Development of an Information System for Supporting Climate Change Impact and Adaptation Strategies Studies within the Prairie's Petroleum Industries

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EXCUTIVE SUMMARY

Petroleum operations range from exploration, production and refining to transportation and storage. Climate change will lead to a number of direct and indirect impacts on this industrial sector. Therefore, a challenging question faced by the industry is how they should adapt to the changing climatic conditions in order to maintain or improve their economic and environmental efficiencies. In this research, initial efforts are made to assess the interrelationships between climate change and petroleum activities in Canada's prairies. A number of processes within the prairies' petroleum industry that are vulnerable to climate change are examined through extensive survey, investigation and analysis. In addition to the organization of workshops, roundtable meetings and panel discussions, many questions were designed and distributed in various ways (mail, email, telephone call, interview, and internet) to collect information of perceived climate-change impacts and adaptation strategies. Many people from industries, research institutions, governments, and non-governmental organizations were contacted for information and knowledge acquisition. Multivariate statistical analyses (chi square test) were conducted to examine potential correlations among various surveying results. These analyses were helpful for identifying potential conflicts of interest, biases and interactions. Thus, more reasonable interpretation of the surveying outputs can be obtained. Based on the investigation and surveying results, an expert system (named ISSCCI) was developed for facilitating integrated climate-change impact assessment and adaptation-strategy analysis within the prairie's petroleum industry. A vast amount of information related to industrial processes, climate-change impacts, potential adaptation alternatives, and system component interactions was integrated within the ISSCCI framework. The developed ISSCCI can provide decision support for the prairie's energy industries and the related governmental organizations to conveniently examine issues of climate-change impacts and potential adaptation options.

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1. Introduction

Climate-change impact analysis and adaptation planning in the prairie's energy sector will be crucial in the effort to improve the industry's economic and environmental efficiencies. In fact, adaptation to the climate-change impacts is a sensitive and complex issue since it is related to many different stakeholders with tremendous conflicts. Due to these sensitivities and complexities, it is often hard to solely use quantitative mathematical models to study such systems. Therefore, application of expert system technology will be more realistic for more effectively linking the quantitative components to the other qualitative, and possibly more important, ones.

Stakeholders related to the prairie's energy sector have accumulated vast amounts of knowledge on the vulnerability of different industrial processes to climate change, the intricate relationships among the criteria for impact assessment, and the many indicators of the related performances under changing climate. However, no effort has been given to the integration of the knowledge within an integrated expert system (ES) for providing decision support. This study is proposed to fill this gap in current studies through development of an ES with the state-of-the-art modeling tools. Expertise from various stakeholders will be acquired using innovative artificial intelligence (AI) techniques, with the developed ES being useful for clarifying various objects as well as a number of heuristics and related decision processes, formalizing and representing the knowledge with a variety of representation methods, and presenting the knowledge in production rules through a knowledge base. Specifically, the objectives of this study include:

(a) to develop an expert system (ES) for integrated climate-change impact assessment within the prairie's energy sector; interactions among climate change, natural condition variations, industrial activities, environmental concerns, and economic objectives, as well as the related policy implications will be comprehensively incorporated within the ES.

(b) to systematically integrate a vast amount of information related to industrial processes, climate-change impacts, integrated assessment, and potential adaptation alternatives within a general ES framework; the ES development will involve innovative and state-of-the-art AI techniques and will fill in the gap in the field of ES application to climate-change impact studies.

(c) to provide decision support for improving the effectiveness in adapting to climate change for energy industries in the prairie provinces.

2. Perception of Petroleum Industries on Climate Change Impacts and Adaptation Strategies

To facilitate the ES development, involvement of industrial and governmental personnel is needed. Both education and investigation programs have been initiated for facilitating this involvement. Information from different industrial and governmental groups was collected, through methods of questionnaire survey, roundtable meetings, and consultation workshops. Feedback from the stakeholders regarding the mechanisms and levels of climate-change impacts on various industrial practices and the possible adaptation strategies was surveyed. The obtained comments, as well as the related interpretations and recommendations, would provide important bases for establishing the ES. Especially, comments for key issues from important stakeholders were highlighted. Thus, interrelations between a number of critical industrial components and climatic conditions could be clarified, and the relevant assessment could be conducted with improved policies and strategies being recommended.

Many factors can affect the industry's perception of climate change impacts. Sandman (1989) referred to “outrage factors” when describing how impacts were evaluated. In particular, impacts that are perceived to be involuntary, artificial, unfair, memorable, and dreaded are considered more risky than those that are voluntary, natural, fair, familiar, not memorable, and not dreaded. Since little information of the perception on the impacts has been available, this research is important in terms of its efforts for obtaining the first-hand feedback.

2.1. Questionnaire Design

Effectively communicating climate change impacts is of importance if industries are to be involved in impact evaluation and adaptation analysis. In order to facilitate effective communication, it is necessary to understand how industries perceive the impacts on their activities. Before designing the questionnaires, a pre-survey was carried out to determine factors that are of concern and industrial processes that are vulnerable to climate change (Huang et al., 2000). Respondents of this pre-survey included stakeholders from a variety of petroleum and petrochemical industries and related governmental organizations. The survey methods consisted of round table meetings, interviews and phone calls. The results indicate that the main climate-change impact factors are:

- increased temperature,
- changed precipitation pattern,
- changed humidity and cloud patterns,
- increased natural hazards.

The above factors will potentially have positive or negative impacts on the following aspects of industrial processes:

- cost,
- operation,
- pollutant emission,
- infrastructure.

The related activities that are vulnerable to climate change are specified in Table 2.1.

Well designed, logical, and easy-to-answer questionnaires can help receive informative feedback. In this research, 39 questions were designed based on a variety of pre-survey and investigation. Each question contained four parts: impacts of climate change, characteristics of the impacts, suggested feedback actions, and recommended adaptation strategies. The detailed questionnaires are provided in appendix A, with a few sample questions provided as follows.

Will increased temperature affect oil exploration processes? (Please choose one)

(a) Significant	[ ]
(b) Some	[ ]
(c) Minor	[ ]
(d) No impact	[ ]
(e) Not sure	[ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	Positively affected	negatively affected	both positive and negative
(a) Site accessibility	[ ]	[ ]	[ ]
(b) Site condition	[ ]	[ ]	[ ]
(c) Testing condition	[ ]	[ ]	[ ]
(d) Equipment operation	[ ]	[ ]	[ ]
(e) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional):

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing	[ ]
(b) Show concerns and be alerted	[ ]
(c) Conduct research to gain insight	[ ]
(d) Conduct research and be prepared to take actions	[ ]
(e) Begin to take adaptation actions + (c) + (d)	[ ]

Table 2.1 Activities in petroleum industries that are vulnerable to climate change

1	oil exploration
2	petroleum exploration
3	drilling and production operations
4	exploration and production infrastructures
5	transportation activities within exploration and production processes
6	cost of exploration and production
7	petroleum refining process
8	pollutant emission from oil refinery processes
9	cost of oil refinery
10	petroleum transportation and storage
11	cost of transportation and storage
12	environmental management activities in petroleum industry

If the answer is (b), (c), (d) or (e), please indicate what detailed action(s) you would like to recommend:

(a) Investigate conditions of related field works [ ]
(b) Change timetable of field activities [ ]
(c) Improve efficiency of field works [ ]
(d) Develop new technology and field instrument [ ]
(e) Others [ ]
Please specify (optional): _____

2.2. Survey

The stakeholders' perceptions of climate change impacts are important because they influence policy making. Knowledge of the impacts would be helpful for them to improve their performance in order to adapt to the changes. In this study, an extensive survey was conducted for industries, research institutions, governments, and non-governmental organizations. Involvement of these stakeholders is important for not only providing necessary information for ES development but also validating the ES inputs/outputs and generating desired decision support. Both investigation and education programs were initiated for facilitating this involvement. Methods of interview, email, workshop, internet, and telephone call were adopted; seminar series and education materials regarding impacts of climate change on industrial practices were also delivered to create an awareness of the research issues.

In February to June 2001, data were collected through the questionnaire survey, with the number of refusals being less than 3%. Each contacted individual spent several hours to a few days to fill the survey forms. The feedback was collected through fax, phone call, email and internet. Especially, an on-line questionnaire system was provided on website http://env.uregina.ca/survey/ to facilitate convenient and quick responses; the participants can thus fill the survey forms through the web directly.

2.3. Analysis of Surveying Results

Forty-five experts were involved in the survey, including professors, engineers, managers, and technicians from industries, governments, research institutions, and non-governmental organizations. The complete set of surveying results is provided in Appendix B. They are also available on line at http://env.uregina.ca/parc/.

The surveying results were analyzed to identify significant impacts and impact factors. In general, the respondents were optimistic in their belief that the environment can be improved. They also desired more information about what they as individuals or individual organizations could do. It was also suggested that the petroleum industry should become more active in the related impact and adaptation studies.

(1) Impacts of increased temperature

Among the climate-change impact factors, increased temperature is of the most significant concern. Its impacts on various aspects of petroleum-related activities were investigated through surveying answers to the following questions:

- Will increased temperature affect oil exploration processes?
- Will increased temperature affect drilling and production operations?
- Will increased temperature affect exploration and production infrastructures?
- Will increased temperature affect the cost of exploration and production?
- Will increased temperature affect the petroleum refining process?
- Will increased temperature affect petroleum transportation and storage?
- Will increased temperature affect environmental management activities in petroleum industry?

(A) Impacts on oil exploration

The results indicate that 11.1% of the respondents agree that the impacts of increased temperature on oil exploration will be significant, 75% confirm that there will be some impacts, 13.9% are not sure. These demonstrate that the majority of the respondents are concerned about the impacts on oil exploration.

Among the respondents, the percentages of individuals who agree that there will be significant or some impacts are 66.7, 71.4, 22.2 and 66.7% for groups of industry, government, research institution and non-governmental organization, respectively. Among these individuals who care about the impacts, 25.8% advise showing concerns and being alerted, 22.6% suggest conducting research to gain insight, 29% recommend conducting research and being prepared to take actions, and 22.6% propose taking adaptation actions.

Among those who suggest taking adaptation actions, the percentages of individuals who agree with actions of (a) investigating conditions of related field works under changing climatic conditions, (b) changing timetable of field works, (c) increasing efficiency for field works to shorten field-work period, and (d) developing new technology and survey instruments are 74.2, 45.1, 35.4, and 45.1%, respectively.

(B) Impacts on drilling and production

The results indicate that 5.6% of the respondents agree that the impacts of increased temperature on drilling and production will be significant, 55.5% confirm that there will be some impacts, 33.3% indicate minor impacts, and 5.6% are not sure. These

demonstrate that over 90% of the respondents are concerned in different degrees about the impacts on drilling and production.

Among the respondents, the percentages of individuals who agree that there will be significant or some impacts are 37.5, 85.7, 72.2 and 66.7% for groups of industry, government, research institution and non-governmental organization, respectively. The percentages of those who indicate minor impacts are 50.0, 14.3 and 27.8% for groups of industry, government, and research institution, respectively. Only 33.3% of individuals from non-governmental organizations indicate “not sure”.

Among individuals who care about the impacts, 2.9% think that no action is needed, 29.4% advise showing concerns and being alerted, 14.7% suggest conducting research to gain insight, 35.3% recommend conducting research and being prepared to take actions, and 17.7% propose taking adaptation actions.

Among those who suggest taking adaptation actions, the percentages of individuals who agree with the following actions are 86.1, 51.2, 36.0, 29.4, 35.3, 23.9, 18.0 and 24.2%, respectively:

- investigate all possible impacts,
- changing timetable of field works
- selecting anti-erosion steel for drilling equipment,
- enhancing maintenance for various instruments,
- introducing new techniques to increase drilling efficiency,
- using high efficiency compressors and motors in drilling operations,
- using steam produced from highly efficient co-generation plants to assist with recovery of heavy oil,
- installing clean-bum compressors and emission-control facilities on dehydrator unit and using compressed air-activated (rather than gas-activated) valves.

(C) Impacts on exploration and production infrastructures

The results indicate that 61.1% of the respondents agree that there will exist impacts of increased temperature on exploration and production infrastructures, 19.4% indicate minor impacts, 5.6% answer no impact, and 13.9% are not sure. In general, over 80% of the respondents are concerned in different degrees about the impacts on exploration and production infrastructures.

Among the respondents, the percentages of individuals who agree that there will be significant or some impacts are 50.0, 42.8, 83.3 and 66.7% for groups of industry, government, research institution and non-governmental organization, respectively. The percentages of those who indicate minor impacts are 25.0, 28.6 and 5.6% for groups of industry, government, and research institution, respectively. Only 33.3% of individuals from non-governmental organizations indicate “not sure”.

Among individuals who care about the impacts, 48.3% suggest conducting research to gain insight, 13.8% recommend conducting research and being prepared to take actions, and 37.9% propose taking adaptation actions.

Among those who suggest taking adaptation actions, the percentages of individuals who agree with the following actions are 82.6, 41.4, 31.0, 65.4, 55.2 and 51.7%, respectively:

- investigating all possible impacts, vulnerabilities, and adaptive responses,
- changing timetable of construction activities,
- improving construction efficiency to shorten project period,
- enhancing maintenance of vulnerable infrastructures,
- redesigning foundations and structures to adapt to changed climatic condition,
- redesigning pipeline systems to adapt to greater variability of temperature.

(D) Impacts on costs of exploration and production

The results indicate that 66.7% of the respondents agree that there will exist impacts of increased temperature on costs of exploration and production, 11.1% indicate minor impacts, 22.2% are not sure. In general, the majority of the respondents are concerned in different degrees about the impacts on costs of exploration and production.

Among the respondents, the percentages of individuals who agree that there will be significant or some impacts are 37.5, 71.4, 77.8 and 66.7% for groups of industry, government, research institution and non-governmental organization, respectively. The percentages of those who indicate minor impacts are 25.0 and 22.2% for groups of industry and research institution, respectively. Also, 37.5, 28.6 and 33.3% of individuals from groups of industry, government, and non-governmental organization, respectively, indicate “not sure”.

Among individuals who care about the impacts, 14.3% think that no action is needed, 39.3% advise showing concerns and being alerted, 14.3% suggest conducting research to gain insight, 7.1% recommend conducting research and being prepared to take actions, and 25% propose taking adaptation actions.

Among those who suggest taking adaptation actions, the percentages of individuals who agree with the following actions are 82.1, 7.1, 32.1, 14.3 and 42.8%, respectively:

- investigating all possible impacts and adaptive processes,
- using more efficient compressors,
- using high-pressure gas feed being rich in liquids and low in energy requirement and hydrogen sulfide generation,
- using dual-action pumps at extraction sites to separate the oil and water from the underground (to eliminate gas emissions and reduce energy consumption for lifting water from underground),
- preventing leaks in processing facilities and installing vapor recovery equipment.

(E) Impacts on petroleum refining processes

The results indicate that 13.9% of the respondents agree that the impacts of increased temperature on petroleum refinery will be significant, 19.4% confirm that there will be some impacts, 33.4% indicate minor impacts, 13.9% answer no impact, and 19.4% are not sure. In general, over 50% of the respondents are concerned about the impacts on petroleum refinery, while over 30% indicate “no impact” or “not sure”.

Among the respondents, the percentages of individuals who agree that there will be significant or some impacts are 25.0, 42.8, 33.3 and 33.3% for groups of industry, government, research institution and non-governmental organization, respectively. The percentages who indicate minor impacts are 25.0, 28.6 and 33.3% for groups of industry, government, and research institution, respectively. Also, 37.5, 28.6, 11.1 and 66.7% of individuals from groups of industry, government, research institution and non-governmental organization, respectively, indicate “not sure”.

Among individuals who care about the impacts, 8.3% think that no action is needed, 25.0% advise showing concerns and being alerted, 8.3% suggest conducting research to gain insight, 41.7% recommend conducting research and being prepared to take actions, and 16.7% propose taking adaptation actions.

Among those who suggest taking adaptation actions, the percentages of individuals who agree with the following actions are 89.4, 27.3, 54.5, 40.9, 16.7, 27.3 and 31.8%, respectively:

- investigating all possible impacts and adaptive processes,
- using innovative techniques to prevent oil leakage, spill, and release,
- installing automatic monitor system to reduce fire risk,
- controlling temperature to prevent thermal cracking of facilities,
- taking anti-erosion actions to decrease corrosion rate of related facilities,
- preventing leaks in processing facilities
- installing oil-vapor recovery systems.

(F) Impacts on pollutant emission from refinery processes

The results indicate that 13.9% of the respondents agree that the impacts of increased temperature on pollutant emission from refinery processes will be significant, 19.4% confirm that there will be some impacts, 13.9% indicate minor impacts, 8.4% answer no impact, and 19.4% are not sure. In general, over 45% of the respondents are concerned about the impacts on pollutant emission from refinery processes, while over 20% indicate “no impact” or “not sure”.

Among the respondents, the percentages of individuals who agree that there will be significant or some impacts are 12.5, 85.7, 66.7 and 66.7% for groups of industry, government, research institution and non-governmental organization, respectively. The percentages who indicate minor impacts are 12.5 and 16.7% for groups of industry and research institution, respectively. Also, 12.5 and 11.1% of individuals from groups of industry and research institution, respectively, indicate "no impact"; 62.5, 14.3, 5.6% and 33.3% of individuals from groups of industry, government, research institution and non-governmental organization, respectively, are "not sure".

Among individuals who care about the impacts, 19.2% advise showing concerns and being alerted, 26.9% suggest conducting research to gain insight, 26.9% recommend conducting research and being prepared to take actions, and 26.9% propose taking adaptation actions.

Among those who suggest taking adaptation actions, the percentages of individuals who agree with the following actions are 92.3, 61.6, 38.5, 42.3, 38.5, 50.0, 38.5 and 15.4%, respectively:

- investigating all possible impacts and adaptive processes,
- improving current techniques to reduce pollutant emissions,
- increasing the use of natural gas to replace petroleum as energy source,
- using CO_2 recovered from refining operations to carbonate soft drinks,
- developing new technologies to convert coal into clean synthesis gas,
- installing oil-vapor recovery systems,
- promoting wider acceptance of diesel engines for offering greater fuel efficiency to lower CO_2 emissions,
- developing improved ethanol-enhanced gasoline.

(G) Impacts on petroleum transportation and storage

The results indicate that 13.9% of the respondents agree that the impacts of increased temperature on petroleum transportation and storage will be significant, 38.9% confirm that there will be some impacts, 41.7% indicate minor impacts, and 5.5% are not sure. In general, in different degrees, over 90% of the respondents are concerned about the impacts on petroleum transportation and storage.

Among the respondents, the percentages of individuals who agree that there will be significant or some impacts are 37.5, 100, 66.7 and 66.7% for groups of industry, government, research institution and non-governmental organization, respectively. The percentages who indicate minor impacts are 50.0 and 33.3% for groups of industry and research institution, respectively. Only 33.3% of individuals from non-governmental organizations are "not sure" of the impacts.

Among individuals who care about the impacts, 38.2% advise showing concerns and being alerted, 23.5% suggest conducting research to gain insight, 17.6% recommend

conducting research and being prepared to take actions, and 20.7% propose taking adaptation actions.

Among those who suggest taking adaptation actions, the percentages of individuals who agree with the following actions are 85.2, 29.5, 58.8, 23.6, 29.4, 29.5, 23.6, 55.9, 29.5, 41.2, 29.5 and 44.1%, respectively:

- investigating all possible impacts and adaptive processes,
- using more accurate measurement instruments,
- redesigning pipelines to enhance foundation and improve stability,
- changing timetable for pipeline installation works,
- improving installation efficiency to shorten field-work duration,
- selecting new materials to prevent pipeline corrosion,
- improving stability of pump station operation,
- redesigning foundation of storage tanks,
- strengthening land-use regulations in damage-prone areas,
- installing fire alarm and prevention system,
- using computerized devices to detect weaknesses in pipeline walls and foundation instability,
- redesigning tanks to reduce spill and leakage.

(H) Impacts on environmental management activities in petroleum industry

The results indicate that 19.4% of the respondents agree that the impacts of increased temperature on environmental management activities in petroleum industry will be significant, 55.6% confirm that there will be some impacts, 19.4% indicate minor impacts, 2.8% suggest no impact, and another 2.8% are not sure. In general, in different degrees, over 90% of the respondents are concerned about the impacts on environmental management activities in petroleum industry.

Among the respondents, the percentages of individuals who agree that there will be significant or some impacts are 37.5, 85.7, 83.3 and 33.3% for groups of industry, government, research institution and non-governmental organization, respectively. The percentages who indicate minor impacts are 50.0, 14.3 and 11.1% for groups of industry, government and research institution, respectively. Also, 5.6 and 66.7% of individuals from groups of industry and non-governmental organization, respectively, are “not sure” of the impacts.

Among individuals who care about the impacts, 14.7% suggest that no action should be taken, 5.9% advise showing concerns and being alerted, 11.8% suggest conducting research to gain insight, 35.3% recommend conducting research and being prepared to take actions, and 32.3% propose taking adaptation actions.

Among those who suggest taking adaptation actions, the percentages of individuals who agree with the following actions are 93.1, 72.4, 62.0, 65.5, 51.7, 41.4, 31.0, 41.4, 24.1 and 37.9%, respectively:

- investigating all possible impacts and adaptive processes and keeping related environmental criteria updated,
- using innovative remediation technologies and developing new ones,
- taking actions to reduce oil leakage and spill, and increasing efficiencies of pollution abatement,
- improving environmental management policies,
- establishing suitable environmental management strategies for petroleum industry,
- installing recovery systems to reuse leaked oil and vapor,
- implementing on-line monitoring system to maximize energy efficiency,
- initiating flare-reduction and emissions-recovery programs,
- developing new technologies to convert coal into clean synthesis gas,
- reinforcing fire alarm and prevention systems.

(I) Summary

Table 2.2 shows a summary of the stakeholders' perception regarding the impacts of increased temperature on various petroleum-related activities. It is indicated that the most vulnerable activities are drilling and production, petroleum transportation and storage, and environmental management works.

(2) Impacts of other changes

Table 2.3 summarizes surveying results of the impacts of changed precipitation patterns on petroleum industry. It is indicated that most of petroleum-related processes are considered vulnerable to changes in precipitation pattern. The most vulnerable activities are related to exploration, drilling, production and environmental management. The least sensitive activities are those associated with refinery. A comparison of results shown in Tables 2.2 and 2.3 indicate that the impacts of increased temperature are stronger than those of changed precipitation pattern.

Table 2.4 summarizes surveying results of the impacts of changed humidity and cloud patterns on petroleum industry. It is indicated that only processes of oil exploration, drilling and production, refinery, and transportation and storage are considered potentially sensitive to changed humidity and cloud patterns. Also, the numbers of respondents to these questions are lower, indicating uncertainties of the perceived impacts.

Table 2.5 provides summarized surveying results of the impacts of increased natural hazards on petroleum industry. It shows that most of the processes in petroleum industry are very sensitive to increased natural hazards. Compared with results shown in Tables

2.2 and 2.3, the significance levels of the impacts from increased natural hazards are equivalent to those from increased temperature, and higher than those from changed precipitation patterns. Also, the majority of feedback from the respondents concentrates in zones of "significant impact" and "some impact".

2.4. Discussions

Clearly, climate-change impacts on petroleum industries are perceived differently by different stakeholders, due to differences in the impacts and the relevant adaptation stategies. Even within an industry, those involved in in-door processing processes would perceive the impacts being minor or even positive, while those responsible to out-door activities are sensitive to any change in climatic conditions.

Due to complicated interactions and extensive uncertainties associated with climatic and industrial factors, some impacts are uncertain or considered insignificant based on the existing knowledge. Further investigation is needed for improved clarity. Detailed knowledge and insight on vulnerability of different parts of petroleum industry to climate change can help to shed light on why oil and gas companies should be concerned about some particular impacts.

Clearly, the goals of petroleum industry are different from those of governmental and research organizations. However, the way in which the climate change impacts are portrayed by the governmental and environmental agencies and the approaches they adopt to evaluate the impacts may have significant influences on industry’s perceptions on climate-change impacts.

