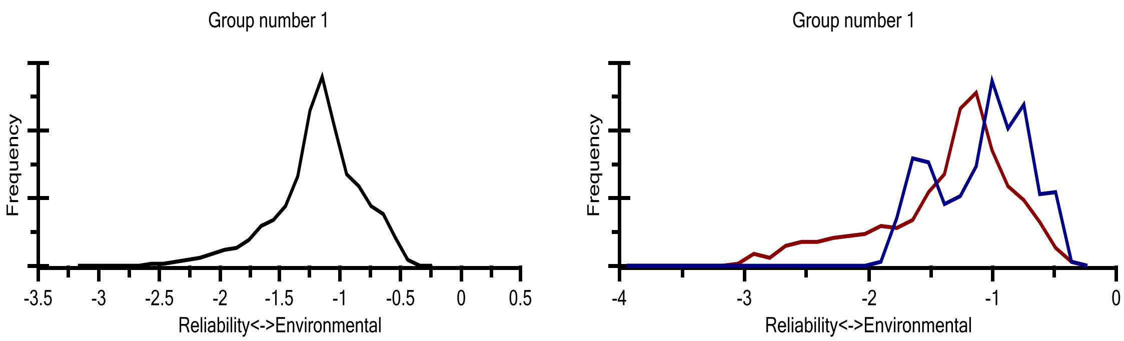


Figure 7.2.8: Covariance of reliability and environmental impact

Cost - Reliability:

The covariance between cost and reliability factor is estimated to be negative -.052 and has a standard error of .049. It gives z=1.073. In other words, the covariance estimate is 1.073 standard error below zero. Therefore, the probability of getting a critical ratio (CR) as large as 1.073 is .283. In other words, the covariance between the cost factor and reliability factor is not significantly different from zero at the 0.05 level.

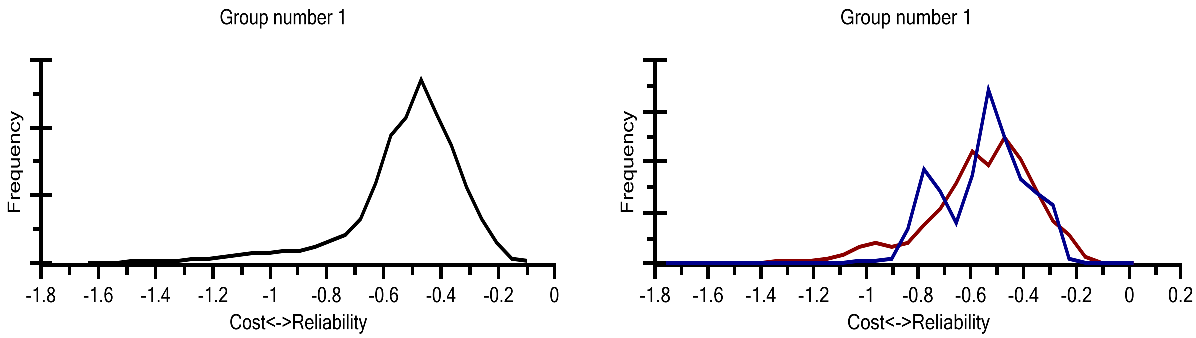


Figure 7.2.9: Covariance of cost and reliability

Operational - Environmental:

The covariance between operational factor and environmental factor is estimated to be .015 and has a standard error of .044. It gives z=.345. In other words, the covariance estimate is ..345 standard error above zero. Therefore, the probability of getting a critical ratio (CR) as large as .345 is .730. In other words, the covariance between social, operational factors, and environmental impact factors is not significantly different from zero at the 0.05 level.

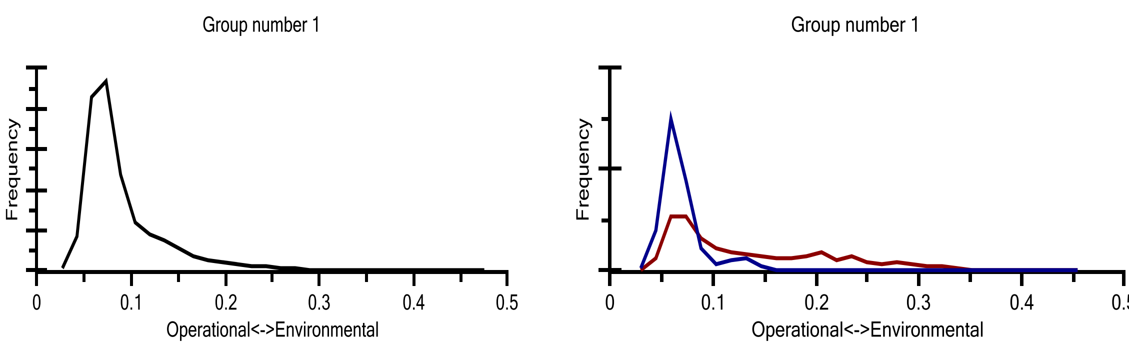


Figure 7.3.1: Covariance of operation and environmental impact

Cost - Operational:

The covariance between social factor and reliability factor is estimated to be negative .006 and has a standard error of .018. It gives z=..343. In other words, the covariance estimate is .343 standard error below zero. Therefore, the probability of getting a critical ratio (CR) as large as .343 is .731. In other words, the covariance between cost factor and operational factor is not significantly different from zero at the 0.05 level.

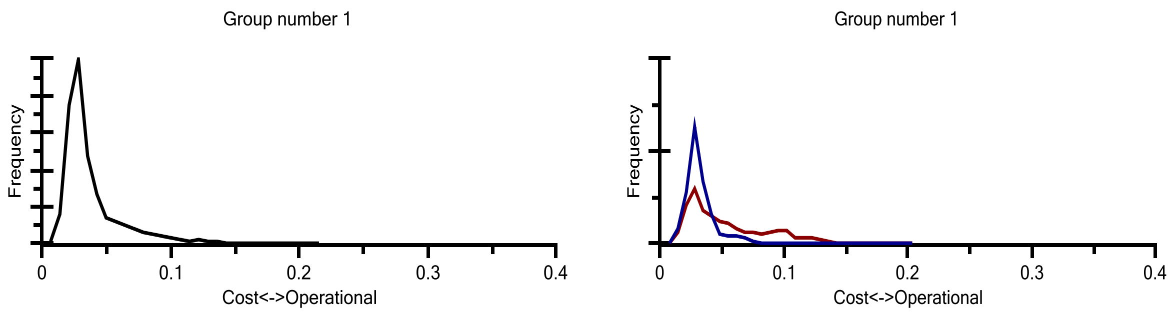


Figure 7.3.2: Covariance of cost and operation

Cost - Environmental :

The covariance between cost factor and environmental impact factor is estimated to be .141 and has a standard error of .052. It gives z=2.702. In other words, the covariance estimate is 2.702 standard error above zero. Therefore, the probability of getting a critical ratio (CR) as large as 2.702 is .007. In other words, the covariance between the social acceptance factor and reliability factor is significantly different from zero at the 0.01 level.

The influence of the six-factor correlated analysis demonstrated and enhanced the model improvement when the covariance analysis performed. The outcome of the model optimized by approximately 12.5 %.

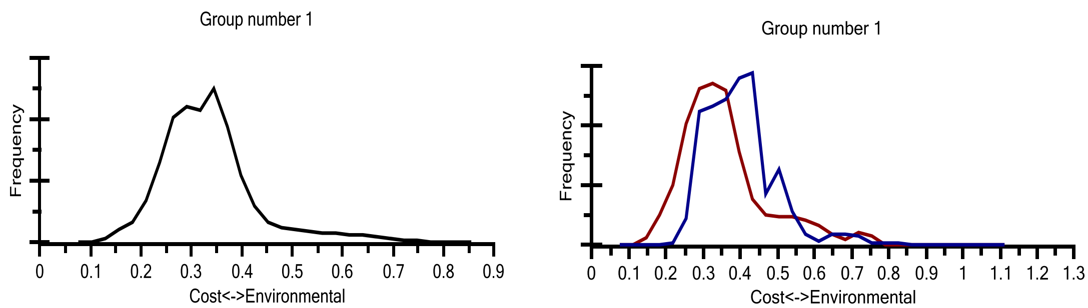


Figure 7.3.3: Covariance of cost and environmental impact

			Estimate	S.E.	C.R.	P
Social	<-->	Safety	-.087	.049	-1.776	.076
Social	<-->	Reliability	-.035	.036	-.995	.320
Social	<-->	Operational	.009	.026	.354	.723
Social	<-->	Environmental	.117	.055	2.135	.033
Cost	<-->	Social	.065	.034	1.913	.056
Safety	<-->	Reliability	.044	.043	1.017	.309
Safety	<-->	Operational	-.009	.026	-.354	.723
Safety	<-->	Environmental	-.120	.056	-2.146	.032
Cost	<-->	Safety	-.053	.029	-1.829	.067
Reliability	<-->	Operational	-.007	.019	-.341	.733
Reliability	<-->	Environmental	-.117	.105	-1.119	.263
Cost	<-->	Reliability	-.052	.049	-1.071	.284
Operational	<-->	Environmental	.016	.044	.357	.721
Cost	<-->	Operational	.006	.018	.355	.723
Cost	<-->	Environmental	.141	.052	2.703	.007

Table 7.2: Covariance estimation between variables

7.3 INFERENTIAL ANALYSIS

7.3.1 PEARSON CORRELATION COEFFICIENT ANALYSIS

Pearson correlation coefficient test illustrates a measurement of the direction and degree of the relationship between two variables. The coefficient of analysis ranged from -1 to +1. Coefficient approaches to +1 or -1 indicate a stronger connection between two variables. A negative value correlation means that an increase in the value of one variable and the value of other variables would be decreased. A positive correlation means that the value of variables would increase or decrease together.

Pearson Correlation Coefficient (PCC) determined the significant relationship between the demographic profile and the variables used in this research. PCC is being used to described income and employment status as the highest correlation, while gender and qualification have average and lower correlation. Overall the PCC results defined all the independent and dependant variables. In PCC, Therefore, the correlation between dependent variables and independent variables is based on the highest between variables. It is providing a further discussion of the variables. Thus, a comparison of the rating level obtained, since these might provide the most relevant information. The results of the analysis in the research illustrate the strength of the PCC Table 7.3.

		qualification level	Gender	highest income	employment status
qualification level	Pearson Correlation	1	0.217	0.039	-0.245
	Sig. (2-tailed)		0.087	0.761	0.053
	N	63	63	63	63
Gender	Pearson Correlation	0.217	1	-0.2	-0.045
	Sig. (2-tailed)	0.087		0.116	0.725
	N	63	63	63	63
highest income	Pearson Correlation	0.039	-0.2	1	.426**
	Sig. (2-tailed)	0.761	0.116		0.002
	N	63	63	63	63
employment status	Pearson Correlation	-0.245	-0.045	.426**	1
	Sig. (2-tailed)	0.053	0.725	0.002	
	N	63	63	63	63
Age	Pearson Correlation	-0.158	0.114	0.167	0.18
	Sig. (2-tailed)	0.217	0.374	0.191	0.158
	N	63	63	63	63

Table 7.3: Pearson correlation coefficients (age, income, qualification, and employment status)

We, therefore, conclude that there is an averagely correlated between the independent variable and dependent variables. The results show that (r = 0.426, p = 0.002), with a significant number of employment status associated with a higher income rating level.

However, what does this ‘strong correlation’ of 0.426 implied in terms of ‘prediction’ one value from another?. In other words, to what extent can we say that the end-user satisfaction rating is related to the income level.

Therefore, we square our value 0.426 to 0.18, and then we multiply this by 100 to get a percentage value of 18 %. Our strong correlation of 0.426 means that only 18% of the variance in rating level is related; there are other factors involved.

The coefficients also draw our attention to an important issue in interpreting and comparing values: a correlation of 0.8 is not twice as strong as a correlation of 0.4. Therefore, approximately 15% of the variance in one variable is accounted for by the other variable. Still, a correlation of 0.8 indicates that 64% of the variance in one variable is accounted for by other variables.

7.3.2 DECISION-MAKING ANALYSIS

There was a research question specified for this study of What factors influence end-users’ decision choice toward CNGv in transport industries? A literature review was used to identify factors that could potentially influence end-users’ selection of CNGv. The literature review provided possible sets of factors, including factors internal to the end-user. Those factors were tested using the SEM method described above, with varying results for each of the identified factors.

Performance and quality may be more important for some types of end-users; for example, the study has mentioned there were more concerned with the performance and quality of safety, reliability, and operation than other services. Although transports (i.e., cars, buses, etc.) do have some flexibility in designing, the study showed that there was a consensus view on the safety and the vital role of safety measures on an end-users decision and do willing to pay for for a safe and reliable vehicle.

7.3.2.1 BAYSIAN ANALYSIS DESIGN

The research aim of using the bays method is to help with making a decision, e.g., whether or not to take action, how much to invest in such a business, etc. Thus, the outcomes of taking actions measured by a utility function. These utilities assign as a weight to each possible outcome; as probability language illustrates, it is merely a random variable. For example, in the research, a decision rule of a combination of the expected utility with evidence for each hypothesis given by the data (e.g., p-values or posterior distributions) into a formal statistical framework for making decisions. In this setting, the frequency considers the expected utility given a hypothesis, $E(U \mid H)$, where U is the random variable representing utility. A combination of the expected utility with p-values of hypotheses to guide decisions. The Bayesian can combine $E(U \mid H)$ with the posterior to create a Bayesian decision rule.

Furthermore, using the Bayesian method in this research is for its ability to specify a prior. In my study, Bayes can also be more effective since the sample size of the study is small, since Bayes does not depend on asymptotics or large sample properties.

Bayesian inference is a statistical inference method in which Baye's theorem applied for updating the probability for a hypothesis as more information becomes available. The design of the Bayesian inference about the Pearson correlation coefficient allows us to draw Bayesian inference by estimating Bayes factors and characterizing posterior distributions. The Bayesian Inference provides options for executing Bayesian inference on Binomial distribution to estimate the probability that may lead to either success or failure. Note that each trial is independent of each other, and the probability remains the same in each trial. Although it is not necessary, a prior from the Beta distribution family is typically chosen when estimating a binomial parameter. The Beta family is conjugate for the binomial family, and as such, leads to the posterior distribution with a closed-form still in the Beta distribution family see Table 7.7. Detailed Bayes analysis outcomes attached to Appendix I.

Therefore, Bayesian inference reinterpreting the events in Bayes' formula as follows:

$$P(H \mid D) = P(D \mid H)P(H) \quad / \quad P(D) \qquad (17)$$

H is a hypothesis and D is a data which may give evidence for or against H, while (H) is the probability that H is true before the data is considered, $P(H \mid D)$ is the probability that H is true after the data is considered, The likelihood $P(D \mid H)$ is the evidence about H provided by the data D, P(D) is the total probability of the data taking into account all possible hypotheses.

7.3.2.2 CHARACTERIZE POSTERIOR DISTRIBUTION

When selected, the Bayesian inference is made from a perspective that is approached by characterizing posterior distributions as described in the following equation. Because the posterior distribution belongs to the same family as the prior distribution, both the prior and posterior have beta distribution (Posterior = Prior * Likelihood).

Furthermore, SEM is integrating new ways of a fitting model. The marginal posterior distribution of the parameter(s) of interest can be investigated by integrating out the other nuisance parameters, and further construct credible intervals to draw a direct inference.

$$X = t + e \qquad (18)$$

X indicates to measured, observed item; t: indicates to predictor or latent variable; e: error

Furthermore, estimating Bayes factors (one of the notable methodologies in Bayesian inference) constitutes a natural ratio to compare the marginal likelihoods between a null and an alternative hypothesis. An illustration of the fitted model presented as the Syntax and Path model described as follows. In the attached Appendix-I. For example, the following model performed as a result of the research sample for proposing a population relationship based on age, average income, job, education, and gender.

$$\text{Re ID} = [\text{ age} + \text{Average income} + \text{occupation} + \text{education} + \text{gender} + (1)\ e1] \qquad (19)$$

In equation 19, Re ID represents the observed item that can be described as the dependent factors (predictors) including (age,average income,occupation, and gender) and the difference between observed value and predicted value, the error (e). It allows us statistically to define what is the observed value and design better relation between observed and predicted values using SEM.

Age	Percent	Valid Percent	Cumulative Percent
> 20	24.8	24.8	24.8
21-30	62.7	62.7	87.7
31-40	12.5	12.5	100.0
Total	100.0	100.0	
Education	Percent	Valid Percent	Cumulative Percent
Bacholar	12.5	12.5	12.5
Diploma	12.5	12.5	25.0
Grad	75.0	75.0	100.0
Total	100.0	100.0	
Gender	Percent	Valid Percent	Cumulative Percent
Male	62.5	62.5	62.5
Female	37.5	37.5	100.0
Total	100.0	100.0	

Table 7.4: Socio-demographic characteristics

There are 62.7% of respondents age between 21 - 30 years old, 24% of respondents age below 20 years old, 12.5% of respondents age between 31 - 40 years old. The responses were the distribution to mainly male, and females by 62% of the respondents are male, and 73% are female. For the educational level attained, respondents with high-degree levels have the highest frequency of 75 %, while the student with Bachelor or Diploma only 12.5 %. As for personal income, 49.7% of respondents have a salary of less than

$30000 annually. There are 37.3% of respondents with salary ($30001- $70000). Respondents with a salary between $70001– $100000, have a lower frequency of 13.0 %. In general, there is a consensus agreement among all respondents on the importance of the transport.

Furthermore, 62 % of the respondents are satisfied with the current transport means system they most frequently used. While there are 37.5%, respondents have a low satisfaction level. There are 75% of the respondents satisfied with the current service and believe that they do not need to change the traditional transportation system.

Incomes	Percent	Valid Percent	Cumulative Percent
0.00-30000	49.7	50.0	50.0
30001-70000	37.3	37.0	87.0
70001-100000	13.0	13.0	100.0
Total	100.0	100.0	
Occupation	Percent	Valid Percent	Cumulative Percent
Student	87.5	87.5	87.5
Government	12.5	12.5	100.0
Total	100.0	100.0	

Table 7.5: Socio-demographic characteristics

The results of the collected data illustrated the maximum and minimum values of the responses as described earlier, which result in creating a more concern among respondents on the safety measures of CNG onboard vehicles. It probably due to the loss and uncertainty of CNG failure and its associated risks.

		Individual respondent ID	Age	qualification level	Gender	highest income	employment status
N	Valid	63	63	63	63	63	63
	Missing	0	0	0	0	0	0
Mean			1.9683	3.5238	1.5556	1.746	1.3333
Std. Deviation			0.8793	0.69229	0.5009	0.82243	0.47519

Table 7.6: Statistical results (age,qualification,gender,income,and employment status)

	N	Posterior			95% Credible Interval	
		Mode	Mean	Variance	Lower Bound	Upper Bound
Age	63	1.9683	1.9683	0.013	1.743	2.1935
qualification level	63	3.5238	3.5238	0.008	3.3465	3.7012
Gender	63	1.5556	1.5556	0.004	1.4272	1.6839
highest income	63	1.746	1.746	0.011	1.5353	1.9567

Table 7.7: Posterior distribution characterization (Prior on Variance: Diffuse. Prior on Mean: Diffuse).

Bayes Factor	Evidence Category	Bayes Factor	Evidence Category	Bayes Factor	Evidence Category
>100	Extreme Evidence for H0	1-3	Anecdotal Evidence for H0	1/30-1/10	Strong Evidence for H1
30-100	Very Strong Evidence for H0	1	No Evidence	1/100-1/30	Very Strong Evidence for H1
10-30	Strong Evidence for H0	1/3-1	Anecdotal Evidence for H1	1/100	Extreme Evidence for H1
3-10	Moderate Evidence for H0	1/10-1/3	Moderate Evidence for H1		

Table 7.8: Commonly used thresholds to define significance of evidence

1- H_0: Null Hypothesis

2- H_1: Alternative Hypothesis

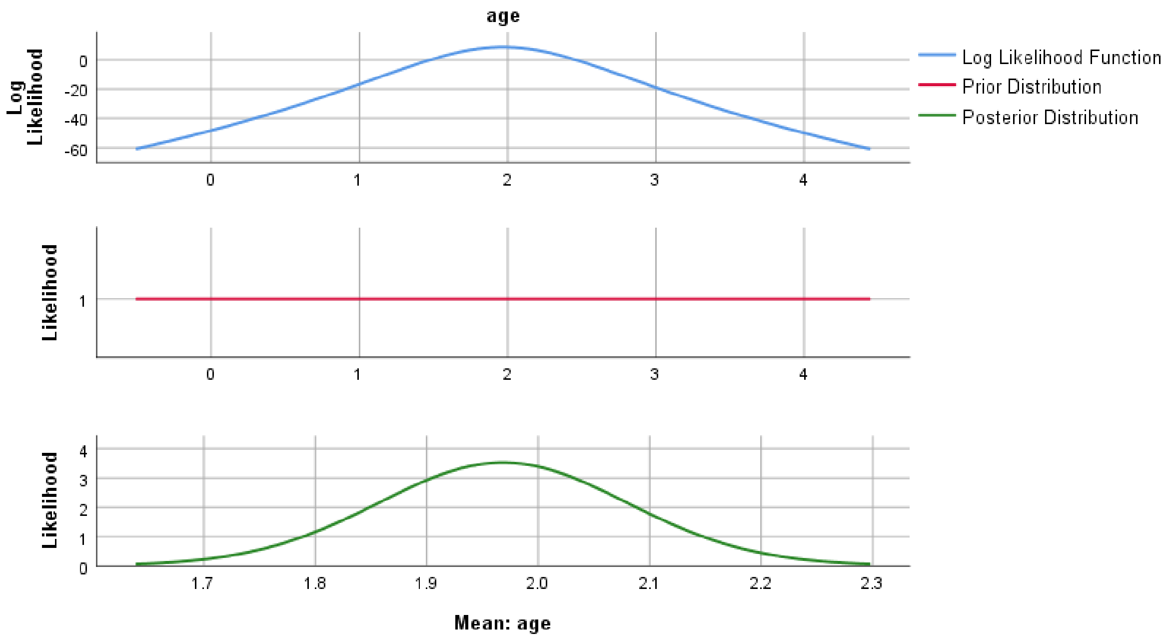


Figure 7.4: A comparison of the models for age

The distributions that represent our probabilities of age on given data provided. The peak values of both the blue and green curves occured around the value of 2.0, which shown above, is the best guess of our log-likelihood function. The fact that other values show that we are not entirely confident of age. A blue curve shows that it is most likely to be between 0, 4.0, whereas the green curve shows that it is likely to be anywhere between 1.7 and 2.2. The fact that the curves are more spread out and have a small peak means that a prior probability expressed by the red curve is “less certain” about the actual value than the other curves.

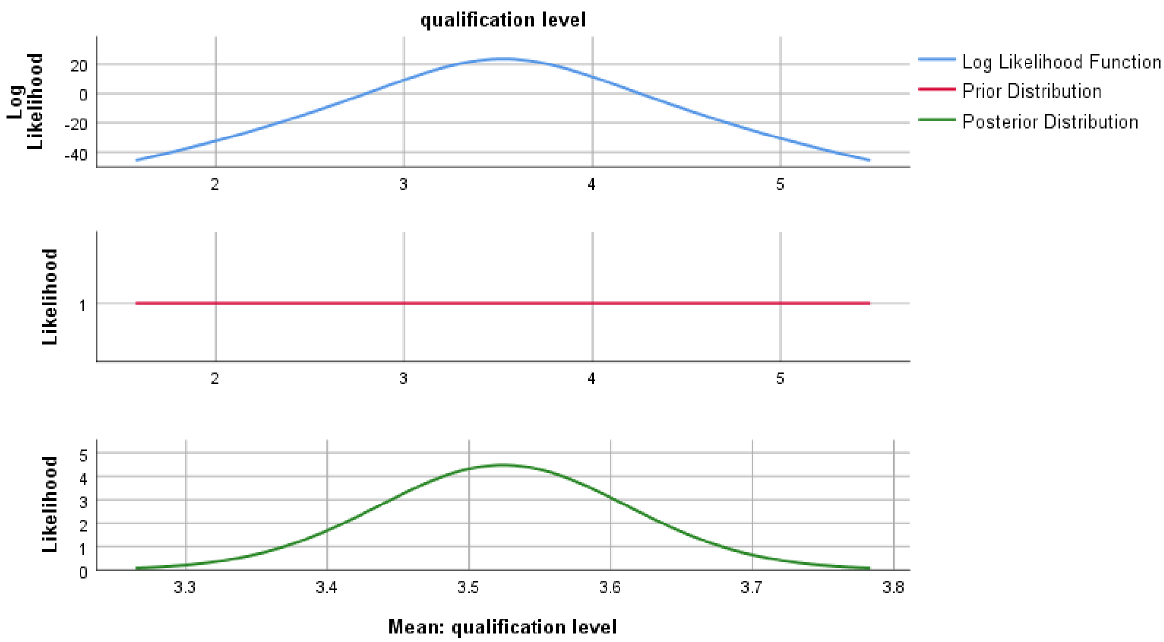


Figure 7.5: Qualification comparison models

The distributions that represent our probabilities of qualification level on given data provided. The peak values of both the blue and green curves occured around the value of 3.55, which shown above, is the best guess of our log-likelihood function. The fact that other values show that we are not entirely confident of qualification level. A blue curve shows that it is most likely to be between (2.0, 5.0), whereas the green curve shows that it is likely to be anywhere between (3.3 and 3.7). The fact that the curves are more spread out and have a small peak means that a prior probability expressed by the red curve is “less certain” about the actual value than others.

