REPUTATION LOSS FRAMEWORK FOR CONSEQUENCE ASSESSMENT OF ONSHORE PIPELINE DAMAGE

LIBRIATI ZARDASTI

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DEDICATION

In the name of ALLAH, the Most Gracious, Most Beneficent.
I dedicate this thesis especially to:

... My beloved parent for their unconditional love…
Nursinah binti Tanggi and the late Zardasti bin Dawi

... My dear siblings who never giving up on me…
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ABSTRACT

Consequence assessment for pipeline damage is exercised to determine the losses of a failure event such as human, asset, production and environmental loss. However, assessment of reputation loss, which is part of failure impact, is usually excluded due to its qualitative nature. Therefore, the need for a quantitative model of reputation loss is of great interest among pipeline risk assessors. The available current model assesses reputation loss qualitatively; it is a self-centered assessment, time-independent loss factors and internal stakeholder's influence are typically neglected. Therefore, the study aimed to develop a quantitative model to quantify reputation loss of the pipeline owner in order to improve the calculation of risk of pipeline damage according to the four different stakeholders' perceptions. A total of 30 reputation loss factors were identified via 30 case studies related to onshore pipeline damage accident reports. These factors were included in a structured online survey which was designed for the stakeholders in Malaysia to rank the factors according to its influence on owner's reputation based on a given imaginary worst case scenario. A total of 200 respondents participated in the survey and the ranking of the factors based on the four different stakeholders were obtained. All stakeholders were in agreement that the factor which most influences the loss of owner reputation is factor D3 "Accident Severity". It is the parent factor of D31 "Multiple fatality and injuries", D32 "Fire extinguished in longer duration", D33 "Destroyed private properties", and D34 "Damaged of vast environment area". Statistical analysis and fuzzy analytic hierarchy process (FAHP) were implemented to prioritize and weigh the factors according to the four different stakeholders' preferences. Four reputation loss models were then proposed to predict the reputation loss due to pipeline explosion. Eight experts from PETRONAS Gas Berhad (PGB) with 15 years of experience in pipeline integrity management were selected for model validation. Model development was presented to the experts for validation survey. The result indicates that this model is considered as comprehensive, fulfilled the objective, well-defined and practical to be used with a moderate level of overall reliability which can be improved by utilizing the model in a real case study. Thus, the proposed model was implemented in a case study of pipeline in Malaysia by taking the 2014 explosion event occurred in Lawas, Sarawak as a benchmark. The value of consequence of failure calculated by the proposed model was 7% lower than the current model from PETRONAS Technical Standard. This reduction has significantly shifted the risk of pipeline failure from "High" to "Moderate" for the rural area. To conclude, the inclusion of the proposed reputation loss model may produce a comprehensive consequence assessment of pipeline damage and provide a higher level of confidence to the pipeline owner to optimize their risk-based inspection and maintenance scheme, hence, prolonging the long-term integrity of their pipeline assets and simultaneously securing the company annual profit margins.