Table 2.2 Impacts of increased temperature on various petroleum-related activities

Activities	Significant	Moderate	Minor	Total
oil exploration	11.1%	75.0%	0	86.1%
drilling and production	5.6%	55.5%	33.3%	94.4%
exploration and production infrastructures	0	61.1%	19.4%	80.5%
transportation activities within exploration and production process	8.3%	55.6%	19.4%	83.3%
cost of exploration and production	0	66.7%	11.1%	77.8%
petroleum refinery	13.9%	19.4%	33.4%	66.7%
pollutant emission from refinery processes	13.9%	44.4%	13.9%	72.2%
cost of petroleum refinery	5.6%	38.8%	33.3%	77.7%
petroleum transportation and storage	13.9%	38.9%	41.7%	94.5%
cost of petroleum transportation and storage	0	47.2%	33.3%	80.5%
environmental management activities in petroleum industry	19.4%	55.6%	19.4%	94.4%

Table 2.3 Surveying results of the impacts of changed precipitation patterns on petroleum industry

Activities	Significant	Moderate	Minor	Total
oil exploration	8.3%	55.6%	22.2%	86.1%
drilling and production	13.9%	50.0%	27.8%	91.7%
exploration and production infrastructures	13.9%	44.4%	19.4%	77.7%
transportation activities within exploration and production process	13.9%	61.1%	5.5%	80.5%
cost of exploration and production	8.3%	55.6%	13.9%	77.8%
petroleum refinery process	0	25.0%	19.4%	44.4%
pollutant emission within petroleum refinery process	5.6%	38.9%	8.3%	52.8%
cost of petroleum refinery process	0	19.4%	25.0%	44.4%
petroleum transportation and storage	11.1%	27.8%	28.9%	67.8%
cost of petroleum transportation and storage	11.1%	19.4%	33.3%	63.8%
environmental management activities in petroleum industry	8.3%	44.4%	25.0%	77.7%

Table 2.4 Surveying results of the impacts of changed humidity and cloud patterns on petroleum industry

Activities	Significant	Moderate	Minor	Total
oil exploration	0	19.4%	44.4%	63.8%
drilling and production operations	5.6%	27.8%	25.0%	58.4%
petroleum refinery	0	16.7%	38.9%	55.6%
petroleum transportation and storage	5.6%	5.6%	38.9%	50.1%

Table 2.5 Surveying results of the impacts of increased natural hazards on petroleum industry

Activities	Significant	Moderate	Minor	Total
oil exploration processes	44.4%	27.8%	13.9%	86.1%
drilling and production operations	33.3%	38.9%	19.5%	91.7%
exploration and production infrastructures	33.3%	38.9%	19.4%	91.6%
transportation activities within exploration and production process	19.4%	58.3%	13.9%	91.6%
cost of exploration and production	33.3%	38.9%	19.4%	91.6%
refinery	25.0%	33.3%	13.9%	72.2%
pollutant emission from refinery	13.9%	44.4%	8.3%	66.6%
petroleum transportation and storage	22.2%	55.6%	8.3%	86.1%
cost of petroleum transportation and storage	8.3%	55.6%	22.2%	86.1%
environmental management activities in petroleum industry	22.2%	55.6%	5.5%	83.3%

3. Analysis of Interactions among Various Impact Factors

3.1. Chi-Square (χ^2) Statistical Test

Chi-square (χ^2) test is used to examine how and why each respondent answers the given questions and the associated interrelationships, and to validate independence of various factors related to climate change impacts.

The questionnaires, which were used to study the respondents' attitudes towards climate-change impacts and adaptation strategies on petroleum industry, consist of a number of categorical data. Analysis of categorical data generally involves the use of data tables. A contingency table, which is a two-way table, can present categorical data by counting the number of observations that fall into each group for two variables, one divided into rows and the other divided into columns. The contingency table provides a foundation for statistical inference, where statistical tests help examine relationships among the variables on the basis of the observed data.

The chi-square (χ^2) test provides a method for testing the association between the row and column variables in the contingency table. The null hypothesis H_0 assumes that there is no association between the variables, while the alternative hypothesis H_a claims that some association does exist. Assume that a sample of size N can be classified into *r* classes by the first variable and into *c* classes by the second, and the frequencies of individuals in each classification can be expressed as n_{rc}. The chi-square test is based on a test statistic that measures the divergence of the observed data from the values that would be expected under the null hypothesis of no association. This requires calculation of the expected values based on the data. The expected value for each cell in the contingency table is equal to (*row total* × *column total*) / *N*. Then the chi-square test statistic χ_c^2 can be formulated as follows (Kanji, 1993):

$$\chi_c^2 = \sum_{i=1}^{r}\sum_{j=1}^{c} \frac{(n_{ij} - n_{i\bullet}n_{\bullet j}/N)^2}{n_{i\bullet}n_{\bullet j}/N}$$

$$n_{i\bullet} = \sum_{j=1}^{c} n_{ij}, \qquad i = 1, 2, \ldots, r$$

$$n_{\bullet j} = \sum_{i=1}^{r} n_{ij}, \qquad j = 1, 2, \ldots, c$$

The distribution of statistic χ_c^2 is chi-square with (*r-1*)(*c-1*) degrees of freedom. The distribution is denoted as χ^2 (df), where df is the number of degrees of freedom. Once χ_c^2 is computed, it compares with the critical value which can be found using the table of χ^2 distribution with (*r-1*)(*c-1*) degrees of freedom. If χ_c^2 exceeds the critical value, the null hypothesis is rejected and the two variables are dependent on each other. Otherwise if χ_c^2

is smaller than the critical value, it can be concluded that the two variables are independent. Critical values for the hypothesis test depend on the test statistic and the significance level, α, which defines the sensitivity of the test. A value of $\alpha = 0.05$ implies that the null hypothesis is rejected 5% of the time when it is in fact true. The choice of α is somewhat arbitrary, although in practice values of 0.1, 0.05, and 0.01 are common.

The calculation of χ_c^2 test statistic can be done by many software packages based on the above principles. Often, most software packages will report the test result as a *P*-value. The *P*-value for the chi-square test is $P(\chi^2 \geq \chi_c^2)$, the probability of observing a value at least as extreme as the test statistic for a chi-square distribution with $(r-1)(c-1)$ degrees of freedom. The *P*-value indicates the chance that one would obtain a test statistic which is more extreme than the observed one when the H_0 is true. Usually the *P*-value is compared against the level of significance α in the problem to decide whether or not to accept or reject the null hypothesis. If $P < \alpha$, the test statistic is in the rejection region and so we should reject H_0, that means that a small *P*-value is an indication of the false null hypothesis. Therefore, the general rule is that high *P*-values support H_0 and low *P*-values support H_a.

3.2. Association between the Respondents' Background and the Level of Climate-Change Impacts

(1) Analysis on Impacts of Temperature

(A) Impacts on Oil Exploration

The occurrences of perceived levels of impacts on oil exploration given by different groups of respondents are described in Figure 3.1. The impact levels are classified into significant, some, minor, no impact, and not sure; the respondents are from industry, government, research institution, and non-governmental organization. It is indicated from Figure 3.1 that all the respondents tend to consider that the increased temperature will have impacts on oil exploration.

In order to investigate whether or not there exist any association between the impact-level selection and the respondents' backgrounds, the χ^2 test is performed by using the software package Analyse-It®. The test results are shown in Table 3.1, where the cell entries in the contingency table are the surveying results with the calculated expected values being bracketed. It is indicated that the *P*-value is 0.1641 under a significance level of $\alpha = 0.05$, demonstrating that that there is no association between the impact-level selection and the respondents' backgrounds.

Therefore, the perceived impacts of increased temperature on oil exploration are independent of the respondents' backgrounds, indicating fairness of the judgments.

(B) Impacts on Drilling and Production

The occurrences of perceived levels of impacts on drilling and production given by different groups of respondents are described in Figure 3.2. The perceived level of impacts of increased temperature on drilling and production would vary between "minor" and "moderate". The χ^2-test results are shown in Table 3.2. It is indicated that the *P*-value is 0.0169, demonstrating that there exist some association between the impact-level selection and the respondents' backgrounds, with a significance level of $\alpha = 0.05$. The respondents who work in governmental and research organizations tend to consider that increased temperature has some impacts on the drilling processes, while those from industries tend to feel that the impacts are minor. This demonstrates the existence of potential biases from the respondents.

(C) Impacts on Exploration and Production Infrastructures

The occurrences of perceived levels of impacts on exploration and production infrastructures given by different respondents are described in Figure 3.3, and the χ^2-test results are shown in Table 3.3. It is indicated that the *P*-value is 0.0554, demonstrating that there exist an association between the impact-level selection and the respondents' backgrounds, with a significance level of $\alpha = 0.05$. Therefore, the respondents' backgrounds could affect their judgment of the impact levels, indicating the existence of potential biases.

(D) Impacts on Transportation Activities within Exploration and Production Processes

The occurrences of perceived levels of impacts on transportation activities within exploration and production processes given by different respondents are described in Figure 3.4. The χ^2-test results are shown in Table 3.4. It is indicated that the *P*-value is 0.1804 under a significance level of $\alpha = 0.05$, demonstrating that that there is no association between the impact-level selection and the respondents' backgrounds.

Therefore, the perceived impacts of increased temperature on transportation activities within exploration and production processes are independent of the respondents' backgrounds, indicating fairness of the judgments.

(E) Impacts on Costs of Exploration and Production

The occurrences of perceived levels of impacts on costs of exploration and production given by different respondents are described in Figure 3.5, and the χ^2-test results are shown in Table 3.5. It is indicated that the *P*-value is 0.1433 under a significance level of $\alpha = 0.05$, demonstrating that that there is no association between the impact-level selection and the respondents' backgrounds.

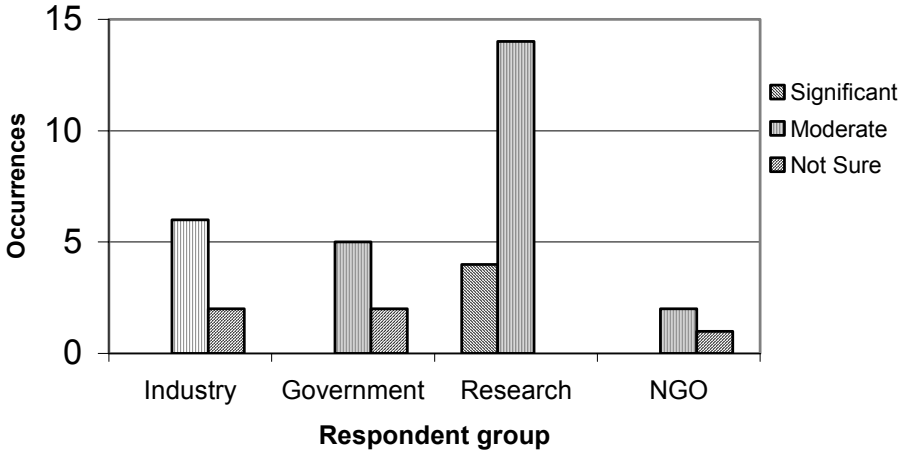

Figure 3.1. Occurrences of perceived levels of impacts on oil exploration given by different respondent groups

Table 3.1 Chi square test of association between the respondents' backgrounds and the judgment of impact levels (for impacts of temperature on oil exploration)

Impact Level	**Respondents' Backgrounds**				
	Industry	Government	Research	NGO	Total
Significant	0 (0.9)	0 (0.8)	4 (2.0)	0 (0.3)	4
Moderate	6 (6.0)	5 (5.3)	14 (13.5)	2 (2.3)	27
Not Sure	2 (1.1)	2 (1.0)	0 (2.5)	1 (0.4)	5
Total	8	7	18	3	36
X^2-Statistic **p**	9.17 0.1641				

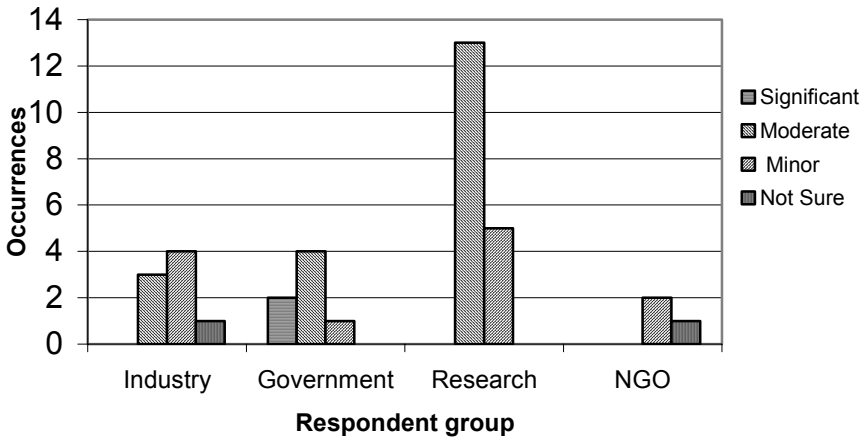

Figure 3.2. Occurrences of perceived levels of impacts on drilling and production given by different respondent groups

Table 3.2 Chi square test of association between the respondents' backgrounds and the impact-level selection (for impacts of temperature on drilling)

Impact lever	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	0	2	0	0	2
	(0.4)	(0.4)	(1.0)	(0.2)	
Moderate	3	4	13	0	20
	(4.4)	(3.9)	(10.0)	(1.7)	
Minor	4	1	5	2	12
	(2.7)	(2.3)	(6.0)	(1.0)	
Not Sure	1	0	0	1	2
	(0.4)	(0.4)	(1.0)	(0.2)	
Total	8	7	18	3	36
X^2 statistic	20.17				
p	0.0169				

Therefore, the perceived impacts of increased temperature on costs of exploration and production are independent of the respondents' backgrounds, indicating fairness of the judgments and high possibility of such impacts.

(F) Impacts on Refining Processes

The occurrences of perceived levels of impacts on refinery given by different respondents are described in Figure 3.6, and the χ^2-test results are shown in Table 3.6. It is indicated that the *P*-value is 0.408 under a significance level of $\alpha = 0.05$, demonstrating that that there is no association between the impact-level selection and the respondents' backgrounds, indicating independence and fairness of the judgments. Thus, there will be a high possibility of such impacts.

(G) Impacts on Pollutant Emission from Oil Refinery Processes

The occurrences of perceived levels of impacts on pollutant emission from oil refinery processes given by different groups of respondents are described in Figure 3.7, and the χ^2-test results are shown in Table 3.7. It is indicated that the *P*-value is 0.0044, demonstrating that there exist an association between the impact-level selection and the respondents' backgrounds, with a significance level of $\alpha = 0.05$. Therefore, the respondents' backgrounds could affect their judgment of the impact levels. Those from governmental and research organizations tend to consider that the impacts are significant and moderate, respectively, indicating the existence of potential biases.

(H) Impact on Petroleum Transportation and Storage

The occurrences of perceived levels of impacts on petroleum transportation and storage given by different groups of respondents are described in Figure 3.8, and the χ^2-test results are shown in Table 3.8. It is indicated that the *P*-value is 0.1257 under a significance level of $\alpha = 0.05$, demonstrating that that there is no association between the impact-level selection and the respondents' backgrounds.

Therefore, the perceived impacts of increased temperature on petroleum transportation and storage are independent of the respondents' backgrounds, indicating fairness of the judgments and high possibility of such impacts. .

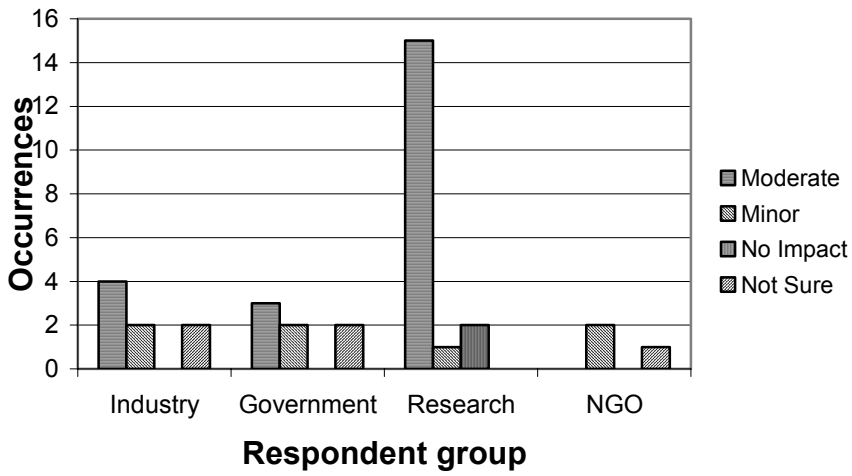

Figure 3.3 Temperature Response to Exploration Infrastructure by Respondents' Background

Table 3.3 Temperature Response to Exploration Infrastructures by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Moderate	4	3	15	0	22
	(4.9)	(4.3)	(11.0)	(1.8)	
Minor	2	2	1	2	7
	(1.6)	(1.4)	(3.5)	(0.6)	
No Impact	0	0	2	0	2
	(0.4)	(0.4)	(1.0)	(0.2)	
Not Sure	2	2	0	1	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Total	8	7	18	3	36
X^2 statistic	16.60				
p	0.0554				

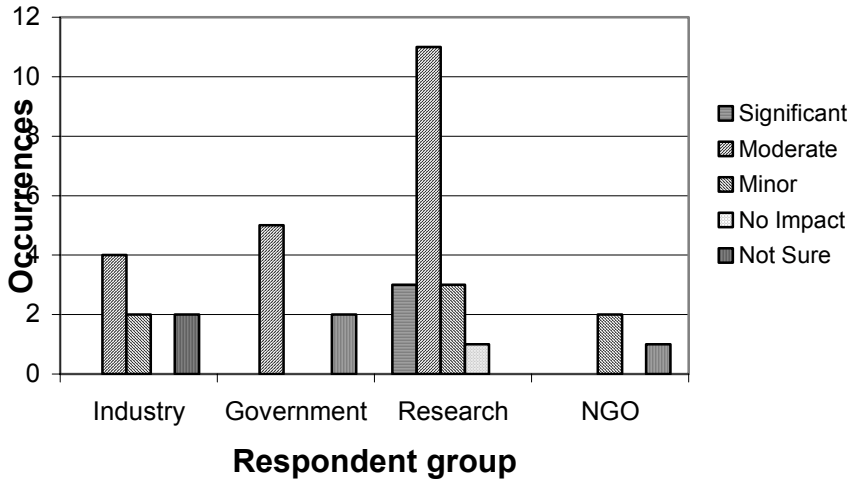

Figure 3.4 Temperature Response to Transportation Activities by Respondents' Background

Table 3.4 Temperature Response to Transportation Activities by Respondents' Background

Impact level	Respondents' Background				
	Industry	Government	Research	NGO	Total
Significant	0	0	3	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Moderate	4	5	11	0	20
	(4.4)	(3.9)	(10.0)	(1.7)	
Minor	2	0	3	2	7
	(1.6)	(1.4)	(3.5)	(0.6)	
No Impact	0	0	1	0	1
	(0.2)	(0.2)	(0.5)	(0.1)	
Not Sure	2	2	0	1	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Total	8	7	18	3	36
X^2 statistic	16.24				
p	0.1804				

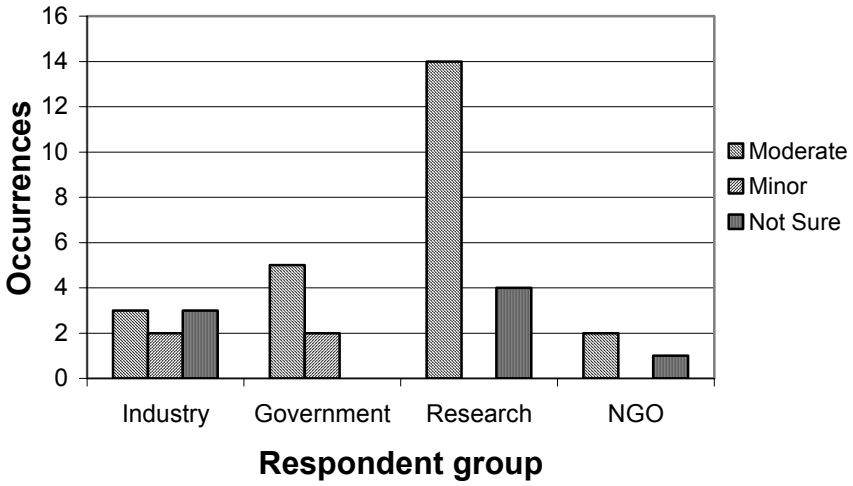

Figure 3.5 Temperature Response to Exploration Cost by Respondents' Background

Table 3.5 Temperature Response to Exploration Cost by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Moderate	3	5	14	2	24
	(5.3)	(4.7)	(12.0)	(2.0)	
Minor	2	2	0	0	4
	(0.9)	(0.8)	(2.0)	(0.3)	
Not Sure	3	0	4	1	8
	(1.8)	(1.6)	(4.0)	(0.7)	
Total	8	7	18	3	36
X^2 statistic	9.58				
p	0.1433				

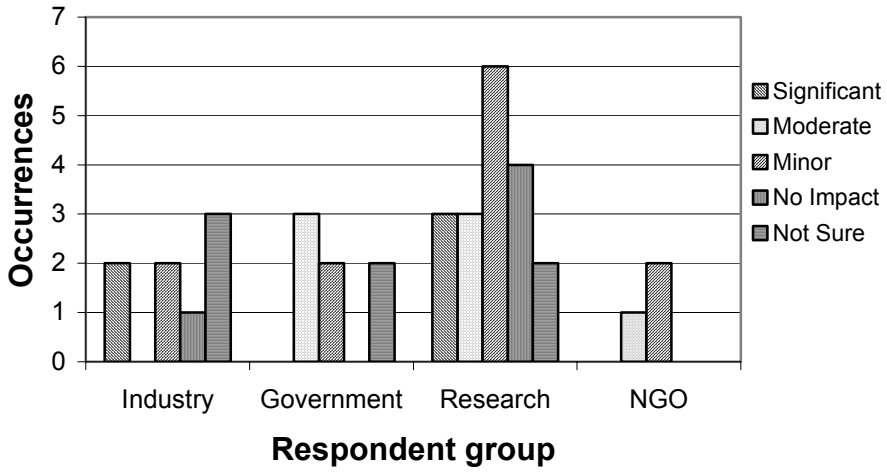

Figure 3.6 Temperature Response to Refining Process by Respondents' Background

(I) Impacts on Costs of Transportation and Storage

The occurrences of perceived levels of impacts on costs of transportation and storage given by different groups of respondents are described in Figure 3.9, and the χ^2-test results are shown in Table 3.9. It is indicated that the *P*-value is 0.1304 under a significance level of $\alpha = 0.05$, demonstrating that that there is no significant association between the impact-level selection and the respondents' backgrounds, indicating independence and fairness of the judgments.

(J) Impacts on Environmental Management Activities in Petroleum Industry

The occurrences of perceived levels of impacts on environmental management activities in petroleum industry given by different groups of respondents are described in Figure 3.10, and the χ^2-test results are shown in Table 3.10. It is indicated that the *P*-value is 0.0744, demonstrating that there exist an association between the impact-level selection and the respondents' backgrounds, with a significance level of $\alpha = 0.05$. Therefore, the respondents' backgrounds could affect their judgment of the impact levels. Those from governmental and research organizations tend to consider that the impacts are significant and moderate, respectively. Respondents from industrial, governmental and research organizations tend to consider that the impacts are minor, significant and moderate, respectively, due mainly to their different backgrounds and standpoints. These indicate the existence of potential biases.