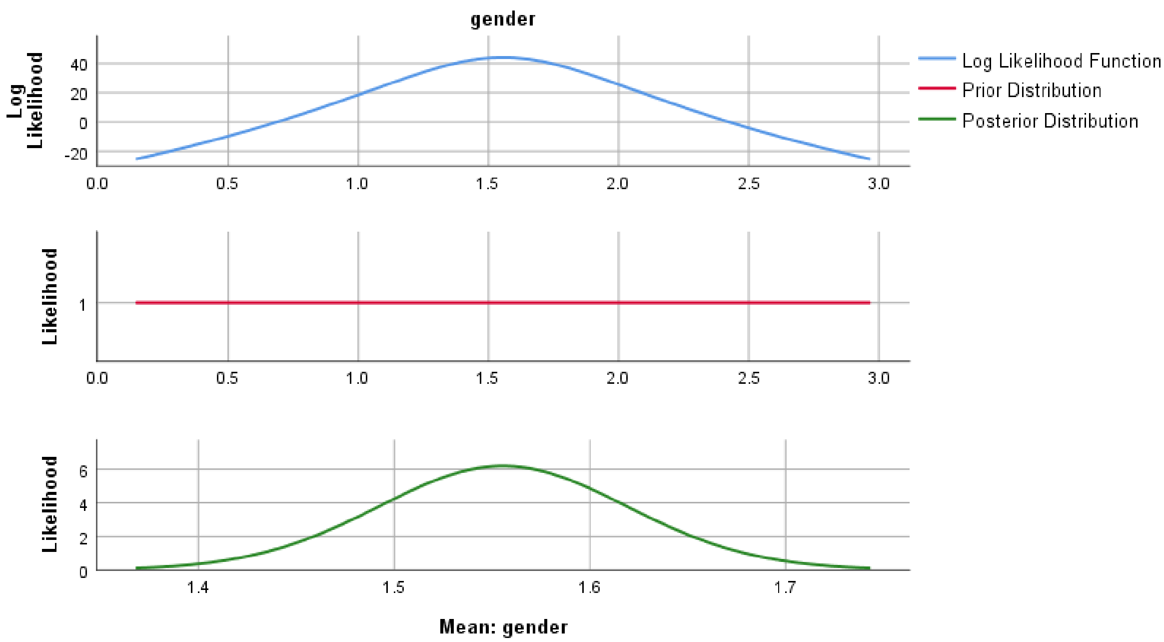


Figure 7.6: Gender comparison models

The distributions that represent our probabilities of gender on given data provided. The peak values of both the blue and green curves occured around the value of 1.5, which shown above, is the best guess of our log-likelihood function. The fact that other values show that we are not entirely confident of gender. A blue curve shows that it is most likely to be between (0.5, 2.5), whereas the green curve shows that it is likely to be anywhere between (1.4 and 1.7). The fact that the curves are more spread out and have a small peak means that a prior probability expressed by the red curve is “less certain” about the actual value than the other curves.

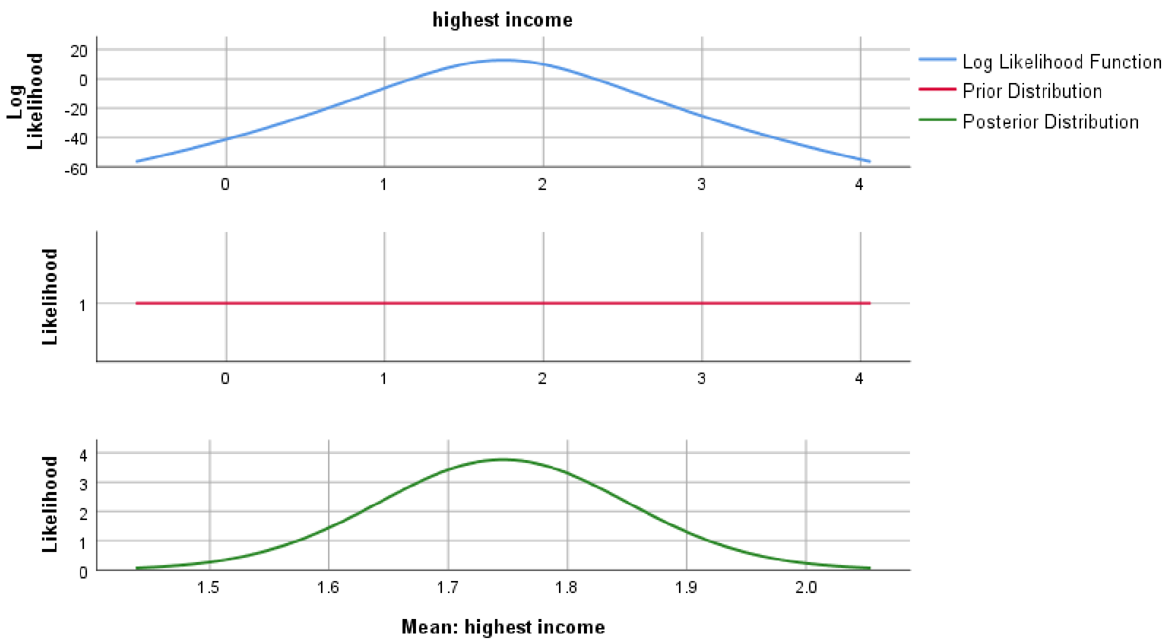


Figure 7.7: Education level comparison models

	Posterior			95% Credible Interval	
	Mode	Mean	Var.	Lower Bound	Upper Bound
Age	0.092	0.104	0.001	0.044	0.187
qualification level	0.631	0.627	0.003	0.509	0.738
Gender	0.554	0.552	0.004	0.433	0.669
highest income	0.046	0.06	0.001	0.017	0.127
employment status	0.338	0.343	0.003	0.235	0.46

Table 7.9: Posterior distribution characterization for binomial inference

a. Prior to Binomial proportion: Beta(2, 2).

Our probabilities of education level distributions that represented in Figure 5.4 shown the peak values of both the blue and green curves occured around the value of 1.75, which is the best guess of our log-likelihood function. The fact that other values show that we are not entirely confident of the level of education. A blue curve shows that it is most likely to be between 0, 4.0, whereas the green curve shows that it is likely to be anywhere between 1.5 and 2.0. The fact that the curves are more spread out and have a small peak means that a prior probability expressed by the red curve is “less certain” about the actual value than the other curves.

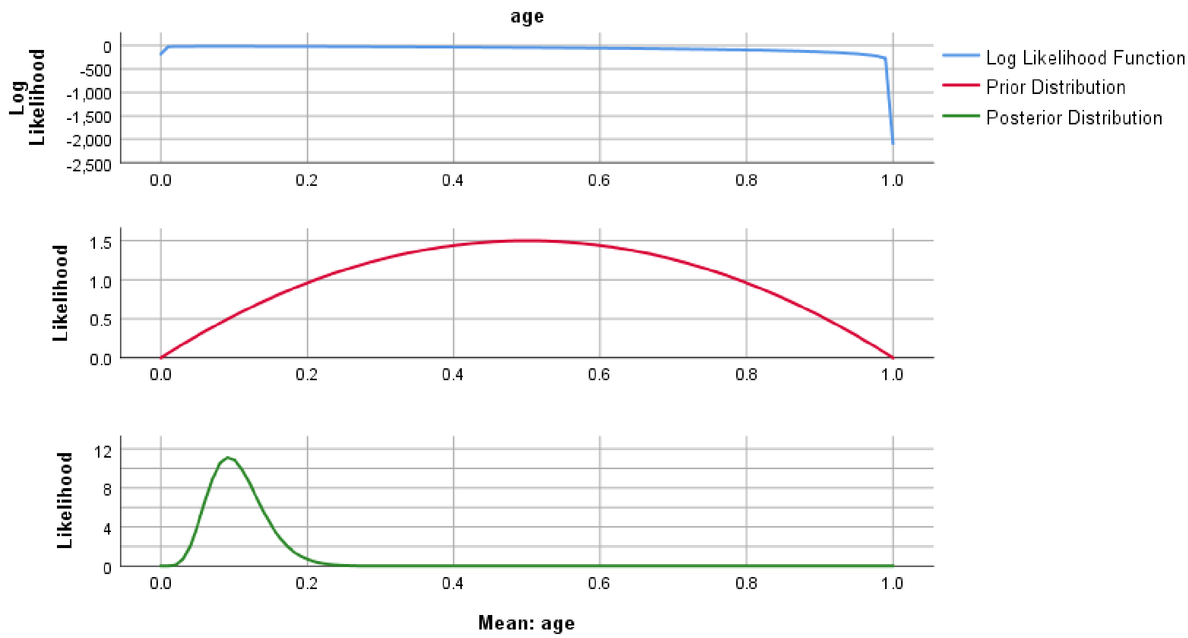


Figure 7.8: Age comparison models using binomial inference

The posterior distribution illustrated in the above figure which is proportional to the prior and the likelihood. It influenced by prior and likelihood respresented by the red and blue curves respectively, Figure 5.6. the outcome of the research response are influenced by both gender and qualification level. They are are given the highest among other demographic variables followed by the employment status.

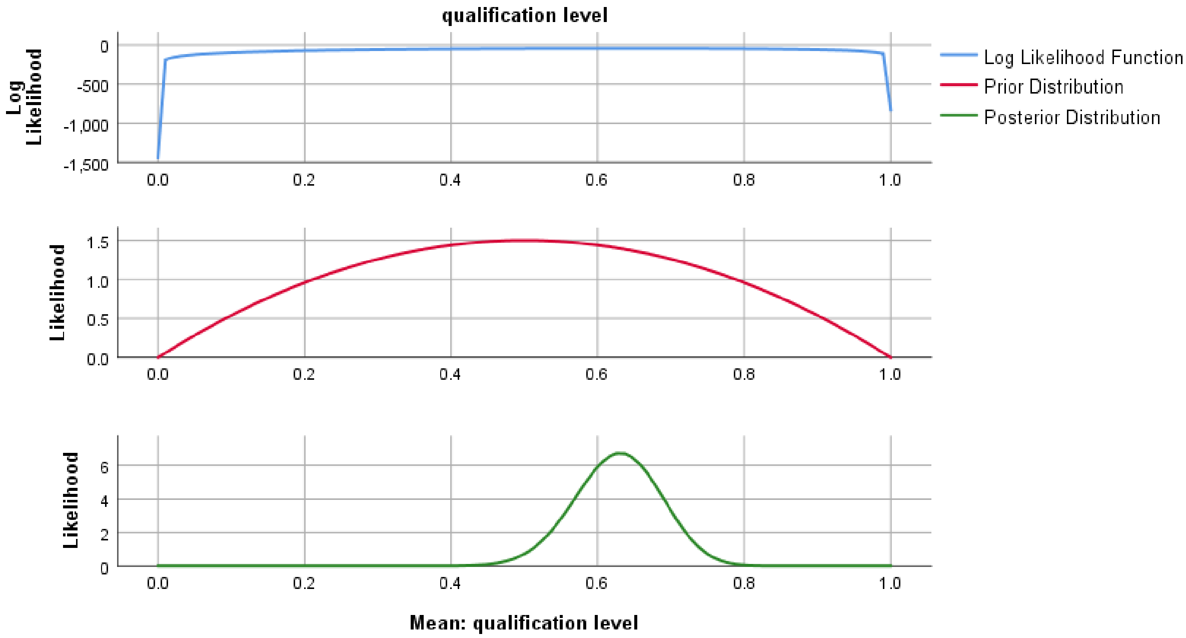


Figure 7.9: Qualification comparison level using binomial inference

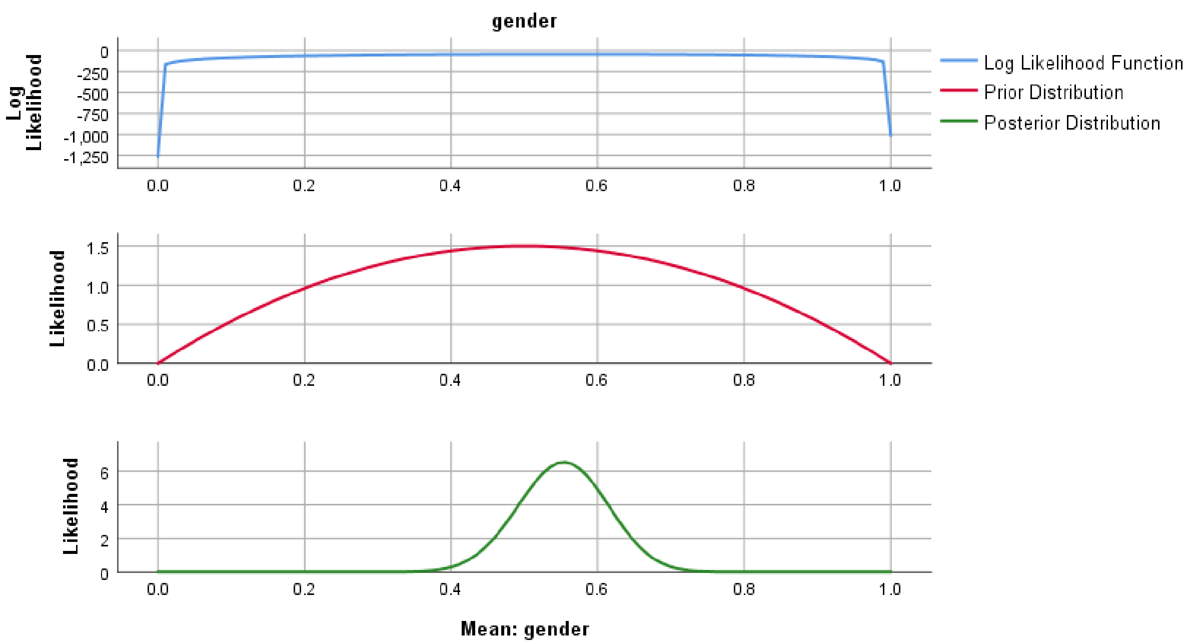


Figure 8.0: Gender comparison for three models using binomial inference

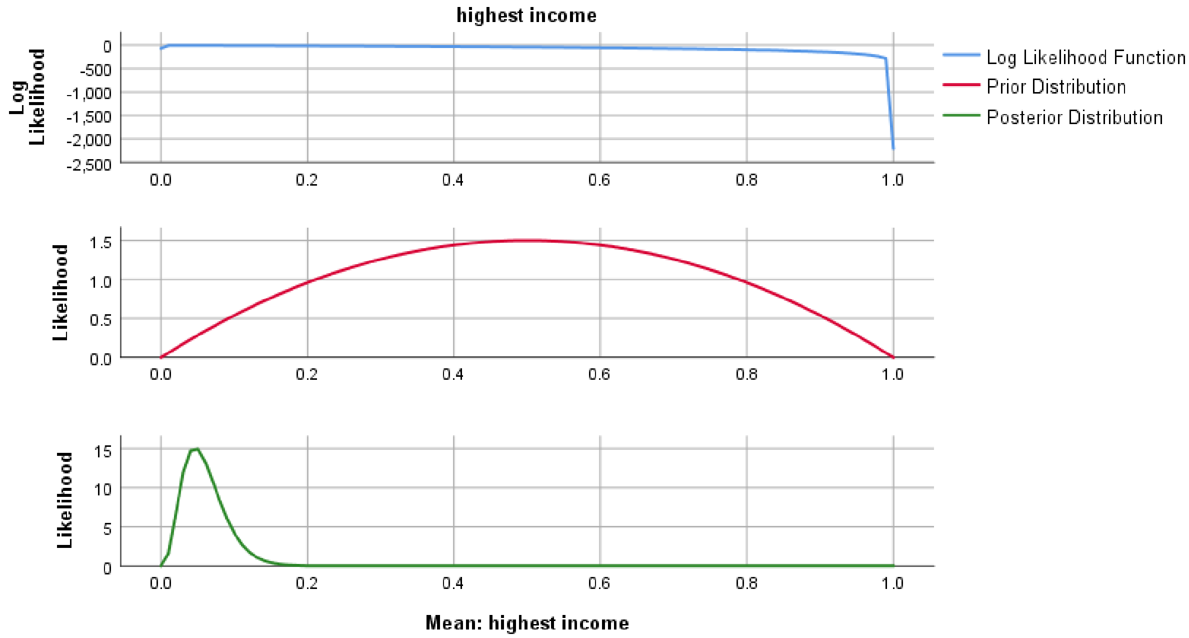


Figure 8.1: Incomes comparison models using binomial inference

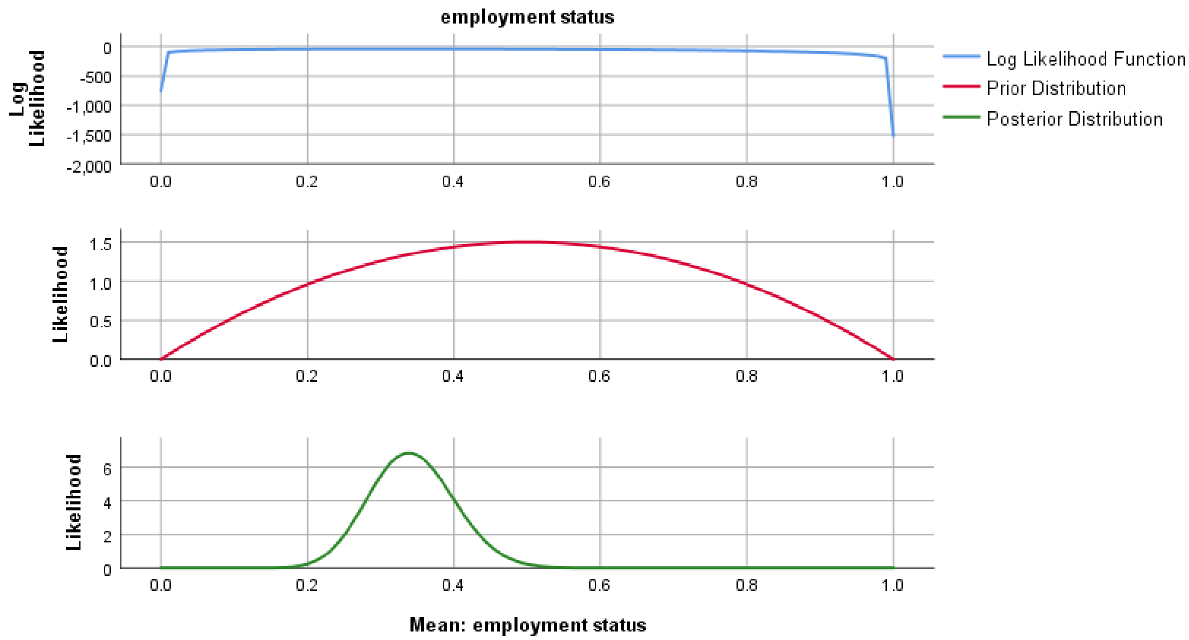


Figure 8.2: Employment comparison models using binomial inference

	Mode	Mean	Var.	95% Credible Interval Lower Bound	95% Credible Interval Upper Bound
Age	1.9231	1.9385	0.03	1.6148	2.2913
qualification level	3.4308	3.4462	0.053	3.0096	3.9118
Gender	1.5231	1.5385	0.024	1.2518	1.8543
highest income	1.7077	1.7231	0.027	1.4188	2.0565
employment status	1.3077	1.3231	0.02	1.0583	1.617

Table 8.0: Posterior distribution characterization for Poisson Inference

a. Prior for Poisson Rate/Intensity: Gamma(2, 2).