ABSTRAK

Penilaian kesan kegagalan paip saluran minyak dan gas dilakukan untuk menentukan kerugian terhadap manusia, harta benda, pengeluaran dan alam sekitar. Walaubagaimanapun, impak lain iaitu kehilangan reputasi kebiasaannya dikecualikan kerana sifat kualitatifnya. Maka, satu model kuantitatif kehilangan reputasi amat diperlukan oleh para penilai risiko. Model sedia ada menilai kehilangan reputasi secara kualitatif. Penilaiannya bersifat kendiri, faktor kehilangan tidak bersandarkan masa, dan pengaruh pihak berkepentingan dalaman diabaikan. Oleh itu, kajian dilakukan untuk membina model kuantitatif untuk mengukur kehilangan reputasi pemilik paip saluran agar penilaian risiko kerosakan paip saluran diperhebatkan berdasarkan persepsi empat jenis pihak berkepentingan. Sebanyak 30 faktor penyebab kehilangan reputasi dikenalpasti melalui 30 kajian kes laporan berkaitan kerosakan saluran paip daratan. Faktor-faktor dimuatkan dalam borang kajiselidik dalam talian yang direkabentuk untuk pihak-pihak berkepentingan di Malaysia bagi menentukan kedudukan faktor mengikut pengaruhnya terhadap reputasi pemilik paip saluran berdasarkan senario bayangan kes terburuk yang disertakan. Seramai 200 responden telah terlibat dan kedudukan faktor-faktor menurut empat pihak berkepentingan berbeza diperoleh. Kesemua pihak berkepentingan bersependapat bahawa faktor D3 “Tahap keterukan kemalangan” adalah faktor yang paling berpengaruh yang merupakan faktor induk kepada faktor D31 “Kematian dan kecederaan berganda”, D32 “Tempoh panjang untuk memadam kebakaran”, D33 “Kemusnahan harta benda awam”, dan D34 “Luas kawasan alam sekitar yang terjejas”. Analisis statistik dan proses hierarki analitik kabur dijalankan untuk menentukan pemberat faktor menurut tahap keutamaan pihak berkepentingan berbeza. Empat model kehilangan reputasi kemudian dicadangkan untuk meramal kehilangan reputasi disebabkan oleh letupan paip saluran. Lapan pakar dari PETRONAS Gas Berhad (PGB) dengan 15 tahun pengalaman dalam pengurusan integriti paip saluran dipilih untuk tujuan pengesahan model. Ia didahului dengan pembentangan pembangunan model untuk tinjauan pengesahan dan keputusan menunjukkan model dianggap menyeluruh, mencapai matlamat, jelas dan praktikal untuk digunakan dengan kebolehpercayaan sederhana. Oleh itu, model telah diimplementasi dalam kajian kes sebenar iaitu kes letupan saluran paip yang berlaku di Lawas, Sarawak pada tahun 2014 bagi meningkatkan kebolehpercayaan. Nilai kesan kegagalan berdasarkan model cadangan adalah 7% lebih rendah berbanding nilai model Piawai Teknikal PETRONAS menyebabkan risiko kegagalan berubah daripada “Tinggi” kepada “Sederhana” bagi kawasan luar bandar. Kesimpulannya, model cadangan kehilangan reputasi menghasilkan penilaian kesan kegagalan paip saluran yang menyeluruh dan meningkatkan tahap keyakinan pemilik untuk mengoptimumkan skema pemeriksaan dan penyelenggaraannya berasaskan risiko. Maka, integriti jangka panjang paip saluran dapat dilanjutkan dan sekaligus melindungi keuntungan tahunan syarikat.

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LIST OF ABBREVIATIONS

AHP	-	Analytic hierarchy process
AI	-	Average Index
ALARP	-	As Low As Reasonably Practicable
BP	-	British Petroleum
CEO	-	Chief Executive Officer
CGTD	-	China General Terminal and Distribution Corporation
CI	-	Consistency Index
CNPC	-	China National Petroleum Corporation
CR	-	Consistency Ratio
CPC	-	CPC Corporation
DNV	-	Det Norske Veritas
EGIG	-	European Gas pipeline Incident data Group
EPNG	-	El Paso Natural Gas Company
E&P	-	Exploration and Production
FAHP	-	Fuzzy analytic hierarchy process
GAIL	-	Gas Authority of India Limited
HCA	-	High Consequence Area
IT	-	Information Technology
KPC	-	Kenya Pipeline Company
LCY	-	LCY Chemical Corporation
LNG	-	liquefied natural gas
MCDM	-	Multi criteria decision making
MYR	-	Malaysia Ringgit
NGO	-	Non-Government Organisation
NIL	-	Not in list
NNPC	-	Nigerian National Petroleum Corporation

NTSB	-	National Transportation Safety Board
OGP	-	International Association of Oil and Gas Producers.
PAER	-	People, Asset, Environment and Reputation
Pemex	-	Petroleos Mexicanos
PETRONAS	-	Petroliam Nasional Berhad
PCG	-	PG&E Corp.'s
PHMSA	-	Pipeline Hazardous Materials Safety Administration
PGB	-	PETRONAS Gas Berhad
PGU	-	Peninsular Gas Utilisation
PG&E	-	Pacific Gas and Electric Co.
PTS	-	PETRONAS Technical Standards
QNG	-	Quebec Natural Gas Corporation
RI	-	Random Index
RII	-	Relative Importance Index
RL	-	Reputation loss
RQ	-	Reputation Quotient
SD	-	*Super Decisions*
SS	-	Sample Size
SPSS	-	Statistical Packages for the Social Sciences
SSGP	-	Sabah-Sarawak Gas Pipeline
S&P	-	Standard & Poor's
TFN	-	Triangular Fuzzy Number
TGT	-	Tennessee Gas Transmission Co.
TSB	-	Transportation Safety Boards
UK	-	United Kingdom
US	-	United States
USA	-	United States of America
USD	-	United States Dollar
WMAC	-	World's Most Admired Companies