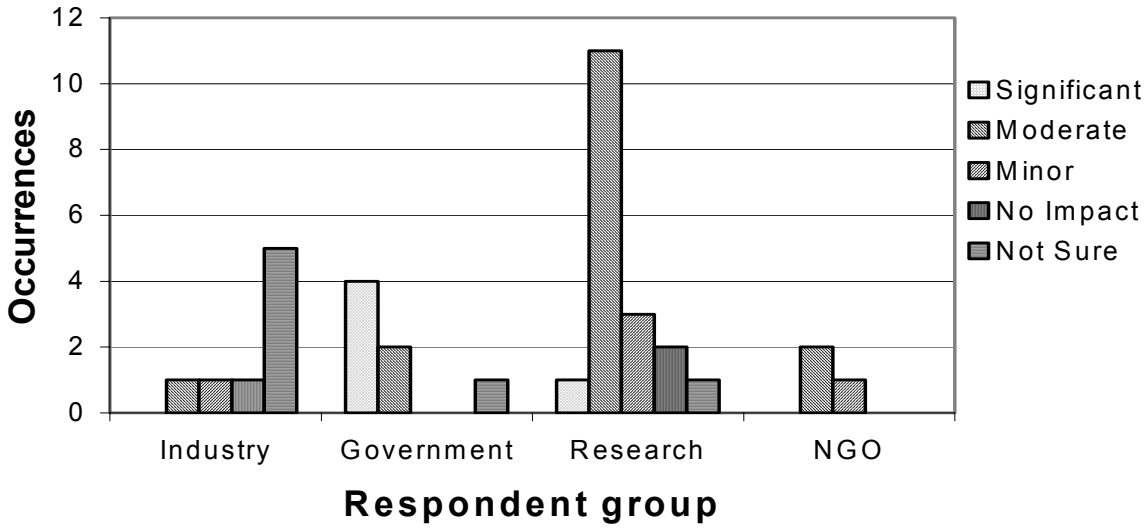

Figure 3.7 Temperature Response to Refinery Pollution by Respondents' Background

Table 3.7 Temperature Response to Refinery Pollution by Respondents' Background

Impact level	Respondents' Background				
	Industry	Government	Research	NGO	Total
Significant	0	4	1	0	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Moderate	1	2	11	2	16
	(3.6)	(3.1)	(8.0)	(1.3)	
Minor	1	0	3	1	5
	(1.1)	(1.0)	(2.5)	(0.4)	
No Impact	1	0	2	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Not Sure	5	1	1	0	7
	(1.6)	(1.4)	(3.5)	(0.6)	
Total	8	7	18	3	36
X^2 statistic	28.71				
p	0.0044				

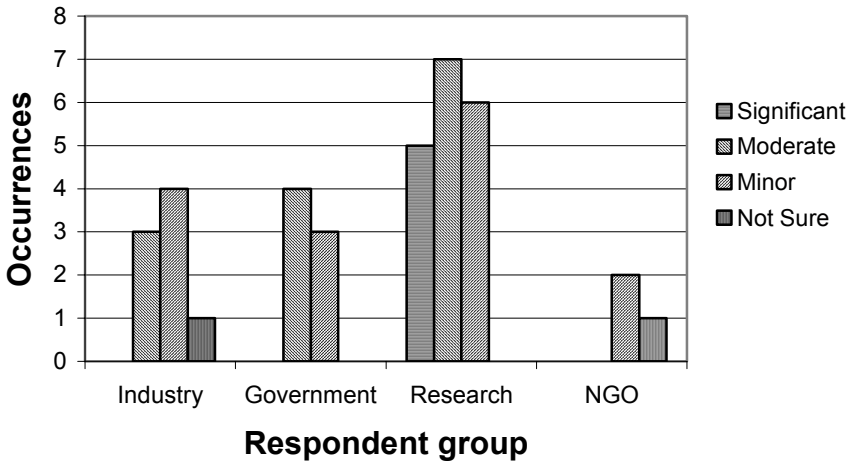

Figure 3.8 Temperature Response to Petroleum Storage by Respondents' Background

Table 3.8 Temperature Response to Petroleum Storage by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	0	0	5	0	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Moderate	3	4	7	0	14
	(3.1)	(2.7)	(7.0)	(1.2)	
Minor	4	3	6	2	15
	(3.3)	(2.9)	(7.5)	(1.3)	
Not Sure	1	0	0	1	2
	(0.4)	(0.4)	(1.0)	(0.2)	
Total	8	7	18	3	36
X^2 statistic	13.91				
p	0.1257				

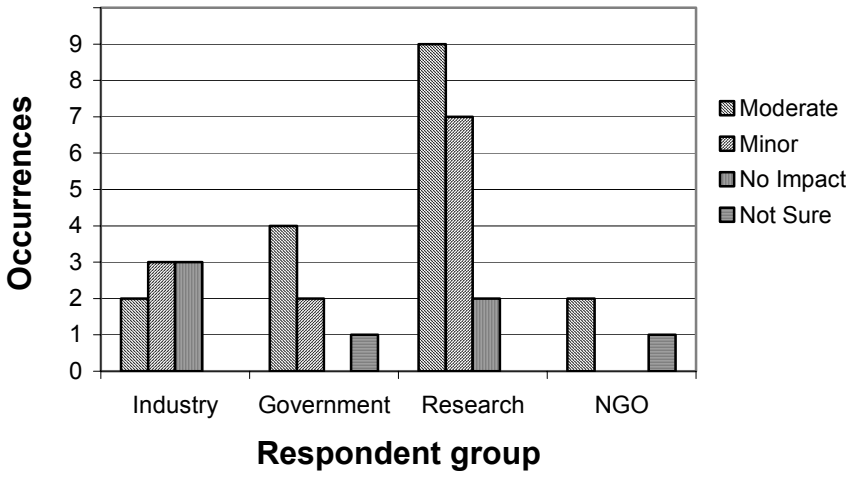

Figure 3.9 Temperature Response to Petroleum Storage Cost by Respondents' Background

Table 3.9 Temperature Response to Petroleum Storage Cost by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Moderate	2	4	9	2	17
	(3.8)	(3.3)	(8.5)	(1.4)	
Minor	3	2	7	0	12
	(2.7)	(2.3)	(6.0)	(1.0)	
No Impact	3	0	2	0	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Not Sure	0	1	0	1	2
	(0.4)	(0.4)	(1.0)	(0.2)	
Total	8	7	18	3	36
X^2 statistic	13.78				
p	0.1304				

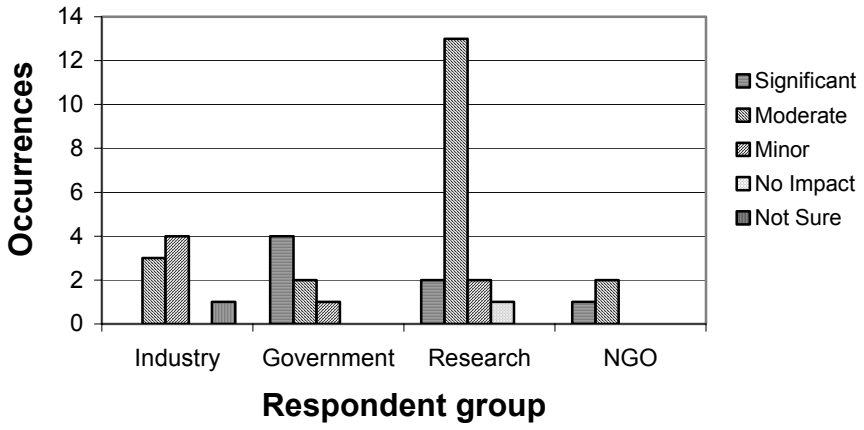

Figure 3.10 Temperature Response to Environmental Activities by Respondents' Background

Table 3.10 Temperature Response to Environmental Activities by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	0	4	2	1	7
	(1.6)	(1.4)	(3.5)	(0.6)	
Moderate	3	2	13	2	20
	(4.4)	(3.9)	(10.0)	(1.7)	
Minor	4	1	2	0	7
	(1.6)	(1.4)	(3.5)	(0.6)	
No Impact	0	0	1	0	1
	(0.2)	(0.2)	(0.5)	(0.1)	
Not Sure	1	0	0	0	1
	(0.2)	(0.2)	(0.5)	(0.1)	
Total	8	7	18	3	36
X^2 statistic	19.63				
p	0.0744				

(2) Impacts of Precipitation-Pattern Variations on Petroleum Industry

The survey and test results of the impacts of precipitation-pattern variations on petroleum industry are described in Figures 3.11 to 3.20 and Tables 3.11 through 3.20. Through analyses of these results, the following summaries can be obtained:

- The changed precipitation patters tend to have moderate or minor impacts on oil exploration processes, and the respondents' backgrounds could affect their judgment of the impact levels, indicating the existence of potential biases;
- The changed precipitation patters tend to have moderate or minor impacts on drilling and production operations, and the respondents' backgrounds would not affect their judgment of the impact levels, indicating independence and fairness of the judgments;
- The changed precipitation patters will have different levels of perceived impacts (significant, moderate, minor, or no impact) on exploration and production infrastructures, and the respondents' backgrounds could affect their judgment of the impact levels;
- The changed precipitation patters will have different levels of perceived impacts (significant, moderate, minor, or no impact) on transportation activities within exploration and production processes, and the respondents' backgrounds could affect their judgment of the impact levels;
- The changed precipitation patters tend to have moderate to significant impacts on costs of exploration and production, and the respondents' backgrounds would not affect their judgment of the impact levels;
- The perceived impacts of changed precipitation on petroleum refining processes are uncertain (the feedback is between "no impact" and "moderate impact"), and the respondents' backgrounds could affect their judgment of the impact levels;
- The perceived impacts of changed precipitation on pollutant emission from refinery processes are uncertain (the feedback is between "not sure" and "moderate impact"), and the respondents' backgrounds would not affect their judgment of the impact levels;
- The changed precipitation patters will have different levels of perceived impacts (minor to moderate) on petroleum transportation and storage, and the respondents' backgrounds could affect their judgment of the impact levels;
- The changed precipitation patters will have different levels of perceived impacts (significant, moderate, minor, or no impact) on costs of petroleum transportation and storage, but the respondents' backgrounds could significantly affect their judgment of the impact levels;
- The changed precipitation patters will have different levels of perceived impacts (significant, moderate, minor, or no impact) on environmental management activities in petroleum industry, but the respondents' backgrounds could significantly affect their judgment of the impact levels.

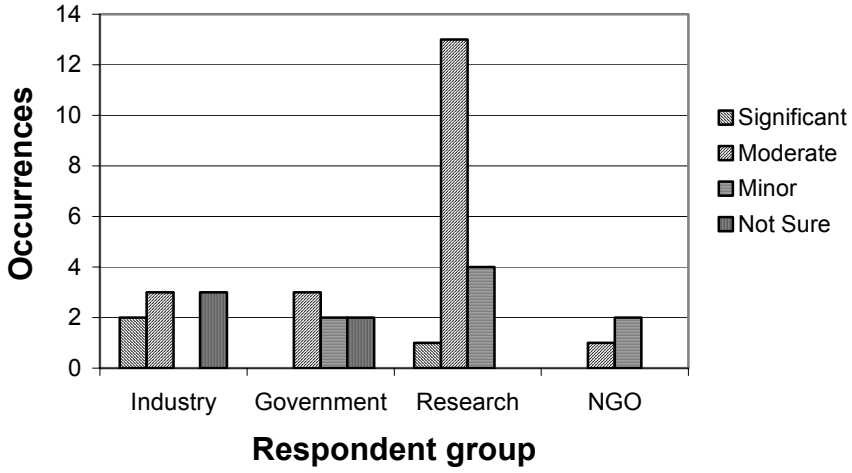

Figure 3.11 Precipitation Response to Exploration Process by Respondents' Background

Table 3.11 Precipitation Response to Exploration Process by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	2	0	1	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Moderate	3	3	13	1	20
	(4.4)	(3.9)	(10.0)	(1.7)	
Minor	0	2	4	2	8
	(1.8)	(1.6)	(4.0)	(0.7)	
Not Sure	3	2	0	0	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Total	8	7	18	3	36
X^2 statistic	17.29				
p	0.0443				

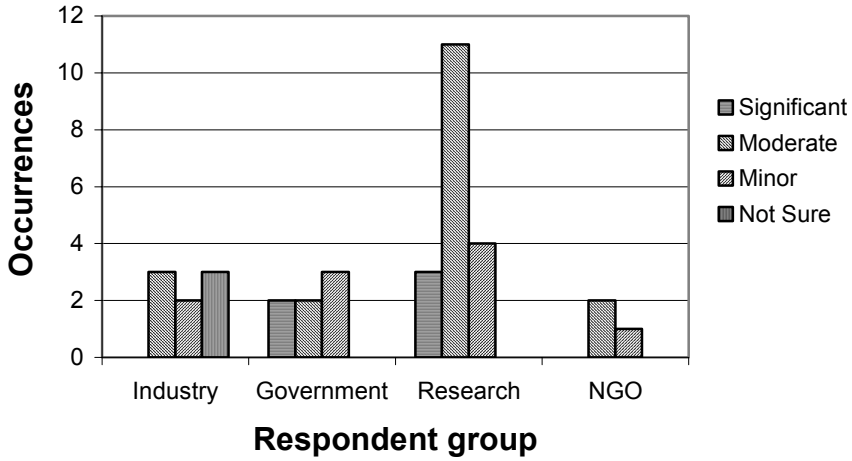

Figure 3.12 Precipitation Response to Drilling Process by Respondents' Background

Table 3.12 Precipitation Response to Drilling Process by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	0	2	3	0	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Moderate	3	2	11	2	18
	(4.0)	(3.5)	(9.0)	(1.5)	
Minor	2	3	4	1	10
	(2.2)	(1.9)	(5.0)	(0.8)	
Not Sure	3	0	0	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Total	8	7	18	3	36
X^2 statistic	15.55				
p	0.0770				

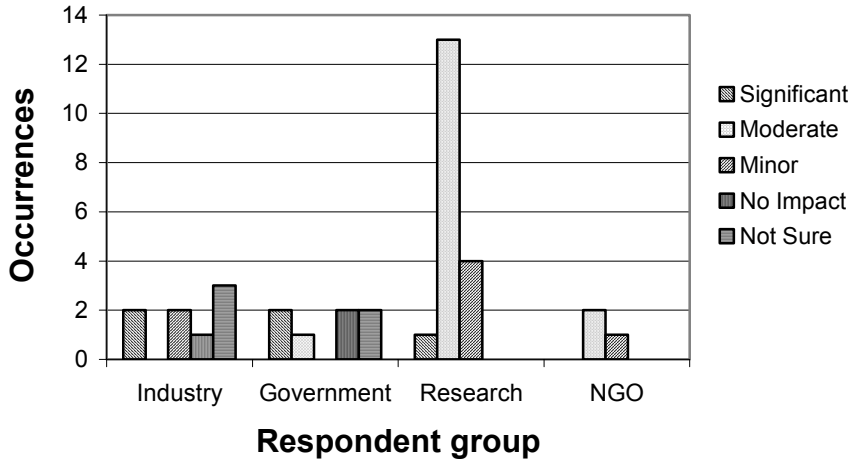

Figure 3.13 Precipitation Response to Exploration Infrastructures by Respondents' Background

Table 3.13 Precipitation Response to Exploration Infrastructures by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	2	2	1	0	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Moderate	0	1	13	2	16
	(3.6)	(3.1)	(8.0)	(1.3)	
Minor	2	0	4	1	7
	(1.6)	(1.4)	(3.5)	(0.6)	
No Impact	1	2	0	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Not Sure	3	2	0	0	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Total	8	7	18	3	36
X^2 statistic	25.99				
p	0.0108				

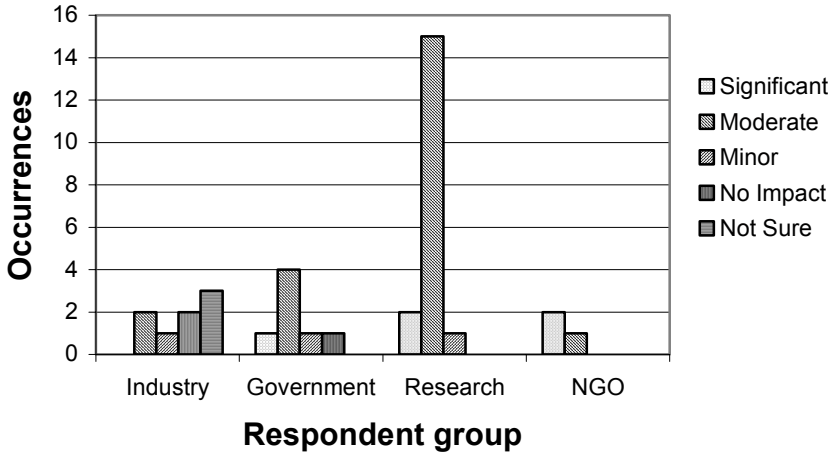

Figure 3.14 Precipitation Response to Transportation Activities by Respondents' Background

Table 3.14 Precipitation Response to Transportation Activities by Respondents' Background

Impact level	Respondents' Background				
	Industry	Government	Research	NGO	Total
Significant	0	1	2	2	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Moderate	2	4	15	1	22
	(4.9)	(4.3)	(11.0)	(1.8)	
Minor	1	1	1	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
No Impact	2	1	0	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Not Sure	3	0	0	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Total	8	7	18	3	36
X^2 statistic	26.88				
p	0.0080				

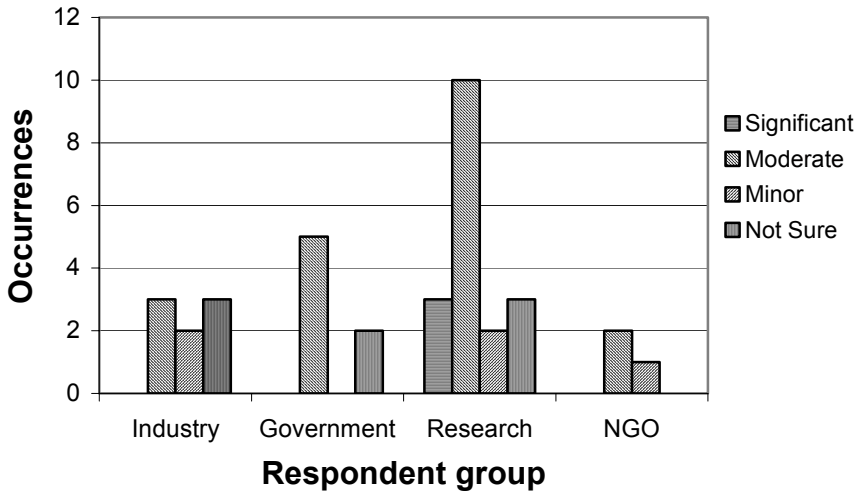

Figure 3.15 Precipitation Response to Exploration Cost by Respondents' Background

Table 3.15 Precipitation Response to Exploration Cost by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	0	0	3	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Moderate	3	5	10	2	20
	(4.4)	(3.9)	(10.0)	(1.7)	
Minor	2	0	2	1	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Not Sure	3	2	3	0	8
	(1.8)	(1.6)	(4.0)	(0.7)	
Total	8	7	18	3	36
X^2 statistic	8.34				
p	0.5005				

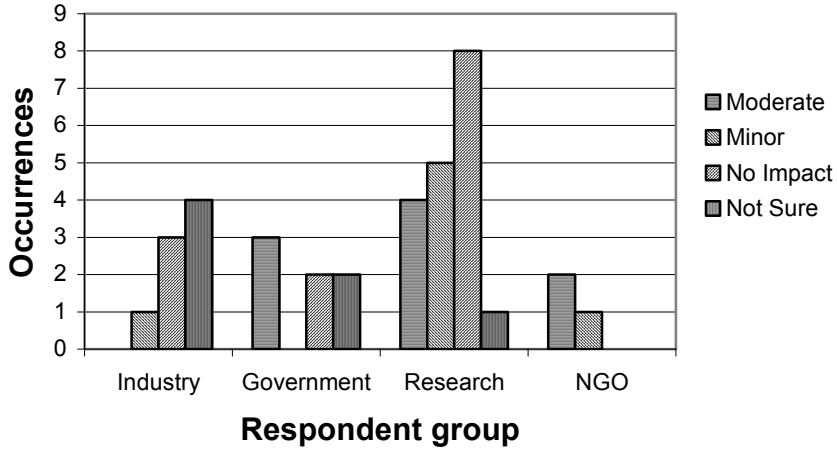

Figure 3.16 Precipitation Response to Refining Process by Respondents' Background

Table 3.16 Precipitation Response to Refining Process by Respondents' Background

Impact level	Respondents' Background				
	Industry	Government	Research	NGO	Total
Moderate	0	3	4	2	9
	(2.0)	(1.8)	(4.5)	(0.8)	
Minor	1	0	5	1	7
	(1.6)	(1.4)	(3.5)	(0.6)	
No Impact	3	2	8	0	13
	(2.9)	(2.5)	(6.5)	(1.1)	
Not Sure	4	2	1	0	7
	(1.6)	(1.4)	(3.5)	(0.6)	
Total	8	7	18	3	36
X^2 statistic	15.59				
p	0.0760				

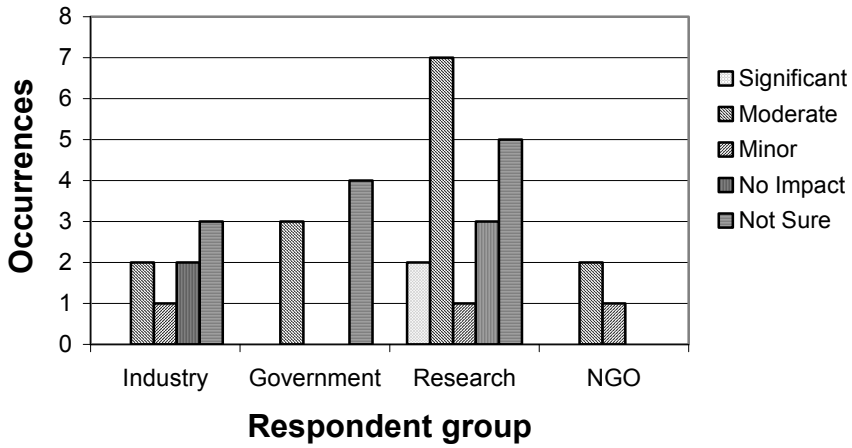

Figure 3.17 Precipitation Response to Refinery Pollution by Respondents' Background

Table 3.17 Precipitation Response to Refinery Pollution by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	0	0	2	0	2
	(0.4)	(0.4)	(1.0)	(0.2)	
Moderate	2	3	7	2	14
	(3.1)	(2.7)	(7.0)	(1.2)	
Minor	1	0	1	1	3
	(0.7)	(0.6)	(1.5)	(0.3)	
No Impact	2	0	3	0	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Not Sure	3	4	5	0	12
	(2.7)	(2.3)	(6.0)	(1.0)	
Total	8	7	18	3	36
X^2 statistic	10.79				
p	0.5474				

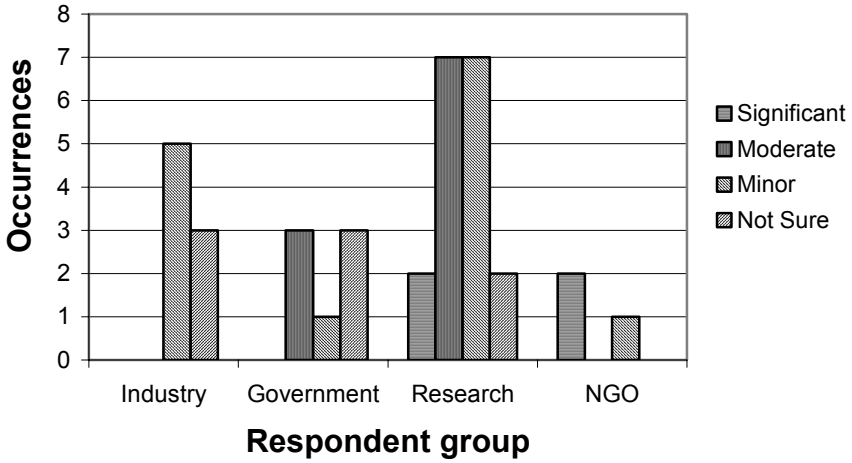

Figure 3.18 Precipitation Response to Petroleum Storage by Respondents' Background

Table 3.18 Precipitation Response to Petroleum Storage by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	0	0	2	2	4
	(0.9)	(0.8)	(2.0)	(0.3)	
Moderate	0	3	7	0	10
	(2.2)	(1.9)	(5.0)	(0.8)	
Minor	5	1	7	1	14
	(3.1)	(2.7)	(7.0)	(1.2)	
Not Sure	3	3	2	0	8
	(1.8)	(1.6)	(4.0)	(0.7)	
Total	8	7	18	3	36
X^2 statistic	20.54				
p	0.0149				

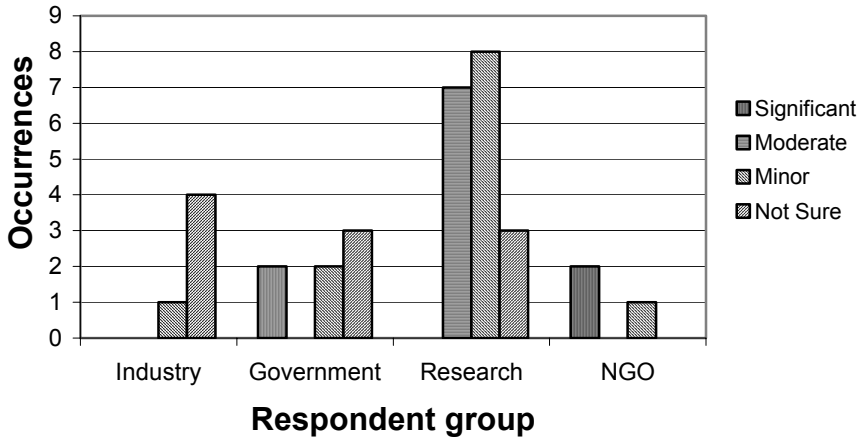

Figure 3.19 Precipitation Response to Petroleum Storage Cost by Respondents' Background