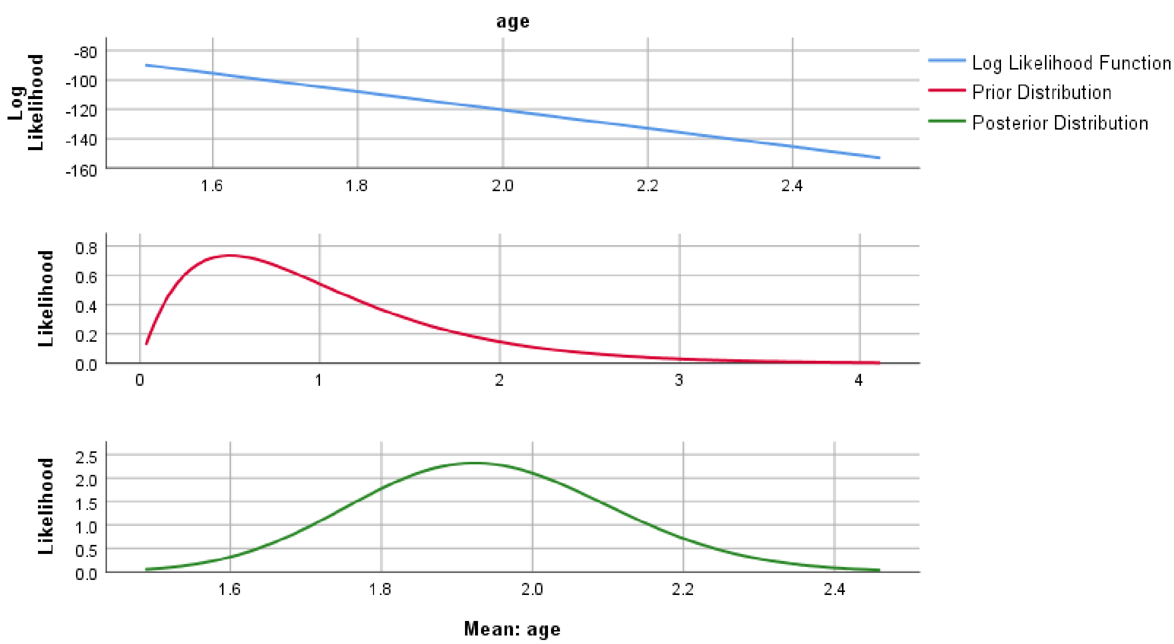


Figure 8.3: Age comparison for three models using Poisson inference

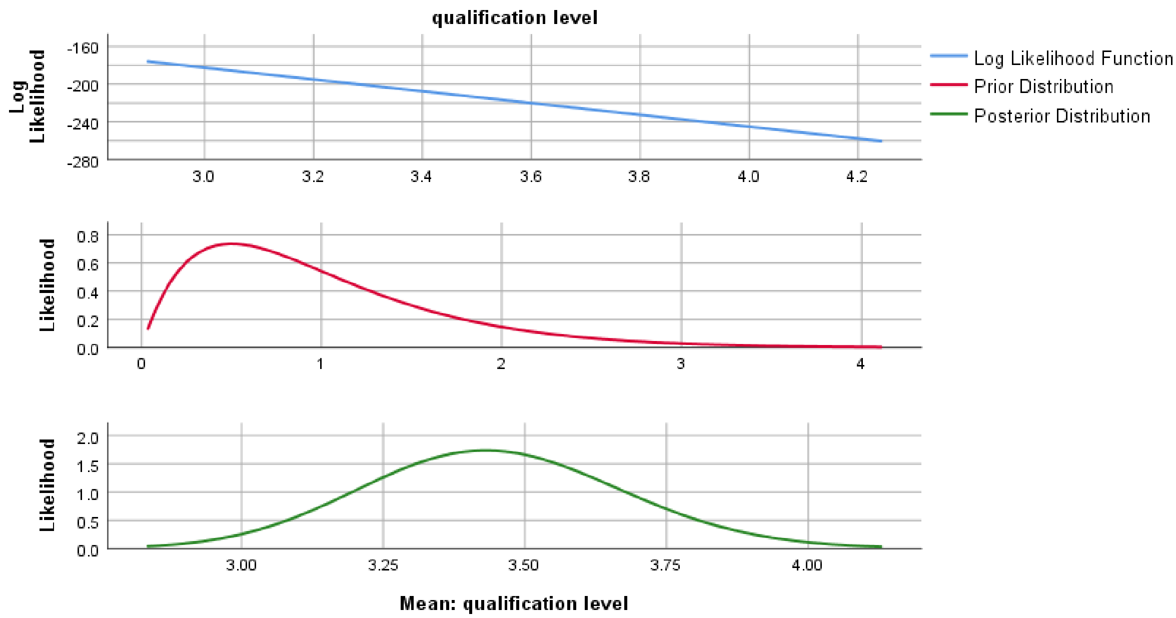


Figure 8.4: Qualification comparison for three models using Poisson inference

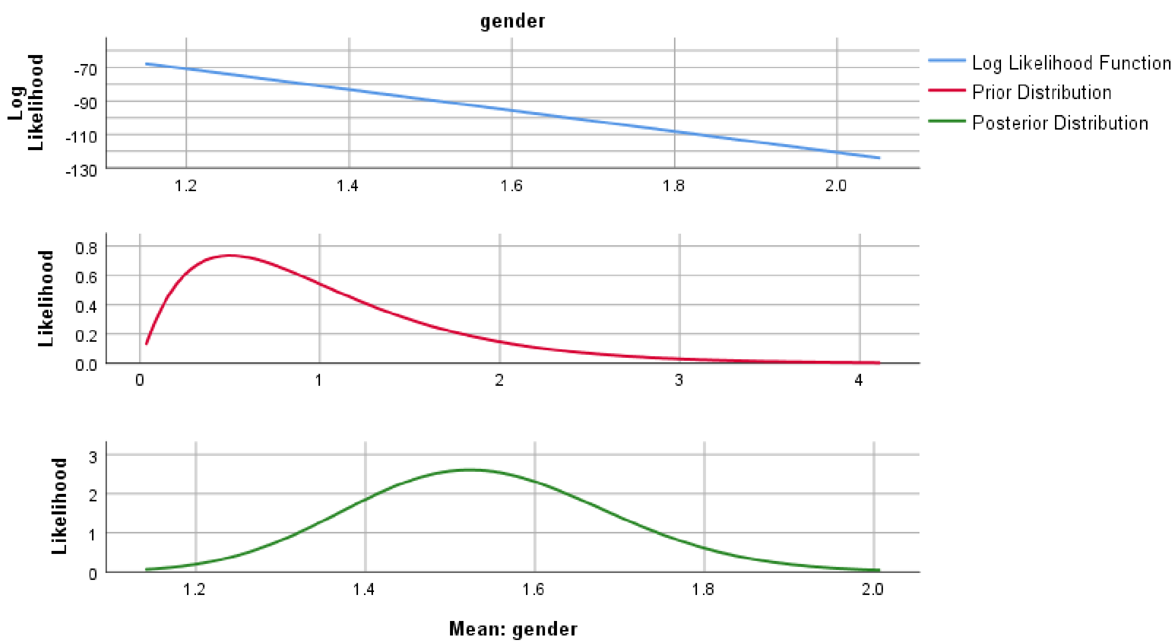


Figure 8.5: Gender comparison for three models using Poisson inference

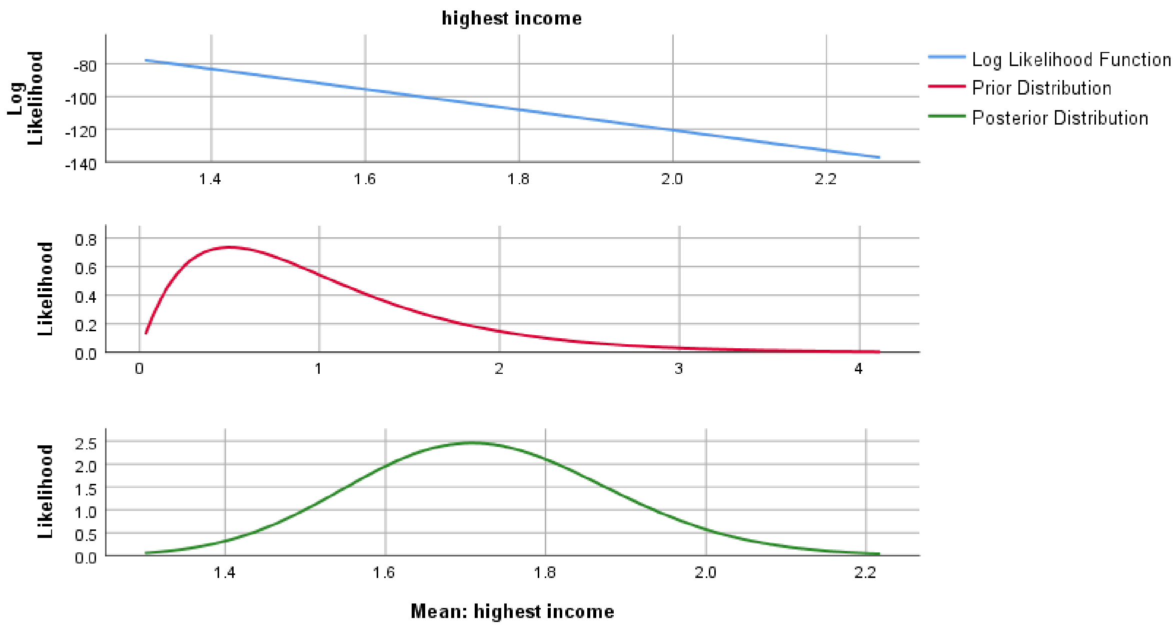


Figure 8.6: Incomes comparison for three models using Poisson inference

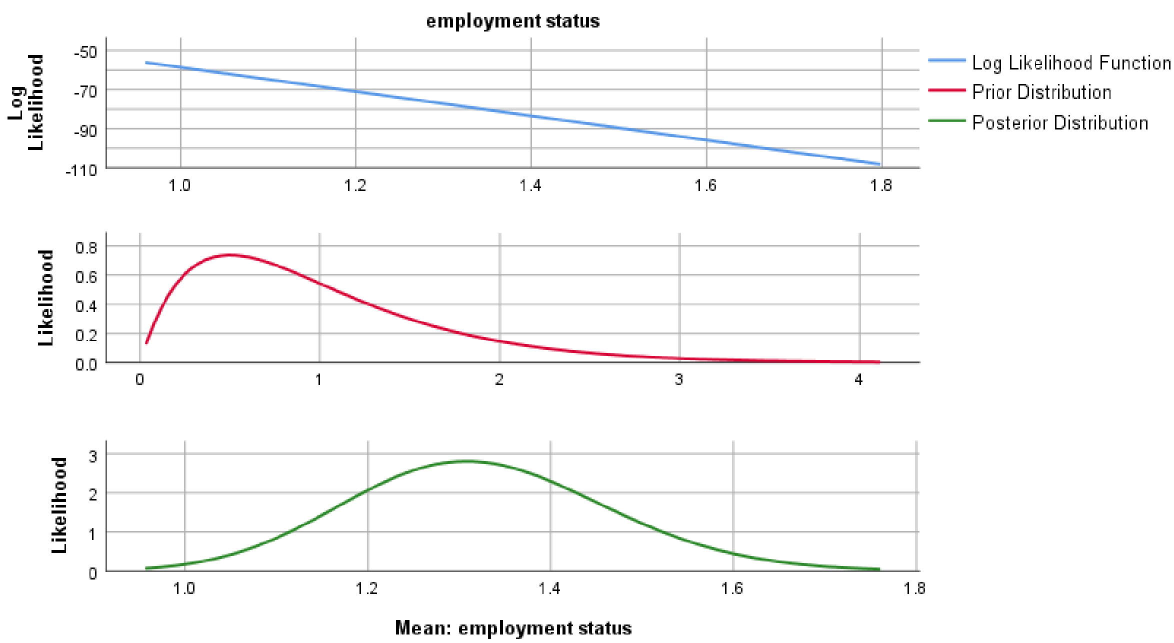


Figure 8.7: Employments comparison for three models using Poisson inference

		Age	qualification level	Gender	highest income	employment status
Posterior	Mode		-0.156	0.113	0.166	0.179
	Mean		-0.149	0.108	0.158	0.17
	Variance		0.015	0.015	0.014	0.014
95% Credible Interval	Lower Bound		-0.383	-0.131	-0.076	-0.067
	Upper Bound		0.086	0.344	0.393	0.399
N		63	63	63	63	63
Posterior	Mode	-0.156		0.215	0.039	-0.243
	Mean	-0.149		0.206	0.037	-0.232
	Variance	0.015		0.014	0.015	0.014
95% Credible Interval	Lower Bound	-0.383		-0.027	-0.204	-0.456
	Upper Bound	0.086		0.433	0.276	-0.002
N		63	63	63	63	63
Posterior	Mode	0.113	0.215		-0.199	-0.045
	Mean	0.108	0.206		-0.19	-0.042
	Variance	0.015	0.014		0.014	0.015
95% Credible Interval	Lower Bound	-0.131	-0.027		-0.42	-0.284
	Upper Bound	0.344	0.433		0.044	0.195
N		63	63	63	63	63
Posterior	Mode	0.166	0.039	-0.199		0.424
	Mean	0.158	0.037	-0.19		0.407
	Variance	0.014	0.015	0.014		0.011
95% Credible Interval	Lower Bound	-0.076	-0.204	-0.42		0.201
	Upper Bound	0.393	0.276	0.044		0.603
N		63	63	63	63	63
Posterior	Mode	0.179	-0.243	-0.045	0.424	
	Mean	0.17	-0.232	-0.042	0.407	
	Variance	0.014	0.014	0.015	0.011	
95% Credible Interval	Lower Bound	-0.067	-0.456	-0.284	0.201	
	Upper Bound	0.399	-0.002	0.195	0.603	
N		63	63	63	63	63

Table 8.1: Posterior distribution characterization for pairwise correlations,(c=0)

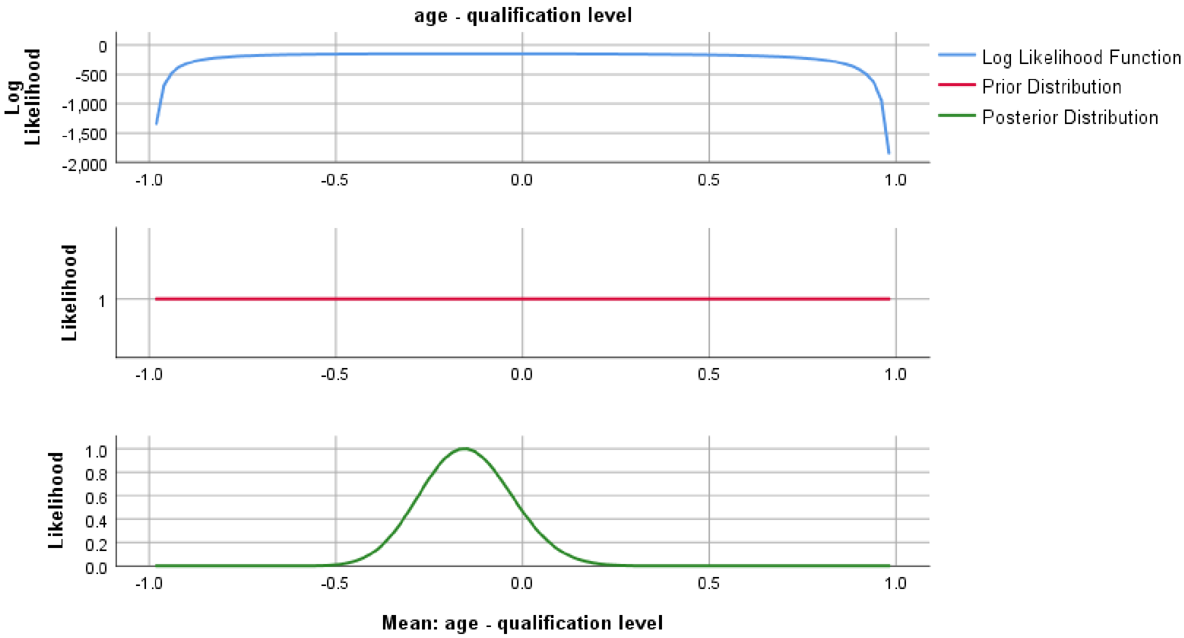


Figure 8.8: Age*Qualification comparison for three models using pairwise correlations

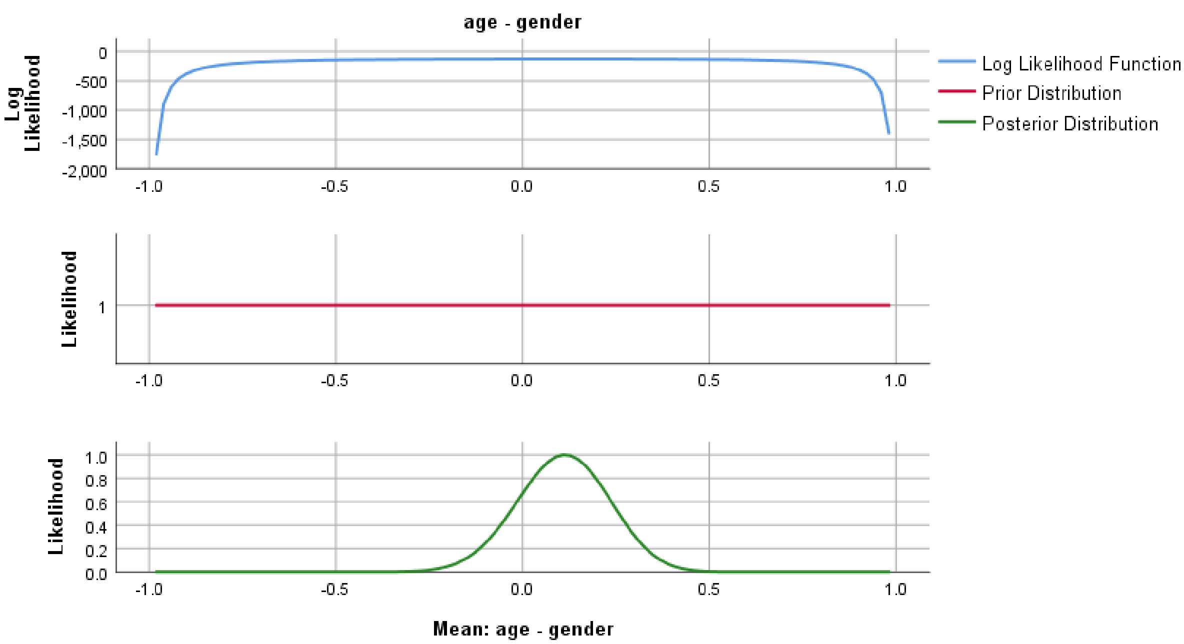


Figure 8.9: Age*Gender comparison for three models using pairwise correlations

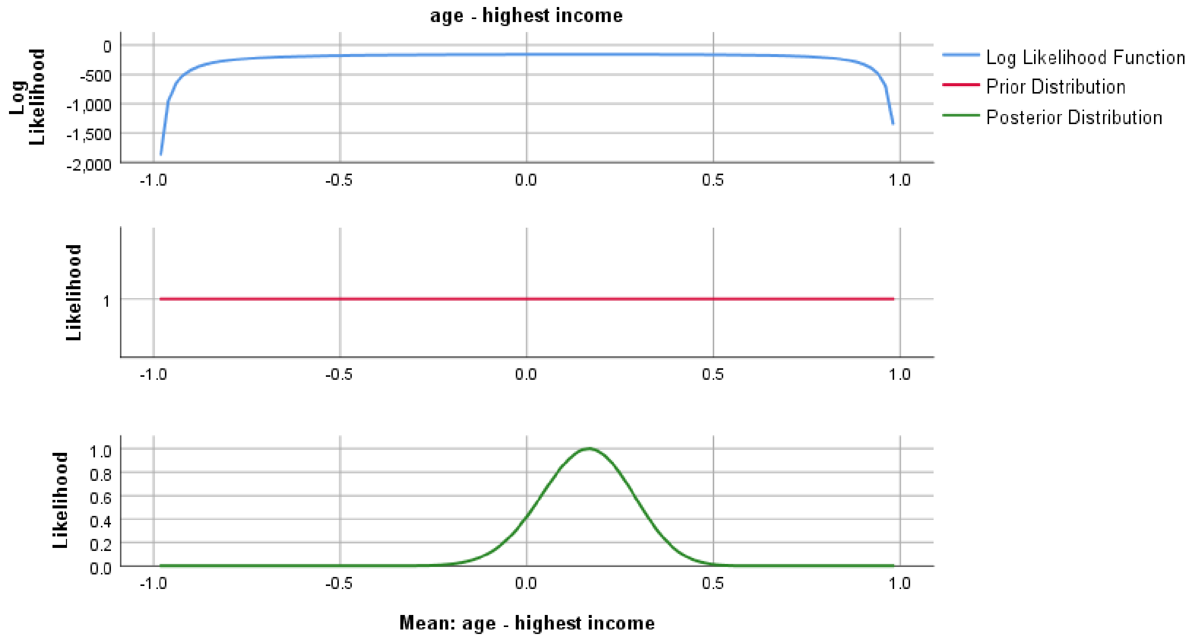


Figure 9.0: Age*Incomes comparison for three models using pairwise correlations

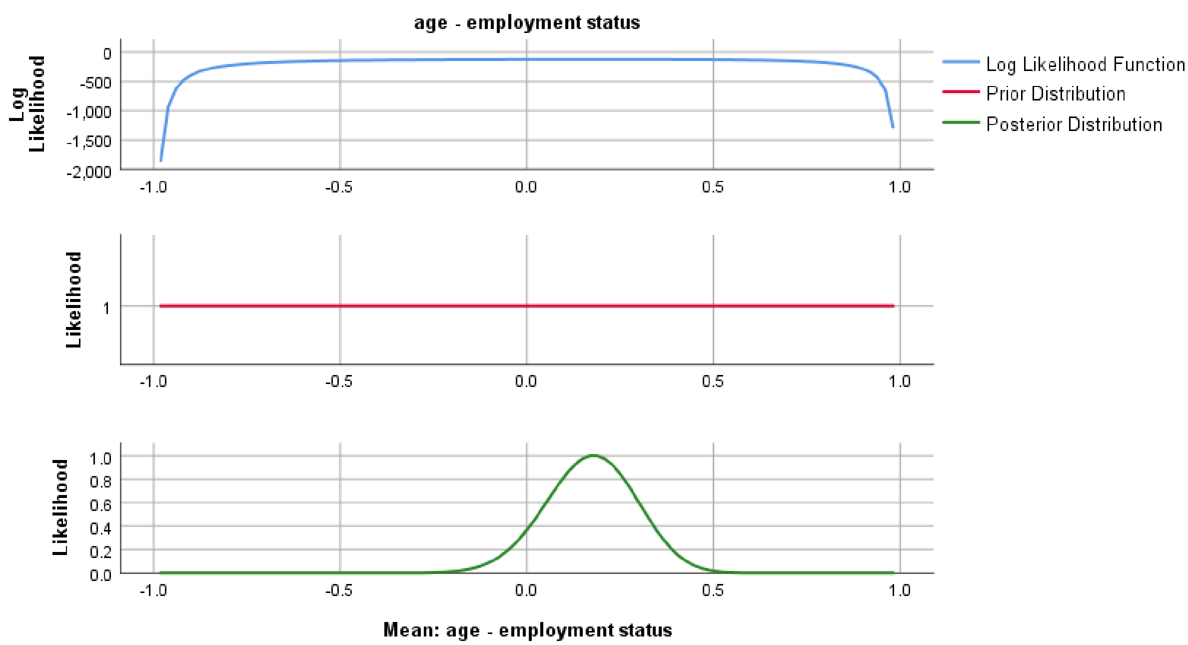


Figure 9.1: Age*Employment comparison for three models using pairwise correlations

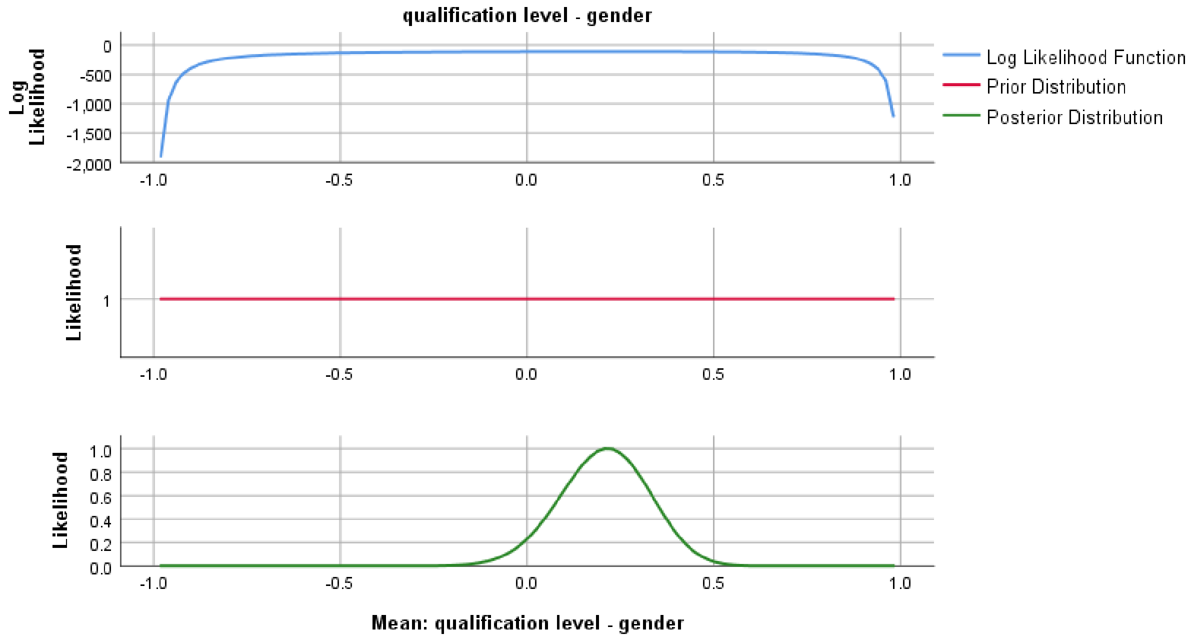


Figure 9.2: Qualification*Gender comparison models using pairwise correlations

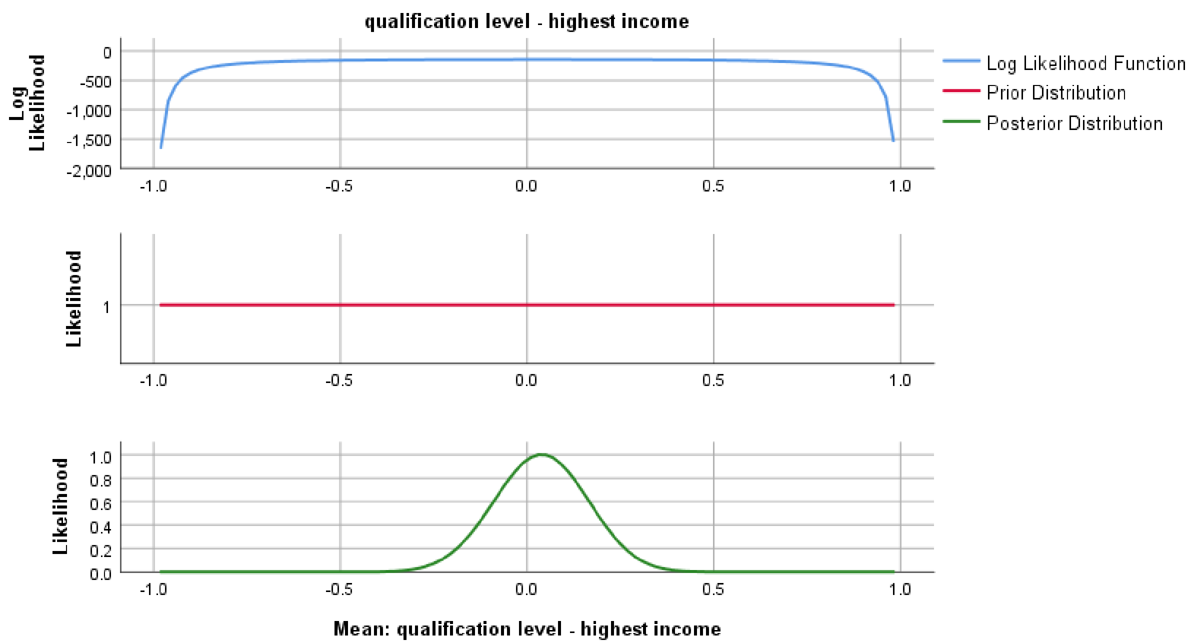


Figure 9.3: Qualification*Education comparison for three models using pairwise correlations

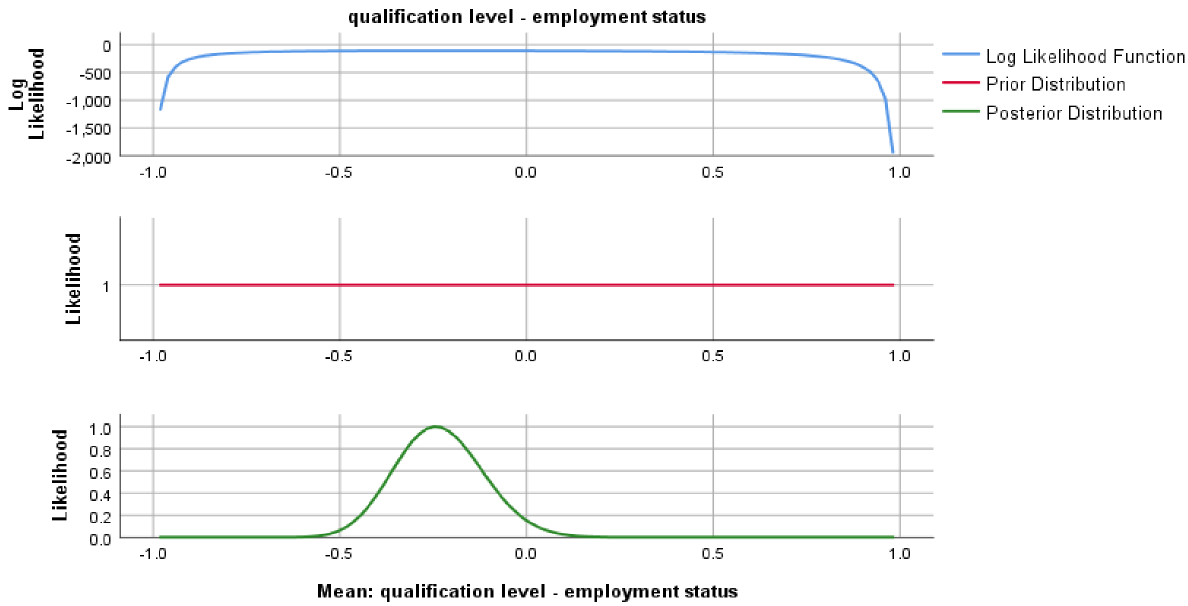


Figure 9.4: Qualification*Employment comparison for three models using pairwise correlations