LIST OF SYMBOLS

A	-	the comparison matrix
α	-	Cronbach's alpha reliability coefficient
a_i	-	is the constant expressing the weight given to *i*,
d	-	degree of accuracy expressed as a proportion (0.05)
d	-	ordinate of the highest intersection point D
f	-	frequency of an observation and
$Index_{max}$	-	maximum index
$Index_{min}$	-	minimum index
λ_{max}		largest eigenvalue
K	-	sample with more than two groups
k	-	convex fuzzy numbers
N	-	number of respondents; population size; number of rating scale index
n_{i}	-	number of respondents who rate the importance or influence of the factor as i = 1 as "very low"; 2 as "low";3 as "moderate"; 4 as "high"; and5 as "very high".
n	-	the dimension of the matrix
P	-	population proportion
s	-	the required sample size
W	-	a non-fuzzy number
w	-	eigenvector
w_i	-	weight of factor *i*
X^2	-	the table value of chi-square
x	-	variable expressing the frequency response for *i* = 1, 2, 3, 4, and 5.

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CHAPTER 1

INTRODUCTION

1.1 Preface

Onshore oil and gas pipeline damage due to explosion, leakage, and etc. is an undesired event. Accidents cause significant negative impact such as loss of life, destruction of private and public property and serious environmental damage. In fact, this event is capable of tarnishing the pipeline owner's reputation as well as jeopardizes the confidence level of their internal and external stakeholders such as investors, employees, customers, public etc. In a famous quote, Warren Buffet, the chief executive officer (CEO) of Berkshire Hathaway warned: "*It takes 20 years to build a reputation and five minutes to ruin it. If you think about that you will do things differently*", (Rochette, 2007; Vallens, 2008; Gaultier-Gaillard, Louisot and Rayner, 2009; Bibi, 2011). This quote emphasized the importance of protecting and enhancing the stability of company reputation. Hence, negative perception among stakeholders decreases and eventually improves company's profit margin.

In the risk assessment of pipeline damage, the impact of an accident in terms of monetary value is most preferable by the owner. Thus human, environment, and economic losses are converted into dollars to assist them in forecasting their losses in each occurrence to obtain risk value in monetary terms. Nevertheless, reputation loss is a function of the impact or consequence of failure as well. It can be included in the consequence assessment of pipeline damage as the impact of the accident on owner's reputation is certainly significant. Therefore, the presence of reputation loss assessment provides comprehensive risk estimation and subsequently allows the owner to prepare an optimum inspection and maintenance schedule, hence boosting annual corporate profit.

1.2 Background and Motivation

Pipelines are susceptible to failure even though it is the most economical, fastest, and safest means of transporting natural gas and hazardous liquids in large amount (Dziubínski *et al*., 2006; Carvalho *et al*., 2008; Brito and Almeida, 2009; Brito *et al*., 2010; Furchtgott-Roth, 2013). A comprehensive Pipeline Integrity Management Program (PIMP) is vital for the maintenance of a safe and reliable oil and gas pipeline. It consists of a foundation of pipeline inspection, assessment, mitigation and communication aimed at minimizing the risk of the pipeline failure to As Low As Reasonably Practicable (ALARP). This program has experienced significant changes since the early 2000's. The number of gas transmission pipeline incidents had increased over the past 15 years according to the United States Department of Transportation (USDOT) of Pipeline and Hazardous Material Safety Administration (PHMSA) online data source (PHMSA, 2015). These failure events can harm the public, the environment, assets and production. The reputation of pipeline owners is endangered regardless of how the pipeline had been operating prior to the failure event. Pipeline failure has great financial costs for pipeline owners. For gas transmission pipelines alone, failure events have cost pipeline owners approximately one billion US Dollars over the last 15 years (2000 – 2015) (PHMSA, 2015). A well-planned pipeline inspection and maintenance program is necessary to avoid pipeline damage and reduce the impact of failure events. PIMP secures the annual profit margins of pipeline owners and protects its reputations.