Table 3.19 Precipitation Response to Petroleum Storage Cost by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	0	2	0	2	4
	(0.9)	(0.8)	(2.0)	(0.3)	
Moderate	0	0	7	0	7
	(1.6)	(1.4)	(3.5)	(0.6)	
Minor	1	2	8	1	12
	(2.7)	(2.3)	(6.0)	(1.0)	
No Impact	3	0	0	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Not Sure	4	3	3	0	10
	(2.2)	(1.9)	(5.0)	(0.8)	
Total	8	7	18	3	36
X^2 statistic	36.03				
p	0.0003				

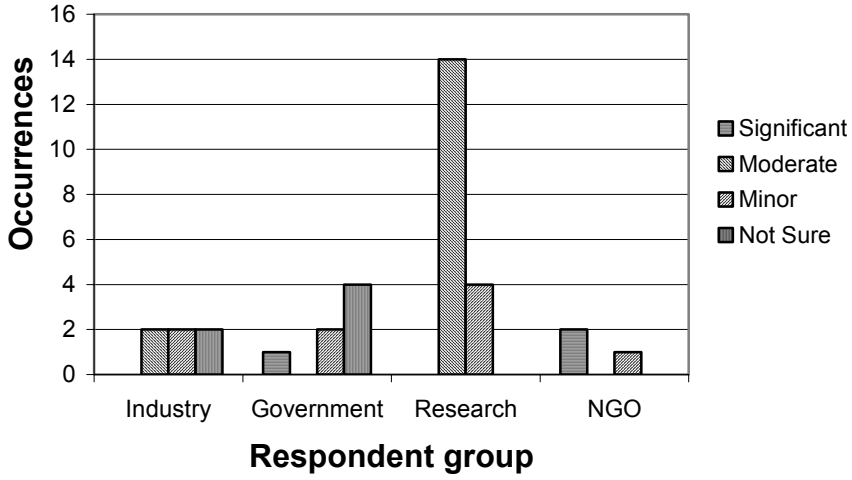

Figure 3.20 Precipitation Response to Environmental Activities by Respondents' Background

Table 3.20 Precipitation Response to Environmental Activities by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	0	1	0	2	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Moderate	2	0	14	0	16
	(3.6)	(3.1)	(8.0)	(1.3)	
Minor	2	2	4	1	9
	(2.0)	(1.8)	(4.5)	(0.8)	
No Impact	2	0	0	0	2
	(0.4)	(0.4)	(1.0)	(0.2)	
Not Sure	2	4	0	0	6
	(1.3)	(1.2)	(3.0)	(0.5)	
Total	8	7	18	3	36
X^2 statistic	42.23				
p	<0.0001				

(3) Impacts of Natural Hazards on Petroleum Industry

The survey and test results of the impacts of natural hazards on petroleum industry are described in Figures 3.21 to 3.30 and Tables 3.21 to 3.30. Through analyses of these results, the following summaries can be obtained:

- The raised natural-hazard frequency introduced by climate change will have different levels of perceived impacts (significant, moderate, or minor) on oil exploration processes, but the respondents' backgrounds could significantly affect their judgment of the impact levels, indicating the existence of potential biases;
- The raised natural-hazard frequency introduced by climate change tends to have moderate to significant impacts on drilling and production operations, and the respondents' backgrounds would not affect their judgment of the impact levels, indicating independence and fairness of the judgments;
- The raised natural-hazard frequency introduced by climate change tends to have moderate to significant impacts on exploration and production infrastructures, and the respondents' backgrounds would not affect their judgment of the impact levels;
- The raised natural-hazard frequency introduced by climate change will have different levels of perceived impacts (significant, moderate, or minor) on transportation activities within exploration and production processes, but the respondents' backgrounds could significantly affect their judgment of the impact levels;
- The raised natural-hazard frequency introduced by climate change will have different levels of perceived impacts (significant, moderate, minor, or not sure) on costs of exploration and production, but the respondents' backgrounds could significantly affect their judgment of the impact levels;
- The raised natural-hazard frequency will have moderate impacts on petroleum refining processes, and the respondents' backgrounds would not affect their judgment of the impact levels;
- The raised natural-hazard frequency will have different levels of perceived impacts (significant, moderate, or not sure) on pollutant emission from refinery processes, but the respondents' backgrounds could significantly affect their judgment of the impact levels;
- The raised natural-hazard frequency will have moderate impacts on petroleum transportation and storage, and the respondents' backgrounds would not affect their judgment of the impact levels;
- The raised natural-hazard frequency will have minor to moderate impacts on costs of petroleum transportation and storage, and the respondents' backgrounds would not affect their judgment of the impact levels;
- The raised natural-hazard frequency will have moderate impacts on environmental management activities in petroleum industry, and the respondents' backgrounds would not affect their judgment of the impact levels;

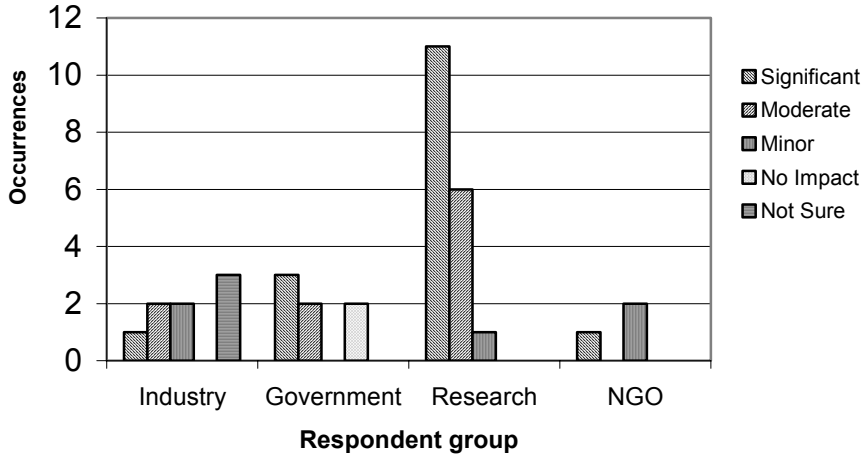

Figure 3.21 Natural Hazard Response to Exploration Process by Respondents' Background

Table 3.21 Natural Hazard Response to Exploration Process by Respondents' Background

Impact level	Respondents' Background				
	Industry	Government	Research	NGO	Total
Significant	1	3	11	1	16
	(3.6)	(3.1)	(8.0)	(1.3)	
Moderate	2	2	6	0	10
	(2.2)	(1.9)	(5.0)	(0.8)	
Minor	2	0	1	2	5
	(1.1)	(1.0)	(2.5)	(0.4)	
No Impact	0	2	0	0	2
	(0.4)	(0.4)	(1.0)	(0.2)	
Not Sure	3	0	0	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Total	8	7	18	3	36
X^2 statistic	31.49				
p	0.0017				

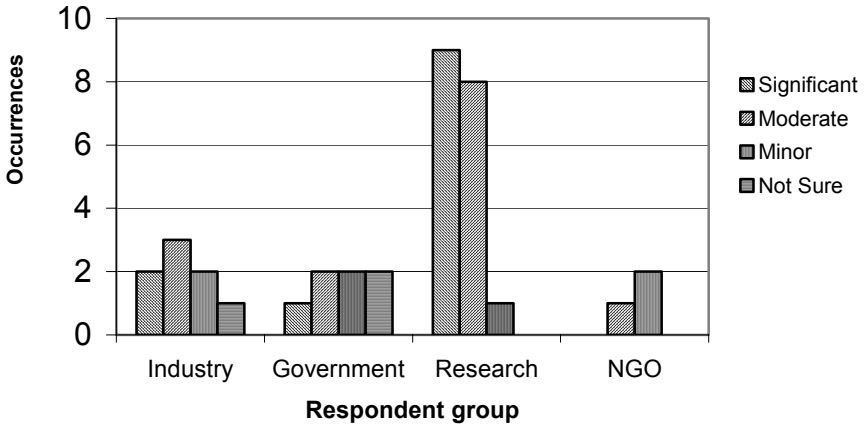

Figure 3.22 Natural Hazard Response to Drilling Process by Respondents' Background

Table 3.22 Natural Hazard Response to Drilling Process by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	2	1	9	0	12
	(2.7)	(2.3)	(6.0)	(1.0)	
Moderate	3	2	8	1	14
	(3.1)	(2.7)	(7.0)	(1.2)	
Minor	2	2	1	2	7
	(1.6)	(1.4)	(3.5)	(0.6)	
Not Sure	1	2	0	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Total	8	7	18	3	36
X^2 statistic	14.80				
p	0.0965				

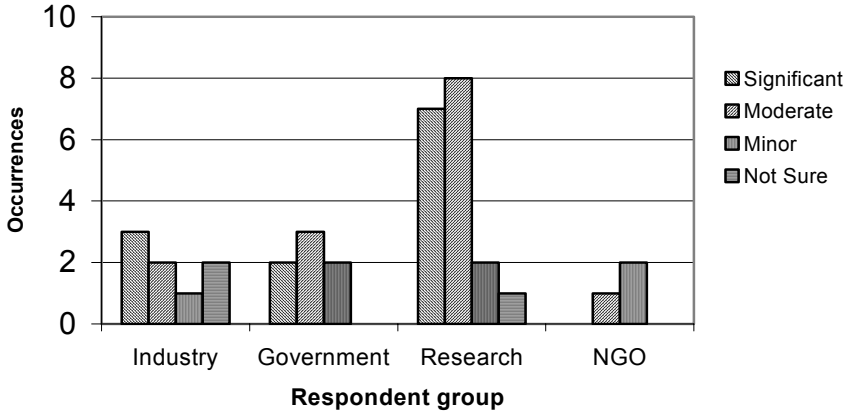

Figure 3.23 Natural Hazard Response to Exploration Infrastructures by Respondents' Background

Table 3.23 Natural Hazard Response to Exploration Infrastructures by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	3	2	7	0	12
	(2.7)	(2.3)	(6.0)	(1.0)	
Moderate	2	3	8	1	14
	(3.1)	(2.7)	(7.0)	(1.2)	
Minor	1	2	2	2	7
	(1.6)	(1.4)	(3.5)	(0.6)	
Not Sure	2	0	1	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Total	8	7	18	3	36
X^2 statistic	10.10				
p	0.3428				

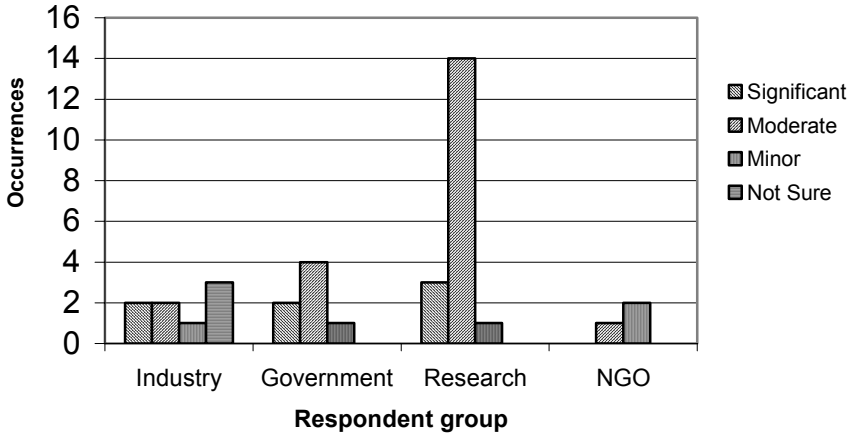

Figure 3.24 Natural Hazard Response to Transportation Activities by Respondents' Background

Table 3.24 Natural Hazard Response to Transportation Activities by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	2	2	3	0	7
	(1.6)	(1.4)	(3.5)	(0.6)	
Moderate	2	4	14	1	21
	(4.7)	(4.1)	(10.5)	(1.8)	
Minor	1	1	1	2	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Not Sure	3	0	0	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Total	8	7	18	3	36
X^2 statistic	21.52				
p	0.0105				

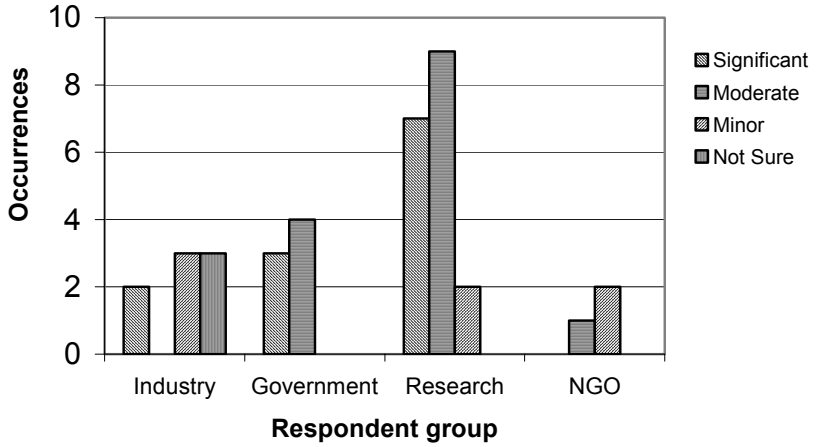

Figure 3.25 Natural Hazard Response to Exploration Cost by Respondents' Background

Table 3.25 Natural Hazard Response to Exploration Cost by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	2	3	7	0	12
	(2.7)	(2.3)	(6.0)	(1.0)	
Moderate	0	4	9	1	14
	(3.1)	(2.7)	(7.0)	(1.2)	
Minor	3	0	2	2	7
	(1.6)	(1.4)	(3.5)	(0.6)	
Not Sure	3	0	0	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Total	8	7	18	3	36
X^2 statistic	23.12				
p	0.0059				

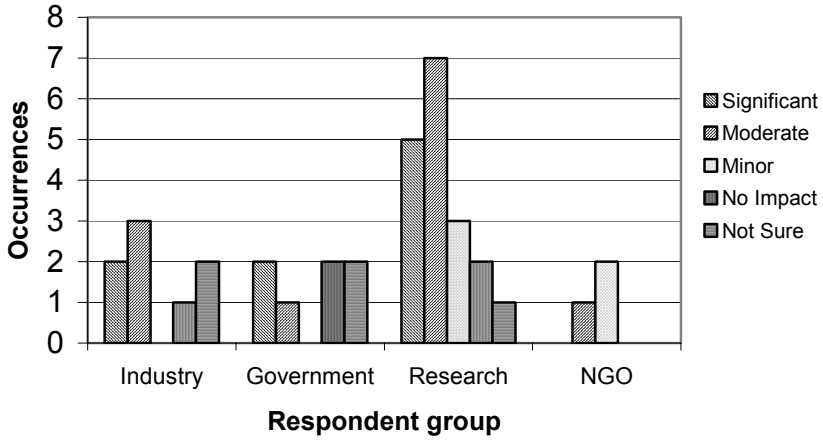

Figure 3.26 Natural Hazard Response to Refining Process by Respondents' Background

Table 3.26 Natural Hazard Response to Refining Process by Respondents' Background

Impact level	Respondents' Background				
	Industry	Government	Research	NGO	Total
Significant	2	2	5	0	9
	(2.0)	(1.8)	(4.5)	(0.8)	
Moderate	3	1	7	1	12
	(2.7)	(2.3)	(6.0)	(1.0)	
Minor	0	0	3	2	5
	(1.1)	(1.0)	(2.5)	(0.4)	
No Impact	1	2	2	0	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Not Sure	2	2	1	0	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Total	8	7	18	3	36
X^2 statistic	14.74				
p	0.2560				

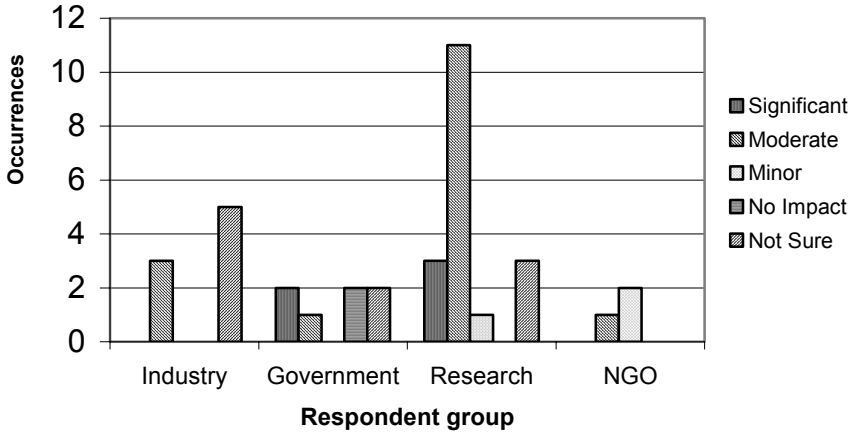

Figure 3.27 Natural Hazard Response to Refinery Pollution by Respondents' Background

Table 3.27 Natural Hazard Response to Refinery Pollution by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	0	2	3	0	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Moderate	3	1	11	1	16
	(3.6)	(3.1)	(8.0)	(1.3)	
Minor	0	0	1	2	3
	(0.7)	(0.6)	(1.5)	(0.3)	
No Impact	0	2	0	0	2
	(0.4)	(0.4)	(1.0)	(0.2)	
Not Sure	5	2	3	0	10
	(2.2)	(1.9)	(5.0)	(0.8)	
Total	8	7	18	3	36
X^2 statistic	32.50				
p	0.0012				

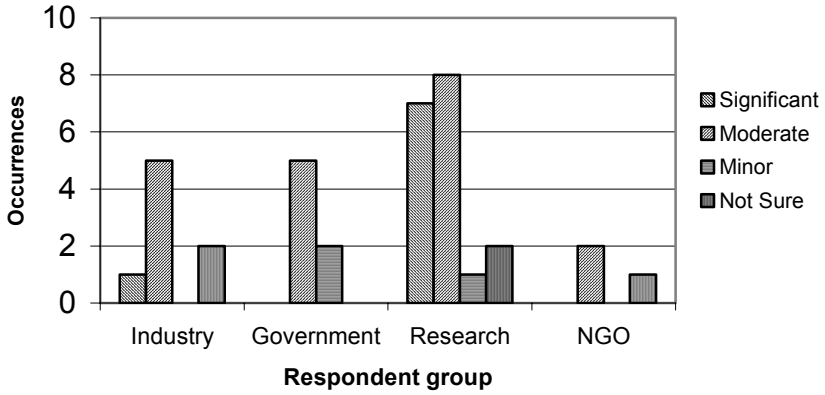

Figure 3.28 Natural Hazard Response to Petroleum Storage by Respondents' Background

Table 3.28 Natural Hazard Response to Petroleum Storage by Respondents' Background

Impact level	Respondents' Background				
	Industry	Government	Research	NGO	Total
Significant	1	0	7	0	8
	(1.8)	(1.6)	(4.0)	(0.7)	
Moderate	5	5	8	2	20
	(4.4)	(3.9)	(10.0)	(1.7)	
Minor	0	2	1	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Not Sure	2	0	2	1	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Total	8	7	18	3	36
X^2 statistic	12.79				
p	0.1723				

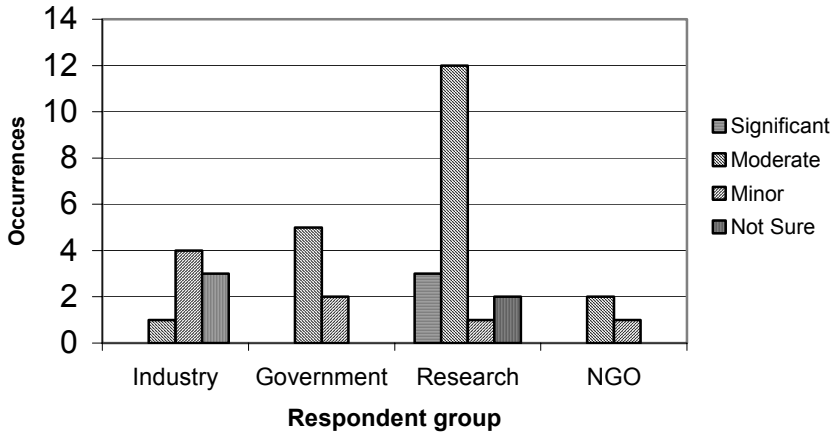

Figure 3.29 Natural Hazard Response to Petroleum Storage Cost by Respondents' Background

Table 3.29 Natural Hazard Response to Petroleum Storage Cost by Respondents' Background

Impact level	Respondents' Background				
	Industry	Government	Research	NGO	Total
Significant	0	0	3	0	3
	(0.7)	(0.6)	(1.5)	(0.3)	
Moderate	1	5	12	2	20
	(4.4)	(3.9)	(10.0)	(1.7)	
Minor	4	2	1	1	8
	(1.8)	(1.6)	(4.0)	(0.7)	
Not Sure	3	0	2	0	5
	(1.1)	(1.0)	(2.5)	(0.4)	
Total	8	7	18	3	36
X^2 statistic	16.48				
p	0.0576				

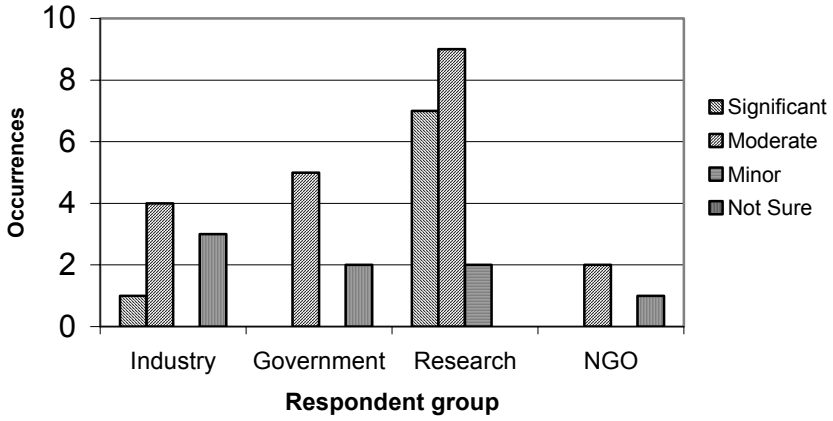

Figure 3.30 Natural Hazard Response to Environmental Activities by Respondents' Background

Table 3.30 Natural Hazard Response to Environmental Activities by Respondents' Background

Impact level	**Respondents' Background**				
	Industry	Government	Research	NGO	Total
Significant	1	0	7	0	8
	(1.8)	(1.6)	(4.0)	(0.7)	
Moderate	4	5	9	2	20
	(4.4)	(3.9)	(10.0)	(1.7)	
Minor	0	0	2	0	2
	(0.4)	(0.4)	(1.0)	(0.2)	
Not Sure	3	2	0	1	6
	(1.3)	(1.2)	(3.0)	(0.5)	
Total	8	7	18	3	36
X^2 statistic	13.52				
p	0.1405				

3.3. Association between the Climatic Factors and the Climate-Change Impact Levels

The survey and test results of the impacts of changed climatic factors (temperature, precipitation, humidity, and natural hazard) on petroleum industry are described in Figures 3.31 to 3.40 and Tables 3.31 to 3.40. Through analyses of these results, the following summaries can be obtained:

- For oil exploration activities, the increased temperature and changed precipitation pattern tend to have moderate impacts, the changed humidity will have minor impacts, and the varied natural-hazard frequency tends to have significant impacts. The relevant impact levels are significantly correlated to the climatic factors, indicating necessity of using multiple strategies for adapting to variations of different climatic factors.
- For drilling and production operations, the increased temperature and changed precipitation pattern tend to have minor to moderate impacts. The impacts from changed humidity are quite uncertain, varying among moderate, minor and "no impact". The varied natural-hazard frequency will have moderate to significant impacts. The relevant impact levels are significantly correlated to the detailed climatic factors.
- For exploration and production infrastructures, the increased temperature and changed precipitation pattern tend to have moderate impacts, and the varied natural-hazard frequency will have moderate to significant impacts on. The relevant impact levels are significantly correlated to the detailed climatic factors.
- The increased temperature, changed precipitation pattern and varied natural-hazard frequency tend to have moderate impacts on transportation activities within exploration and production processes. These impacts are not correlated to detailed climatic factors, indicating equivalency of the impacts from the three climatic factors.
- On costs of exploration and production, the increased temperature and changed precipitation pattern tend to have moderate impacts, and the varied natural-hazard frequency tends to have moderate to significant impacts. The relevant impact levels are significantly correlated to the climatic factors, indicating necessity of using multiple strategies for adapting to variations of different climatic factors.
- On petroleum refining processes, the increased temperature tends to have minor impacts, the changed precipitation pattern will have no impacts, the changed humidity tends to have minor impacts, and the varied natural-hazard frequency will have moderate impacts. The relevant impact levels are significantly correlated to the climatic factors.
- The increased temperature, changed precipitation pattern and varied natural-hazard frequency tend to have moderate impacts on pollutant emission from refinery processes. These impacts are not correlated to detailed climatic factors, indicating equivalency of the impacts from the three climatic factors.