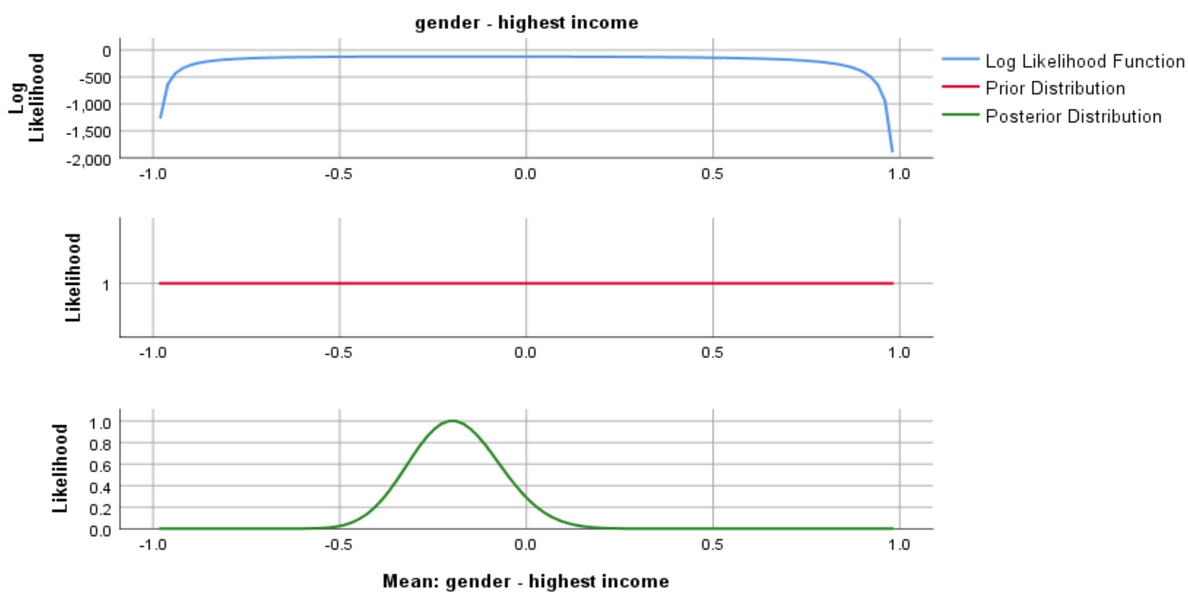


Figure 9.5: Gender*Incomes comparison for three models using pairwise correlations

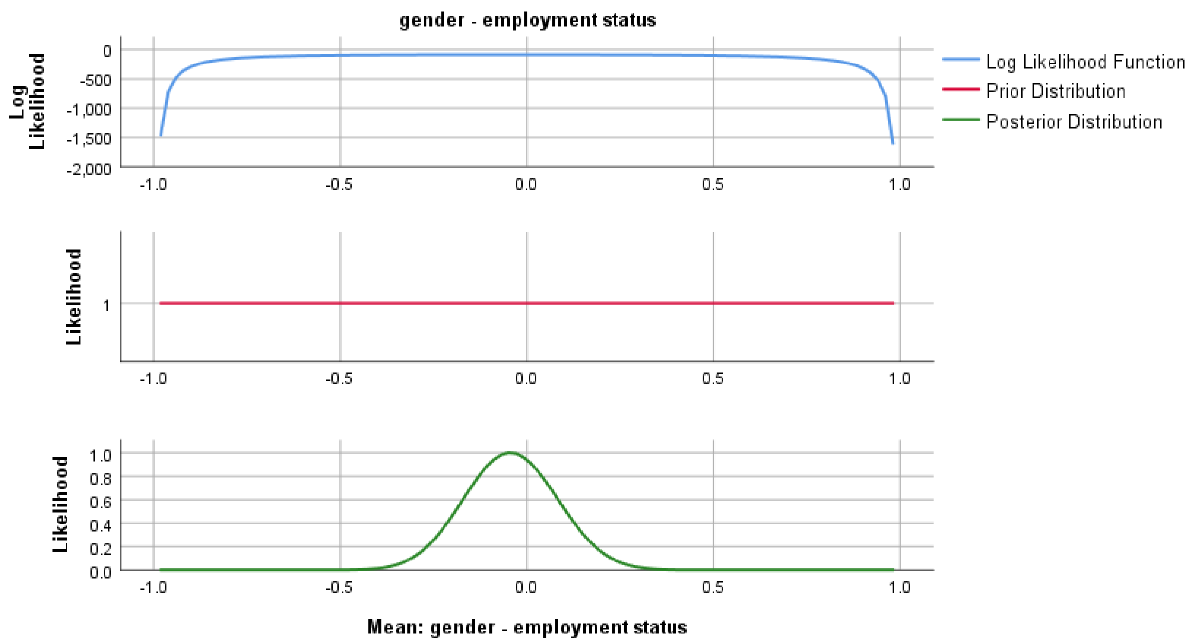


Figure 9.6: Gender*Emploment comparison for three models using pairwise correlations

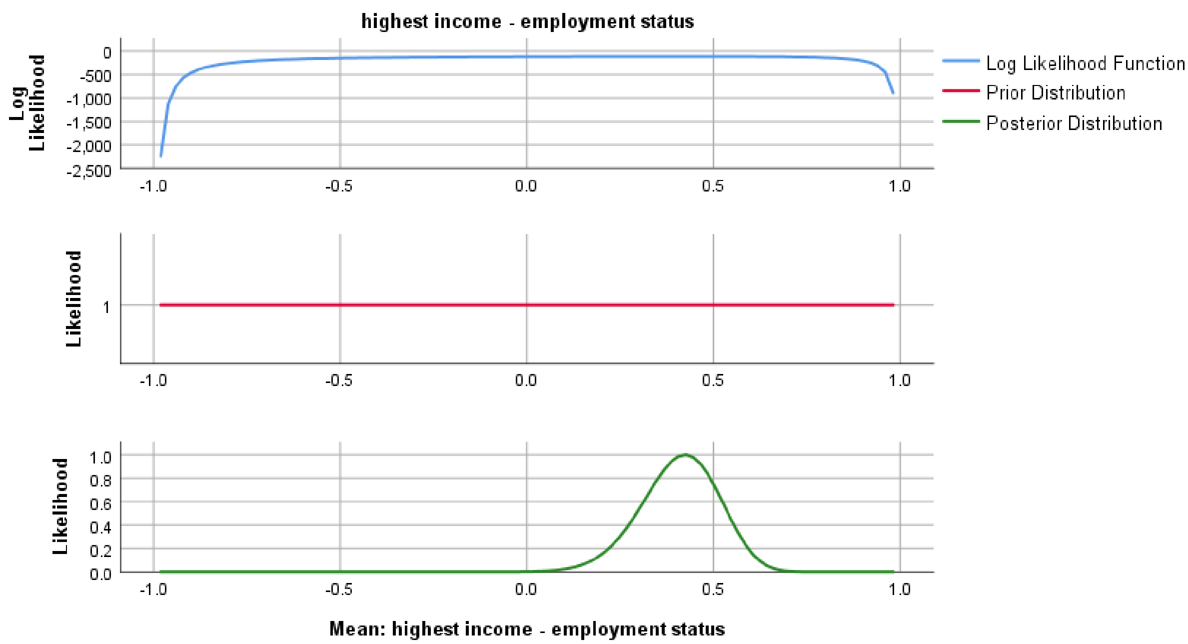


Figure 9.7: Incomes*Emploment comparison models using pairwise correlations

Several of correlations are presented in this section as in Figure 8.8-9.7 including age and qualification level and gender and employment status and other pairs as given in the previous figures .The correlations showed that the multiple population means in pairs to determine whether they are siginificnt or not. The basic idea of the method of analysis is to examine any two parameters at the same time. The correlations provided insights into the relatiohship between characteristics that can be explored further. Pairwise discover the potential relation of interest where associations are investigated based upon prior knowledge.

7.4 CONCLUSION AND CONTRIBUTION

The research provided two types of methodology index items that were specified based on the end-users' needs, including fixed items (i.e., safety and variable items (i.e., cost). The study investigated that the end-users' biggest concern comes from the threat or misunderstanding of CNG onboard vehicle safety measures and applications. At the same time, the influence of cost is variable due to the cost of utilities as gas prices, electricity, raw materials, and by-products. Therefore, it is worthy of mentioning that the specification of items (i.e., parameter changes, purity requirements, delivery time, and inventory level) may lead to cost reduction.

In any fuel, including those used in motor vehicles, can be dangerous if mishandled. Fuel contains energy, which is released when the fuel is ignited. For example, gasoline is a potentially dangerous fuel if treated incorrectly. The same is true for CNG. It can be used safely if physically and chemically understood under safety regulations.

The study has provided several values according to various tasks:

1. A state-of-art review of risk-based acceptance index modeling in a compressed natural gas onboard vehicle. This presents tools and knowledge that are available for general CNG

vehicular modeling. It provides a good understanding of the relevant processes.

2. A model can identify the potential factors which affect CNG in the transport industry. A comparison of the output of the risk-based index (RBIs) model towards CNGV provides the basis for an alternative and promising modeling.

3. An experiment to study the effect of propose index on the end-user decision. It provides an understanding of the mechanism of the adopted product presentation. Identifying and understanding this process contribute to developing the response and recovery methods in the transportation sector. Thus, improvement of the choice process can be achieved.

4. Prediction of end-user behaviors towards compressed natural gas for transportation purposes. Identification of strengths and weaknesses of individuals and providing direction towards the proposed method.

5. The risk assessment in the compressed natural gas cylinder can be a useful tool for developing an integrated risk assessment framework. It provides policy guidance and principle towards CNGV.

The research attempts to overcome the defined gap by taking several steps, including the development of RBAI's for transportation preparation design as a primary contribution, increasing the competency, and enhancing the safety of CNGV's. Another contribution of the study is to adapt the acceptance index and end-user behavior towards CNGV's. In order to establish a risk-based index to support the design of CNGV.

Also, modeling the RBIs influence on compressed natural gas vehicle design requires a consideration of the dependency of RBIs and associated actions, quantify the impact of different RBIs on the end-user behaviors, quantify the influence of each RBIs on the CNGV design, and conducting the experiment (survey) to measure the potential impact of each factor (weighting factor).

However, the research defines individually the study tool, which is considered as varied from one to another, unlike artificial tools. Thus, the RBI's influence may varied result in more focus on the decision making by an individual who may vary. It helps to understand the mechanism of the individual behavior process and decision making. Therefore, this research presents a non-artificial tool as a diagnostic tool to measure the applicability of alternatives to be completed by measuring sensitivity towards RBIs individually and identified the potential elements. The research formulated using social and industrial factors relationship. This relationship can be characterized appropriately and scientifically as if RBIs. The RBIs can also be used to predict and evaluate the performance and reliability of alternatives.

The Illustration of knowledge into a risk assessment framework definitely would support industry for optimum alternative technology design. Therefore, the RBI’s is a useful methodology to convert the societal response into an industrial observation tool that benefits industry and upgrade system, productivity, device, and create a safe and promising design.

The study has several limitations. The main concern is that the survey sample of the study was self-selected and may not represent fairly the border of the community of individual safety and quality professionals. Those who were interested and most knowledgable about CNG safety are likely over presented among participants. Another important one is that it is possible that respondents misrepresented their level of familiarity with the CNG design model, and that results would have been better among true experts. Nevertheless, the discrepancy between self-perceived familiarity with the adopted CNG model and variable interpretations of the design feature is striking.

Due to the factors constrains, it is suggested to increase more significant independent variables, and the insignificant independent variables should be eliminated to get an accurate decision of CNGV selection made by end-users. The additional independent variables should be related to the research title and supported by evidence.

Finally, it is recommended to carry out another risk analysis in the future, following this approach. We should expand the coverage of the location. Thus, a further survey form recommended to collect precise outcomes and improve the technical language of the questionnaire sample rather than survey forms only. Then, a concentrates on the system and process operation required for improving its safety through further risk analysis.

Also, CNG onboard vehicle safety is dependent on design, materials, installation, operating conditions, and maintenance, not just the cylinder. The study has shown that safety and quality, such as operation, reliability, environment, cost, are considerably varied in their interpretation of the acceptance risk-based index model applied to automobile incidents. This finding echoes the variability in interpretation that exists even for basic terms of safety, for example," error or incident. Thus, a comprehensive model illustrates the requirement of strict government CNG onboard vehicle regulations.

GLOSSARY

Risk A Combination of the probability (between 0 and 1) of occurrence of harm and the severity of harm ("combination" typically means "product," whereas additional factors, such as risk aversion, are part of the risk evaluation process).
Harm Physical injury or damage to the health of human beings, or damage to property or the environment.
Risk assessment Overall process of risk analysis and risk evaluation.
Risk analysis Systematic evaluation of available information to identify hazards (potential sources of harm) and to estimate the risk.
Risk estimation Process used to assign values to the probability and the consequence of a risk.
Risk evaluation Procedure based on the risk analysis to determine whether the tolerable risk has been achieved.
Risk criteria Reference parameters by which the significance of risk is assessed.
Risk management The overall process of risk assessment, decision, risk treatment, and its control (see figure 1).
Risk-based Method A style of method that focuses upon the analysis and identification of risks with the highest potential impact
Decision criteria comprise especially risk treatment and include risks and social, economic, and political considerations (supplementary definition is not part of ISO/IEC Guides 51 or 73).
The decision Selection process for risk treatment measures based on the decision criteria (supplementary definition is not part of ISO/IEC Guides 51 or 73).
Tolerable risk is accepted in the decision phase based on the decision criteria and which, in a given context, in particular, embraces justifiable ideals of society.
Analysis A statistical technique commonly used to examine differences between three or more samples/group means (compared to, for example, a test that examines differences for just two samples/group means).
Categorical data This is data that represents different categories, rather than a scale, e.g., sex of patients, ethnic background.
Chi-square is a statistical test primarily associated with cross-tabulation to test for the 'independence' or 'association' between two categorical variables.
Confidence intervals Where a mean difference in two samples is observed, 95 percent confidence intervals provide lower and upper values around this mean difference with a 95 percent probability that the true difference lies within these parameters.
Correlation is a correlation assesses the relationship between two continuous variables to see if values on one variable vary concerning the other, e.g., height and weight.
Cross-tabulation Where two or more variables are presented in a table to compare relative frequencies across categories.
Dependent variable A variable, the outcome of which is predicted to be dependent on allocation to the treatment or independent variable; for example, level of back pain (dependent variable) depend on the type of treatment a patient was allocated to by the researcher (e.g., physiotherapy or acupuncture).
Descriptive statistics provide summary information about data, for example, describing the sample in terms of age, gender, and other characteristics. Measures of central tendency may be used along with graphs and other means of representing data.

Frequencies The number of times a particular value is represented in a sample, e.g., the number of males and the number of females.
Hypothesis A prediction that is being tested.
Independent samples t-test A statistical test used to determine whether the mean scores from two independent samples (e.g., males/females) differ significantly.
Independent variable A term typically used in the experimental design which refers to the variable manipulated by the researcher, e.g., assignment of patients to treatment A or treatment B. It is sometimes referred to as the treatment variable.
Interval data This is data that takes the form of a scale in which the numbers go from low to high in equal intervals.
The statistical test is a non-parametric statistical test to determine differences in two independent samples.
Mean The arithmetic mean is the most common measure of central tendency and is produced by calculating the sum of the values and then dividing by the number of values.
Measures of central tendency are used to provide the typical or average values for a sample of data, e.g., the mean age of the sample. The mean, median, or mode may be used depending on the distribution of the data.
Median A measure of central tendency is the midpoint of an ordered distribution of values.
Mode A measure of central tendency referring to the most frequently occurring value in a set of scores.
Nominal data This is another term for categorical data, whereby discrete categories may be nominated a numerical code, e.g., code male as 1 and female as 2.
Normal distribution A frequency distribution where the majority of values are in the middle of the range, tailing off at either end of the scale producing a symmetrical bell-shaped curve.
Null hypothesis This is the hypothesis that is proposed to be nullified or refuted, e.g., there is no difference between the two samples.
One-tailed test A test where the hypothesis predicts an effect in one direction, e.g., predicting that levels of anxiety would reduce as a result of counseling (compared to a 2-tailed test which abstains from making a directional prediction, i.e., that advice would affect levels of anxiety - but we cannot be certain if this would lead to a reduction or increase in levels of concern).
Ordinal data This is data that can be put into an ordered sequence. For example, the rank order of runners in a race: 1st, 2nd, 3rd. Outliers Data, which lies outside the majority of scores.
Probability This refers to the likelihood of an event occurring by chance. If the event cannot happen, the probability is zero; if the event is certain to happen, the probability is one.
P-value This refers to the probability of the outcomes occurring by chance, expressed numerically as ranging from zero to one. The convention is to accept a p-value of 0.05 or less as being statistically significant, which translates to a probability of 1 in 20 of the results occurring by chance.
Ratio scale A scale where equal intervals separate points with a true zero, e.g., height, weight, age, length.

Regression analysis is an assessment of the relationship between one or more dependent variables and independent variables to find a line that best predicts the relationship between the two. It is then possible to estimate the values of a dependent variable from the values of an independent variable.

Related samples t-test A statistical test used to determine whether the mean scores from two related samples differ significantly.

Standard deviation A measure of the amount of deviation from the mean in a sample of scores.

Statistical significance An observation that is unlikely to have occurred by chance at a specified level of probability.

T-test A statistical technique for examining differences in means between two samples.

Two-tailed test A test where the hypothesis does not specify a direction for effect (non-directional), e.g., the treatment would affect, but we cannot be certain if this leads to an increase or decrease in patient ratings.

Structural Equation Modeling (SEM) is a methodology of representing, estimating, and testing a network of relationships between variables.

Cognitive analysis An analytic field that tries to mimic the human brain by drawing inferences from existing data and pattern

Risk Perceptions are beliefs about potential harm or the possibility of a loss. It is a subjective judgment that people make about the characteristics and severity of a risk

Likert-type is a type of rating scale used to measure attitudes or opinions. With such a scale, respondents are asked to rate items on a level of agreement (i.e., strongly agree, agree, strongly disagree)

An empirical evaluation

REFERENCE

1.O'Hare D.," Cognitive failure analysis for aircraft accident investigation," Ergonomics, vol. 37, no. 11, pp. 1855-1869, Nov. 1994.

2.Global'sNaturalGasVehicleStatisticsSummary,NGV.December,2018, http://www.iangv.org/stats/NGV_Global_Stats1.htm

3. A Practical Guide to Natural Gas Vehicles, RP Publishing, CO,1996

4.Acker, G., "Experience Using LNG as a Marine Engine Fuel," MARINE TECHNOLOGY; Vol. 23, No. 2, June 1989, pp. 33-39.

5.Hill P. L. and Mtui, P. G., "Natural Gas Fueling of Diesel Engines," Automotive Engineering, November 1996, pp. 87-90

6. Butler, C. A., and Casarella, R. P., The Safe Guide to Natural Gas Vehicles. RP Publishing, Inc., CO, 1996.

7.Rygh, K. "Accident Investigations-Meeting the challenge of new technology," in Constituents of Modern System-safety Thinking. F. Redmill and T. Anderson, Eds. London, UK: Springer, 2005.

8. The National Fire Code – 2019 Alberta Edition based on the National Fire Code of Canada 2015.

9. Dekker S., Ten Questions About Human Error: A New View of Human Factors and System Safety. Mahwah, NJ: Lawrence Erlbaum Associate Inc., 2005

10. Verhoeff W. from the Dutch Safety Board, personal communication, November 2009.

11.Hammer, W." Handbook of system and product safety". Englewood Cliffs, NJ: Prentice-Hall, 1972.

12. Woods D., Behind human error: Cognitive systems, computers, and hindsight.Wright Patterson AFB, OH: Crew System Ergonomics Information Analysis Center, 1994.

13.Leveson N. "Moving beyond normal accidents and high-reliability organizations: A systems approach to safety in complex systems," vol. 30 no. 2-3, pp. 227, 2009.

14. Stringfellow M. "Healthcare Industry Incentive Structures Pressure System Operators to Operate in a High-risk Risk State," in Proceedings of the International System Dynamics Conference, Albuquerque, NM, 2009.

15. Dejan, D. and Darja, T., "Introduction to Structural Equation Modeling: Review, Methodology, and Practical Applications," The International Conference on Logistics & Sustainable Transport 2014, 19–21 June 2014 Celje, Slovenia.

16. Kerm H., Elizabeth D., Margaret A., Pascale C., Ronda H. 2008 "Understanding Adverse Events: A Human Factors Framework "Department of Sociology, Johns Hopkins University, Johns Hopkins University.

17. Baalisampang T., Abbassi R., Garaniya V., Khan F*, Dadashzadeh M. 2018. "Review and analysis of fire and explosion accidents in maritime transportation," a National Centre for Maritime Engineering and Hydrodynamics, Australian Maritime College (AMC), Ocean Engineering 158 (2018) 350–366.

18. Organization For Economic Co-Operation And Development, OECD. Stat. portal, Oct. 2019, www. https://stats.oecd.org/Index.aspx?DataSetCode=IRTAD_CASUAL_BY_AGE#

19. Chiu, Y.C., and Tzeng, G.H. The market acceptance of electric motorcycles in Taiwan experience through a stated preference analysis. Transp. Res. D, 1999, 4, 127–146.

20. Xiu C. H., Li H., and Zhang Y. "Integrated Assessment on Pollution Contribution in Iron and Steel Manufacturing Process." 21, (3), 207, 2008.

21. Canadian Motor Vehicle Traffic Collision Statistics (2015), Canadian Council of Motor Transport Administrators.

22. Kahenman, D. and Tversky, A. 1979 "Prospect Theory: An Analysis of Decision under Risk." Econometrica 47(2) 263-91.

23. McFadden, D, Morikawa, T., and Ben-Akiva, M., 2002. Discrete choice models are incorporating revealed Preferences and psychometric Data, Econometric Models in Marketing, Volume 16, 29-55.

24. Cheron, E.; Zins, M. Electric vehicle purchasing intentions: The concern over battery charge duration. Transp. Res. 1997, 30, 235–243.

25. Janovsky, P. Selesovsky, J. Horkel, L. Vejs, " Vented confined explosion in Stramberk experimental mine and Auto Rea Gas simulation" Loss Prevention in The Industries, 19.pp.280-287.

26. Ben-Akiva, M. McFadden, K. Train, J. Walker, C. Bhat, M. 2002 "Hybrid Choice Models: Progress and Challenges" Marketing Letters, 13: 163-75.

27. Everett, J.G., & Frank, P.B. (1996). Costs of accidents and injuries to the construction industry. Journal of Construction Engineering and Management, 122, 158-164.

28. Fuchs, G., and Reichel. 2011 "An Explanatory Inquiry into Risk Perceptions and Risk Reduction.

29. Azim, T. A. (2009). "The relationship between the perception of Risk and decision-Making Process of Travel" An International Multidisciplinary Journal of Tourism 5(2): 29-47.

30. Jaselskis, E.,Anderson, S., "Strategies for Achieving Excellence in Construction Safety Performance," JournalofConstructionEngineeringandManagement 122(1)· March1996, https://www.researchgate.net/profile/Jeffrey_Russell2

31. Khan, F.and Sadiq R. (2006) "An Integrated Approach for risk-based life cycle assessment."

32. Bollen, K. (1989). "Structural Equations with Latent Variables" John Wiley & Sons, Inc, April 28, 1989 ISBN:9780471011712.

33. Ullman, J., Bentler, P. "Structural Equation Modeling: **Par Four. Data Analysis Methods" April 15, 2003, https://doi.org/10.1002/0471264385.wei0224**

34. Trochim, W.M., 2006. The Research Methods Knowledge Base, 2nd Edition. Retrieved May 31, 2011, from http://www.socialresearchmethods.net/kb/

35. Chuan, C. L. , 2006 "SAMPLE SIZE ESTIMATION USING KREJCIE AND MORGAN AND COHEN STATISTICAL POWER ANALYSIS: A COMPARISON," Jurnal Penyelidikan IPBL, Jilid 7, pp.78-86.

36. Gravetter, F., Forzano, L. 2018 "Research methods for the behavioral Sciences" Belmont, CA, Wadsworth Cengage Learning: Brockport Bookshelf. 43.https://digitalcommons.brockport.edu/bookshelf/43

37. Dowdell, E.; Burgess, A.; Flores, J. "Patterns Among Adolescents, Young Adults, and Sexual Offenders" AJN The American Journal of Nursing: 2011,111(7),pp.28-36. doi: 10.1097/01.NAJ.0000399310.83160.73

38. Brown, J. 2012 “Understanding the Better Than Average Effect: Motives Matter” Personality and Social Psychology Bulletin 38(2) 209–219 **DOI: 10.1177/0146167211432763**

39. Zumbo, B. D., Gadermann, A. M., & Zeisser, C.,2007: Ordinal versions of coefficients alpha and theta for Likert rating scales. Journal of Modern Applied Statistical Methods, 6, 21-29.

40. Brinkley, S.R, Jr., and Lewis, B., Seventh Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, pp. 807–811, 1959

41. W.G. Houf, G.H. Evans, E. Merilo, M. Goethe, S.C. James: Releases from hydrogen fuel-cell vehicles in tunnels Int. J Hydrogen Energy, 37 (1) (2012), pp. 715-719

42.Hazardous-Materials-Information-Review-Regulations,SOR/88-456,2019. https://lois-laws.justice.gc.ca/eng/regulations/SOR-88-456/page-1.html

43. The National Fire Code – 2019 Alberta Edition is based on the National Fire Code of Canada.

44. Dekker, S.,2005, Ten Questions About Human Error: A New View of Human Factors and System Safety. Mahwah, NJ: Lawrence Erlbaum Associate Inc.