The previous time-based inspection of pipeline integrity management was improved by the implementation of Risk-Based Inspection (RBI). RBI allows pipeline owners to choose the most cost effective pipeline inspection scheme. RBI optimizes maintenance scheduling and reduces unnecessary inspections. As a part of a RBI module, pipeline damage risk is assessed as a product of the likelihood or frequency of pipeline damage probability and the impact or consequence of such an event. Existing consequence assessments are quite effective in evaluating the monetary loss of pipeline failure, such as the number of fatalities and injuries, cost of asset damages, cost of production loss, and the cost of environmental pollution fines. This assessment does not calculate the actual cost of pipeline damage due to the qualitative nature of a company's reputation influencing factors. This may be due to time dependency, difficulties in quantifying factors into monetary value, or lack of identification of reputation loss impact on local conditions. Onshore pipelines buried underground are laid across various types of geographical surfaces with different demographic populations. These various conditions contribute to different impacts on company's reputation due to a failure event. The impact of pipeline failure causing an explosion in Europe is different from an explosion in Nigeria due to different education levels. Public awareness of safe and reliable pipeline operation varies between countries.

The reputation of a company depends on stakeholder beliefs. Each company has at least four major stakeholders, including investors, customers, employees and the public. Pipeline accidents impact all stakeholders directly or indirectly. Stakeholder post-accident negative beliefs and responses to loss of human life, economic damage and environmental damage due to a pipeline damage event can be considered indicators of company reputation loss. Stakeholder perceptions and expectations differ and are highly incident-dependent. Pipeline damage may affect stakeholders physically or mentally and has a negative impact on the pipeline owner's reputation – an intangible asset that could be capable of generating tangible loss. Current risk assessment for pipeline damage includes an assessment of failure event effects on owner reputation. If a pipeline owner can identify the reputation loss factors influenced by the views of external and internal stakeholder prior to a failure event, a comprehensive consequence assessment for pipeline damage can be established.

1.3 Research Problem

Onshore pipeline accidents have become common in recent years. In 2014, there were a number of pipeline explosion events such as Kaohsiung in Taiwan, Andhra Pradesh in India, and Sarawak in Malaysia. Current consequence of failure assessment calculates the monetary losses of these pipeline damage events i.e. human loss, production loss, asset loss and environmental loss because they are quantitatively countable and visible, in addition to reputation loss. This loss assessment is assessor-centered and ranges from very low to very high. The effects of post-accident reputation loss on stakeholder perceptions is neglected due to difficulties in quantifying factors (Khan and Haddara, 2004; Arunraj and Maiti, 2009). The effects of post-accident reputation loss are vital to most organizations (Cravens *et al*., 2003); as it endangers profit margins (Money and Hillenbrand, 2006).

Most industry players choose to exclude post-accident reputation loss due to its qualitative nature and the subjectivity of its factors. The factors for reputation loss are as follows: time-dependent (Dunbar and Schwalbach, 2000; Bie, 2006); multidimensional (Fombrun, 1996); behavior-dependent (Bie, 2006); and influenced by stakeholder experience (Spence, 2011). Current practices for pipeline risk assessment assume that the cost of reputation loss is equivalent to business interruption costs (Muhlbauer, 2004). The loss of company reputation is judged and calculated based on fluctuations in share price over a period of time in order to simplify assessment procedures (Vergin and Qoronfleh, 1998; Money and Hillenbrand, 2006; Tonello, 2007; Scandizzo, 2011). This type of reputation loss quantification is time-dependent, but affects only a single stakeholder (investors). The expectations of other stakeholders have similar impacts i.e. jeopardizing the reputation of the company and significantly influencing company operations (Macnamara, 2006). Public perception prior to a pipeline damage event is crucial as it forces pipeline operators to apply mitigation measures. Public pressure for pipeline safety differs by geographical location and the status of the pipeline owner.