- On petroleum transportation and storage, the increased temperature and changed precipitation pattern tend to have minor to moderate impacts, the varied natural-hazard frequency will have moderate to significant impacts, and the impacts from the changed humidity are uncertain (minor or no impacts). The relevant impact levels are significantly correlated to the climatic factors.
- On costs of petroleum transportation and storage, the increased temperature and varied natural-hazard frequency tend to have moderate impacts, and the changed precipitation pattern will have minor or "not sure" impacts. The relevant impact levels are significantly correlated to the climatic factors.
- The increased temperature, changed precipitation pattern and varied natural-hazard frequency tend to have moderate impacts on environmental management activities in petroleum industry. These impacts are not correlated to detailed climatic factors, indicating equivalency of the impacts from the three climatic factors.

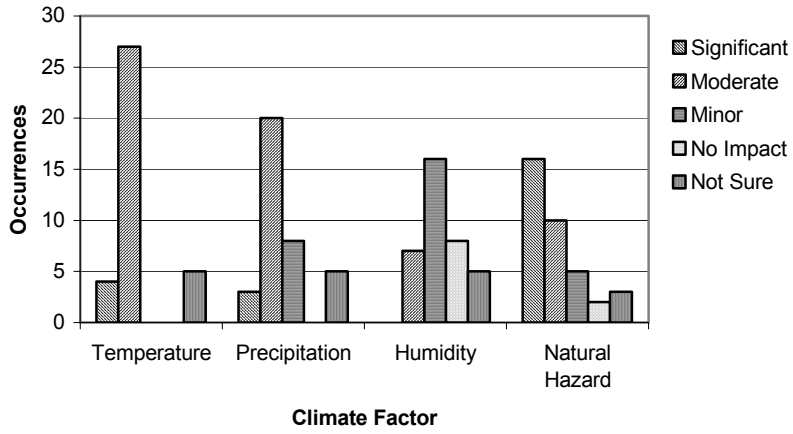

Figure 3.31 Response to Exploration Process by Climate Factor

Table 3.31 Response to Exploration Process by Climate Factor

Impact level	**Climate Factor**				
	Temperature	Precipitation	Humidity	Natural Hazard	Total
Significant	4	3	0	16	23
	(5.8)	(5.8)	(5.8)	(5.8)	
Moderate	27	20	7	10	64
	(16.0)	(16.0)	(16.0)	(16.0)	
Minor	0	8	16	5	29
	(7.3)	(7.3)	(7.3)	(7.3)	
No Impact	0	0	8	2	10
	(2.5)	(2.5)	(2.5)	(2.5)	
Not Sure	5	5	5	3	18
	(4.5)	(4.5)	(4.5)	(4.5)	
Total	36	36	36	36	144
X^2 statistic	78.20				
p	<0.0001				

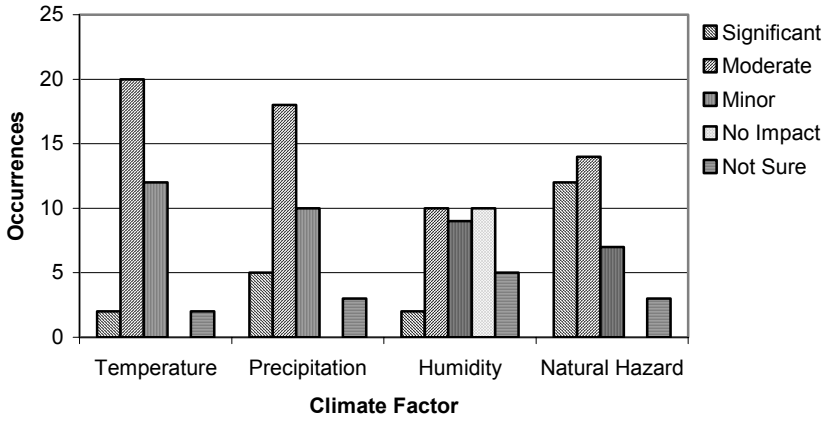

Figure 3.32 Response to Drilling Process by Climate Factor

Table 3.32 Response to Drilling Process by Climate Factor

Impact level	**Climate Factor**				
	Temperature	Precipitation	Humidity	Natural Hazard	Total
Significant	2	5	2	12	21
	(5.3)	(5.3)	(5.3)	(5.3)	
Moderate	20	18	10	14	62
	(15.5)	(15.5)	(15.5)	(15.5)	
Minor	12	10	9	7	38
	(9.5)	(9.5)	(9.5)	(9.5)	
No Impact	0	0	10	0	10
	(2.5)	(2.5)	(2.5)	(2.5)	
Not Sure	2	3	5	3	13
	(3.3)	(3.3)	(3.3)	(3.3)	
Total	36	36	36	36	144
X^2 statistic	49.35				
p	<0.0001				

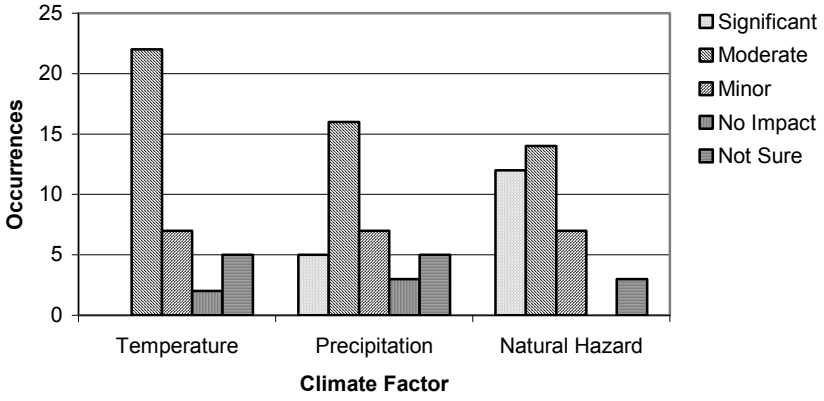

Figure 3.33 Response to Exploration Infrastructure by Climate Factor

Table 3.33 Response to Exploration Infrastructure by Climate Factor

Impact level	**Climate Factor**			
	Temperature	Precipitation	Natural Hazard	Total
Significant	0	5	12	17
	(5.7)	(5.7)	(5.7)	
Moderate	22	16	14	52
	(17.3)	(17.3)	(17.3)	
Minor	7	7	7	21
	(7.0)	(7.0)	(7.0)	
No Impact	2	3	0	5
	(1.7)	(1.7)	(1.7)	
Not Sure	5	5	3	13
	(4.3)	(4.3)	(4.3)	
Total	36	36	36	108
X^2 statistic	18.24			
p	0.0195			

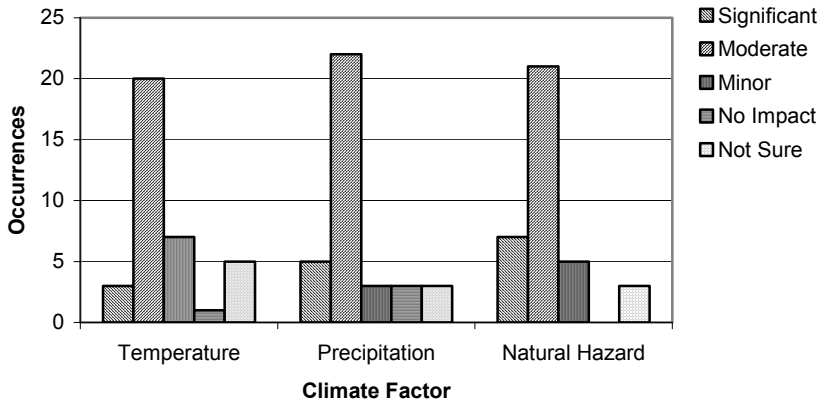

Figure 3.34 Response to Transportation Activities by Climate Factor

Table 3.34 Response to Transportation Activities by Climate Factor

Impact level	**Climate Factor**			
	Temperature	Precipitation	Natural Hazard	Total
Significant	3	5	7	15
	(5.0)	(5.0)	(5.0)	
Moderate	20	22	21	63
	(21.0)	(21.0)	(21.0)	
Minor	7	3	5	15
	(5.0)	(5.0)	(5.0)	
No Impact	1	3	0	4
	(1.3)	(1.3)	(1.3)	
Not Sure	5	3	3	11
	(3.7)	(3.7)	(3.7)	
Total	36	36	36	108
X^2 statistic	7.52			
p	0.4814			

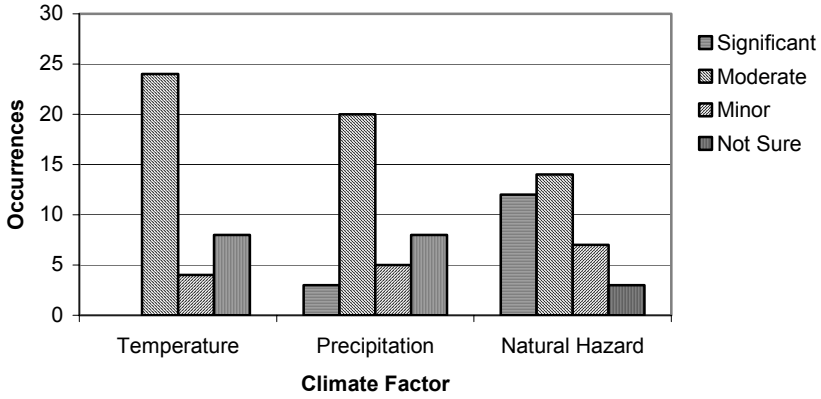

Figure 3.35 Response to Exploration Cost by Climate Factor

Table 3.35 Response to Exploration Cost by Climate Factor

Impact level	**Climate Factor**			
	Temperature	Precipitation	Natural Hazard	Total
Significant	0	3	12	15
	(5.0)	(5.0)	(5.0)	
Moderate	24	20	14	58
	(19.3)	(19.3)	(19.3)	
Minor	4	5	7	16
	(5.3)	(5.3)	(5.3)	
Not Sure	8	8	3	19
	(6.3)	(6.3)	(6.3)	
Total	36	36	36	108
X^2 statistic	21.73			
p	0.0014			

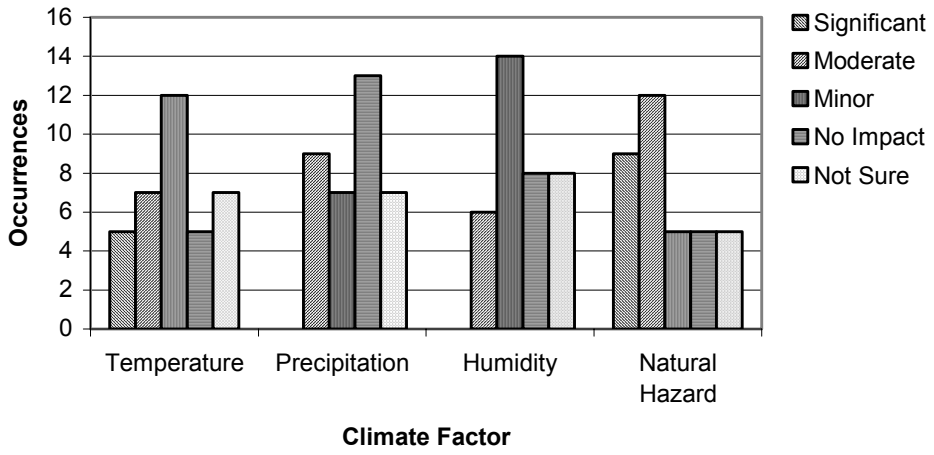

Figure 3.36 Response to Refining Process by Climate Factor

Table 3.36 Response to Refining Process by Climate Factor

Impact level	**Climate Factor**				
	Temperature	Precipitation	Humidity	Natural Hazard	Total
Significant	5	0	0	9	14
	(3.5)	(3.5)	(3.5)	(3.5)	
Moderate	7	9	6	12	34
	(8.5)	(8.5)	(8.5)	(8.5)	
Minor	12	7	14	5	38
	(9.5)	(9.5)	(9.5)	(9.5)	
No Impact	5	13	8	5	31
	(7.8)	(7.8)	(7.8)	(7.8)	
Not Sure	7	7	8	5	27
	(6.8)	(6.8)	(6.8)	(6.8)	
Total	36	36	36	36	144
X^2 statistic	30.56				
p	0.0023				

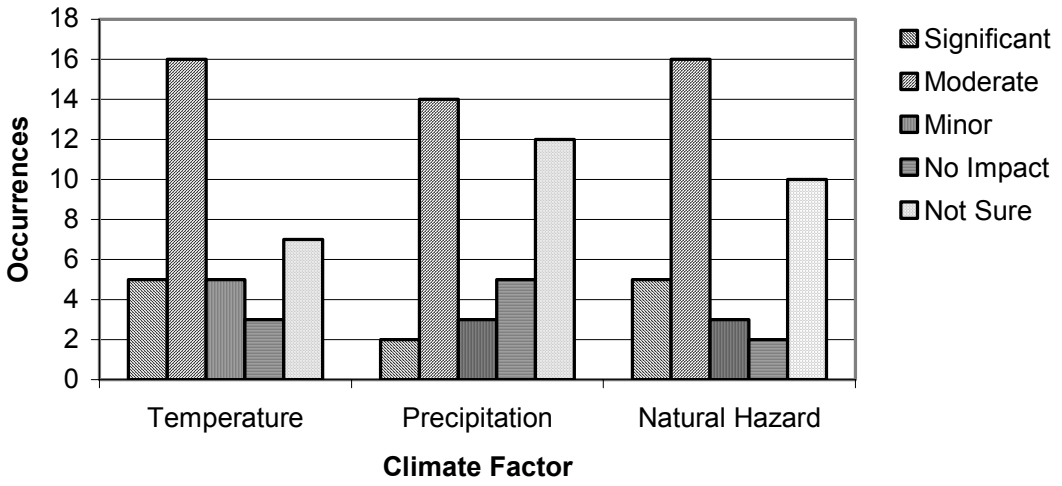

Figure 3.37 Response to Refinery Pollution by Climate Factor

Table 3.37 Response to Refinery Pollution by Climate Factor

Impact level	**Climate Factor**			
	Temperature	Precipitation	Natural Hazard	Total
Significant	5	2	5	12
	(4.0)	(4.0)	(4.0)	
Moderate	16	14	16	46
	(15.3)	(15.3)	(15.3)	
Minor	5	3	3	11
	(3.7)	(3.7)	(3.7)	
No Impact	3	5	2	10
	(3.3)	(3.3)	(3.3)	
Not Sure	7	12	10	29
	(9.7)	(9.7)	(9.7)	
Total	36	36	36	108
X^2 statistic	5.11			
p	0.7456			

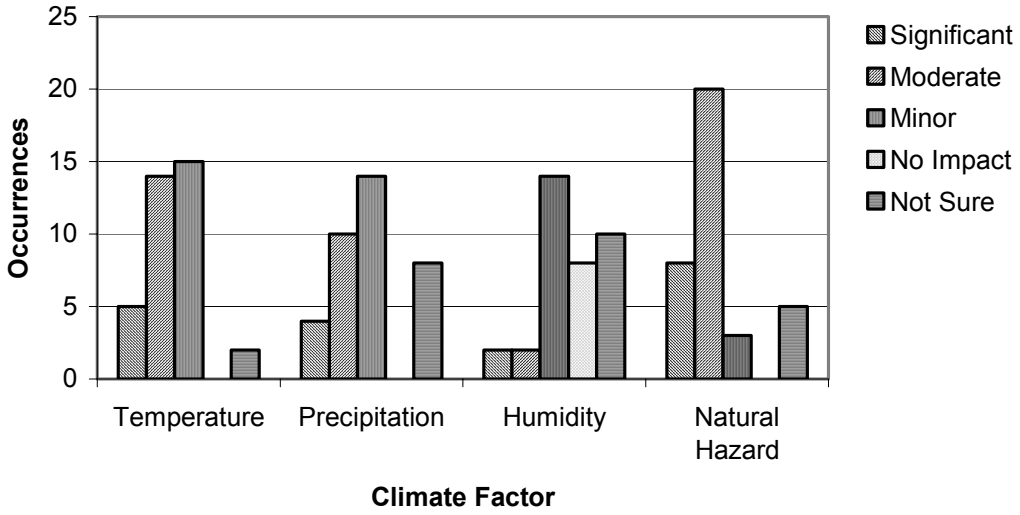

Figure 3.38 Response to Petroleum Storage by Climate Factor

Table 3.38 Response to Petroleum Storage by Climate Factor

Impact level	Climate Factor				
	Temperature	Precipitation	Humidity	Natural Hazard	Total
Significant	5	4	2	8	19
	(4.8)	(4.8)	(4.8)	(4.8)	
Moderate	14	10	2	20	46
	(11.5)	(11.5)	(11.5)	(11.5)	
Minor	15	14	14	3	46
	(11.5)	(11.5)	(11.5)	(11.5)	
No Impact	0	0	8	0	8
	(2.0)	(2.0)	(2.0)	(2.0)	
Not Sure	2	8	10	5	25
	(6.3)	(6.3)	(6.3)	(6.3)	
Total	36	36	36	36	144
X^2 statistic	57.13				
p	<0.0001				

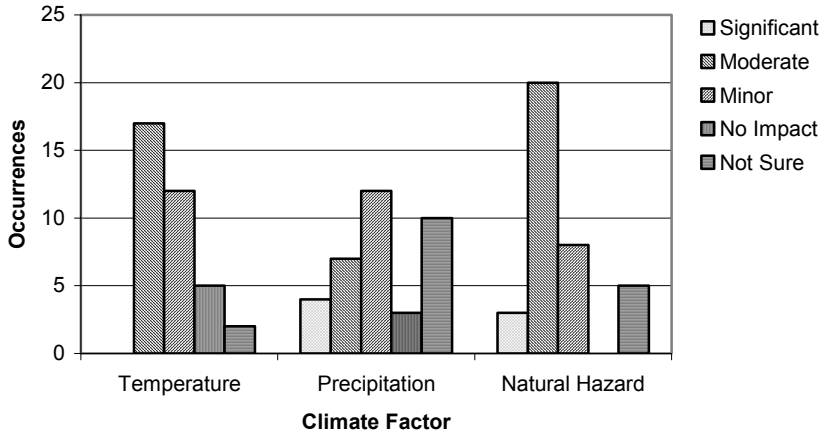

Figure 3.39 Response to Petroleum Storage Cost by Climate Factor

Table 3.39 Response to Petroleum Storage Cost by Climate Factor

Impact level	Climate Factor			
	Temperature	Precipitation	Natural Hazard	Total
Significant	0	4	3	7
	(2.3)	(2.3)	(2.3)	
Moderate	17	7	20	44
	(14.7)	(14.7)	(14.7)	
Minor	12	12	8	32
	(10.7)	(10.7)	(10.7)	
No Impact	5	3	0	8
	(2.7)	(2.7)	(2.7)	
Not Sure	2	10	5	17
	(5.7)	(5.7)	(5.7)	
Total	36	36	36	108
X^2 statistic	21.55			
p	0.0058			

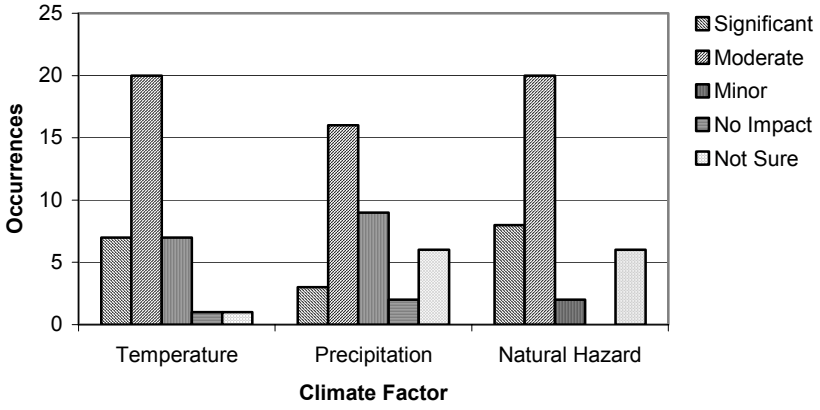

Figure 3.40 Response to Environmental Activities by Climate Factor

Table 3.40 Response to Environmental Activities by Climate Factor

Impact level	**Climate Factor**			
	Temperature	Precipitation	Natural Hazard	Total
Significant	7	3	8	18
	(6.0)	(6.0)	(6.0)	
Moderate	20	16	20	56
	(18.7)	(18.7)	(18.7)	
Minor	7	9	2	18
	(6.0)	(6.0)	(6.0)	
No Impact	1	2	0	3
	(1.0)	(1.0)	(1.0)	
Not Sure	1	6	6	13
	(4.3)	(4.3)	(4.3)	
Total	36	36	36	108
X^2 statistic	13.08			
p	0.1090			

4. Expert System Development

Understanding climate-change impacts is important to the prairies' petroleum industries, especially for those located in the northern parts. An expert system (ES) will not only facilitate such understanding but also provide the related decision support. Development of the ES is based on extensive information survey and field investigation, and is intended for effectively linking the impact-assessment and adaptation-strategy-analysis results to practical decisions. Information on various energy industries, governmental organizations, regional communities, regional economic factors, and applicable climate-change adaptation techniques will all be relevant elements for ES development. In fact, stakeholders experienced the industrial practices have accumulated vast amounts of knowledge on the vulnerability of different processes to climate change, the intricate relationships among the criteria for impact assessment, and the many indicators of an industry's performance under changing climate. These experiences are investigated and represented in the developed expert system, which can support assessment of the climate-change impacts and interpretation of the adaptation planning results.

An important feature of the ES is its facilitating systematic compilation of the related information for supporting integrated impact assessment and adaptation planning. It is clear that there are many areas of concern in the prairie. For example, oil/gas production and transportation can be affected by increased erosion due to permafrost thaw under warming climate, especially in sloping terrain. Pipelines built on permafrost may require structural retrofitting if the permafrost melts. The production and transportation activities may also be affected by increased frequency and severity of forest fires in the neighboring areas due to climate change. Oil/gas production and processing facilities may also be subject to damage by extreme weather, which could increase in intensity and frequency under climate change. The developed ES will be able to compile a vast amount of related information within a general framework. For various stakeholders, it can facilitate (a) identifying issues related to the socio-economic impacts of climate change on energy sector in the prairie provinces, (b) reviewing and assessing various methods and techniques for analyzing short and long term impacts of climate change, and (c) suggesting possible adaptive responses to climate change and variability.

In detail, the SQL query commands are constructed according to user inputs, and are used to index the database. Visual Basic 6.0 is used to develop the main part of this expert system, and Microsoft Access is employed to develop the database (Figure 4.1). Information from experts, stakeholders and other knowledge bases is divided into two categories, with one of them being stored in the database as basic knowledge base, and the other being provided as html files with the file names being listed in the database as indices. Tables 4.1 to 4.4 show some example survey results.

The database is organized into four sheets. Three of them act as index tables, including activity index, process index, and climate-change index. In these index tables, all the impact factors are classified and indexed as integers; they are then used in the program to

construct query commands using the standard SQL language. The fourth table is the main one, providing the relationships between the impact factors and the respondents' answers.

The index tables contain two parts: indexing and analysis. The indexing part is composed of integers that are larger than zero, and the analysis part is flexible for inputting texts. The main table contains four fields, including climatic factors, petroleum-related processes, activities, and answers. The first three fields are defined as integers, while the last one is composed of file names.

Results of the statistical analyses are converted to html files, considering the factors of standardization and expansibility. The html is a widely accepted format for documentation and presentation and is convenient for information storage and transfer.

The developed expert system predigests in its simple use interfaces. Users can simply choose any climate-change factors and concerned petroleum-related processes to acquire desired impact and adaptation outputs (Figure 4.1). Details of the concerned petroleum-related activities and climate-change impacts are also provided in the expert system to help users understand the problems and use the developed system effectively (Figure 4.2).