45. http://www.naturalgas.org/overview/background.asp.

46. Lewis, B. And von Elbe, G., Combustion, Flame, and Explosion of Gases, Academic, 1987. 3rd edition, pp. 566-573.

47. Dalmine, S. p. “A technical drawing datasheet,” Tenaris S. A., 2000, Italy.

48.Jeffrey M.,2014 “ CNG: A SAFE FUEL FOR ADR TRUCKS” presented to WP15 -Transport of Dangerous Goods, NGV Global, United Nations, Geneva, ECE-TRANS-WP15-97-infXX

49. Cozzani V., Gubinelli G., and Salzano E., 2006, “Escalation threshold in the assessment of domino accident events. Journal of Hazardous Materials, 129: 1-21.

50. Kashkarov S., Li Z., Malkov V. Nomograms for assessment of hazard distance from a blast wave after high-pressure hydrogen cylinder rupture in a fire (ISFEM8), Hefei; China;2016.

51. Groth K., Hecht E., HyRAM: a methodology and toolkit for quantitative risk assessment of hydrogen systems. Int. Journal Hydrogen Energy, 2017;42:7485-93.

52. LaChance J, Tchouvelev A, Engebo A. Development of Uniform harm criteria for use in quantitative risk analysis of the hydrogen infrastructure. Int. Hydrogen Energy 2011;35(3):2381-8

53. Haugom G., Rikheim H., Nilsen S. Hydrogen application. Risk acceptance criteria and risk assessment methodology. In: Europe hydrogen energy conference, Grenoble(France);2003.

54.Molkov V., Makarov D., Kashkarov S., Composite pressure vessel for hydrogen storage. In: UK 2017.

55. Zel’dovich, Ya.B., Librovich, V.B., Makhviladze, G.M. and Sivashinsky, G.I., August 1969: 2nd International Colloquium on Explosion and Reacting Systems Gas dynamics, 24–29., p.10.

56. George, R. 2010 “Visitor Perceptions of Crime-Safety and attitudes towards Risk” Tourism Management 31(6): 806-15.

57. Kane, M. (2006). Validation. In R. Brennan (Ed.), Educational measurement (4th ed., pp. 17-64). Washington, DC: American Council on Education and National Council

58. Estimating ordinal reliability for Likert-type and ordinal item response data: A conceptual, empirical, and practical guide Anne M. Gadermann, Harvard Medical School Martin Guhn & Bruno D. Zumbo, University of British Columbia.

59. Bentler, P. (2009). Alpha, dimension-free, and model-based internal consistency reliability. Psychometrika, 74, 137-143. doi: 10.1007/s11336-008-9100-1

60. Bernards, C. A., & Jennrich, R. I., 2005: Gradient projection algorithms and software for arbitrary rotation criteria in factor analysis. Educational and Psychological Measurement, 65, 676–696. doi: 10.1177/0013164404272507

61. Brennan, R. L., 2001, Generalizability Theory. New York: Springer-Verlag.

62. Carroll, J. B. 1961: The nature of data, or how to choose a correlation coefficient. Psychometrika, 26, 347-372. doi: 10.1007/BF02289768

63. Cizek, G. J., Rosenberg, S., & Koons, H. (2008). Sources of validity evidence for educational and psychological tests. Educational and Psychological Measurement, 68, 397-412. doi:10.1177/0013164407310130

64. Cohen, J. 1988: Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

65. Cohen, J., Cohen, P., West, S. G., & Aiken, L. S., 2003. “Applied multiple regression/correlation analysis for the behavioral sciences” (3rd ed.). Maywah, NJ: Erlbaum.

66. Cortina, J. M. (1993). What is the coefficient alpha? An examination of theory and applications. Journal of Applied Psychology, 78, 98-104. doi: 10.1037/0021-9010.78.1.98

67. Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometrika, 16, 297-334. doi:10.1007/BF02310555

68. Cronbach, L. J. (2004). My current thoughts on coefficient alpha and successor procedures. Educational and Psychological Measurement, 64, 391-418. doi:10.1177/0013164404266386

69. Cronbach, L. J., Gleser, G. C., Nanda, H., & Rajaratnam, N. (1972). The dependability of behavioral measurements. New York: Wiley.

70. Elosua Oliden, P., & Zumbo, B. D. (2008). Coeficientes de fiabilidad para escalas de respuesta categórica ordenada. Psicothema, 20, 896-901.

71. Flora, D. B., & Curran, P. J. (2004). An empirical evaluation of alternative methods of estimation for confirmatory factor analysis with ordinal data. Psychological Methods, 9, 466-491. doi: 10.1037/1082-989X.9.4.466

72. Alexander N.; Jacob Z.; Pavel S.; Vaclav P.: Numerical Analysis of Explosion to Deflagration Process due to Methane Gas Explosion in Underground Structures. Czech Technical University in Prague, Faculty of Engineering, Prague, Czech Republic.

73. Khan MI, Yasmin T (2014) Development of natural gas as a vehicular fuel in Pakistan: issues and prospects. J Nat Gas Sci Eng 17:99–109.

74. TIAX LCC, 2007;” Full Fuel Cycle Assessment” California Energy Commission Consultant Report CEC-600-2007-004-F, California.

APPENDICES

Appendix A

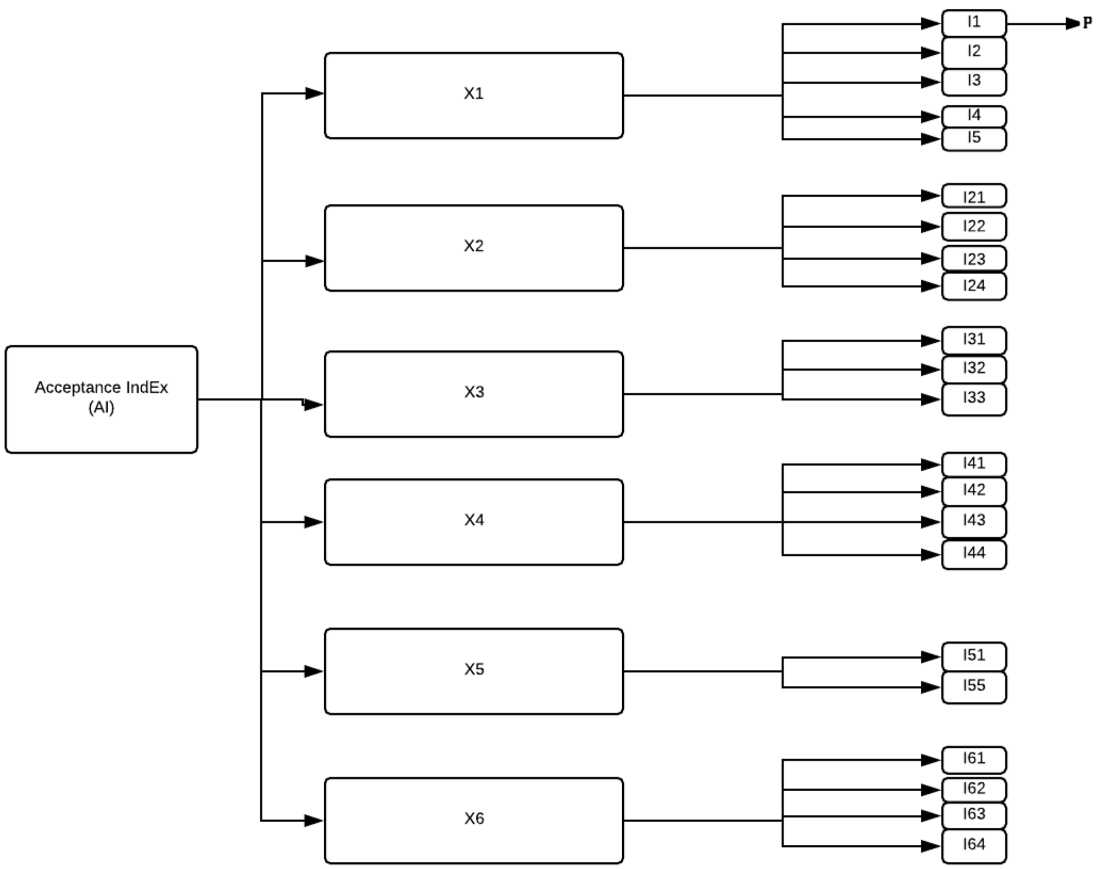


Figure A-1: The framework of Acceptance Index

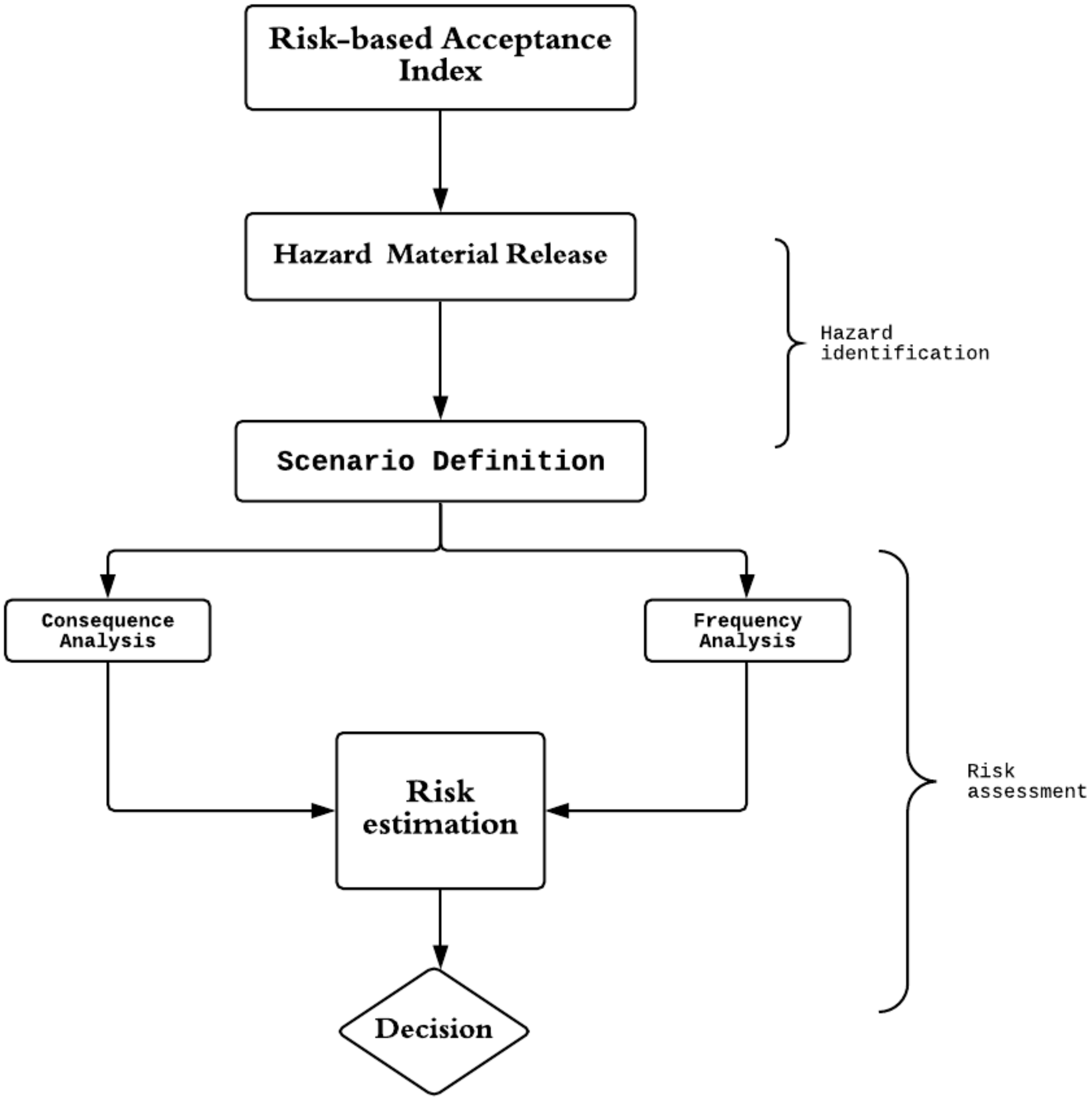


Figure A-2: Risk-based Acceptance Index (RBAI)

Gas	LEL	UEL
Acetone	2.6	13.0
Acetylene	2.5	100.0
Acrylonitrile	3.0	17
Allene	1.5	11.5
Ammonia	15.0	28.0
Benzene	1.3	7.9
1,3-Butadiene	2.0	12.0
Butane	1.8	8.4
n-Butanol	1.7	12.0
1-Butene	1.6	10.0
Cis-2-Butene	1.7	9.7
Trans-2-Butene	1.7	9.7
Butyl Acetate	1.4	8.0
Carbon Monoxide	12.5	74.0
Carbonyl Sulfide	12.0	29.0
Chlorotrifluoroethylene	8.4	38.7
Cumene	0.9	6.5
Cyanogen	6.6	32.0
Cyclohexane	1.3	7.8
Cyclopropane	2.4	10.4
Deuterium	4.9	75.0
Diborane	0.8	88.0
Dichlorosilane	4.1	98.8
Diethylbenzene	0.8	-
1,1-Difluoro-1-Chloroethane	9.0	14.8
1,1-Difluoroethane	5.1	17.1
1,1-Difluoroethylene	5.5	21.3
Dimethylamine	2.8	14.4
Dimethyl Ether	3.4	27.0
2,2-Dimethylpropane	1.4	7.5
Ethane	3.0	12.4
Ethanol	3.3	19.0
Ethyl Acetate	2.2	11.0
Ethyl Benzene	1.0	6.7
Ethyl Chloride	3.8	15.4
Heptane	1.1	6.7
Hexane	1.2	7.4
Hydrogen	4.0	75.0
Hydrogen Cyanide	5.6	40.0
Hydrogen Sulfide	4.0	44.0
Isobutane	1.8	8.4
Isobutylene	1.8	9.6
Isopropanol	2.2	-
Methane	5.0	15.0
Methanol	6.7	36.0
Methylacetylene	1.7	11.7
Methyl Bromide	10.0	15.0
3-Methyl-1-Butene	1.5	9.1
Methyl Cellosolve	2.5	20.0
Methyl Chloride	7.0	17.4
Methyl Ethyl Ketone	1.9	10.0
Methyl Mercaptan	3.9	21.8
Methyl Vinyl Ether	2.6	39.0
Monoethylamine	3.5	14.0
Monomethylamine	4.9	20.7
Nickel Carbonyl	2.0	-
Pentane	1.4	7.8
Picoline	1.4	-
Propane	2.1	9.5
Propylene	2.4	11.0
Propylene Oxide	2.8	37.0
Styrene	1.1	-
Tetrafluoroethylene	4.0	43.0
Tetrahydrofuran	2.0	-
Toluene	1.2	7.1
Trichloroethylene	12.0	40.0
Trimethylamine	2.0	12.0
Turpentine	0.7	-
Vinyl Acetate	2.6	-
Vinyl Bromide	9.0	14.0

Table A-3: Flammable Compressed and Liquefied Gases (NFPA HEALTH 3,4)

Importance	Distribution	Risk-based Index Description
Most	Male & Female	Safety, Reliability, Operational, Price
Less	Male & Female	Pollution, Convenience

Table A-4: The importance of risk level

How many times do you often drive a car?

		Percent	Valid Percent	Cumulative Percent
Valid	one time/day	37.5	37.5	37.5
	2 -3 times /day	37.5	37.5	75.0
	More than 3 times a day	25.0	25.0	100.0
	Total	100.0	100.0	

Table A-5: The behavior scale

How many times per year do you do full service for your car?

		Percent	Valid Percent	Cumulative Percent
Valid	once a year	62.5	62.5	62.5
	twice a year	37.5	37.5	100.0
	Total	100.0	100.0	

Table A-6: The behavior scale

How would you rate your understanding in Compressed Natural Gas vehicle-(CNGV)

		Percent	Valid Percent	Cumulative Percent
Valid	Neutral	75.0	75.0	75.0
	somewhat high	25.0	25.0	100.0
	Total	100.0	100.0	

Table A-7: The Attitudinal scale

How would you rate the effectiveness of the car speed on you when you decide to buy a car

		Percent	Valid Percent	Cumulative Percent
Valid	somewhat low	37.2	37.0	37.5
	Neutral	37.8	38.0	75.0
	somewhat high	25.0	25.0	100.0
	Total	100.0	100.0	

Table A-8: The Attitudinal scale

How would you rate the effectiveness of the car size on you when you decide to buy a car

		Percent	Valid Percent	Cumulative Percent
Valid	somewhat low	25.0	25.0	25.0
	Neutral	62.5	62.5	87.5
	somewhat high	12.5	12.5	100.0
	Total	100.0	100.0	

Table A-9: The Attitudinal scale

How would you rate your confidence that driving CNGV contribute to global warming reduction

		Percent	Valid Percent	Cumulative Percent
Valid	somewhat low	12.5	12.5	12.5
	Neutral	62.5	62.5	75.0
	somewhat high	25.0	25.0	100.0
	Total	100.0	100.0	

Table A-10: The Attitudinal scale

How you would measure the impact of GHG's on the health

		Percent	Valid Percent	Cumulative Percent
Valid	Neutral	25.0	25.0	25.0
	somewhat high	50.0	50.0	75.0
	High	25.0	25.0	100.0
	Total	100.0	100.0	

Table A-11: The Attitudinal scale

How would you rate the effect of energy secure on you

		Percent	Valid Percent	Cumulative Percent
Valid	somewhat high	12.5	12.5	12.5
	High	25.0	25.0	37.5
	strongly high	62.5	62.5	100.0
	Total	100.0	100.0	

Table A-12: The Attitudinal scale

How would you rate your understanding of low carbon future effect on you

		Percent	Valid Percent	Cumulative Percent
Valid	Neutral	12.5	12.5	12.5
	somewhat high	37.5	37.5	50.0
	High	25.0	25.0	75.0
	strongly high	25.0	25.0	100.0
	Total	100.0	100.0	

Table A-13: The Attitudinal scale

How would you rate your confidence to buy CNGV if it cost more than current gasoline cars?

		Percent	Valid Percent	Cumulative Percent
Valid	strongly low	37.5	37.5	37.5
	Low	62.5	62.5	100.0
	Total	100.0	100.0	

Table A-14: The Attitudinal scale

How would you rate your acceptance of the current CNGV Price range?

		Percent	Valid Percent	Cumulative Percent
Valid	strongly low	25.0	25.0	25.0
	Low	50.0	50.0	75.0
	somewhat low	25.0	25.0	100.0
	Total	100.0	100.0	

Table A-15: The Attitudinal scale

	N	Mean		Std. Deviation
	Statistic	Statistic	Std. Error	Statistic
Age	63	1.11106	0.059294	0.470598
qualification level	63	0.80628	0.050752	0.40279
Gender	63	0.5015	0.04221	0.334982
highest income	63	0.19672	0.033668	0.267174
employment status	63	-0.10806	0.025126	0.199366

Table A-16: Descriptive Statistics Analysis

N	Mean		Std. Deviation
	Statistic	Std. Error	Statistic
1	1	0	0
2	1.127	0.04229	0.33563
3	1.2698	0.05637	0.44744
4	2.4921	0.0711	0.56434
5	1.4444	0.06311	0.5009
6	3.5238	0.11943	0.94795
7	2.4762	0.06343	0.50344
8	4.3016	0.10027	0.79585
9	5.6984	0.11678	0.92693
10	5.5714	0.60748	4.82171
11	4.8254	0.10502	0.83356
12	5.4444	0.12955	1.02827
13	4.6667	0.14131	1.12163
14	5.9206	0.63774	5.06188
15	5.6349	0.11823	0.93845
16	4.3333	0.07839	0.62217
17	5.9048	0.11475	0.91077
18	5.6667	0.11085	0.87988
19	2.7302	0.10901	0.86521
20	5.0794	0.11823	0.93845
21	1.7619	0.10299	0.81744
22	3.9524	0.14912	1.18361
23	4.2222	0.15085	1.19737
24	5.4921	0.14108	1.11981
25	5.746	0.10362	0.82243
26	4.381	0.63336	5.02712
27	4.6984	0.11457	0.90936
28	3.6349	0.13634	1.08214
29	2.3492	0.08208	0.65152
30	3.7143	0.19522	1.54949
31	2.873	0.11425	0.90682
32	4.5556	0.11709	0.92941
33	4.6349	0.11605	0.92111
34	4.6349	0.09136	0.72516
35	4.3016	0.10766	0.85449
36	2.7143	0.48607	3.85808
37	2.5873	0.13123	1.04163
38	2.381	0.11411	0.90569
39	5.8254	0.99655	7.90985
40	5.3651	0.1266	1.00485
41	5.5714	0.10544	0.83694
42	5.3016	0.12109	0.9611
43	5.9841	0.0999	0.79295
44	5.7778	0.12068	0.95789
45	4.8571	0.18082	1.43524
46	5.5556	0.09269	0.73568

Table A-17: Mean and S.D. of Items

Appendix B

Dear Participant

I invite you to participate in a research study entitled Risk-based Behavioural Effect on Alternative Compressed Natural Gas vehicular Choice (CNGV). I am enrolled as a Ph.D candidate in the Oil and Gas Engineering at Memorial University and am in the process of writing my Ph.D. Thesis. The purpose of the research is to predict the potential effects of human behaviors on an alternative CNGV choice. By doing this study, we hope to learn why some people would routinely choose one transport/fuel over another in a particular social situation but might make a different selection in a separate case. What are the consequences?

Your participation in the research is entirely voluntary. You can decline altogether, or leave blank any questions you do not wish to answer. There are no known risks to participation beyond those encountered in everyday life. Your responses remain confidential and anonymous. Data from this research would be reported only as a collective combined total. Survey Monkey would administrate the study, and data collected from you as part of your participation in this project would be stored electronically. Thus, no one can identify you. Your answers would be stored in a password protected electronic format. SurveyMonkey does not collect identifying information such as your name, email address, or IP address (IP addresses would not be obtained). Therefore, the responses remain anonymous. The survey sample can electronically be completed via email, and you can answer the survey questions at your convenient time. You would first be asked some questions about your background, such as where you have lived, the level of your education, and how often you use your vehicle, etc. Then you would be asked questions concerning the characteristics of the alternative transportation fuel that would cause you to choose your vehicle over the current fossil fuels in an individual social setting.

Furthermore, please note that by clicking submit at the end of the study, you are providing your consent for participation. By consenting to participate, you are not waiving any of your legal rights as a research participant. If you agree to participate in this project, please answer the questions on the questionnaire as best as you can. It would take approximately twenty-five minutes to complete.

If you have any questions about this project, feel free to contact Ibrahim A., a Ph.D. student at iaa134@mun.ca. Information on the rights of human subjects in research is available through http://www.mun.ca/research/ethics/humans/icehr,or you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.

By clicking on the following link and submitting this survey constitutes consent and implies your agreement to the above statements: https://www.surveymonkey.com/r/2DD8HQJ

Thank you for participating in our study. Your feedback is vital.

Section One

Classification

Socio-Demographic Factors

1. Gender?

( ) Male ( ) Female

2. Age?

( ) 20 or younger ( ) 21-30 years

( ) 31-40 years ( ) 41-50 years

( ) 51-60 years ( ) Older than 60 years

3. Education Level?

( ) School Certificate ( ) Bachelor's degree

( ) diploma ( ) Post graduate degree

4. Monthly Incomes?

( ) 0.00 - $30,000 ( ) $30,001- $70,000

( ) $70,001- $100,000 ( ) More than $100,000

Occupation?

( ) Student ( ) Private company employee

( ) Governmental employee ( ) Business owner

( ) Unemployed ( ) Other, please specify

Section Two

The Perception

1. Would you agree with the impact of transportation systems on your daily life is significant?

YES NO

2. Are you satisfied with the current transportation system?

YES NO

3. Are you satisfied with the current transportation system's value of money?

YES NO

4. Do you agree, changing the layout of the transportation system is necessary?

YES NO

5. When you go to the gas station, do you choose natural gas fuel as the first choice to fill up your car?

YES NO

6. Are you aware of using the compressed natural gas vehicle (do you have any concern/issue about it)?

YES NO

Section Three

Behavioral Questions (Facts)

The Purchasing Frequency

1. How many times do you often drive a car?

( ) never
( ) 2 to 3 times per day
( ) Once a day
( ) More than three times per day

2. How many times per year do you do full service for your car?

( ) None
( ) Once a year
( ) Twice a year
( ) Three times per year
( ) More than three times

3. How far have you traveled in the distance?

( ) 0-10 KM
( ) 51-100 KM
( ) 11-50 KM
( ) 101-200 KM
( ) More than 200KM

4. Which of the following do encourage you to purchase a new automobile? Please select all that apply.

( ) It is a better Price that current car I already use

( ) It is better quality than the current car I already use

( ) It covers a need of mine that is currently do not met

( ) Other (please specify…………………………)

5. What type of car do you typically use?

( ) GMC ( ) Honda ( ) Toyota ( ) Nissan ( ) Chevrolet
( ) Mazda ( ) Specify please (……..)