Efforts have been made to quantify reputation loss for pipeline owners (E&P 6.54/246, 1996; Muhlbauer, 2004; PTS 30.40.60.33, 2012). Despite these efforts, a model to calculate intangible reputation loss based on overall stakeholders' perspectives, whether internal or external is currently unavailable. None of the current available models prioritize reputation loss factors to assists operators in responding to the most severe factors affecting the perspective of company stakeholders. Reputation loss models for onshore pipeline damage do not yet exist, but models covering reputation loss in other industries such as the banking and retail do (Muller and Vercouter, 2008; APCO Insight, 2010; Li *et al*., 2010; Cherchiello, 2011; He and Wu, 2013).

As pipelines age and the risk of a failure event increases, there is a need to account for additional factors in pipeline risk assessments such as reputation loss. The inclusion of reputation loss in pipeline risk assessments makes those assessments more conservative. If reputation loss, which is currently neglected in calculations of monetary impact, has a significant contribution to total cost of a failure event, neglecting it may result in the inaccurate assessment of failure consequences. Planning errors for pipeline inspections and maintenance program impose additional costs due to unnecessary inspections programs, affecting a company's annual profit margins. If a reputation loss model is successfully developed, pipeline damage can be prevented with reasonable increments in inspection frequency as pipeline operators pay more attention to higher risk pipelines. Great effort is needed to develop a comprehensive consequence assessment model incorporating the intangible elements of reputation loss for comprehensive risk assessment. To reach this milestone, a detail investigation on reputation loss factors is crucial.

1.4 Research Aim and Objectives

This study aims to develop a quantitative consequence assessment model for pipeline failure associated with the reputation loss of the owner, based on a Malaysian stakeholder perspective. The proposed model is unique in that reputation-threat factors are both time-dependent and time-independent. This model is tailored for onshore oil and gas pipeline damage resulting from an explosion. The objectives of this study are:

1. To identify owner reputation-threat factors which lead to negative perceptions among stakeholders in Malaysia prior to pipeline damage as reported in selected onshore pipeline explosion case studies.

2. To determine the priority vector of the identified stakeholder-influenced reputation-threat factors according to the degree of negative perceptions among the major constituents of a company i.e. investor, customer, employee and the public using Multi Criteria Decision Making (MCDM) method.

3. To evaluate the impact of reputation loss on pipeline owners by applying stakeholder-oriented priority vectors for reputation-threat factors as a consequence assessment of pipeline damage, including the prediction and validation of the model via expert interviews and case studies in Malaysia.

These outcomes may contribute to the consequence assessment for pipeline damage by exploring a selection of reputation loss factors for future pipeline owner reputation loss modelling.

1.5 Research Scope

There are numbers of factors that may influence an oil and gas company's reputation. This study focuses on the relationship between reputation loss and stakeholder perceptions resulting from a pipeline explosion by observing company stakeholders' responses (investor, customer, employee and public) prior to the event. This study focuses on the geographical area of Malaysia, limited to the stakeholders of the country's oil and gas companies. Unstructured interviews and questionnaire surveys are carried out for this study. Qualitative experts' judgments were transformed into quantitative information using fuzzy and Analytic Hierarchy Processes (AHP) in order to reduce errors and increase accuracy. Statistical analysis was used to identify the relationships between reputation loss and stakeholder perceptions. The index method was used to rate the severity level of a company's reputation loss for modelling purposes. The model was then validated via expert interviews and case studies in Malaysia.

1.6 Research Significance

The main challenge of reputation loss model development is to understand factor selection in order to obtain an accurate model. This model is to be used by pipeline risk assessors for engineering analysis. Previous studies did not include reputation-threat factors towards pipeline owner in their assessment of pipeline damage. The outcome of this study shows the influence negative stakeholder perceptions have on a company's reputation loss prior to an accident. A comprehensive consequence assessment for onshore oil and gas pipeline damage can be obtained by incorporating post-accident owner reputation-threat factors.