A simplified version of the developed expert system is also available in the web site of http://env.uregina.ca/parc/.

The developed system will enable decision-makers to conveniently examine various policies related to climate-change adaptation within the prairie's energy sector. Through application of the developed ES, interpretation of the generated outputs, and explication of interactions among various system components, insight of relationships between climate change and socio-economic/environmental goals as well as the associated tradeoffs in the prairie's energy sector can be gained.

Many questions, such as "How will the prairie's energy sector modify their strategies to adapt to the climate change?" and "What adaptation policies should be formulated to avoid or reduce negative impacts on environmental and socio-economic subsystems?", can be answered based on this ES.

In detail, effectiveness of the existing developmental plans for industries can be justified or potentially modified. The potential modifications could involve not only formulation, variation, or supplementation of related policies, but also generation of more effective strategies. Where policies for significant concerns identified through this ES are unavailable, establishment of them could then be highlighted.

Table 4.1. Example survey result of number of answers

	Significant	Moderate	Minor	No impact	Not sure
Number of answers	4	32	0	0	6

Table 4.2. Example survey result of potential adaptation actions

	Number of answers	Significant	Moderate	Minor
(a) Do nothing				
(b) Show concerns and be alerted	10	0	10	0
(c) Conduct research to gain insight	8	2	6	0
(d) Conduct research and be prepared to take actions	10	2	8	0
(e) Begin to take adaptation actions + (c) + (d)	8	0	8	0

Table 4.3. Example survey result of detailed adaptation actions

	(b) Show concerns and be alerted	(c) Conduct research to gain insight	(d) Conduct research and be prepared to take actions	(e) Begin to take adaptation actions + (c) + (d)
Investigate conditions of related field works under increased temperature	10	8	6	2
Change timetable of field works	4	6	2	0
Increase efficiency of field works to shorten outdoor-activity durations	0	2	8	4
Develop new technologies and instruments	2	4	6	2

Table 4.4. Example survey result of feedback from different respondent groups

	Industry	Government	Research institution	Non-governmental organization	Others
Significant	0	0	4	0	0
Moderate	6	6	18	2	0
Minor	0	0	0	0	0
No impact	0	0	0	0	0
Not sure	4	2	0	0	0

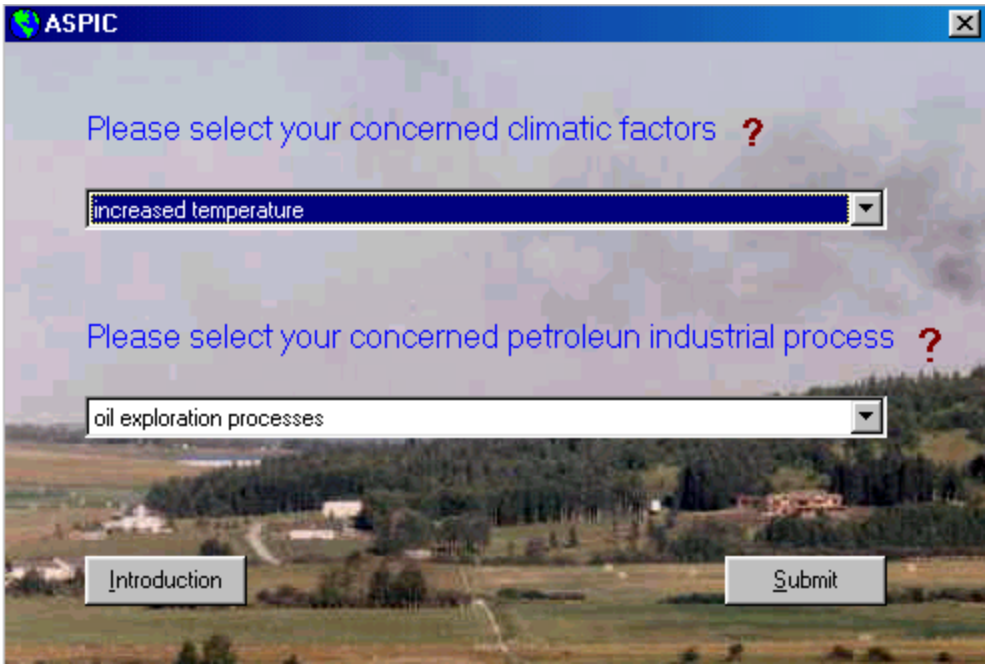

Figure 4.1. User interface of the developed expert system

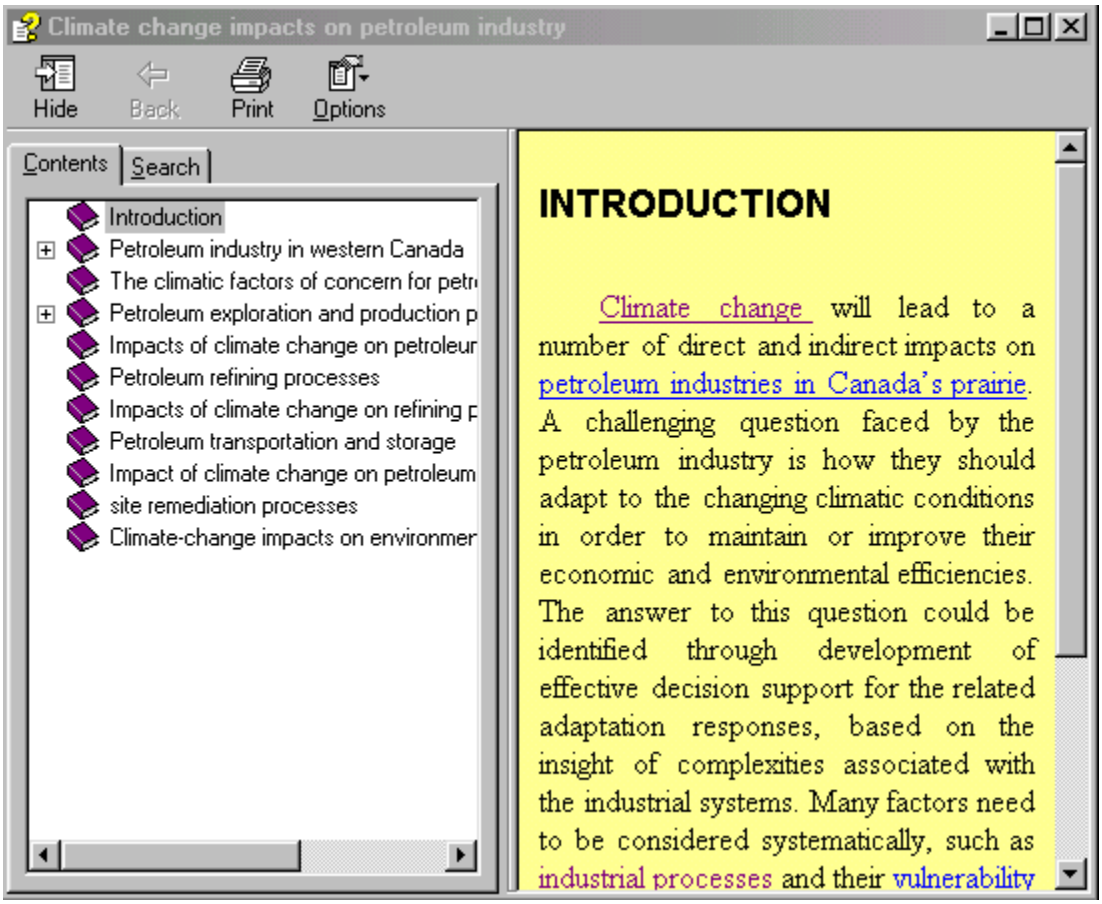

Figure 4.2. Details of the concerned petroleum-related activities and climate-change impacts

5. Conclusions

Petroleum operations range from exploration, production and refining to transportation and storage. They are associated with many activities that are vulnerable to climate change.

In this research, a number of processes within the prairies' petroleum industry that are vulnerable to climate change are examined through extensive survey, investigation and analysis. Many petroleum-related processes that are vulnerable to climate change are analyzed, the associated impacts assessed. In addition to the organization of workshops, roundtable meetings and panel discussions, many questions were designed and distributed in various ways (mail, email, telephone call, interview, and internet) to collect information of perceived climate-change impacts and adaptation strategies. Many people from industries, research institutions, governments, and non-governmental organizations were contacted for information and knowledge acquisition. Their perceptions to the climate-change impacts and the related governmental policies were investigated through a number of interactions.

Multivariate statistical analyses (chi square test) were conducted to examine potential correlations among various surveying results. These analyses were helpful for identifying potential conflicts of interest, biases and interactions. Thus, more reasonable interpretation of the surveying outputs can be obtained.

Based on the investigation and surveying results, an expert system (named ISSCCI) was developed for facilitating integrated climate-change impact assessment and adaptation-strategy analysis within the prairie's petroleum industry. A vast amount of information related to industrial processes, climate-change impacts, potential adaptation alternatives, and system component interactions was integrated within the ISSCCI framework. The developed ISSCCI can provide decision support for the prairie's energy industries and the related governmental organizations to conveniently examine issues of climate-change impacts and potential adaptation options.

This study represents a unique contribution to research in developing an information system for supporting climate-change impact studies within the prairie's petroleum industries. By uploading the developed survey and expert systems to the web site, interactions between the researchers and the respondents/stakeholders are enhanced. Through browsing in the internet directly, users can easily approach the developed expert system and examine system outputs under various conditions of climate-factor variations and industrial activities. The information acquisition and statistical analysis methods developed in this study can also be extended to impact and adaptation studies for other energy sectors within the prairie provinces.

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Appendix A

Questionnaire for

Development of an Information System for Supporting Climate Change Impact and Adaptation Strategies Studies within the Prairie's Petroleum Industries

Web address: http://env.uregina.ca/survey/

Faculty of Engineering

UNIVERSITY OF REGINA

Please provide the following profile information:

Prefix:	Mr.	[ ]
	Ms.	[ ]
Education:	Post-graduate	[ ]
	Undergraduate	[ ]
	Others	[ ]
Age range:	< 30	[ ]
	30-40	[ ]
	41-50	[ ]
	>50	[ ]
Company/Institution:	Industry	[ ]
	Government	[ ]
	Research institution	[ ]
	Non-governmental organization	[ ]
	Others	[ ]

****

Please go to the first question

****

(1) Will increased temperature affect oil exploration processes?

(Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Site accessibility	[ ]	[ ]	[ ]
(b) Site condition	[ ]	[ ]	[ ]
(c) Testing condition	[ ]	[ ]	[ ]
(d) Equipment operation	[ ]	[ ]	[ ]
(e) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____ _____

_____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate the condition of related field works under increased temperature [ ]
(b) Change the timetable of field survey [ ]
(c) Increase the efficiency of field works to shorten the survey period [ ]
(d) Develop new technology and survey instruments [ ]
(e) Others [ ] Please specify (optional): _____

_____

_____

**********Please go to the next question, thank you very much**********

(2) Will changed precipitation pattern affect petroleum exploration processes? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Site accessibility	[ ]	[ ]	[ ]
(b) Site condition	[ ]	[ ]	[ ]
(c) Testing condition	[ ]	[ ]	[ ]
(d) Equipment operation	[ ]	[ ]	[ ]
(e) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate the changed condition of related field works [ ]
(b) Change the timetable of field survey [ ]
(c) Increase the efficiency of field works to shorten the survey period [ ]
(d) Find new method to make it easier to deliver heavy equipment [ ]
(e) Take actions to protect instruments in the rainy season [ ]
(f) Others [ ] Please specify (optional): _____

_____

_____

**********Please go to the next question, thank you very much**********

(3) Will changed humidity and cloud pattern affect petroleum exploration processes? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Site condition	[ ]	[ ]	[ ]
(b) Testing condition	[ ]	[ ]	[ ]
(c) Equipment operation	[ ]	[ ]	[ ]
(d) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____ _____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate the changed condition of related field works [ ]
(b) Change the timetable of field survey [ ]
(c) Increase the efficiency of field works to shorten the survey period [ ]
(d) Take actions to prevent operation instruments from erosion as possible [ ]
(e) Others [ ] Please specify (optional): _____

_____

_____

**********Please go to the next question, thank you very much**********

(4) Will increased natural hazards affect petroleum exploration processes? **(Please choose one)**

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Site accessibility	[ ]	[ ]	[ ]
(b) Site condition	[ ]	[ ]	[ ]
(c) Testing condition	[ ]	[ ]	[ ]
(d) Equipment operation	[ ]	[ ]	[ ]
(e) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

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_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate the possible extreme events [ ]
(b) Change the timetable of field survey [ ]
(c) Introduce new instruments which can work under extreme conditions [ ]
(d) Enhance the maintenance of various instruments [ ]
(e) Others [ ] Please specify (optional): _____

_____

_____ ____

**********Please go to the next question, thank you very much**********

(5) Will increased temperature affect drilling and production operations? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Site accessibility	[ ]	[ ]	[ ]
(b) Site condition	[ ]	[ ]	[ ]
(c) Instruments maintenance	[ ]	[ ]	[ ]
(d) Equipment operation	[ ]	[ ]	[ ]
(e) Production amount	[ ]	[ ]	[ ]
(f) Emission of flared natural gas	[ ]	[ ]	[ ]
(g) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

_____ _____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts [ ]
(b) Change the timetable of drilling and production [ ]
(c) Select anti-erosion steel for drilling equipment [ ]
(d) Enhance the maintenance of various instruments [ ]
(e) Introduce new technique to increase drilling efficiency [ ]
(f) Use high-efficiency compressors and motors in drilling operations [ ]
(g) Use steam produced from highly efficient co-generation plants to assist with recovery of heavy oil [ ]
(h) Install a clean-bum compressor and emission controls on a dehydrator unit and use compressed air-activated, rather than gas-activated, valves [ ]
(i) Others [ ] Please specify (optional): _____

_____

_____ _____

**********Please go to the next question, thank you very much**********

(6) Will changed precipitation pattern affect drilling and production operations? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Site accessibility	[ ]	[ ]	[ ]
(b) Drilling and production timetable	[ ]	[ ]	[ ]
(c) Instruments maintenance	[ ]	[ ]	[ ]
(d) Equipment selection and operation	[ ]	[ ]	[ ]
(e) Product yield	[ ]	[ ]	[ ]
(f) Emission of flared natural gas	[ ]	[ ]	[ ]
(g) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____ _____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts [ ]
(b) Change the timetable of drilling and production [ ]
(c) Select anti-erosion steel for drilling equipment [ ]
(d) Enhance the maintenance of various instruments [ ]
(e) Introduce new technique to increase drilling and production efficiency to compensate abbreviated operation seasons [ ]
(f) Use high-efficiency compressors and motors in drilling operations [ ]
(g) Use new technique to replace of heavy-duty mud pump [ ]
(h) Use steam produced from highly efficient co-generation plants to assist with recovery of heavy oil [ ]
(i) Install a clean-bum compressor and emission controls on a dehydrator unit and use compressed air-activated, rather than gas-activated, valves [ ]
(j) Others [ ] Please specify (optional): _____

_____

_____

**********Please go to the next question, thank you very much**********

(7) Will changed humidity and cloud pattern affect drilling and production operations? **(Please choose one)**

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Site accessibility	[ ]	[ ]	[ ]
(b) Site condition	[ ]	[ ]	[ ]
(c) Instruments maintenance	[ ]	[ ]	[ ]
(d) Equipment selection and operation	[ ]	[ ]	[ ]
(e) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____ _____

_____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts [ ]
(b) Select anti-erosion steel for drilling equipment [ ]
(c) Use high-efficiency compressors and motors in drilling operations [ ]
(d) Install a clean-bum compressor and emission controls on a dehydrator unit and use compressed air-activated, rather than gas-activated, valves [ ]
(e) Others [ ] Please specify (optional): _____

_____ _____

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**********Please go to the next question, thank you very much**********

(8) Will increased natural hazards affect drilling and production operations? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Site accessibility	[ ]	[ ]	[ ]
(b) Drilling and production timetable	[ ]	[ ]	[ ]
(c) Site condition	[ ]	[ ]	[ ]
(d) Instruments maintenance	[ ]	[ ]	[ ]
(e) Equipment selection and operation	[ ]	[ ]	[ ]
(f) Product yield	[ ]	[ ]	[ ]
(g) Emission of flared natural gas	[ ]	[ ]	[ ]
(h) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible extreme events and their possible impacts [ ]
(b) Change the timetable of drilling and production [ ]
(c) Enhance the maintenance of various instruments [ ]
(d) Upgrade and/or move of facilities and structures, strengthen land use planning regulations, particularly in damage-prone areas, redesign related infrastructures [ ]
(e) Reinforce flood control system [ ]
(f) Develop storm forecasting system to decrease the storms detriment to drilling and production activities [ ]
(g) Take measures to prevent drilling casing from damage due to permafrost-melting under extreme high temperature [ ]
(h) Others [ ] Please specify (optional): _____ _____

_____

_____

**********Please go to the next question, thank you very much**********

(9) Will increased temperature affect exploration and production infrastructures? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Infrastructures structure	[ ]	[ ]	[ ]
(b) Construction timetables for access road, production facilities, and other supporting buildings	[ ]	[ ]	[ ]
(c) Infrastructures foundation stability	[ ]	[ ]	[ ]
(d) Material selection for access-road and field-building constructions	[ ]	[ ]	[ ]
(e) Stability of existing road bases and structures	[ ]	[ ]	[ ]
(f) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts and the vulnerabilities of related activities, adaptive process, and potential measures [ ]
(b) Change the timetable of constructions [ ]
(c) Improve the construction efficiency to shorten project period [ ]
(d) Enhance the maintenance of various constructions [ ]
(e) Redesign the foundations and structures to adapt to changed condition [ ]
(f) Redesign pipeline system to handle greater variability of temperature [ ]
(g) Others [ ] Please specify (optional): _____

_____

_____

**********Please go to the next question, thank you very much**********

(10) Will changed precipitation pattern affect exploration and production infrastructures? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Infrastructures structure	[ ]	[ ]	[ ]
(b) Construction timetables for access road, production facilities, and other supporting buildings	[ ]	[ ]	[ ]
(c) Infrastructures foundation stability	[ ]	[ ]	[ ]
(d) Material selection for access-road and field-building constructions	[ ]	[ ]	[ ]
(e) Engine efficiency of construction and maintenance vehicles	[ ]	[ ]	[ ]
(f) Stability of existing road bases and structures	[ ]	[ ]	[ ]
(g) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts and the vulnerabilities of related activities, adaptive process, and potential measures [ ]
(b) Change the timetable of constructions [ ]
(c) Improve the construction efficiency to shorten project period [ ]
(d) Select anti-erosion material for constructions [ ]
(e) Enhance the maintenance of various constructions [ ]
(f) Redesign the foundations and structures to adapt to changed condition [ ]
(g) Redesign pipeline systems to handle greater variability of precipitation [ ]
(h) Others [ ] Please specify (optional): _____

_____

_____

**********Please go to the next question, thank you very much**********

(11) Will increased natural hazards affect exploration and production infrastructures? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Infrastructures structure	[ ]	[ ]	[ ]
(b) Infrastructures foundation stability	[ ]	[ ]	[ ]
(c) Design life of access road and field building	[ ]	[ ]	[ ]
(d) Building safety	[ ]	[ ]	[ ]
(e) Stability of existing road bases and structures	[ ]	[ ]	[ ]
(f) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

_____ _____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts and the vulnerabilities of related activities, adaptive process, and potential measures [ ]
(b) Redesign the construction of infrastructures for weather extremes [ ]
(c) Enhance the building security/integrity [ ]
(d) Select anti-erosion material for constructions [ ]
(e) Enhance the maintenance of various constructions [ ]
(f) Redesign pipeline system to handle extreme events [ ]
(g) Others [ ] Please specify (optional): _____

_____ _____

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**********Please go to the next question, thank you very much**********

(12) Will increased temperature affect transportation activities within exploration and production processes? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Pipeline rupture and erosion	[ ]	[ ]	[ ]
(b) Pipeline routing and setting	[ ]	[ ]	[ ]
(c) Accessibility to underground portion for maintenance	[ ]	[ ]	[ ]
(d) Efficiencies of turbine engines in pipeline pumping	[ ]	[ ]	[ ]
(e) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

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_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts and vulnerabilities of related activities, adaptive process, and potential measures [ ]
(b) Select anti-erosion and anti-rupture material for pipeline [ ]
(c) Redesign pipelines routing and enhance the foundation of pipeline to improve its stability [ ]
(d) Introduce new turbine engines to increase efficiencies [ ]
(e) Redesign the ways to access the underground portion for maintenance [ ]
(f) Others [ ] Please specify (optional): _____

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_____

**********Please go to the next question, thank you very much**********

(13) Will changed precipitation pattern affect transportation activities within exploration and production processes? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Pipeline rupture and erosion	[ ]	[ ]	[ ]
(b) Pipeline routing and setting	[ ]	[ ]	[ ]
(c) Accessibility to underground portion for maintenance	[ ]	[ ]	[ ]
(d) Efficiencies of turbine engines in pipeline pumping	[ ]	[ ]	[ ]
(e) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts and the vulnerabilities of related activities, adaptive process, and potential measures [ ]
(b) Select anti-erosion and anti-rupture material for pipeline [ ]
(c) Redesign pipeline routing and enhance the foundation of pipeline to improve its stability [ ]
(d) Introduce new turbine engines to increase efficiencies [ ]
(e) Redesign the ways to access the underground portion for maintenance [ ]
(f) Reinforce flood control system [ ]
(g) Others [ ] Please specify (optional): _____

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_____

**********Please go to the next question, thank you very much**********

(14) Will changed humidity and cloud pattern affect transportation activities within exploration and production processes? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Pipeline rupture and erosion	[ ]	[ ]	[ ]
(b) Efficiencies of turbine engines in pipeline pumping	[ ]	[ ]	[ ]
(c) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts and vulnerabilities of related activities [ ]
(b) Select anti-erosion and anti-rupture material for pipeline [ ]
(c) Introduce new turbine engines to increase efficiencies [ ]
(d) Others [ ] Please specify (optional): _____

_____

_____

**********Please go to the next question, thank you very much**********

(15) Will increased natural hazards affect transportation activities within exploration and production processes? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Pipeline rupture and erosion	[ ]	[ ]	[ ]
(b) Pipeline routing and setting	[ ]	[ ]	[ ]
(c) Accessibility to underground portion for maintenance	[ ]	[ ]	[ ]
(d) Efficiencies of turbine engines in pipeline pumping	[ ]	[ ]	[ ]
(e) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

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_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts and the vulnerabilities of related activities, adaptive process, and potential measures [ ]
(b) Select anti-erosion and anti-rupture material for pipeline [ ]
(c) Redesign pipelines routing and enhance the foundation of pipeline to improve its stability to handler the extreme events [ ]
(d) Redesign the way to access to the underground portion for maintenance [ ]
(e) Reinforce flood control system [ ]
(f) Others [ ] Please specify (optional): _____

_____

_____ _____

**********Please go to the next question, thank you very much**********

(16) Will increased temperature affect the cost of exploration and production? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Demand of electricity	[ ]	[ ]	[ ]
(b) Cost of production drilling	[ ]	[ ]	[ ]
(c) Cost of installation of facilities	[ ]	[ ]	[ ]
(d) Cost of on-site drainage system	[ ]	[ ]	[ ]
(e) Cost of maintenance	[ ]	[ ]	[ ]
(f) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

_____ _____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Use more efficient compressors [ ]
(c) Use high-pressure gas feed, which is rich in liquids and low in hydrogen sulfide, thus lower energy requirements [ ]
(d) Use dual-action pumps at extraction sites to separate the oil and water from the underground, virtually eliminate gas emissions and reduce the amount of energy used to lift the water from underground [ ]
(e) Find and repair leaks in facilities and processing equipment, install vapor recovery equipment [ ]
(f) Others [ ] Please specify (optional): _____

_____

_____

**********Please go to the next question, thank you very much**********

(17) Will changed precipitation patter affect on the cost of exploration and production? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Electricity demand	[ ]	[ ]	[ ]
(b) Cost of production drilling	[ ]	[ ]	[ ]
(c) Cost of installation of facilities	[ ]	[ ]	[ ]
(d) Cost of on-site drainage system	[ ]	[ ]	[ ]
(e) Cost of maintenance	[ ]	[ ]	[ ]
(f) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Use high-pressure gas feed, which is rich in liquids and low in hydrogen sulfide, thus lower energy requirements [ ]
(c) Develop new technique to increase exploration and production efficiency [ ]
(d) Find and repair leaks in facilities and processing equipment, install vapor recovery equipment [ ]
(e) Reinforce the foundation and stability of constructions to reduce the damage [ ]
(f) Others [ ] Please specify (optional): _____