6. What are the biggest concerns about buying a car?

( ) Price

( ) Safety

( ) Operational issue

( ) Reliability and Resilience

( ) Air Pollution

( ) Convenience

7. What would make you more likely to drive a car?

( ) Price

( ) Safety

( ) Operational issue

( ) Reliability and Resilience

( ) Air Pollution

( ) Convenience

Section Four

Attitudinal Questions (Opinions)

Answer the following questions by choosing only one number as explained below:

Statement of the sample

(SL)						**(SH)**
Strongly Low	**Low**	**somewhat Low**	**Neutral**	**somewhat High**	**High**	**Strongly High**
1	**2**	**3**	**4**	**5**	**6**	**7**

Questions:

A. Social Acceptance: (Convenience, Brand, Automation, Speed)

1. How would you rate your understanding of Compressed Natural Gas vehicle-(CNGV)?

2. How would you rate the effectiveness of the brand name of the company when you decide to buy an automobile?

3. How would you rate the effectiveness of the car speed on you when choosing an automobile?

4. How would you rate the effectiveness of the transmission options when choosing an automobile?

5. How would you rate the effectiveness of the car size when choosing an automobile?

6. How essential is a convenience when choosing a car?

7. How safe do you think/feel if you use a compressed natural gas vehicle?

8. How would you rate the reputation of CNGV

9. Having used CNGV, do you think the price is high, low, about right

B. Safety

10. How would you rate the importance of fuel type on your car power (NG, Gasoline, Diesel, Ethanol)

11. How would you rate your understanding in operational safety of CNGV

12. How would you rate the importance of increasing safety measures of CNGV

13. How strongly you agree that driving a CNG car is safe

14. How much are you confident that CNGV would absorb energy in a crash?

C. Reliability and Resilience

15. How important is the reliability when choosing a car

16. How significant is the effect of fuel “Resilience” when choosing a car

17. How important is the availability of spare parts when choosing a car?

18. How would you rate your confidence if CNGV continuously required a maintenance service more than current gasoline vehicles?

19. How would you rate the importance of traveling/driving time (productivity of transport) when choosing a car?

D. Operation

20. How would you rate the importance of the performance of CNG as vehicular fuel compared to current gasoline/diesel fuels?

21. How would you rate your confidence in driving a CNGV if it has a short life cycle engine compared to a gasoline engine?

22. How would you rate the importance of the fuel sources supply chains when choosing a car?

23. How would you rate the importance of improving and adjusting the future of conventional fuel supply market

24. How would you rate the importance of a decision when you decide to buy a car in your life? (The effect of buying CNGV on your entire life)?

25. How would you rate the importance of the need to overcome technology challenges?

26. Do you think that CNGV has more operational severe problems due to mechanical failure, high pressure, complex process

E. Environmental Impact

27. How would you rate that compressed natural gas (CNG) contribute to global warming reduction

28. How you would measure the impact of the transportation sector on greenhouse gases GHG's.

29. How would you rate the effect of technology on the energy secure

F. Cost

30. How would you rate the effect of cost/benefit of renewable fuels(e.g., natural gas) when choosing a car

31. How would you rate for the current price of conventional transportation fuels (gasoline, diesel)

32. How would you rate the governmental contribution to increase knowledge and suitability of alternative transports /fuels and encourage informed choices

33. What is your first reaction to the compressed natural gas (CNGV)

Appendix D

Approval Letter

Interdisciplinary Committee on Ethics in Human Research (ICEHR)

St. John's, NL Canada A1C 5S7

Tel: 709 864-2561 icehr@mun.ca

www.mun.ca/research/ethics/humans/icehr

Dear Mr. Altuwair:

Thank you for your correspondence to address the issues raised by the Interdisciplinary Committee on Ethics in Human Research (ICEHR) concerning the research named earlier project.

ICEHR has re-examined the proposal with the clarification and revisions submitted and is satisfied that the concerns raised by the Committee adequately addressed. Following the Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans (TCPS2), the project has been granted full ethics clearance to August 31, 2018. ICEHR approval applies to the ethical acceptability of the research, as per Article 6.3 of the TCPS2. Researchers are responsible for adherence to any other relevant University policies and funded or non-funded agreements that may be associated with the project.

If you need to make changes during the project, which may raise ethical concerns, please submit an amendment request with a description of these changes for the Committee's consideration. Also, the TCPS2 requires to submit an annual update to ICEHR before August 31, 2018. If you plan to continue the project, you need to request the renewal of your ethics clearance and include a summary of the progress of your research. When the project no longer involves contact with human participants, is completed, and/or terminated, you are required to provide the annual update with a final summary, and your file would be closed.

Annual updates and amendment requests can submit from your Researcher Portal account by clicking the Applications: Post-Review link on your Portal homepage.

We wish you success with your research.

Human Research Department-HRD

Appendix E

Informed Consent Form

You are invited to take part in a research project entitled “Risk-based Behavioural effect on Compressed Natural Gas.”This form is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. It also describes your right to withdraw from the study. To decide whether you wish to participate in this research study, you should understand enough about its risks and benefits to be able to make an informed decision. It is the informed consent process. Take time to read this carefully and to understand the information given to you. Please contact the researcher, Ibrahim Altuwair, if you have any questions about the study or would like more information before you consent. It is entirely up to you to decide whether to take part in this research. If you choose not to take part in this research or if you decide to withdraw from the research once it has started, there will be no negative consequences to you, now or in the future.

Introduction: You are being invited to take part in a research study about why people use vehicles driven by fossil fuels such as gasoline and diesel over others such as compressed natural gas. The study is to determine the factors Influencing Human behavior towards compressed natural gas vehicles. You are invited to participate in this research study because you are enrolled in a university of Memorial in the Newfoundland and Labrador area. If you take part in this study, you will be one of 100 to do so. Your participation is entirely voluntary. Your decision whether or not to participate will not affect your grades or academic standing. Please ask questions if there is anything you do not understand. The person doing this study is Ibrahim Altuwair, a graduate student in Engineering at Memorial University. He is being guided in this research by Prof. Faisal Khan in Oil and Gas Department of the Engineering College. No funding has received for this study, and neither Mr. Altuwair nor Prof. Khan expects to receive any extra money from companies because of the results of this study.

Purpose of Study: The purpose of this study is to predict the potential effects of human behavior on an alternative transport fuel choice. By doing this study, we hope to learn why some people will routinely choose one transport fuel over another in a particular social situation but will make a different selection in a separate case. What are the consequences?

What You Will Do in this Study: Survey Monkey will administrate the research. You do not need to come or present at any location to complete a survey. The survey sample can be completed electronically and will be emailed to you, and you can answer the survey question at your convenient time. In the survey, you will first be asked some questions about your background, such as where you have lived, the level of your education, and how often you use your vehicle, etc. Then you will be asked questions concerning the characteristics of the alternative transportation fuel that would cause you to choose your vehicle over the current fossil fuels/liquid fuels (gasoline and diesel) in an individual social setting. Furthermore, please note that by clicking submit at the end of the study, you are providing your consent for participation. By consenting to participate, you are not waiving any of your legal rights as a research participant.

Length of Time: The total amount of time you will ask to volunteer for this study is expected to be 20-25 minutes.

Compensation: You will not be compensated for participating in this study.

Withdrawal from the Study: Participation in this research is entirely voluntary, and you can withdraw your consent at any point up to clicking the submit button at the end of the survey. However, because the survey is anonymous, once you click the submit button at the end of the survey, the researchers will not be able to determine which survey answers belong to you so your information cannot be withdrawn after that point. Thus, refusal to participate or withdrawal will not affect you at any stand and will involve no penalty to you.

Possible Benefits: You will not receive any direct benefit from being in this research study.

Appendix F Recruitment Documents

My name is Ibrahim Altuwair, and I am a student in the Engineering Department at the Memorial University of Newfoundland. I am conducting a research project called Factors Influencing Human behavioral on towards Compressed Natural Gas Vehicles for my Ph.D. degree under the supervision of Dr. Faisal Khan The purpose of the study is to investigate the human behavioral effect on the choice process and related risk for alternative compressed natural gas vehicles.

I am contacting you to invite you to participate in an online survey in which you will be asked to answer general questions about the use of compressed natural gas as an alternative transportation fuel. Participation will not be required. Its online Monkey survey.

If you are interested in participating in this study, please click the link below to access the online survey.

https://www.surveymonkey.com/r/2DD8HQJ

If you have any questions, please contact me by email at iaa134@mun.ca, or by phone at 7097708080.

If you know anyone who may be interested in participating in this study, please give them a copy of this information.

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to comply with Memorial University's ethics policy. Any ethical concerns about the research, such as your rights as a participant, you may contact the Chairperson of the ICEHR at icehr.chair@mun.ca or by telephone at 709-864-2861.

Appendix G The Instrumental Sample

1. What is your gender?

Female

Male

Other

2. What is your age?

18 to 24

25 to 34

35 to 44

45 to 54

55 to 64

65 to 74

75 or older

3. What is the highest level of education you have completed?

Did not attend school

Graduated from high school

diploma

Bachelor’s degree

Postgraduate degree

4. What is your approximate average household income?

$0-$29,999

$30,000-$69,999

$70,000-$99,999

$100,000 and Up

5. Which of the following best describes your current occupation?

Student

Employee

Business owner

Unemployed

6. The impact of transportation on society is significant

YES

NO

I do not know

7. Are you satisfied with the current public transportation?

YES

NO

I DO NOT KNOW

8. Are you satisfied with the value of money for current transportation?

YES

NO

I DO NOT KNOW

9. Do you agree with changing the layout the transportation system is necessary

YES

NO

I DO NOT KNOW

10. Are you aware of using a compressed natural gas vehicle (do you have any concern/issue about it)

YES

NO

I DO NOT KNOW

11. How many times do you often drive a car

never drive a car

2 to 3 times per day

Once a day

More than three times per day

12. How many times per year do you do full service for your car

None

Once a year

Twice a year

Three times per year

More than three times

13. How far have you traveled in the distance?

0 - 10 KM

51-100 KM

11 - 50 KM

101-200 KM

More than 200 KM

14. Which of the following are the reasons that might purchase a new automobile? Please select all that apply.

It is a better Price that current car I already use

It is better quality than the current vehicle I already use

It serves a need of mine that not currently met

Others, please specify…………………………

15. What should your favorite car company do to cover your needs/demands? Please specify

Reduce the Price of the Vehicle

Reduce the price of the operational cost

Improve the safety measures

Improve the reliability of the car

Improve the engine consumption

Change the external shape

I do not know

16. What type of car do you typically use?

GMC

Honda

Toyota

Nissan

Chevrolet

Mazda

Specify, please................................

17. What are the biggest concerns about buying a car?

Price

Safety

Operational issue

Reliability of the car

Air Pollution

Convenience

18. What would make you more likely to use a car?

Price

Safety

The power of the car (Engine efficiency)

Reliability of the car

Air Pollution

Convenience

19. In your words, what are the things you would like to improve in your car?

20. How would you rate the impact of the brand name of the Automobile company when you decide to buy a car

1) 2) 3) 4) 5) 6) 7)

21. How would you rate the impact of the car speed on you when you decide to buy a car

1) 2) 3) 4) 5) 6) 7)

22. How would you rate the impact of the transmission options when you decide to buy a car

1) 2) 3) 4) 5) 6) 7)

23. How would you rate the car size on your choice when you decide to buy a car

1) 2) 3) 4) 5) 6) 7)

24. How important is the convenience/automation system when you buy a car?

1) 2) 3) 4) 5) 6) 7)

25. How would you rate the safety when you buy a car?

1) 2) 3) 4) 5) 6) 7)

26. I think the efficiency of any car is important?

1) 2) 3) 4) 5) 6) 7)

27. If the CNGV is highly developed and equipped with necessary safety measures, I will buy one.

1) 2) 3) 4) 5) 6) 7)

28. If the CNGV is highly safe and reliable but costly compared to gasoline/diesel vehicles, I will buy one

1) 2) 3) 4) 5) 6) 7)

29. How confident do you agree that driving a CNGV is safe when an accident/crash occurred?

1) 2) 3) 4) 5) 6) 7)

30. How important is reliability when you decide to buy a car?

1) 2) 3) 4) 5) 6) 7)

31. How important is the effect of fuel “Resilience” when you decide to buy a car?

1) 2) 3) 4) 5) 6) 7)

32. How important is the availability of spare parts when you decide to buy a car?

1) 2) 3) 4) 5) 6) 7)

33. How would you rate your confidence if CNGV is continuously required a maintenance service more than usually current gasoline vehicles required?

1) 2) 3) 4) 5) 6) 7)

34. How would you rate the productivity (importance of traveling/driving time) of the car when you buy a car?

1) 2) 3) 4) 5) 6) 7)

35. How would you rate that the fuel cost of the vehicle is important and number one when you decide to buy a car?

1) 2) 3) 4) 5) 6) 7)

36. How would you rate the importance of fuel sources and infrastructure?

1) 2) 3) 4) 5) 6) 7)

37. If you know that CNGV has more operational problems than traditional transportation, how would you rate your confidence to buy one?

1) 2) 3) 4) 5) 6) 7)

38. How would you rate that the improvement in current transportation fuels (gasoline/diesel) has become essential?

1) 2) 3) 4) 5) 6) 7)

39. How would you rate your agreement that compressed natural gas vehicular(CNGV) contribute to global warming reduction

1) 2) 3) 4) 5) 6) 7)

40. How would you measure the impact of the transportation sector on greenhouse gases GHG's?

1) 2) 3) 4) 5) 6) 7)

41. How would you rate the effect of technology on the energy secure?

1) 2) 3) 4) 5) 6) 7)

42. How would you rate the effectiveness of the cost/benefit of renewable fuels (e.g., compressed natural gas) when you buy a car?

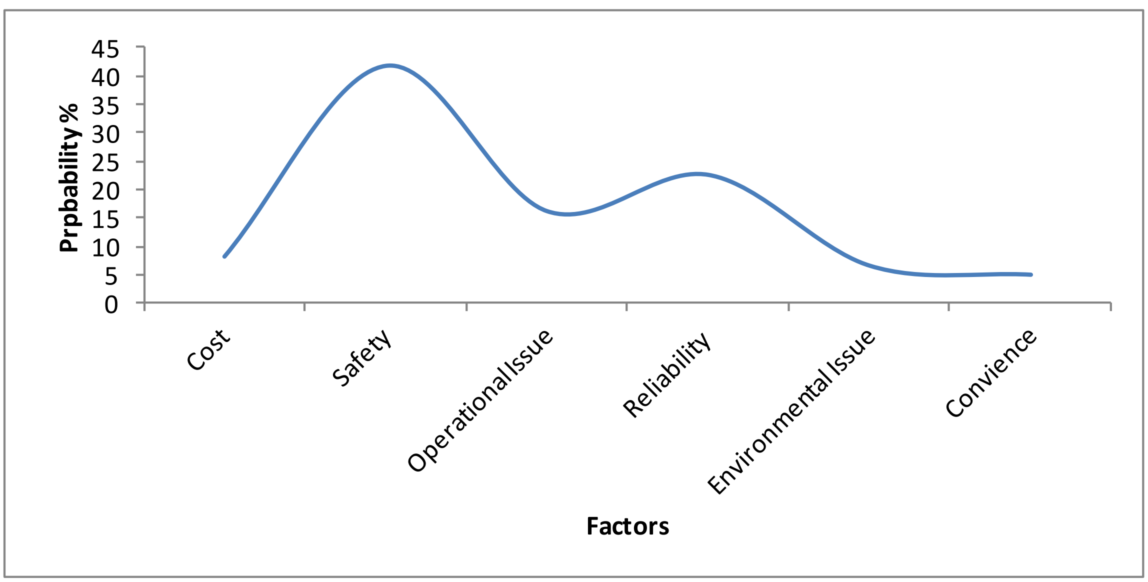
1) 2) 3) 4) 5) 6) 7)

43. How would you rate your acceptance of the price of traditional transportation fuels (gasoline, diesel)?

1) 2) 3) 4) 5) 6) 7)

44. How would you rate your first reaction to the compressed natural gas vehicle (CNGV)?

1) 2) 3) 4) 5) 6) 7)



Appendix F-1: The experimental distribution of factors

Appendix I:

Statistical Package for Social Science- SPSS

SPSS is a program designed to be used for statistical data presentation and analysis. As such, it is a powerful program that can manipulate and display data and perform a wide range of statistical operations. It has its origins as long ago as 1968, when the innovative software package SPSS was launched. SPSS continued under that name until 2010 when IBM acquired it. Initially, the name became PASW (Predictive Analytics Software), but with copyright issues settled, the latest version is known as IBM SPSS Statistics. The SPSS stands for Statistical Package for the Social Sciences. Other popular statistical software includes SAS, SYSTAT, and MINITAB. SPSS is well suited to the analysis of survey data. Like all statistical packages, SPSS works with a table of data with cases as rows and variables as columns (just like an Excel Table, you can import Excel tables directly to SPSS and vice versa). For survey data, each case is a respondent or questionnaire, and each variable is usually a numeric coding of the response to a single question on the survey instrument. Statistical packages prefer to analyze data in digital form, so one codes variables like GENDER as something like 1=male, 2=female (1=male, 0=female is better).

Variable Transformations: Sometimes, you want to change the coding of a variable or compute a new variable. RECODING AND COMPUTING procedures are used to improve the coding of a variable (maybe to collapse into fewer groups or reassign missing codes) and COMPUTE to compute new variables.

a. RECODE Changes coding of a variable. First, choose whether you want to put new codes in the same variable or a different (new) one. The latter preserves old codes and sets up a new variable with new codes. To preserve the original coding on the file, choose to recode "into a new variable." Then you must add a name for the new variable and press the CHANGE button. In either case, specify coding changes as follows. A select variable you want to change codes for and choose the "old and new values" option.

b. COMPUTE: To compute new variables from old. Choose transform, Compute. Enter a name for the new variable in the Target Variable box. Then enter a mathematical expression after the = sign indicating how the original variable is computed. A new variable is added. You may now use this variable in any procedure (refer to it by the name you assigned).

c. WEIGHTS: Weights can be used to adjust the sample to represent the population better or to expand cases from sample to the population. The HCMA file has two sets of weights: VSTWT adjusts and expands the sample to the population. The weights adjust the sample to the actual distribution, correcting for disproportionate sampling and different response rates.

In our research analysis, these expansion weights cannot be utilized when conducting statistical tests, as all hypotheses will be. Instead, an adjustment may be applied for disproportionate sampling, but then normalize weights back to the actual sample size, so statistical tests are based on the actual sample size.

d. The confidence interval for an average. In the DESCRIPTIVES procedure (Analyze, Descriptive Statistics, Descriptives) to compute the SE mean (Standard error of the mean). To get a 95% confidence interval, you add and subtract two standard errors from the sample mean.

e. Differences in means: which gives, for example, the age of the respondents (interval scale) by choosing dependent variable - the interval scale one = AGE, then independent or subgroup variable - nominal or ordinal scale with a small number of categories.

For the statistical test of hypotheses that all the subgroup means are determined. Also, you could perform the independent samples T-test.

f. Chi-square: Tests for relationships in a crosstab table between two nominal/ordinal variables. Are higher-income participants more likely to use CNGV? Note INCOME is measured in a small number of categories (nominal or ordinal) by running the Crosstab procedure (Analyze, Descriptive Statistics, Crosstabs) with INCOME. In Statistics, choose Chi-square.

g. Correlations: For two-interval scale variables. The procedure is to Analyze, Correlate, Bivariate.

The general rules for interpreting hypothesis tests defined

1. You test a NULL hypothesis: The NULL hypothesis is a statement of NO relationship between the two variables (e.g., means are the same for different subgroups, correlation is zero, no relationship between row and column variable in a crosstab table).

2. TESTS conducted at a given "confidence level" - most common is a 95% level. At this level, there is a 5% chance of incorrectly rejecting the null hypothesis when it is true. For the stricter test, use a 99% confidence level and look for SIG's <.01. Weaker, use 90% , SIG's < .10.

3. On the computer, the output looks for the Significance or Probability associated with the test. The F, T, Chi-square, etc. are the actual "test statistics," but the SIG's are what you need to complete the test. SIG gives the probability you could get results like those you see from a random sample of this size IF there were no relationship between the two variables in the population from which it is drawn. If a small probability (<.05), you REJECT the assumption of no relationship (the null hypothesis). For the 95% level, you REJECT null hypothesis if SIG <.05. If SIG > .05, you FAIL TO REJECT. Therefore, REJECTING NULL HYPOTHESIS means the data suggest that there is a relationship.

4. Hypothesis tests are evaluating whether you can generalize from information in the sample to conclude relationships in the population. With very small samples, most null hypotheses cannot be rejected, while with very large samples, almost any hypothesized relationship will be "statistically significant" - even when not practically significant. Be aware of the sample size (N) when making tests.

Risk	Nuclear Energy	Coal Energy	Renewable Energy	CNG
Knowledge				
Energy Knowledge	1.072(.302)	.081(.033)	.429(.308)	.111(.098)
Attitudinal				.161(.396)
Trust media	.045(.032)	-.009(.033)	.090(.034)	.119(.003)
Trust expert	-.053(.036)	.217(.037)	.177(.038)	.110(.552))
Trust Industry	.093(.030)	-.180(.032)	-.161(.032)	.108(.352)
Trust Government	.064(.082)	.153(.082)	.131(.083)	.486(.088)
Energy shortage	.162(.053)	.052(.054)	.245(.055)	.237(.501)
Nuclear regulated	.550(.081)			
Coal regulated		-.427(.082)		
Wind regulated			.147(.213)	
Solar regulated			.001(.223)	
Safety				.154(.479)
Operation				.206(.775)
Environmental impact	-.041(.059)	.272(.062)	.248(.059)	.119(.005)
Reliability				.122(.523)
Cost				.208(.198)
Demographic Indicator				
Age	.010(.003)	-.006(.003)	-.008(.003)	.114(.374)
Gender	-.588(.107)	.074(.106)	-.061(.108)	-.045(.725)
Level of Education	.012(.019)	-.015(.019)	.029(.020)	.039(.761)
Occupation				-.245(.053)
Income				.426(.002)
Likelihood ratio	424.75	674.89	270.72	365.12
McFadden's	.1103	.1747	.0759	.0936
log likelihood	-1753.231	-1593.681	-1648.886	-1600.562

Table I-1: The Public Support for Energy Policy Comparison with CNG

Note: Standard errors in parentheses-two-tailed test

Appendix I: Path Fit Model (PFM)