1.7 Research Methodology

Qualitative and quantitative approaches were conducted in this study. It consists of four stages: preliminary study, data collection, data interpretation and analysis and conclusions and recommendations. The first stage requires a comprehensive review of literatures on pipeline risk assessment and reported onshore pipeline post-accident damages in the past 50 years on a worldwide basis. It was achieved through literature search via reports, journals, articles, books, internet sources, online newspapers archives, informal discussion with experts and researchers. This stage attains background knowledge of the topic, knowledge gaps relating to the research problems, which eventually produces research aim and objectives within a reachable research scope and the significance.

Second stage requires a wide-ranging literature search as well. All reviews are supported with trusted sources to comply with statement validity. It includes collecting data from case study, interviews with experts in pipeline risk management and questionnaire survey distribution to the respective stakeholders namely investor, customer, employee and public. This secondary data is able to identify the following requirements: post-accident reputation-threat factor; the importance of the reputation loss factor; the influence of reputation loss factor towards pipeline owner; the impact of reputation loss factors on pipeline company's stakeholders; and validation of reputation loss severity scale for modelling.

The next stage interpreted and analyzed successfully answered questionnaire surveys. The significance of reputation loss factors are tested before modelling is developed. Statistical analysis, AHP method and fuzzy AHP method were implemented in the priority vector calculation processes with the aid of Microsoft Excel and *Super Decisions*. The experts are involved in the validation process to justify the obtained values of factors priority. The evaluation of reputation loss is formulated later using the priority vector for each factor obtained from different stakeholders. The model is developed to classify the level of degradation of pipeline owner's reputation. It is then imposed on the selected onshore pipeline explosion case studies to assess the respective level of reputation loss of pipeline owners. The final stage concluded the findings that attain the research objectives and derive recommendations within the research scope along with advice for future study.

1.8 Structure of Thesis

This thesis consists of eight chapters structured in the following manner:

1. Chapter 1 shares the introduction of the study. It covers the motivation and background of the research, problems, aim and objectives, scope and significance of the research. A brief research methodology with the approach and method is stated. The outlines of the research are mentioned at the end of this chapter.

2. Chapter 2 provides a comprehensive literature review which covers the pipeline accident documentations, the overviews of oil and gas pipeline risk assessment and the consequence assessment including the loss categories in terms of risk, the extensive explanation on reputation loss and its definition, the relationship between reputation and expectations, the current reputation model and reputation index in various research field, the reputation loss indicators in various pipeline explosion case, and the prioritization method of reputation loss is reviewed in this chapter.

3. Chapter 3 demonstrates the overall methodology of the study. Overview of research design, data collection methods, techniques to identify reputation loss factors and the prioritization is explained comprehensively. The reputation loss severity level and the model are presented and the model validation procedures are described.

4. Chapter 4 produces the analysis and results for questionnaire survey distributed to the respective pipeline owner's stakeholder namely investor, customer, employee and public. The reliability of the survey, sample size and return rate, the demographic of the respondents and the given 5-point rating of reputation loss level of each factor from all types of survey is presented. The average index and ranking for each factor in various surveys is calculated and the significant difference in rating given by the respondents of all surveys between stakeholder and the significant difference between surveys is tested.

5. Chapter 5 presented the priority vector of the reputation-threat or reputation loss factor using analytic hierarchy process method and fuzzy analytic hierarchy process with the aid of Microsoft Excel software and *Super Decisions* software. The significant difference of rating given by respondents between methods of obtaining priority vector is tested. These priority vectors are validated done by the experts. The correlated factors according to respective stakeholders are extracted as well.

6. Chapter 6 transforms the previous priority vectors into a formulation to assess pipeline owner's reputation loss prior to pipeline accident. The level of severity for all reputation-threat factors discussed with the experts is listed in a scale of 1 to 5. This severity level produces range of reputation loss values, which the class of reputation loss index is explained. Simultaneously, a reputation loss model with ranges of reputation loss index is presented, and the model validation scores given by the experts are provided. The implementation of the model in the selected case studies is applied.

7. Chapter 7 discusses the results obtained in previous three chapters. This chapter deliberates on the relevance of analysis in order to

accomplish all research objectives. The achievement of the aim of this study is declared at the end of this chapter.

8. Chapter 8 concludes the accomplishment of the research objectives and the aim of the study. It also stated the contribution of this study towards the industry of oil and gas. Research limitation and recommendation is specified for future study.

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