_____ _____

_____

**********Please go to the next question, thank you very much**********

(18) Will increased natural hazards affect on the cost of exploration and production? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Electricity demand and	[ ]	[ ]	[ ]
(b) Cost of production drilling	[ ]	[ ]	[ ]
(c) Cost of installation of facilities	[ ]	[ ]	[ ]
(d) Cost of on-site drainage system	[ ]	[ ]	[ ]
(e) Cost of maintenance	[ ]	[ ]	[ ]
(f) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____ _____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Use high-pressure gas feed, which is rich in liquids and low in hydrogen sulfide, thus lower energy requirements [ ]
(c) Develop new technique to increase exploration and production efficiency [ ]
(d) Find and repair leaks in facilities and processing equipment, install vapor recovery equipment [ ]
(e) Reinforce the foundation and stability of constructions to reduce the damage [ ]
(f) Reinforce flood control system
(g) Others [ ] Please specify (optional): _____

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**********Please go to the next question, thank you very much**********

(19) Will increased temperature affect the petroleum refining process? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Crude oil pretreatment (Desalting)	[ ]	[ ]	[ ]
(b) Crude oil distillation	[ ]	[ ]	[ ]
(c) Solvent extraction and dewaxing	[ ]	[ ]	[ ]
(d) Cracking and alkylation	[ ]	[ ]	[ ]
(e) Catalytic reforming and hydrotreating	[ ]	[ ]	[ ]
(f) Sweetening and treating	[ ]	[ ]	[ ]
(g) Unsaturated and saturated gas plant	[ ]	[ ]	[ ]
(h) Asphalt and hydrogen production	[ ]	[ ]	[ ]
(i) Pipelines, tanks and auxiliary instrument	[ ]	[ ]	[ ]
(j) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

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What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Innovate the technique to prevent oil leakage, spill, and release [ ]
(c) Install automatic monitor system to reduce the fire risk [ ]
(d) Control temperature to prevent thermal cracking within facilities [ ]
(e) Take anti-erosion action to decrease the rates of corrosion of the related facilities [ ]
(f) Find and repair the leakage [ ]
(g) Install oil vapor recovery system [ ]
(h) Others [ ] Please specify (optional): _____

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**********Please go to the next question, thank you very much**********

(20) Will changed precipitation pattern affect the petroleum refining process? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Crude oil pretreatment (Desalting)	[ ]	[ ]	[ ]
(b) Solvent extraction and dewaxing	[ ]	[ ]	[ ]
(c) Cracking and isomerization	[ ]	[ ]	[ ]
(d) Catalytic reforming and hydrotreating	[ ]	[ ]	[ ]
(e) Polymerization and alkylation	[ ]	[ ]	[ ]
(f) Sweetening and treating	[ ]	[ ]	[ ]
(g) Unsaturated and saturated gas plant	[ ]	[ ]	[ ]
(h) Asphalt and hydrogen production	[ ]	[ ]	[ ]
(i) Pipelines, tanks and auxiliary instrument	[ ]	[ ]	[ ]
(j) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

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What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Innovate the technique to prevent oil leakage, spill, and release [ ]
(c) Install automatic monitor system to reduce the fire risk [ ]
(d) Take anti-erosion action to decrease the rates of corrosion for the facilities [ ]
(e) Find and repair the leakage [ ]
(f) Install oil vapor recovery system [ ]
(g) Reinforce flood control system [ ]
(h) Others [ ] Please specify (optional): _____

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**********Please go to the next question, thank you very much**********

(21) Will changed humidity and cloud pattern affect the petroleum refining process? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Solvent extraction and dewaxing	[ ]	[ ]	[ ]
(b) Cracking and isomerization	[ ]	[ ]	[ ]
(c) Catalytic reforming and hydrotreating	[ ]	[ ]	[ ]
(d) Polymerization and alkylation	[ ]	[ ]	[ ]
(e) Sweetening and treating	[ ]	[ ]	[ ]
(f) Unsaturated and saturated gas plant	[ ]	[ ]	[ ]
(g) Asphalt and hydrogen production	[ ]	[ ]	[ ]
(h) Pipelines, tanks and auxiliary instruments	[ ]	[ ]	[ ]
(i) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

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What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Innovate the technique to prevent oil leakage, spill, and release [ ]
(c) Take anti-erosion action to decrease the rates of corrosion for the facilities [ ]
(d) Find and repair the leakage [ ]
(e) Others [ ] Please specify (optional): _____

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**********Please go to the next question, thank you very much**********

(22) Will increased natural hazards affect the petroleum refining process? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Crude oil pretreatment (Desalting)	[ ]	[ ]	[ ]
(b) Crude oil distillation	[ ]	[ ]	[ ]
(c) Solvent extraction and dewaxing	[ ]	[ ]	[ ]
(d) Cracking and isomerization	[ ]	[ ]	[ ]
(e) Catalytic reforming and hydrotreating	[ ]	[ ]	[ ]
(f) Polymerization and alkylation	[ ]	[ ]	[ ]
(g) Sweetening and treating	[ ]	[ ]	[ ]
(h) Unsaturated and saturated gas plant	[ ]	[ ]	[ ]
(i) Asphalt and hydrogen production	[ ]	[ ]	[ ]
(j) Pipelines, tanks and auxiliary instrument	[ ]	[ ]	[ ]
(k) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____ ____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Innovate the technique to prevent oil leakage, spill, and release [ ]
(c) Install automatic monitor system to reduce the fire risk [ ]
(d) Redesign the associated facilities to handle the extreme events [ ]
(e) Take anti-erosion action to decrease the rates of corrosion for the facilities [ ]
(f) Enhance the maintenance, find and repair the leakage [ ]
(g) Enforce flood control system, fire prevent system [ ]
(h) Others [ ] Please specify (optional): _____

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_____

**********Please go to the next question, thank you very much**********

(23) Will increased temperature affect the pollutant emission within oil refinery process? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Crude oil pretreatment (Desalting)	[ ]	[ ]	[ ]
(b) Crude oil distillation	[ ]	[ ]	[ ]
(c) Solvent extraction and dewaxing	[ ]	[ ]	[ ]
(d) Cracking and isomerization	[ ]	[ ]	[ ]
(e) Catalytic reforming and hydrotreating	[ ]	[ ]	[ ]
(f) Polymerization and alkylation	[ ]	[ ]	[ ]
(g) Sweetening and treating	[ ]	[ ]	[ ]
(h) Unsaturated and saturated gas plant	[ ]	[ ]	[ ]
(i) Asphalt and hydrogen production	[ ]	[ ]	[ ]
(j) Pipelines, tanks and auxiliary instrument	[ ]	[ ]	[ ]
(k) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Innovate current techniques to reduce the pollutant emission of each process unit [ ]
(c) Increasing the use of natural gas, replacing petroleum as the facility's source of energy [ ]
(d) Using the CO_2 recovered from refining operations to carbonate soft drinks [ ]
(e) Develop new technologies to convert coal into clean synthesis gas for use in making electricity, chemicals, feels and fertilizer [ ]
(f) Install oil vapor recovery system [ ]
(g) Promoting wider acceptance of diesel engines for offering greater fuel efficiency to lower CO_2 emissions [ ]
(h) Develop improved ethanol-enhanced gasoline [ ]
(i) Others [ ] Please specify (optional): _____

_____

**********Please go to the next question, thank you very much**********

(24) Will changed precipitation pattern affect the pollutant emission within oil refinery process? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Crude oil pretreatment (Desalting)	[ ]	[ ]	[ ]
(b) Crude oil distillation	[ ]	[ ]	[ ]
(c) Solvent extraction and dewaxing	[ ]	[ ]	[ ]
(d) Cracking and isomerization	[ ]	[ ]	[ ]
(e) Catalytic reforming and hydrotreating	[ ]	[ ]	[ ]
(f) Polymerization and alkylation	[ ]	[ ]	[ ]
(g) Sweetening and treating	[ ]	[ ]	[ ]
(h) Unsaturated and saturated gas plant	[ ]	[ ]	[ ]
(i) Asphalt and hydrogen production	[ ]	[ ]	[ ]
(j) Pipelines, tanks and auxiliary instrument	[ ]	[ ]	[ ]
(k) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Innovate current techniques to reduce the pollutant emission of each process unit [ ]
(c) Increasing the use of natural gas, replacing petroleum as the facility's source of energy [ ]
(d) Develop new technologies to convert coal into clean synthesis gas for use in making electricity, chemicals, feels and fertilizer [ ]
(e) Install oil vapor recovery system [ ]
(f) Enhance the maintenance, find and repair the leakage [ ]
(g) Promoting wider acceptance of diesel engines for offering greater fuel efficiency to lower CO_2 emissions [ ]
(h) Improve the drainage treatment system to reduce the pollutant emission [ ]
(i) Others [ ] Please specify (optional): _____

_____

_____

**********Please go to the next question, thank you very much**********

(25) Will increased natural hazard affect the pollutant emission within oil refinery process? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Crude oil pretreatment (Desalting)	[ ]	[ ]	[ ]
(b) Crude oil distillation	[ ]	[ ]	[ ]
(c) Solvent extraction and dewaxing	[ ]	[ ]	[ ]
(d) Cracking and isomerization	[ ]	[ ]	[ ]
(e) Catalytic reforming and hydrotreating	[ ]	[ ]	[ ]
(f) Polymerization and alkylation	[ ]	[ ]	[ ]
(g) Sweetening and treating	[ ]	[ ]	[ ]
(h) Unsaturated and saturated gas plant	[ ]	[ ]	[ ]
(i) Asphalt and hydrogen production	[ ]	[ ]	[ ]
(j) Pipelines, tanks and auxiliary instrument	[ ]	[ ]	[ ]
(k) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

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What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Redesign associated facilities to handle the extreme events, prevent facilities disrupt, crack resulting in pollutant emission [ ]
(c) Redesign pipeline and other auxiliary equipment to prevent leakage [ ]
(d) Change plant location, facilities location to avoid extreme events [ ]
(e) Improve fire alarm and prevent system [ ]
(f) Enhance flood control system [ ]
(g) Others [ ] Please specify (optional): _____ _____

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**********Please go to the next question, thank you very much**********

(26) Will increased temperature affect the cost of oil refinery process? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Crude oil pretreatment (Desalting)	[ ]	[ ]	[ ]
(b) Crude oil distillation	[ ]	[ ]	[ ]
(c) Solvent extraction and dewaxing	[ ]	[ ]	[ ]
(d) Cracking and isomerization	[ ]	[ ]	[ ]
(e) Catalytic reforming and hydrotreating	[ ]	[ ]	[ ]
(f) Polymerization and alkylation	[ ]	[ ]	[ ]
(g) Sweetening and treating	[ ]	[ ]	[ ]
(h) Unsaturated and saturated gas plant	[ ]	[ ]	[ ]
(i) Asphalt and hydrogen production	[ ]	[ ]	[ ]
(j) Pipelines, tanks and auxiliary instrument	[ ]	[ ]	[ ]
(k) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Improve fire alarm and prevent system to reduce the damage resulting from fire [ ]
(c) Select new material for facilities and associated constructions to prevent disrupt, oil leakage [ ]
(d) Innovate current technique to reduce oil spill and release [ ]
(e) Install oil vapor recovery system [ ]
(f) Reinforce the maintenance of related facilities [ ]
(g) Others [ ] Please specify (optional): _____

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**********Please go to the next question, thank you very much**********

(27) Will changed precipitation pattern affect the cost of oil refinery process? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Crude oil pretreatment (Desalting)	[ ]	[ ]	[ ]
(b) Crude oil distillation	[ ]	[ ]	[ ]
(c) Solvent extraction and dewaxing	[ ]	[ ]	[ ]
(d) Cracking and isomerization	[ ]	[ ]	[ ]
(e) Catalytic reforming and hydrotreating	[ ]	[ ]	[ ]
(f) Polymerization and alkylation	[ ]	[ ]	[ ]
(g) Sweetening and treating	[ ]	[ ]	[ ]
(h) Unsaturated and saturated gas plant	[ ]	[ ]	[ ]
(i) Asphalt and hydrogen production	[ ]	[ ]	[ ]
(j) Pipelines, tanks and auxiliary instrument	[ ]	[ ]	[ ]
(k) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

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_____ _____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Improve fire alarm and prevent system to reduce the damage resulting from fire [ ]
(c) Select new material for facilities and associated constructions to prevent disrupt, oil leakage [ ]
(d) Innovate current technique to reduce oil spill and release [ ]
(e) Install oil vapor recovery system [ ]
(f) Reinforce flood control system to reduce the damage resulting from flood [ ]
(g) Reinforce the maintenance of related facilities [ ]
(h) Others [ ] Please specify (optional): _____

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**********Please go to the next question, thank you very much**********

(28) Will changed humidity and cloud pattern affect the cost of oil refinery process? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Crude oil pretreatment (Desalting)	[ ]	[ ]	[ ]
(b) Crude oil distillation	[ ]	[ ]	[ ]
(c) Solvent extraction and dewaxing	[ ]	[ ]	[ ]
(d) Cracking and isomerization	[ ]	[ ]	[ ]
(e) Catalytic reforming and hydrotreating	[ ]	[ ]	[ ]
(f) Polymerization and alkylation	[ ]	[ ]	[ ]
(g) Sweetening and treating	[ ]	[ ]	[ ]
(h) Unsaturated and saturated gas plant	[ ]	[ ]	[ ]
(i) Asphalt and hydrogen production	[ ]	[ ]	[ ]
(j) Pipelines, tanks and auxiliary instrument	[ ]	[ ]	[ ]
(k) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Improve fire alarm and prevent system to reduce the damage resulting from fire [ ]
(c) Select new material for facilities and associated constructions to prevent disrupt, oil leakage [ ]
(d) Innovate current technique to reduce oil spill and release [ ]
(e) Install oil vapor recovery system [ ]
(f) Others [ ] Please specify (optional): _____

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**********Please go to the next question, thank you very much**********

(29) Will increased natural hazards affect the cost of oil refinery process? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Crude oil pretreatment (Desalting)	[ ]	[ ]	[ ]
(b) Crude oil distillation	[ ]	[ ]	[ ]
(c) Solvent extraction and dewaxing	[ ]	[ ]	[ ]
(d) Cracking and isomerization	[ ]	[ ]	[ ]
(e) Catalytic reforming and hydrotreating	[ ]	[ ]	[ ]
(f) Polymerization and alkylation	[ ]	[ ]	[ ]
(g) Sweetening and treating	[ ]	[ ]	[ ]
(h) Unsaturated and saturated gas plant	[ ]	[ ]	[ ]
(i) Asphalt and hydrogen production	[ ]	[ ]	[ ]
(j) Pipelines, tanks and auxiliary instrument	[ ]	[ ]	[ ]
(k) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Improve fire alarm and prevent system to reduce the damage resulting from fire [ ]
(c) Select new material for facilities and associated constructions to prevent disrupt, oil leakage [ ]
(d) Innovate current technique to reduce oil spill and release [ ]
(e) Reinforce flood control system to reduce the damage resulting from fire [ ]
(f) Change behavior, change use and change location to reduce the impacts from extreme events [ ]
(g) Others [ ] Please specify (optional): _____

_____ _____

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**********Please go to the next question, thank you very much**********

(30) Will increased temperature affect petroleum transportation and storage? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Accurate measurement of quantities	[ ]	[ ]	[ ]
(b) Pipeline design and installation	[ ]	[ ]	[ ]
(c) Pipeline corrosion	[ ]	[ ]	[ ]
(d) Pumping stations design, installation and operation	[ ]	[ ]	[ ]
(e) In-land mobile transportation	[ ]	[ ]	[ ]
(f) Storage container installation	[ ]	[ ]	[ ]
(g) Road and rail tanks	[ ]	[ ]	[ ]
(h) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

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_____ _____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Use more accurate measurement instruments [ ]
(c) Redesign pipeline to enhance the foundation to improve the stability of pipeline [ ]
(d) Change the timetable of pipeline installation [ ]
(e) Improve the installation efficiency to abbreviate the installation period [ ]
(f) Select new material to prevent corrosion of pipeline [ ]
(g) Improve the stability of pump station operation [ ]
(h) Redesign the foundation of storage tanks [ ]
(i) Strengthening of land use planning regulations in damage-prone areas [ ]
(j) Install fire alarm and prevention system [ ]
(k) Use computerized devices to detect weaknesses in pipeline walls and foundation instability [ ]
(l) Redesign tanks to reduce the spill and leakage [ ]
(m) Others [ ] Please specify (optional):_____

_____

_____

**********Please go to the next question, thank you very much**********

(31) Will changed precipitation patter affect petroleum transportation and storage? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Accurate measurement of quantities	[ ]	[ ]	[ ]
(b) Pipeline design and installation	[ ]	[ ]	[ ]
(c) Pipeline corrosion	[ ]	[ ]	[ ]
(d) Pumping stations design, installation and operation	[ ]	[ ]	[ ]
(e) In-land mobile transportation	[ ]	[ ]	[ ]
(f) Storage container installation	[ ]	[ ]	[ ]
(g) Road and rail tanks	[ ]	[ ]	[ ]
(h) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____ _____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Invest money to construct additional roads in case of waterways dysfunctional, and road networks are destroyed [ ]
(c) Redesign pipeline to enhance the foundation to improve the stability of pipeline [ ]
(d) Change the timetable of pipeline installation [ ]
(e) Improve the installation efficiency to abbreviate the installation period [ ]
(f) Select new material to prevent corrosion of pipeline [ ]
(g) Improve the stability of pump station operation [ ]
(h) Redesign the foundation of storage tanks [ ]
(i) Reinforce flood control system [ ]
(j) Strengthening of land use planning regulations in damage-prone areas [ ]
(k) Use computerized devices to detect weaknesses in pipeline walls and foundation instability [ ]
(l) Others [ ] Please specify (optional): _____

_____

_____ _____

**********Please go to the next question, thank you very much**********

(32) Will changed humidity and cloud pattern affect petroleum transportation and storage? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Accurate measurement of quantities	[ ]	[ ]	[ ]
(b) Pipeline corrosion	[ ]	[ ]	[ ]
(c) Pumping stations design, installation and operation	[ ]	[ ]	[ ]
(d) In-land mobile transportation	[ ]	[ ]	[ ]
(e) Road and rail tanks	[ ]	[ ]	[ ]
(f) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

_____ _____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Take action to prevent measurement instruments from erosion [ ]
(c) Select new material to prevent corrosion of pipeline [ ]
(d) Install fire alarm and prevention system [ ]
(e) Redesign tanks to reduce the spill and leakage [ ]
(f) Others [ ] Please specify (optional): _____

_____

_____

**********Please go to the next question, thank you very much**********

(33) Will increased natural hazards affect petroleum transportation and storage? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Accurate measurement of quantities	[ ]	[ ]	[ ]
(b) Pipeline design and installation	[ ]	[ ]	[ ]
(c) Pipeline corrosion	[ ]	[ ]	[ ]
(d) Pumping stations design, installation and operation	[ ]	[ ]	[ ]
(e) In-land mobile transportation	[ ]	[ ]	[ ]
(f) Storage container installation	[ ]	[ ]	[ ]
(g) Road and rail tanks	[ ]	[ ]	[ ]
(h) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process, and potential measures [ ]
(b) Redesign pipeline to enhance the foundation to improve the stability of pipeline [ ]
(c) Change the timetable of pipeline installation [ ]
(d) Improve the installation efficiency to abbreviate the installation period [ ]
(e) Improve the stability of pump station operation [ ]
(f) Redesign the foundation of storage tanks [ ]
(g) Strengthening of land use planning regulations in damage-prone areas [ ]
(h) Install fire alarm and prevention system [ ]
(i) Redesign tanks to reduce the spill and leakage [ ]
(j) Reinforce flood control system [ ]
(k) Change in-land mobile transportation routes [ ]
(l) Others [ ] Please specify (optional): _____ _____

_____

_____

**********Please go to the next question, thank you very much**********

(34) Will increased temperature affect the cost of transportation and storage? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Related instruments maintenance	[ ]	[ ]	[ ]
(b) Pipeline design and installation	[ ]	[ ]	[ ]
(c) Pipeline maintenance and repair	[ ]	[ ]	[ ]
(d) Pumping stations design, installation and operation	[ ]	[ ]	[ ]
(e) In-land mobile transportation	[ ]	[ ]	[ ]
(f) Storage container installation	[ ]	[ ]	[ ]
(g) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process [ ]
(b) Use computerized devices to supply early warning to correct problems before incidents occur, preventing natural gas leaks and pipeline rupture [ ]
(c) Improve the installation efficiency to abbreviate the installation period [ ]
(d) Realize the automatic control of operation to improve the stability of transportation and storage system [ ]
(e) Install fire alarm and prevention system [ ]
(f) Redesign tanks to reduce the spill and leakage [ ]
(g) Develop new loading process for in-land mobile transportation to prevent hydrocarbon escape [ ]
(h) Change in-land mobile transportation routes [ ]
(i) Install recovery system to recycle vapors back into operations [ ]
(j) Others [ ] Please specify (optional): _____

_____

_____

**********Please go to the next question, thank you very much**********

(35) Will changed precipitation pattern affect the cost of transportation and storage? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Related instruments maintenance	[ ]	[ ]	[ ]
(b) Pipeline design and installation	[ ]	[ ]	[ ]
(c) Pipeline maintenance and repair	[ ]	[ ]	[ ]
(d) Pumping stations design, installation and operation	[ ]	[ ]	[ ]
(e) In-land mobile transportation	[ ]	[ ]	[ ]
(f) Storage container installation	[ ]	[ ]	[ ]
(g) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process [ ]
(b) Use computerized devices to supply early warning to correct problems before incidents occur, preventing natural gas leaks and pipeline rupture [ ]
(c) Improve the installation efficiency to abbreviate the installation period [ ]
(d) Realize the automatic control of operation to improve the stability of transportation and storage system [ ]
(e) Redesign tanks to reduce the spill and leakage [ ]
(f) Reinforce flood control system [ ]
(g) Develop new loading process for in-land mobile transportation to prevent hydrocarbon escape [ ]
(h) Change in-land mobile transportation routes [ ]
(i) Install recovery system to recycle vapors back into operations [ ]
(j) Others [ ] Please specify (optional): _____

_____

_____

**********Please go to the next question, thank you very much**********

(36) Will increased natural hazards affect the cost of transportation and storage? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Related instruments maintenance	[ ]	[ ]	[ ]
(b) Pipeline design and installation	[ ]	[ ]	[ ]
(c) Pipeline maintenance and repair	[ ]	[ ]	[ ]
(d) Pumping stations design, installation and operation	[ ]	[ ]	[ ]
(e) In-land mobile transportation	[ ]	[ ]	[ ]
(f) Storage container installation	[ ]	[ ]	[ ]
(g) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____ _____

_____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, adaptive process [ ]
(b) Use computerized devices to supply early warning to correct problems before incidents occur, preventing natural gas leaks and pipeline rupture [ ]
(c) Install fire alarm and prevention system [ ]
(d) Redesign tanks to reduce the spill and leakage [ ]
(e) Reinforce flood control system [ ]
(f) Change in-land mobile transportation routes [ ]
(g) Install recovery system to recycle vapors back into operations [ ]
(h) Redesign the foundation of pipelines and storage tanks to handle extreme events [ ]
(i) Others [ ] Please specify (optional): _____

_____ _____

_____

**********Please go to the next question, thank you very much**********

(37) Will increased temperature affect environmental management activities in petroleum industry? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Pollutant discharge criteria	[ ]	[ ]	[ ]
(b) Pollution control technology			
(c) Costs for pollution abatement	[ ]	[ ]	[ ]
(d) Amount of pollutant generated	[ ]	[ ]	[ ]
(e) Pollutant control efficiency	[ ]	[ ]	[ ]
(f) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, update criteria of environmental management [ ]
(b) Innovate current remediation technology, develop new technology [ ]
(c) Take actions to reduce the oil leakage, spill, increase the treatment efficiency to lower the cost for pollution abatement [ ]
(d) Establish new environmental management policy to increase the pollution control efficiency [ ]
(e) Establish special environmental management system for petroleum industry [ ]
(f) Install recovery system to recycle, leakage oil, vapors back into operations [ ]
(g) Implement an on-line energy monitoring system, maximize energy efficiency [ ]
(h) Install a flare-reduction and emissions-recovery program [ ]
(i) Develop new technologies to convert coal into clean synthesis gas for use in making electricity, chemicals, fuels and fertilizer [ ]
(j) Reinforce fire alarm and prevention system [ ]
(k) Others [ ] Please specify (optional): _____ _____