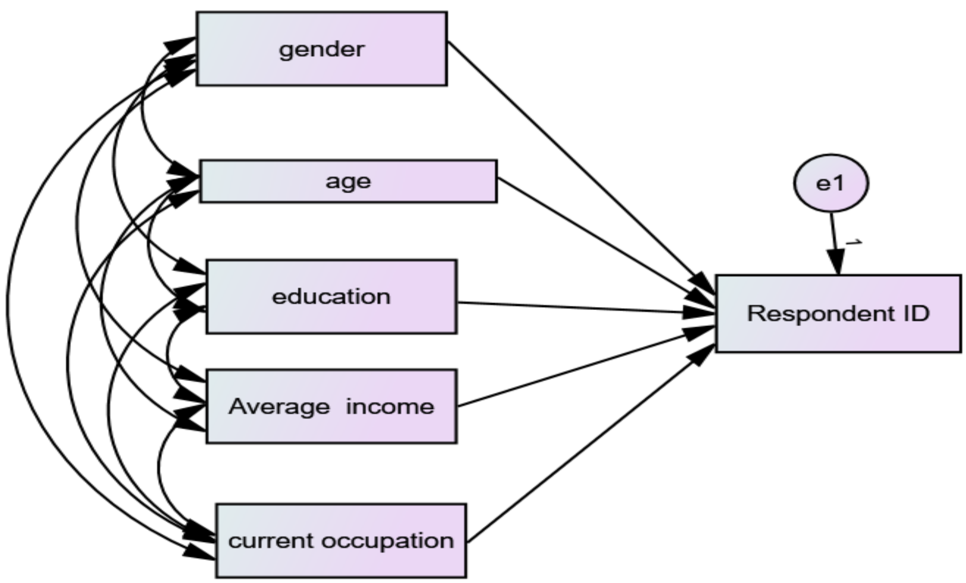


Figure I-1: Path fit model of the socio-demographic population

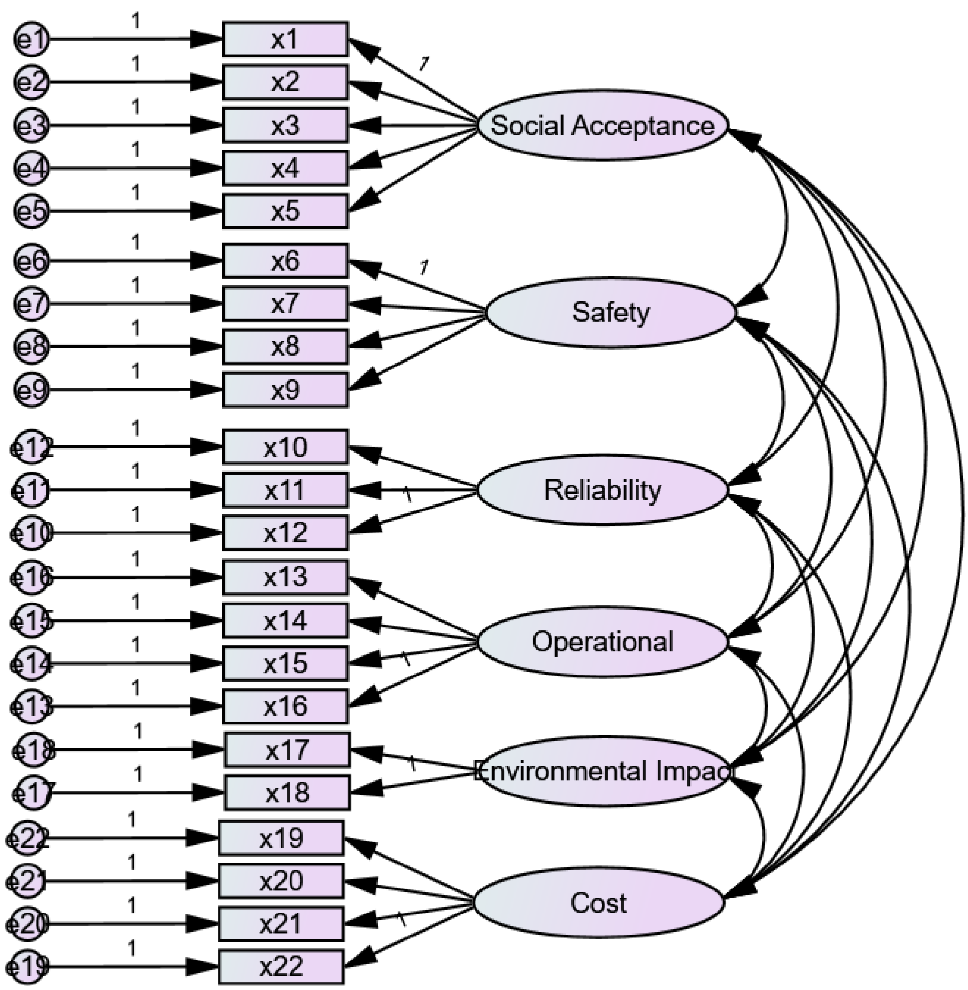


Figure I-2: Path model fit of six-correlated factors

Syntax Path Fit Model

Automation = () + Social + (1) e3
Brand = () + Social + (1) e2
Comfort = () + Social + (1) e4
Conclusion = () + (1) e39 + Safety
Convenience_1 = () + (1) Social + (1) e1
Convenience_2 = () + Social + (1) e22
Cost_1 = () + (1) Cost + (1) e18
Cost_2 = () + Cost + (1) e19
Cost_3 = () + Cost + (1) e20
Cost_4 = () + Cost + (1) e21
Cost_5 = () + Cost + (1) e32
Cost_6 = () + Cost + (1) e44
Efficiency_1 = () + (1) e10 + Operational
Efficiency_2 = () + (1) e11 + Operational
Efficiency_3 = () + Operational + (1) e12
Efficiency_4 = () + Operational + (1) e31
Enviro_1 = () + (1) Environmental + (1) e16
Enviro_2 = () + Environmental + (1) e17
Enviro_3 = () + Environmental + (1) e40
Enviro_4 = () + Environmental + (1) e41
Enviro_5 = () + Environmental + (1) e42
Enviro_6 = () + (1) e43 + Environmental
Maintainance_1 = () + (1) e25 + Reliability
Prductivity_4 = () + Operational + (1) e29
Productivity_1 = () + Operational + (1) e27
Productivity_2 = () + Operational + (1) e30
Productivity_3 = () + Operational + (1) e28
Productivity_6 = () + Operational + (1) e37
Readiness_1 = () + (1) e33 + Operational
Refueling = () + (1) e9 + (1) Operational
Refueling_2 = () + (1) e34 + Operational
Reliability_1 = () + (1) e13 + (1) Reliability
Reliability_2 = () + (1) e15 + Reliability
Reliability_3 = () + Reliability + (1) e26
Reliability_4 = () + (1) e14 + Reliability
Safety_1 = () + Safety + (1) e6
Safety_2 = () + Safety + (1) e7
Safety_3 = () + Safety + (1) e8
Safety_4 = () + Safety + (1) e24
Safety_5 = () + (1) e35 + Safety
Safety_6 = () + (1) e36 + Safety
Safety_7 = () + Safety + (1) e38
Speed = () + (1) e5 + (1) Safety

Safety <> Social
Operational <> Social
Reliability <> Social
Environmental <> Social
Cost <> Social
Operational <> Safety
Reliability <> Safety
Environmental <> Safety
Cost <> Safety
Reliability <> Operational
Environmental <> Operational
Cost <> Operational
Environmental <> Reliability
Cost <> Reliability
Cost <> Environmental

Social (0), ()
e1 (0), ()
e2 (0), ()
e3 (0), ()
e4 (0), ()
Safety (0), ()
e5 (0), ()
e6 (0), ()
e7 (0), ()
e8 (0), ()
Operational (0), ()
e9 (0), ()
e10 (0), ()
e11 (0), ()
e12 (0), ()
Reliability (0), ()
e13 (0), ()
e14 (0), ()
e15 (0), ()
Environmental (0), ()
e16 (0), ()
e17 (0), ()
Cost (0), ()
e18 (0), ()
e19 (0), ()
e20 (0), ()
e21 (0), ()
e22 (0), ()
e24 (0), ()

e25 (0), ()
e26 (0), ()
e27 (0), ()
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e33 (0), ()
e34 (0), ()
e35 (0), ()
e36 (0), ()
e37 (0), ()
e38 (0), ()
e39 (0), ()
e40 (0), ()
e41 (0), ()
e42 (0), ()
e43 (0), ()
e44 (0), ()

	Mean	S.E.	S.D.	C.S.	Skewness	Kurtosis	Min	Max
Regression weights								
Brand<--Social	7.614	1.517	7.298	1.021	1.221	1.032	-5.849	31.106
Automation<--Social	5.476	0.530	2.460	1.023	0.377	-0.987	0.358	11.243
Comfort<--Social	3.792	0.400	1.935	1.021	0.646	-0.349	-0.369	8.892
Safety_1<--Safety	-1.723	0.173	0.917	1.018	0.093	-0.496	-3.827	1.193
Safety_2<--Safety	0.316	0.336	1.584	1.022	-0.305	-0.308	-4.417	3.735
Safety_3<--Safety	2.218	0.135	0.730	1.017	0.012	-0.682	-0.009	4.252
Efficiency_2<--Operational	8.174	0.441	1.999	1.024	-0.800	-0.378	1.868	11.739
Efficiency_3<--Operational	6.503	0.420	1.874	1.025	-0.743	-0.452	1.504	9.399
Reliability_4<--Reliability	-0.037	0.008	0.066	1.007	0.088	0.174	-0.283	0.208
Reliability_2<--Reliability	-0.555	0.039	0.185	1.022	-0.809	-0.320	-1.084	-0.179
Enviro_2<--Environmental	0.706	0.017	0.109	1.012	0.178	-0.397	0.375	1.073
Cost_2<--Cost	2.240	0.084	0.496	1.014	0.476	-0.068	0.859	3.929
Cost_3<--Cost	0.464	0.058	0.347	1.014	0.227	0.348	-0.480	1.928
Cost_4<--Cost	0.318	0.037	0.249	1.011	0.174	-0.052	-0.630	1.280
Convenience_2<--Social	-5.849	1.198	6.243	1.018	-0.971	1.297	-26.976	10.761
Safety_4<--Safety	8.128	0.409	1.901	1.023	-0.460	0.337	1.202	11.839
Maintainance_1<--Reliability	-0.134	0.008	0.052	1.011	-0.381	0.098	-0.342	0.019
Reliability_3<--Reliability	0.132	0.027	0.165	1.013	0.366	-0.118	-0.335	0.613
Productivity_3<--Operational	-0.546	0.217	1.091	1.020	0.241	-0.239	-3.202	2.161
Prductivity_4<--Operational	-0.664	0.217	1.043	1.021	0.269	-0.031	-3.162	2.938
Productivity_2<--Operational	-0.227	0.193	0.942	1.021	-0.100	-0.608	-2.853	2.057
Efficiency_4<--Operational	6.035	0.317	1.459	1.023	-0.489	-0.910	1.848	8.284
Cost_5<--Cost	1.344	0.043	0.318	1.009	0.598	0.604	0.541	2.677
Readiness_1<--Operational	4.621	0.914	4.745	1.018	-1.102	1.275	-12.805	16.616
Safety_5<--Safety	-2.669	0.303	1.426	1.022	0.251	-1.234	-5.072	0.700
Safety_6<--Safety	19.636	1.364	7.535	1.016	0.543	0.008	-2.351	43.554
Safety_7<--Safety	3.760	0.284	1.318	1.023	-0.541	-0.273	-0.024	6.345
Conclusion<--Safety	5.312	0.374	1.809	1.021	-0.966	0.523	-0.834	8.507
Enviro_3<--Environmental	0.913	0.021	0.123	1.015	-0.211	-0.173	0.522	1.251
Enviro_4<--Environmental	-0.126	0.024	0.205	1.007	0.175	0.393	-0.827	0.598
Enviro_5<--Environmental	-0.441	0.017	0.119	1.011	0.330	-0.364	-0.757	-0.114
Enviro_6<--Environmental	-0.069	0.024	0.158	1.011	0.269	0.116	-0.562	0.663
Cost_6<--Cost	-0.011	0.034	0.242	1.010	0.618	0.159	-0.633	0.839
Productivity_1<--Operational	-4.491	0.285	1.329	1.023	0.482	-0.202	-7.249	-0.314

Efficiency_1<--Operational	9.623	0.447	2.065	1.023	-1.090	0.502	2.780	12.958
Productivity_6<--Operational	7.682	0.413	1.870	1.024	-0.923	-0.302	2.063	10.357
Refueling_2<--Operational	-0.011	0.241	1.183	1.020	-0.037	-0.972	-3.014	2.798

Intercepts

Convenience_1	5.671	0.015	0.108	1.009	0.252	0.189	5.331	6.057
Brand	5.534	0.123	0.753	1.013	0.634	0.986	3.766	8.172
Automation	5.444	0.024	0.145	1.013	-0.243	0.052	4.982	5.888
Comfort	4.663	0.023	0.140	1.013	-0.347	0.058	4.221	5.097
Speed	4.818	0.012	0.098	1.007	-0.123	-0.103	4.503	5.155
Safety_1	2.727	0.016	0.109	1.011	0.259	0.010	2.352	3.056
Safety_2	5.078	0.019	0.123	1.012	-0.239	0.066	4.549	5.444
Safety_3	1.714	0.014	0.098	1.010	-0.113	0.018	1.416	2.050
Refueling	5.613	0.013	0.095	1.009	-0.078	-0.072	5.228	5.973
Efficiency_1	4.259	0.037	0.200	1.017	-0.308	-0.655	3.708	4.684
Efficiency_2	5.543	0.021	0.136	1.012	-0.172	0.501	5.028	6.119
Efficiency_3	5.776	0.027	0.142	1.019	-0.999	0.726	5.296	6.145
Reliability_1	4.203	0.092	0.619	1.011	0.117	0.158	2.104	6.659
Reliability_4	4.677	0.014	0.100	1.010	0.221	-0.409	4.389	4.990
Reliability_2	3.676	0.021	0.132	1.013	-0.089	-0.044	3.179	4.131
Enviro_1	5.344	0.025	0.136	1.016	-0.395	0.440	4.846	5.688
Enviro_2	6.004	0.017	0.107	1.013	-0.506	0.112	5.609	6.279
Cost_1	5.405	0.026	0.147	1.016	0.102	-0.732	5.047	5.835
Cost_2	5.721	0.022	0.155	1.010	-0.123	0.199	5.154	6.205
Cost_3	2.271	0.020	0.132	1.011	0.442	0.199	1.902	2.690
Cost_4	2.276	0.015	0.109	1.010	0.511	0.503	1.912	2.741
Convenience_2	5.712	0.134	0.775	1.015	-0.851	1.702	2.559	8.392
Safety_4	3.959	0.025	0.155	1.013	-0.430	0.229	3.448	4.414
Maintainance_1	2.355	0.012	0.078	1.012	-0.027	-0.058	2.095	2.618
Reliability_3	3.678	0.029	0.186	1.012	-0.014	0.043	3.061	4.408
Productivity_1	2.877	0.017	0.110	1.012	0.233	-0.180	2.511	3.214
Productivity_3	4.566	0.012	0.100	1.007	0.295	-0.225	4.255	4.911
Prductivity_4	4.595	0.019	0.118	1.013	0.095	-0.493	4.262	4.982
Productivity_2	4.616	0.011	0.089	1.008	0.099	0.374	4.344	5.058
Efficiency_4	4.328	0.013	0.095	1.009	-0.247	-0.119	3.977	4.686
Cost_5	4.429	0.022	0.138	1.013	-0.297	-0.267	4.041	4.786
Readiness_1	2.892	0.075	0.482	1.012	0.354	-0.273	1.525	4.512

Refueling_2	2.618	0.022	0.141	1.013	0.044	-0.350	2.233	3.065
Safety_5	2.328	0.018	0.118	1.012	0.228	-0.190	1.877	2.709
Safety_6	5.683	0.151	0.990	1.012	0.481	0.384	2.703	9.754
Productivity_6	5.396	0.019	0.126	1.011	0.026	-0.038	4.929	5.922
Safety_7	5.573	0.018	0.107	1.014	-0.033	-0.273	5.260	5.883
Conclusion	5.122	0.033	0.203	1.013	0.207	0.327	4.445	5.773
Enviro_3	5.813	0.021	0.135	1.012	-0.239	-0.329	5.394	6.174
Enviro_4	4.793	0.031	0.197	1.013	0.219	0.254	4.110	5.450
Enviro_5	5.529	0.012	0.086	1.010	0.438	0.388	5.224	5.861
Enviro_6	5.378	0.017	0.108	1.012	-0.050	-0.131	5.063	5.774
Cost_6	4.782	0.018	0.111	1.013	0.022	-0.329	4.375	5.069

Covariances

Social<->Safety	0.017	0.002	0.011	1.019	1.742	3.318	0.000	0.085
Social<->Operational	0.011	0.002	0.008	1.018	1.658	2.705	-0.003	0.056
Social<->Reliability	-0.187	0.021	0.107	1.019	-0.947	0.456	-0.623	0.007
Social<->Environmental	0.090	0.009	0.043	1.019	0.583	-0.315	-0.003	0.250
Cost<->Social	0.052	0.005	0.026	1.019	0.582	-0.418	-0.007	0.149
Safety<->Operational	0.012	0.002	0.009	1.019	2.677	8.888	0.002	0.081
Safety<->Reliability	-0.125	0.012	0.068	1.015	-1.092	1.934	-0.511	0.022
Safety<->Environmental	0.071	0.005	0.028	1.013	1.724	5.040	0.009	0.268
Cost<->Safety	0.032	0.003	0.015	1.015	1.422	3.958	-0.002	0.124
Operational<->Reliability	-0.140	0.014	0.072	1.020	-1.111	1.013	-0.519	-0.016
Operational<->Environmental	0.075	0.006	0.029	1.018	1.261	2.177	0.026	0.285
Cost<->Operational	0.035	0.002	0.014	1.015	1.221	1.967	0.007	0.111
Reliability<->Environmental	-1.282	0.094	0.444	1.022	-0.108	-0.917	-2.738	-0.410
Cost<->Reliability	-0.605	0.045	0.222	1.020	-1.109	1.459	-1.555	-0.203
Cost<->Environmental	0.338	0.015	0.079	1.018	0.353	-0.039	0.133	0.629

Variances

Social	0.035	0.005	0.024	1.019	0.927	-0.008	0.003	0.120
Safety	0.015	0.002	0.011	1.016	3.173	13.564	0.002	0.109
Operational	0.011	0.002	0.008	1.019	2.445	7.981	0.002	0.087
Reliability	3.952	0.383	1.810	1.022	0.082	-0.358	0.403	9.528
Environmental	0.747	0.031	0.172	1.016	0.272	0.237	0.314	1.441

Cost	0.225	0.012	0.065	1.017	0.090	-0.721	0.058	0.415
e1	0.874	0.030	0.175	1.014	0.594	-0.231	0.505	1.410
e2	25.473	0.674	4.731	1.010	0.258	-0.193	14.093	43.492
e3	0.491	0.043	0.229	1.018	-0.266	0.002	-0.242	1.101
e4	1.022	0.025	0.178	1.010	0.207	-0.175	0.552	1.599
e5	0.653	0.012	0.099	1.007	0.807	1.016	0.385	1.081
e6	0.784	0.023	0.143	1.013	0.202	-0.500	0.341	1.236
e7	0.886	0.024	0.177	1.009	1.004	1.101	0.430	1.521
e8	0.649	0.016	0.109	1.011	0.271	0.066	0.347	1.097
e9	0.877	0.019	0.138	1.010	0.219	-0.404	0.480	1.309
e10	0.830	0.025	0.160	1.012	0.206	-0.279	0.398	1.361
e11	0.767	0.021	0.144	1.010	0.708	0.793	0.403	1.471
e12	0.468	0.011	0.082	1.010	0.310	0.047	0.250	0.821
e13	23.914	0.545	4.020	1.009	0.073	-0.057	13.054	41.075
e14	0.876	0.019	0.141	1.009	0.123	-0.390	0.508	1.333
e15	0.433	0.035	0.207	1.015	0.113	0.049	-0.257	1.091
e16	0.272	0.016	0.088	1.017	1.069	1.894	0.029	0.737
e17	0.309	0.009	0.064	1.010	0.832	1.931	0.145	0.667
e18	0.655	0.025	0.146	1.014	0.584	0.394	0.317	1.243
e19	0.575	0.039	0.213	1.017	0.587	1.315	-0.050	1.342
e20	0.910	0.017	0.141	1.008	0.722	0.538	0.542	1.506
e21	0.783	0.022	0.143	1.012	0.982	1.072	0.450	1.345
e22	27.655	1.354	6.866	1.019	0.840	-0.175	13.167	47.942
e24	0.867	0.033	0.190	1.015	0.199	-0.417	0.394	1.509
e25	0.373	0.011	0.076	1.011	1.301	3.150	0.204	0.792
e26	2.446	0.065	0.434	1.011	0.598	0.380	1.334	4.826
e27	0.715	0.021	0.129	1.013	0.607	-0.045	0.308	1.160
e28	0.884	0.019	0.144	1.009	0.091	-0.437	0.506	1.354
e29	0.941	0.022	0.159	1.009	0.443	0.069	0.539	1.452
e30	0.606	0.025	0.132	1.017	0.516	-0.358	0.315	1.048
e31	0.449	0.010	0.076	1.009	0.842	2.196	0.257	0.864
e32	0.669	0.022	0.139	1.012	0.098	-0.171	0.263	1.118
e33	15.472	0.303	2.421	1.008	0.328	0.206	8.254	26.471
e34	1.237	0.043	0.253	1.014	0.653	0.069	0.674	2.120
e35	0.854	0.017	0.137	1.008	0.584	1.095	0.474	1.580
e36	63.327	1.700	11.597	1.011	0.540	0.796	30.240	108.003
e37	0.756	0.021	0.138	1.012	0.306	-0.251	0.382	1.266
e39	2.025	0.041	0.313	1.008	0.428	-0.057	1.194	3.152

e40	0.433	0.014	0.097	1.011	0.240	-0.637	0.173	0.737
e41	2.136	0.064	0.396	1.013	0.520	0.090	1.259	3.618
e42	0.467	0.012	0.078	1.011	0.327	0.204	0.244	0.833
e43	0.659	0.020	0.124	1.013	0.757	0.401	0.410	1.148
e44	0.645	0.015	0.107	1.009	0.539	-0.048	0.381	0.986
e38	0.675	0.026	0.154	1.014	0.546	0.041	0.321	1.155

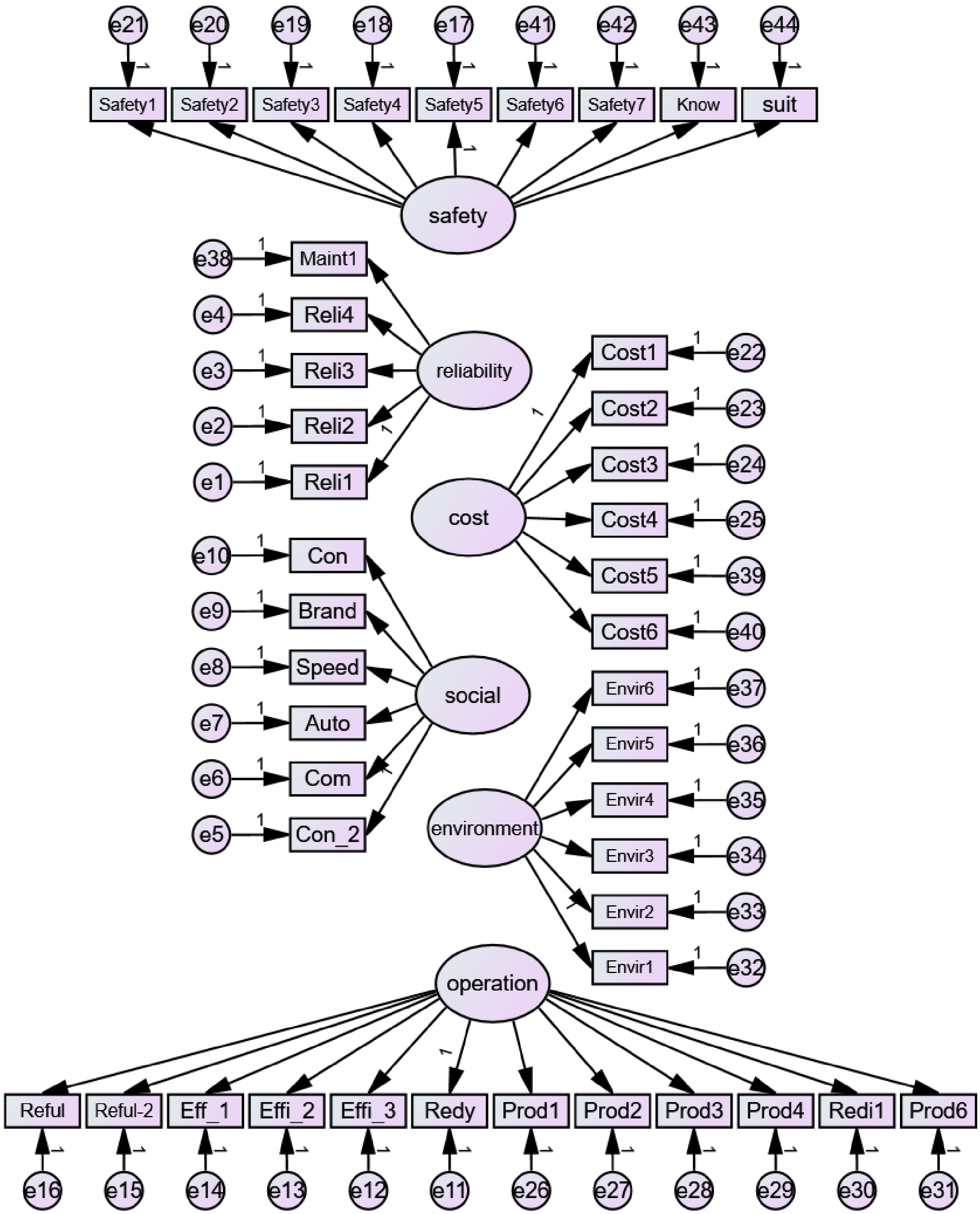

Figure I-3: Designed path model fit of uncorrelated factors

Models

Maximum Likelihood Estimates

Regression Weights: (Uncorrelated factors)

			Estimate	S.E.	C.R.	P
Convenience_1	<---	Social	1.000			
Brand	<---	Social	10.372	19.931	.520	.603
Speed	<---	Social	-1.028	2.345	-.438	.661
Automation	<---	Social	19.358	37.326	.519	.604
Safety_1	<---	Safety	1.000			
Safety_2	<---	Safety	-.144	.775	-.186	.852
Safety_3	<---	Safety	-1.247	1.084	-1.150	.250
Safety_4	<---	Safety	-4.942	3.722	-1.328	.184
Reliability_3	<---	Reliability	1.000			
Reliability_2	<---	Reliability	-2.695	2.278	-1.183	.237
Reliability_1	<---	Reliability	1.000			
Productivity_1	<---	Operational	1.000			
Efficiency_3	<---	Operational	2.657	1.893	1.403	.160
Efficiency_2	<---	Operational	2.183	1.701	1.283	.199
Efficiency_1	<---	Operational	1.000			
Enviro_2	<---	Environmental	1.000			
Enviro_1	<---	Environmental	1.528	.296	5.169	***
Cost_4	<---	Cost	1.000			
Cost_3	<---	Cost	1.516	.786	1.927	.054
Cost_2	<---	Cost	4.445	2.046	2.173	.030

			Estimate	S.E.	C.R.	P
Cost_1	<---	Cost	1.000			
Comfort	<---	Social	6.438	11.255	.572	.567
Convenience_2	<---	Social	-11.728	22.223	-.528	.598
Convenience_3	<---	Social	4.180	7.378	.567	.571
Type	<---	Social	-.154	1.182	-.131	.896
Safety_5	<---	Safety	1.749	1.409	1.242	.214
Safety_6	<---	Safety	-4.077	7.050	-.578	.563
Safety_7	<---	Safety	-2.517	1.862	-1.352	.177
Conclusion	<---	Safety	-1.871	1.782	-1.050	.294
Reliability_4	<---	Reliability	-.289	.524	-.551	.581
Maintainance_1	<---	Reliability	-1.125	.929	-1.211	.226
Readiness	<---	Reliability	-1.043	.921	-1.133	.257
Efficiency_4	<---	Operational	-32.626	116.082	-.281	.779
Productivity_2	<---	Operational	1.305	1.042	1.252	.210
Enviro_3	<---	Environmental	1.409	.276	5.110	***
Enviro_4	<---	Environmental	-.037	.369	-.101	.920
Enviro_5	<---	Environmental	-.598	.195	-3.066	.002
Enviro_6	<---	Environmental	-.130	.209	-.621	.534
Cost_5	<---	Cost	2.360	1.002	2.355	.019
Cost_6	<---	Cost	.289	.485	.596	.551
Productivity_3	<---	Operational	.398	.807	.493	.622
Prductivity_4	<---	Operational	-.859	.943	-.911	.362
Refueling	<---	Reliability	-.947	.874	-1.083	.279

			Estimate	S.E.	C.R.	P
Refueling_2	<---	Cost	-.763	.687	-1.110	.267
Readiness_1	<---	Reliability	-.835	2.114	-.395	.693

Standardized Regression Weights: (Uncorrelated factors)

			Estimate
Convenience_1	<---	Social	.065
Brand	<---	Social	.129
Speed	<---	Social	-.074
Automation	<---	Social	1.131
Safety_1	<---	Safety	.215
Safety_2	<---	Safety	-.028
Safety_3	<---	Safety	-.283
Safety_4	<---	Safety	-.775
Reliability_3	<---	Reliability	.191
Reliability_2	<---	Reliability	-.746
Reliability_1	<---	Reliability	.060
Enviro_2	<---	Environmental	.678
Enviro_1	<---	Environmental	.854
Cost_4	<---	Cost	.259
Cost_3	<---	Cost	.364
Cost_2	<---	Cost	.864
Cost_1	<---	Cost	.278
Comfort	<---	Social	.345
Convenience_2	<---	Social	-.139

			Estimate
Convenience_3	<---	Social	.276
Type	<---	Social	-.015
Safety_5	<---	Safety	.359
Safety_6	<---	Safety	-.096
Safety_7	<---	Safety	-.558
Conclusion	<---	Safety	-.229
Reliability_4	<---	Reliability	-.095
Maintainance_1	<---	Reliability	-.518
Readiness	<---	Reliability	-.355
Enviro_3	<---	Environmental	.790
Enviro_4	<---	Environmental	-.014
Enviro_5	<---	Environmental	-.436
Enviro_6	<---	Environmental	-.086
Cost_5	<---	Cost	.563
Cost_6	<---	Cost	.087
Refueling	<---	Reliability	-.302
Refueling_2	<---	Cost	-.171
Readiness_1	<---	Reliability	-.065

Intercepts: (Uncorrelated factors)

	Estimate	S.E.	C.R.	P
Convenience_1	5.698	.117	48.558	***
Brand	5.571	.607	9.172	***
Speed	4.825	.105	45.947	***

	Estimate	S.E.	C.R.	P
Automation	5.444	.130	41.995	***
Safety_1	2.730	.109	25.046	***
Safety_2	5.079	.118	42.960	***
Safety_3	1.762	.103	17.108	***
Safety_4	3.952	.149	26.505	***
Reliability_3	3.714	.198	18.777	***
Reliability_2	3.635	.136	26.661	***
Reliability_1	4.381	.625	7.009	***
Productivity_1	2.873	.118	24.308	***
Efficiency_3	5.746	.103	55.548	***
Efficiency_2	5.492	.141	38.957	***
Efficiency_1	4.222	.147	28.637	***
Enviro_2	5.984	.100	59.899	***
Enviro_1	5.302	.121	43.783	***
Cost_4	2.302	.114	20.245	***
Cost_3	2.286	.123	18.620	***
Cost_2	5.683	.151	37.509	***
Cost_1	5.365	.106	50.640	***
Comfort	4.667	.141	33.052	***
Convenience_2	5.921	.638	9.285	***
Convenience_3	5.905	.115	51.495	***
Type	4.333	.078	55.282	***

	Estimate	S.E.	C.R.	P
Safety_5	2.381	.114	20.866	***
Safety_6	5.825	.997	5.846	***
Safety_7	5.571	.105	52.838	***
Conclusion	5.111	.191	26.785	***
Reliability_4	4.698	.115	41.010	***
Maintainance_1	2.349	.082	28.620	***
Readiness	5.667	.111	51.118	***
Efficiency_4	4.302	.105	41.015	***
Productivity_2	4.635	.091	50.761	***
Enviro_3	5.778	.121	47.875	***
Enviro_4	4.857	.181	26.861	***
Enviro_5	5.556	.093	59.939	***
Enviro_6	5.381	.102	52.613	***
Cost_5	4.429	.123	35.903	***
Cost_6	4.762	.098	48.646	***
Productivity_3	4.556	.117	38.906	***
Prductivity_4	4.635	.116	39.945	***
Refueling	5.635	.118	47.659	***
Refueling_2	2.587	.131	19.715	***
Readiness_1	2.714	.486	5.584	***

Variances: (Uncorrelated factors)

	Estimate	S.E.	C.R.	P	Label

	Estimate	S.E.	C.R.	P	Label
Social	.004	.013	.280	.779	
Environmental	.034	.048	.709	.479	
Reliability	.088	.139	.638	.523	
Operational	-.003	.011	-.286	.775	
Safety	.284	.102	2.791	.005	
Cost	.054	.042	1.286	.198	
e2	.850	.153	5.572	***	
e3	22.492	4.039	5.569	***	
e4	.680	.122	5.573	***	
e5	-.291	1.095	-.266	.790	
e6	.703	.129	5.446	***	
e7	.866	.156	5.566	***	
e8	.605	.113	5.341	***	
e9	.550	.325	1.693	.091	
e10	2.338	.428	5.457	***	
e11	.511	.302	1.693	.090	
e12	24.131	4.340	5.560	***	
e13	.869	.155	5.608	***	
e14	.685	.148	4.641	***	
e15	1.247	.232	5.377	***	
e16	1.351	.240	5.622	***	
e17	.335	.072	4.624	***	

	Estimate	S.E.	C.R.	P	Label
e18	.246	.098	2.502	.012	
e19	.748	.137	5.455	***	
e20	.811	.154	5.258	***	
e21	.361	.358	1.008	.313	
e22	.642	.118	5.430	***	
e23	1.089	.229	4.757	***	
e24	24.718	4.442	5.565	***	
e25	.753	.144	5.238	***	
e26	.381	.068	5.568	***	
e27	.703	.136	5.162	***	
e28	61.009	11.002	5.545	***	
e29	.474	.120	3.969	***	
e30	2.139	.394	5.427	***	
e31	.806	.146	5.541	***	
e32	.306	.076	4.031	***	
e33	.666	.131	5.080	***	
e34	3.893	12.049	.323	.747	
e35	.522	.096	5.419	***	
e36	.339	.097	3.495	***	
e37	2.027	.364	5.568	***	
e38	.431	.081	5.323	***	
e39	.644	.116	5.560	***	

	Estimate	S.E.	C.R.	P	Label
e40	.644	.155	4.162	***	
e41	.590	.106	5.556	***	
e42	.851	.153	5.564	***	
e43	.837	.151	5.545	***	
e44	.788	.150	5.244	***	
e45	1.036	.188	5.520	***	
e46	14.587	2.626	5.555	***	

Squared Multiple Correlations: (Uncorrelated factors)

	Estimate
Readiness_1	.004
Refueling_2	.029
Refueling	.091
Prductivity_4	-.003
Productivity_3	-.001
Cost_6	.008
Cost_5	.317
Enviro_6	.007
Enviro_5	.190
Enviro_4	.000
Enviro_3	.624
Productivity_2	-.010
Efficiency_4	-4.709
Readiness	.126

	Estimate
Maintainance_1	.268
Reliability_4	.009
Conclusion	.053
Safety_7	.312
Safety_6	.009
Safety_5	.129
Type	.000
Convenience_3	.076
Convenience_2	.019
Comfort	.119
Cost_1	.077
Cost_2	.746
Cost_3	.132
Cost_4	.067
Enviro_1	.730
Enviro_2	.459
Efficiency_1	-.002
Efficiency_2	-.012
Efficiency_3	-.032
Productivity_1	-.003
Reliability_1	.004
Reliability_2	.557
Reliability_3	.036

	Estimate
Safety_4	.601
Safety_3	.080
Safety_2	.001
Safety_1	.046
Automation	1.279
Speed	.005
Brand	.017
Convenience_1	.004

Model Fit Summary for Uncorrelated factors

CMIN

Model	RMSEA	CMIN	DF	CFI	CMIN/DF
Default model	.144	2162.532	948	.117	2.281
Independence model	.150	2366.172	990	.000	2.390

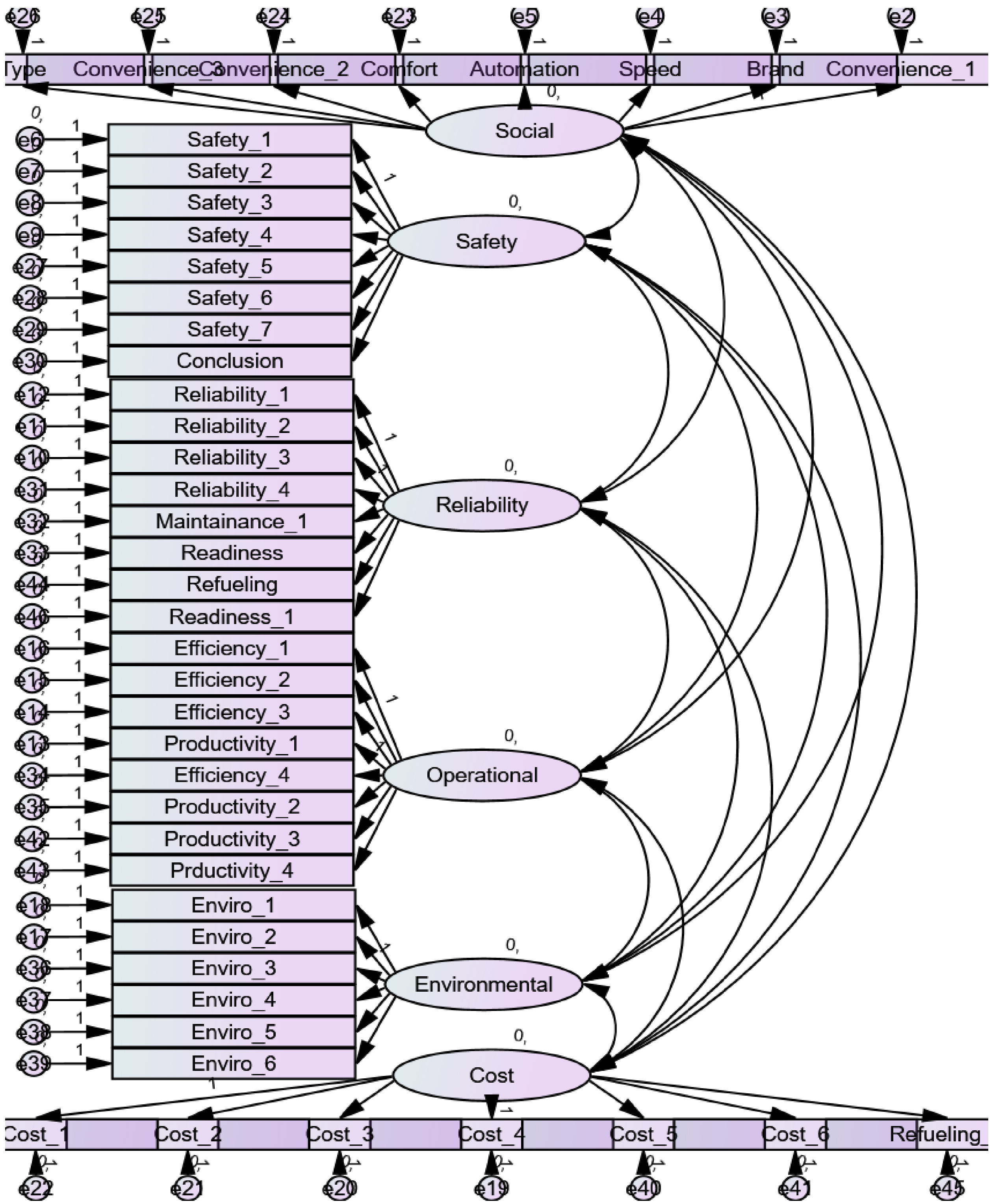

Figure I-4: Designed Path fit model (PFM) of six-correlated factors

Models

Maximum Likelihood Estimates

Regression Weights(Correlated factors):

			Estimate	S.E.	C.R.	P	Label
Convenience_1	<---	Social	1.000				
Brand	<---	Social	-.847	2.060	-.411	.681	
Speed	<---	Social	.740	.441	1.678	.093	
Automation	<---	Social	1.839	.790	2.327	.020	
Safety_1	<---	Safety	1.000				
Safety_2	<---	Safety	.072	.438	.164	.870	
Safety_3	<---	Safety	-.738	.464	-1.588	.112	
Safety_4	<---	Safety	-2.531	1.066	-2.373	.018	
Reliability_3	<---	Reliability	1.000				
Reliability_2	<---	Reliability	-3.516	3.064	-1.148	.251	
Reliability_1	<---	Reliability	1.000				
Productivity_1	<---	Operational	1.000				
Efficiency_3	<---	Operational	18.020	52.113	.346	.730	
Efficiency_2	<---	Operational	22.608	65.405	.346	.730	
Efficiency_1	<---	Operational	1.000				
Enviro_2	<---	Environmental	1.000				
Enviro_1	<---	Environmental	1.477	.236	6.254	***	
Cost_4	<---	Cost	1.000				
Cost_3	<---	Cost	.794	.521	1.524	.127	

			Estimate	S.E.	C.R.	P	Label
Cost_2	<---	Cost	3.596	1.098	3.276	.001	
Cost_1	<---	Cost	1.000				
Comfort	<---	Social	1.193	.639	1.868	.062	
Convenience_2	<---	Social	-3.313	2.447	-1.354	.176	
Convenience_3	<---	Social	2.023	.822	2.460	.014	
Type	<---	Social	.197	.272	.723	.470	
Safety_5	<---	Safety	.905	.533	1.697	.090	
Safety_6	<---	Safety	-9.069	4.926	-1.841	.066	
Safety_7	<---	Safety	-1.213	.586	-2.070	.038	
Conclusion	<---	Safety	-2.423	1.123	-2.158	.031	
Reliability_4	<---	Reliability	-.990	.997	-.993	.321	
Maintainance_1	<---	Reliability	-1.032	.959	-1.077	.282	
Readiness	<---	Reliability	-1.829	1.642	-1.114	.265	
Efficiency_4	<---	Operational	19.600	56.674	.346	.729	
Productivity_2	<---	Operational	.782	3.663	.214	.831	
Enviro_3	<---	Environmental	1.307	.233	5.598	***	
Enviro_4	<---	Environmental	-.129	.342	-.376	.707	
Enviro_5	<---	Environmental	-.633	.177	-3.576	***	
Enviro_6	<---	Environmental	-.037	.194	-.191	.849	
Cost_5	<---	Cost	2.284	.759	3.011	.003	
Cost_6	<---	Cost	.102	.384	.266	.790	
Productivity_3	<---	Operational	-2.501	8.109	-.308	.758	

			Estimate	S.E.	C.R.	P	Label
Prductivity_4	<---	Operational	4.654	13.923	.334	.738	
Refueling	<---	Reliability	-1.651	1.510	-1.093	.274	
Refueling_2	<---	Cost	-.012	.513	-.023	.982	
Readiness_1	<---	Reliability	-.661	2.320	-.285	.776	

Standardized Regression Weights:(Correlated factors)

			Estimate
Convenience_1	<---	Social	.294
Brand	<---	Social	-.048
Speed	<---	Social	.242
Automation	<---	Social	.487
Safety_1	<---	Safety	.315
Safety_2	<---	Safety	.021
Safety_3	<---	Safety	-.246
Safety_4	<---	Safety	-.583
Reliability_3	<---	Reliability	.136
Reliability_2	<---	Reliability	-.691
Reliability_1	<---	Reliability	.043
Productivity_1	<---	Operational	.031
Efficiency_3	<---	Operational	.618
Efficiency_2	<---	Operational	.569
Efficiency_1	<---	Operational	.024
Enviro_2	<---	Environmental	.699

			Estimate
Enviro_1	<---	Environmental	.852
Cost_4	<---	Cost	.298
Cost_3	<---	Cost	.220
Cost_2	<---	Cost	.808
Cost_1	<---	Cost	.323
Comfort	<---	Social	.290
Convenience_2	<---	Social	-.178
Convenience_3	<---	Social	.605
Type	<---	Social	.086
Safety_5	<---	Safety	.272
Safety_6	<---	Safety	-.313
Safety_7	<---	Safety	-.395
Conclusion	<---	Safety	-.436
Reliability_4	<---	Reliability	-.232
Maintainance_1	<---	Reliability	-.337
Readiness	<---	Reliability	-.442
Efficiency_4	<---	Operational	.647
Productivity_2	<---	Operational	.030
Enviro_3	<---	Environmental	.756
Enviro_4	<---	Environmental	-.050
Enviro_5	<---	Environmental	-.477
Enviro_6	<---	Environmental	-.025

			Estimate
Cost_5	<---	Cost	.631
Cost_6	<---	Cost	.035
Productivity_3	<---	Operational	-.076
Prductivity_4	<---	Operational	.142
Refueling	<---	Reliability	-.374
Refueling_2	<---	Cost	-.003
Readiness_1	<---	Reliability	-.036

Intercepts (Correlated factors)

	Estimate	S.E.	C.R.	P	Label
Convenience_1	5.698	.117	48.795	***	
Brand	5.571	.607	9.171	***	
Speed	4.825	.105	45.947	***	
Automation	5.444	.130	42.024	***	
Safety_1	2.730	.109	25.046	***	
Safety_2	5.079	.118	42.960	***	
Safety_3	1.762	.103	17.108	***	
Safety_4	3.952	.149	26.503	***	
Reliability_3	3.714	.197	18.888	***	
Reliability_2	3.635	.136	26.661	***	
Reliability_1	4.381	.629	6.968	***	
Productivity_1	2.873	.116	24.732	***	
Efficiency_3	5.746	.103	55.528	***	

	Estimate	S.E.	C.R.	P	Label
Efficiency_2	5.492	.141	38.972	***	
Efficiency_1	4.222	.148	28.433	***	
Enviro_2	5.984	.100	59.897	***	
Enviro_1	5.302	.121	43.780	***	
Cost_4	2.302	.114	20.115	***	
Cost_3	2.286	.123	18.620	***	
Cost_2	5.683	.152	37.507	***	
Cost_1	5.365	.105	50.911	***	
Comfort	4.667	.141	33.023	***	
Convenience_2	5.921	.638	9.284	***	
Convenience_3	5.905	.115	51.457	***	
Type	4.333	.078	55.282	***	
Safety_5	2.381	.114	20.866	***	
Safety_6	5.825	.997	5.845	***	
Safety_7	5.571	.105	52.836	***	
Conclusion	5.111	.191	26.785	***	
Reliability_4	4.698	.115	41.010	***	
Maintainance_1	2.349	.082	28.620	***	
Readiness	5.667	.111	51.118	***	
Efficiency_4	4.302	.107	40.015	***	
Productivity_2	4.635	.091	50.732	***	
Enviro_3	5.778	.121	47.872	***	

	Estimate	S.E.	C.R.	P	Label
Enviro_4	4.857	.181	26.861	***	
Enviro_5	5.556	.093	59.938	***	
Enviro_6	5.381	.102	52.613	***	
Cost_5	4.429	.123	35.902	***	
Cost_6	4.762	.098	48.646	***	
Productivity_3	4.556	.117	38.906	***	
Prductivity_4	4.635	.116	39.942	***	
Refueling	5.635	.118	47.659	***	
Refueling_2	2.587	.131	19.715	***	
Readiness_1	2.714	.486	5.584	***	

Covariances: (Correlated factors)

			Estimate	S.E.	C.R.	P	Label
Social	<-->	Safety	-.088	.049	-1.777	.076	
Social	<-->	Reliability	-.035	.036	-.997	.319	
Social	<-->	Operational	.009	.026	.343	.732	
Social	<-->	Environmental	.117	.055	2.136	.033	
Cost	<-->	Social	.065	.034	1.914	.056	
Safety	<-->	Reliability	.044	.043	1.019	.308	
Safety	<-->	Operational	-.009	.026	-.343	.732	
Safety	<-->	Environmental	-.120	.056	-2.146	.032	
Cost	<-->	Safety	-.053	.029	-1.829	.067	
Reliability	<-->	Operational	-.006	.019	-.331	.741	

			Estimate	S.E.	C.R.	P	Label
Reliability	<-->	Environmental	-.117	.105	-1.122	.262	
Cost	<-->	Reliability	-.052	.049	-1.073	.283	
Operational	<-->	Environmental	.015	.044	.345	.730	
Cost	<-->	Operational	.006	.018	.343	.731	
Cost	<-->	Environmental	.141	.052	2.702	.007	

Correlations: (Correlated factors)

			Estimate
Social	<-->	Safety	-1.198
Social	<-->	Reliability	-.622
Social	<-->	Operational	1.175
Social	<-->	Environmental	.785
Cost	<-->	Social	.902
Safety	<-->	Reliability	.768
Safety	<-->	Operational	-1.180
Safety	<-->	Environmental	-.809
Cost	<-->	Safety	-.734
Reliability	<-->	Operational	-1.083
Reliability	<-->	Environmental	-1.010
Cost	<-->	Reliability	-.922
Operational	<-->	Environmental	.986
Cost	<-->	Operational	.813
Cost	<-->	Environmental	.957

Variances: (Correlated factors)

	Estimate	S.E.	C.R.	P	Label
Social	.073	.059	1.243	.214	
Safety	.073	.059	1.248	.212	
Reliability	.045	.077	.575	.566	
Operational	.001	.005	.173	.863	
Environmental	.303	.099	3.062	.002	
Cost	.072	.044	1.650	.099	
e2	.773	.137	5.620	***	
e3	22.827	4.098	5.570	***	
e4	.644	.115	5.612	***	
e5	.794	.145	5.481	***	
e6	.664	.120	5.542	***	
e7	.866	.156	5.568	***	
e8	.618	.111	5.559	***	
e9	.910	.179	5.075	***	
e10	2.353	.422	5.572	***	
e11	.602	.134	4.500	***	
e12	24.465	4.394	5.568	***	
e13	.836	.150	5.569	***	
e14	.410	.075	5.507	***	
e15	.832	.148	5.617	***	
e16	1.366	.245	5.569	***	
e17	.316	.062	5.089	***	

	Estimate	S.E.	C.R.	P	Label
e18	.249	.062	4.036	***	
e19	.740	.134	5.514	***	
e20	.889	.160	5.539	***	
e21	.493	.136	3.612	***	
e22	.617	.112	5.502	***	
e23	1.134	.202	5.620	***	
e24	24.415	4.363	5.595	***	
e25	.518	.102	5.052	***	
e26	.378	.068	5.575	***	
e27	.747	.135	5.554	***	
e28	55.557	10.023	5.543	***	
e29	.582	.106	5.496	***	
e30	1.828	.335	5.454	***	
e31	.770	.138	5.575	***	
e32	.370	.067	5.562	***	
e33	.613	.112	5.495	***	
e34	.417	.077	5.412	***	
e35	.517	.093	5.569	***	
e36	.386	.079	4.879	***	
e37	2.022	.363	5.567	***	
e38	.412	.076	5.428	***	
e39	.648	.116	5.567	***	

	Estimate	S.E.	C.R.	P	Label
e40	.568	.112	5.081	***	
e41	.593	.107	5.567	***	
e42	.845	.152	5.575	***	
e43	.818	.146	5.592	***	
e44	.745	.134	5.548	***	
e45	1.068	.192	5.568	***	
e46	14.629	2.627	5.568	***	

Squared Multiple Correlations: (Correlated factors)

	Estimate
Readiness_1	.001
Refueling_2	.000
Refueling	.140
Prductivity_4	.020
Productivity_3	.006
Cost_6	.001
Cost_5	.398
Enviro_6	.001
Enviro_5	.227
Enviro_4	.002
Enviro_3	.572
Productivity_2	.001
Efficiency_4	.419

	Estimate
Readiness	.195
Maintainance_1	.114
Reliability_4	.054
Conclusion	.190
Safety_7	.156
Safety_6	.098
Safety_5	.074
Type	.007
Convenience_3	.366
Convenience_2	.032
Comfort	.084
Cost_1	.104
Cost_2	.654
Cost_3	.049
Cost_4	.089
Enviro_1	.726
Enviro_2	.489
Efficiency_1	.001
Efficiency_2	.324
Efficiency_3	.382
Productivity_1	.001
Reliability_1	.002

	Estimate
Reliability_2	.478
Reliability_3	.019
Safety_4	.340
Safety_3	.061
Safety_2	.000
Safety_1	.099
Automation	.237
Speed	.059
Brand	.002
Convenience_1	.086

Model Fit Summary (Correlated factors)

CMIN

Model	RMSEA	CMIN	DF	CFI	CMIN/DF
Default model	.131	1922.340	933	.281	2.060
Independence model	.150	2366.172	990	.000	2.390