_____

_____

**********Please go to the next question, thank you very much**********

(38) Will changed precipitation pattern affect environmental management activities in petroleum industry? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Pollutant discharge criteria	[ ]	[ ]	[ ]
(b) Pollution control technology			
(c) Costs for pollution abatement	[ ]	[ ]	[ ]
(d) Amount of pollutant generated	[ ]	[ ]	[ ]
(e) Pollutant control efficiency	[ ]	[ ]	[ ]
(f) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____ _____

_____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, update criteria of environmental management [ ]
(b) Innovate current remediation technology, develop new technology [ ]
(c) Take actions to reduce the oil leakage, spill, increase the treatment efficiency to lower the cost for pollution abatement [ ]
(d) Establish new environmental management policy to increase the pollution control efficiency [ ]
(e) Establish special environmental management system for petroleum industry [ ]
(f) Install recovery system to recycle, leakage oil, vapors back into operations [ ]
(g) Improve drainage system to prevent the pollutant directly moving into ambient [ ]
(h) Implement an on-line energy monitoring system, maximize energy efficiency [ ]
(j) Install a flare-reduction and emissions-recovery program
(j) Develop new technologies to convert coal into clean synthesis gas for use in making electricity, chemicals, fuels and fertilizer [ ]
(k) Others [ ] Please specify (optional): _____

_____

_____

**********Please go to the next question, thank you very much**********

(39) Will increased natural hazard affect environmental management activities in petroleum industry? (Please choose one)

(a) Significant [ ]
(b) Moderate [ ]
(c) Minor [ ]
(d) No impact [ ]
(e) Not sure [ ]

If the answer is (a), (b) or (c), please check if the following activities will be affected by climate change?

	positively affected	negatively affected	both positive and negative
(a) Pollutant discharge criteria	[ ]	[ ]	[ ]
(b) Pollution control technology			
(c) Costs for pollution abatement	[ ]	[ ]	[ ]
(d) Amount of pollutant generated	[ ]	[ ]	[ ]
(e) Pollutant control efficiency	[ ]	[ ]	[ ]
(f) Others	[ ]	[ ]	[ ]

Please explain more details of the impacts (optional): _____

_____

_____

What approach to adapt to the above impacts? (Please choose one)

(a) Do nothing [ ]
(b) Show concerns and be alerted [ ]
(c) Conduct research to gain insight [ ]
(d) Conduct research and be prepared to take actions [ ]
(e) Begin to take adaptation actions + (c) + (d) [ ]

If the answer is (b), (c), (d) or (e), please indicate what detailed actions you would like to recommend:

(a) Investigate all possible impacts, update criteria of environmental management [ ]
(b) Take actions to reduce the oil leakage, spill, increase the treatment efficiency to lower the cost for pollution abatement [ ]
(c) Establish special environmental management system for petroleum industry [ ]
(d) Install recovery system to recycle, leakage oil, vapors back into operations [ ]
(e) Improve drainage system to prevent the pollutant directly moving into ambient [ ]
(f) Implement an on-line energy monitoring system, maximize energy efficiency [ ]
(g) Install a flare-reduction and emissions-recovery program
(h) Develop new technologies to convert coal into clean synthesis gas for use [ ]
(i) Reinforce fire alarm and prevention system [ ]
(j) Develop new technologies to convert coal into clean synthesis gas for use in making electricity, chemicals, fuels and fertilizer [ ]
(k) Others [ ] Please specify (optional): _____

_____

_____

**********The end, thank you very much**********

Appendix B

Surveying Results

Development of an Information System for Supporting Climate Change Impact and Adaptation Strategies Studies within the Prairie's Petroleum Industries

Web address: http://env.uregina.ca/parc/

Faculty of Engineering

UNIVERSITY OF REGINA

Table 1 the perception to the impacts of increased temperature on oil exploration processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant			22.2%		11.1%
Moderate	66.7%	71.4%	77.8%	66.7%	75.0%
Minor					
No impact					
Not sure	33.3%	28.6%		33.3%	13.9%
Total	100%	100%	100%	100%	100%

Table 2 the adaptation strategy to the impacts of increased temperature on oil exploration processes

	Number of answers	Significant	Moderate	Minor
Do nothing				
Show concerns and be alerted	25.8%		25.8%	
Conduct research to gain insight	22.6%	6.5%	16.1%	
Conduct research and be prepares to take actions	29.0%	6.4%	22.6%	
Begin to take adaptation actions +(c)+(d)	22.6%		22.6%	

Table 3 the detailed adaptation activities to the impacts of increased temperature on oil exploration processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate the condition of related field works under increased temperature	25.8%	22.6%	19.4%	6.4%
Change the timetable of field survey	16.1%	22.6%	6.4%	
Increase the efficiency of field works to shorten the survey period		6.4%	22.6%	6.4%
Develop new technology and survey instruments	6.4%	12.9%	19.4%	6.4%

Table 4 the perception to the impacts of increased temperature on drilling and production processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant		28.6%			5.6%
Moderate	37.5%	57.1%	72.2%		55.5%
Minor	50.0%	14.3%	27.8%	66.7%	33.3%
No impact					
Not sure	12.5%			33.3%	5.6%
Total	100%	100%	100%	100%	100%

Table 5 the adaptation strategy to the impacts of increased temperature on drilling and production processes

	Number of answers	Significant	Moderate	Minor
Do nothing	2.9%		2.9%	
Show concerns and be alerted	29.4%	5.9%	8.8%	14.7%
Conduct research to gain insight	14.7%			14.7%
Conduct research and be prepares to take actions	35.3%		29.4%	5.9%
Begin to take adaptation actions +(c)+(d)	17.7%		17.7%	

Table 6 the detailed adaptation activities to the impacts of increased temperature on drilling and production processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts	23.5%	14.7%	30.3%	17.6%
Change the timetable of drilling and production	5.9%	12.1%	27.3%	5.9%
Select anti-erosion steel for drilling equipment	5.9%	12.1%	5.9%	12.1%
Enhance the maintenance of various instruments		14.7%	8.8%	5.9%
Introduce new technique to increase drilling efficiency		14.7%	14.7%	5.9%
Use high-efficiency compressors and motors in drilling operations		5.9%	12.1%	5.9%
Use steam produced from highly efficient co-generation plants to assist with recovery of heavy oil		12.1%	5.9%	
Install a clean-bum compressor and emission controls on a dehydrator unit and use compressed air-activated, rather than gas-activated, valves		12.1%	12.1%	

Table 7 the perception to the impacts of increased temperature on exploration and production infrastructures

	Industry	Government	Research organization	Non-governmental organization	Total
Significant					
Moderate	50.0%	42.8%	83.3%		61.1%
Minor	25.0%	28.6%	5.6%	66.7%	19.4%
No impact			11.1%		5.6%
Not sure	25.0%	28.6%		33.3%	13.9%
Total	100%	100%	100%	100%	100%

Table 8 the adaptation strategy to the impacts of increased temperature on exploration and production infrastructure

	Number of answers	Significant	Moderate	Minor
Do nothing				
Show concerns and be alerted				
Conduct research to gain insight	48.3%		24.1%	24.2%
Conduct research and be prepares to take actions	13.8%		13.8%	
Begin to take adaptation actions +(c)+(d)	37.9%		37.9%	

Table 9 the detailed adaptation activities to the impacts of increased temperature on exploration and production infrastructures

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts and the vulnerabilities of related activities, adaptive process, and potential measures		44.8%	6.9%	34.5%
Change the timetable of constructions		27.6%	13.8%	
Improve the construction efficiency to shorten project period		13.8%	6.9%	10.3%
Enhance the maintenance of various constructions		24.1%	10.3%	31.0%
Redesign the foundations and structures to adapt to changed condition		20.7%	6.9%	27.6%
Redesign pipeline system to handle greater variability of temperature		31.0%		20.7%

Table 10 the perception to the impacts of increased temperature on transportation activities within exploration and production processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant			16.7%		8.3%
Moderate	50.0%	71.4%	61.1%		55.6%
Minor	25.5%		16.7%	66.7%	19.4%
No impact			5.5%		2.8%
Not sure	25.5%	28.6%		33.3%	13.9%
Total	100%	100%	100%	100%	100%

Table 11 the adaptation strategy to the impacts of increased temperature on transportation activities within exploration and production processes

	Number of answers	Significant	Moderate	Minor
Do nothing	3.3%			3.3%
Show concerns and be alerted	16.7%		10.0%	6.7%
Conduct research to gain insight	33.3%		20.0%	13.3%
Conduct research and be prepares to take actions	30.0%	3.3%	26.7%	
Begin to take adaptation actions +(c)+(d)	16.7%	6.7%	10.0%	

Table 12 the detailed adaptation activities to the impacts of increased temperature on transportation activities within exploration and production processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts and vulnerabilities of related activities adaptive process, and potential measures	16.7%	26.7%	30.0%	16.7%
Select anti-erosion and anti-rupture material for pipeline		20.0%	13.3%	6.7%
Redesign pipelines routing and enhance the foundation of pipeline to improve its stability		20.0%		13.3%
Introduce new turbine engines to increase efficiencies		6.7%	6.7%	6.7%
Redesign the ways to access the underground portion for maintenance		10.05		6.7%

Table 13 the perception to the impacts of increased temperature on cost of exploration and production

	Industry	Government	Research organization	Non-governmental organization	Total
Significant					
Moderate	37.5%	71.4%	77.8%	66.7%	66.7%
Minor	25.0%	28.6%			11.1%
No impact					
Not sure	37.5%		22.2%	33.3%	22.2%
Total	100%	100%	100%	100%	100%

Table 14 adaptation strategies to the impacts of increased temperature on cost of exploration and production

	Number of answers	Significant	Moderate	Minor
Do nothing	14.3%			14.3%
Show concerns and be alerted	39.3%		39.3%	
Conduct research to gain insight	14.3%		14.3%	
Conduct research and be prepares to take actions	7.1%		7.1%	
Begin to take adaptation actions +(c)+(d)	25.0%		25.0%	

Table 15 the adaptation activities to the impacts of increased temperature on cost of exploration and production

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	35.7%	14.3%	7.1%	25.0%
Use more efficient compressors				7.1%
Use high-pressure gas feed, which is rich in liquids and low in hydrogen sulfide, thus lower energy requirements	17.8%			14.3%
Use dual-action pumps at extraction sites to separate the oil and water from the underground, virtually eliminate gas emissions and reduce the amount of energy used to lift the water from underground				14.3%
Find and repair leaks in facilities and processing equipment, install vapor recovery equipment	7.1%	14.3%		21.4%

Table 16 the perception to the impacts of increased temperature on petroleum refinery process

	Industry	Government	Research organization	Non-governmental organization	Total
Significant	25.0%		16.7%		13.9%
Moderate		42.8%	16.7%	33.3%	19.4%
Minor	25.0%	28.6%	33.3%	66.7%	33.4%
No impact	13.5%		22.2%		13.9%
Not sure	37.5%	28.6%	11.1%		19.4%
Total	100%	100%	100%	100%	100%

Table 17 the adaptation strategy to the impacts of increased temperature on petroleum refinery process

	Number of answers	Significant	Moderate	Minor
Do nothing	8.3%			8.3%
Show concerns and be alerted	25.0%		12.5%	12.5%
Conduct research to gain insight	8.3%	8.3%		
Conduct research and be prepares to take actions	41.7%	12.5%	16.7%	12.5%
Begin to take adaptation actions +(c)+(d)	16.7%			16.7%

Table 18 the detailed adaptation activities to the impacts of increased temperature on petroleum refinery process

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	22.7%	9.1%	40.9%	16.7%
Innovate the technique to prevent oil leakage, spill, and release			27.3%	
Install automatic monitor system to reduce the fire risk	9.1%		45.4%	
Control temperature to prevent thermal cracking within facilities			40.9%	
Take anti-erosion action to decrease the rates of corrosion of the related facilities			16.7%	
Find and repair the leakage			27.3%	
Install oil vapor recovery system			31.8%	

Table 19 the perception to the impacts of increased temperature on pollutant emission within refining process

	Industry	Government	Research organization	Non-governmental organization	Total
Significant		57.1%	5.6%		13.9%
Moderate	12.5%	28.6%	61.1%	66.7%	44.4%
Minor	12.5%		16.7%	33.3%	13.9%
No impact	12.5%		11.1%		8.4%
Not sure	62.5%	14.3%	5.5%		19.4%
Total	100%	100%	100%	100%	100%

Table 20 the adaptation strategy to the impacts of increased temperature on pollutant emission within refining process

	Number of answers	Significant	Moderate	Minor
Do nothing				
Show concerns and be alerted	19.2%	7.7%	3.8%	7.7%
Conduct research to gain insight	26.9%		23.1%	3.8%
Conduct research and be prepares to take actions	26.9%	11.5%	15.4%	
Begin to take adaptation actions +(c)+(d)	26.9%		19.2%	7.7%

Table 21 the detailed adaptation activities to the impacts of increased temperature on pollutant emission within refining process

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	15.4%	26.9%	26.9%	23.1%
Innovate current techniques to reduce the pollutant emission of each process unit	7.7%	15.4%	23.1%	15.4%
Increase the use of natural gas, replacing petroleum as the facility's source of energy	15.4%		15.4%	7.7%
Use the CO2 recovered from refining operations to carbonate soft drinks	7.7%	7.7%	15.4%	11.5%
Develop new technologies to convert coal into clean synthesis gas for use in making electricity, chemicals, feels and fertilizer	7.7%	15.4%	7.7%	7.7%
Install oil vapor recovery system	15.4%		26.9%	7.7%
Promote wider acceptance of diesel engines for offering greater fuel efficiency to lower CO2 emissions	7.7%	7.7%	15.4%	7.7%
Develop improved ethanol-enhanced gasoline			7.7%	7.7%

Table 22 the perception to the impacts of increased temperature on cost of oil refinery processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant				66.7%	5.6%
Moderate	25.0%	42.8%	50.0%		38.8%
Minor	25.0%	42.8%	38.9%		33.3%
No impact	12.5%			33.3%	5.6%
Not sure	37.5%	14.4%	11.1%		16.7%
Total	100%	100%	100%	100%	100%

Table 23 adaptation strategies to the impacts of increased temperature on cost of oil refinery processes

	Number of answers	Significant	Moderate	Minor
Do nothing	17.8%			17.8%
Show concerns and be alerted	21.5%		14.3%	7.2%
Conduct research to gain insight	21.4%	7.1%	10.7%	3.6%
Conduct research and be prepares to take actions	14.3%			14.3%
Begin to take adaptation actions +(c)+(d)	25.0%		25.0%	

Table 24 the detailed adaptation activities to the impacts of increased temperature on cost of oil refinery processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	26.1%	26.1%	17.4%	30.4%
Improve fire alarm and prevent system to reduce the damage resulting from fire		21.7%	17.4%	17.4%
Select new material for facilities and associated constructions to prevent disrupt, oil leakage		17.4%		17.4%
Innovate current technique to reduce oil spill and release		21.7%	13.0%	17.4%
Install oil vapor recovery system		21.7%	8.7%	21.7%
Reinforce the maintenance of related facilities		17.4%	17.4%	17.4%

Table 25 the perception to the impacts of increased temperature on petroleum transportation and storage infrastructures

	Industry	Government	Research organization	Non-governmental organization	Total
Significant			27.8%		13.9%
Moderate	37.5%	57.1%	38.9%		38.9%
Minor	50.0%	42.9%	33.3%	66.7%	41.7%
No impact					
Not sure	12.5%			33.3%	5.5%
Total	100%	100%	100%	100%	100%

Table 26 adaptation strategies to impacts of increased temperature on petroleum transportation and storage

	Number of answers	Significant	Moderate	Minor
Do nothing				
Show concerns and be alerted	38.2%	2.9%	17.6	17.7%
Conduct research to gain insight	23.5%		5.9%	17.6%
Conduct research and be prepares to take actions	17.6%	5.9%	5.9%	5.8%
Begin to take adaptation actions +(c)+(d)	20.7%	5.9%	11.9%	2.9%

Table 27 the detailed adaptation activities to the impacts of increased temperature on petroleum transportation and storage

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	32.3%	14.7%	17.6%	20.6%
Use more accurate measurement instruments	11.8%	5.9%	11.8%	
Redesign pipeline to enhance the foundation to improve the stability of pipeline	11.8%	11.8%	17.6%	17.6%
Change the timetable of pipeline installation	11.8%	5.9%	5.9%	
Improve the installation efficiency to abbreviate the installation period	11.8%		17.6%	
Select new material to prevent corrosion of pipeline	11.8%		11.8%	5.9%
Improve the stability of pump station operation	5.9%	11.8%	5.9%	
Redesign the foundation of storage tanks	11.8%	14.7%	17.6%	11.8%
Strengthen land use planning regulations in damage-prone areas	5.9%	5.9%	5.9%	11.8%
Install fire alarm and prevention system	11.8%	14.7%	14.7%	
Use computerized devices to detect weaknesses in pipeline walls and foundation instability	5.9%	5.9%	11.8%	5.9%
Redesign tanks to reduce the spill and leakage	5.9%	17.6%	5.9%	14.7%

Table 28 the perception to the impacts of increased temperature on cost of transportation and storage

	Industry	Government	Research organization	Non-governmental organization	Total
Significant					
Moderate	25.0%	57.1%	50.0%	66.7%	47.2%
Minor	37.5%	28.6%	38.9%		33.3%
No impact	37.5%		11.1%		13.9%
Not sure		14.3%		33.3%	5.6%
Total	100%	100%	100%	100%	100%

Table 29 the adaptation strategy to the impacts of increased temperature on cost of transportation and storage

	Number of answers	Significant	Moderate	Minor
Do nothing	3.4%			3.4%
Show concerns and be alerted	13.8%			13.8%
Conduct research to gain insight	31.0%		13.8%	17.2%
Conduct research and be prepares to take actions	31.1%		24.2%	6.9%
Begin to take adaptation actions +(c)+(d)	20.7%		20.7%	

Table 30 the detailed adaptation activities to the impacts of increased temperature on cost of transportation and storage

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process	14.3%	25.0%	32.1%	21.4%
Use computerized devices to supply early warning to correct problems before incidents occur, preventing natural gas leaks and pipeline rupture	7.1%		7.1%	7.1%
Improve the installation efficiency to abbreviate the installation period	7.1%		7.1%	7.1%
Realize the automatic control of operation to improve the stability of transportation and storage system	7.1%		7.1%	10.7%
Install fire alarm and prevention system	10.7%	21.4%	14.3%	14.3%
Redesign tanks to reduce the spill and leakage	7.1%	14.3%	7.1%	
Develop new loading process for in-land mobile transportation to prevent hydrocarbon escape	7.1%		7.1%	14.3%
Change in-land mobile transportation routes	7.1%	14.3%	10.7%	7.1%
Install recovery system to recycle vapors back into operations		7.1%	10.7%	14.3%

Table 31 the perception to the impacts of increased temperature on environmental management activities in petroleum industries

	Industry	Government	Research organization	Non-governmental organization	Total
Significant		57.1%	11.1%	33.3%	19.4%
Moderate	37.5%	28.6%	72.2%	66.7%	55.6%
Minor	50.0%	14.3%	11.1%		19.4%
No impact			5.6%		2.8%
Not sure	12.5%				2.8%
Total	100%	100%	100%	100%	100%

Table 32 the adaptation strategy to the impacts of increased temperature on environmental management activities in petroleum industries

	Number of answers	Significant	Moderate	Minor
Do nothing	14.7%			14.7%
Show concerns and be alerted	5.9%		5.9%	
Conduct research to gain insight	11.8%		5.9%	5.9%
Conduct research and be prepares to take actions	35.3%	14.7%	20.6%	
Begin to take adaptation actions +(c)+(d)	32.3%	5.9%	26.4%	

Table 33 the detailed adaptation activities to the impacts of increased temperature on environmental management activities in petroleum industries

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, update criteria of environmental management	6.9%	13.8%	37.9%	34.5%
Innovate current remediation technology, develop new technology	6.9%	6.9%	34.5%	24.1%
Take actions to reduce the oil leakage, spill, increase the treatment efficiency to lower the cost for pollution abatement			31.0%	31.0%
Establish new environmental management policy to increase the pollution control efficiency		6.9%	31.0%	27.6%
Establish special environmental management system for petroleum industry		6.9%	20.7%	24.1%
Install recovery system to recycle, leakage oil, vapors back into operations			20.7%	20.7%
Implement an on-line energy monitoring system, maximize energy efficiency			24.1%	6.9%
Install a flare-reduction and emissions-recovery program			27.6%	13.8%
Develop new technologies to convert coal into clean synthesis gas for use in making electricity, chemicals, fuels and fertilizer			24.1%	
Reinforce fire alarm and prevention system			20.7%	17.2%

Table 34 the perception to the impacts of changed precipitation pattern on exploration and production processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant	25.0%		5.6%		8.3%
Moderate	37.5%	42.8%	72.2%	33.3%	55.6%
Minor		28.6%	22.2%	66.7%	22.2%
No impact					
Not sure	37.5%	28.6%			13.9%
Total	100%	100%	100%	100%	100%

Table 35 the adaptation strategy to the impacts of changed precipitation pattern on exploration and production processes

	Number of answers	Significant	Moderate	Minor
Do nothing	3.2%			3.2%
Show concerns and be alerted	29.0%	3.2%	12.9%	12.9%
Conduct research to gain insight	22.6%		16.1%	6.5%
Conduct research and be prepares to take actions	16.1%		12.9%	3.2%
Begin to take adaptation actions +(c)+(d)	29.0%	6.4%	22.6%	

Table 36 the detailed adaptation activities to the impacts of changed precipitation pattern on exploration and production processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate the changed condition of related field works	30.0%	23.3%	16.7%	20.0%
Change the timetable of field survey	20.0%	13.3%	6.7%	20.0%
Increase the efficiency of field works to shorten the survey period		20.0%	13.3%	
Find new method to make it easier to deliver heavy equipment		13.3%	16.7%	6.7%
Take actions to protect instruments in the rainy season	20.0%	6.7%	6.7%	16.7%

Table 37 the perception to the impacts of changed precipitation pattern on drilling and production processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant		28.6%	16.7%		13.9%
Moderate	37.5%	28.6%	61.1%	66.7%	50.0%
Minor	25.0%	42.8%	22.2%	33.3%	27.8%
No impact					
Not sure	37.5%				8.3%
Total	100%	100%	100%	100%	100%

Table 38 the adaptation strategy to the impacts of changed precipitation pattern on drilling and production processes

	Number of answers	Significant	Moderate	Minor
Do nothing	3.0%			3.0%
Show concerns and be alerted	12.1%			12.1%
Conduct research to gain insight	21.2%		12.1%	9.1%
Conduct research and be prepares to take actions	30.4%	9.1%	15.2%	6.1%
Begin to take adaptation actions +(c)+(d)	33.3%	6.1%	27.2%	

Table 39 the detailed adaptation activities to the impacts of changed precipitation pattern on drilling and production processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts	12.5%	15.6%	28.1%	28.1%
Change the timetable of drilling and production		18.7%	6.2%	18.7%
Select anti-erosion steel for drilling equipment		12.5%	18.7%	25.0%
Enhance the maintenance of various instruments		6.2%	12.5%	
Introduce new technique to increase drilling and production efficiency to compensate abbreviated operation seasons		12.5%	9.4%	25.0%
Use high-efficiency compressors and motors in drilling operations		6.2%		12.5%
Use new technique to replace of heavy-duty mud pump		12.5%	6.2%	6.2%
Use steam produced from highly efficient co-generation plants to assist with recovery of heavy oil		3.1%	9.4%	15.6%
Install a clean-bum compressor and emission controls on a dehydrator unit and use compressed air-activated, rather than gas-activated, valves		12.5%	6.2%	

Table 40 the perception to the impacts of changed precipitation pattern on exploration and production infrastructure

	Industry	Government	Research organization	Non-governmental organization	Total
Significant	25.0%	28.6%	5.6%		13.9%
Moderate		14.2%	72.2%	66.7%	44.4%
Minor	25.0%		22.2%	33.3%	19.4%
No impact	12.5%	28.6%			8.3%
Not sure	37.5%	28.6%			13.9%
Total	100%	100%	100%	100%	100%

Table 41 the adaptation strategy to the impacts of changed precipitation pattern on exploration and production infrastructure

	Number of answers	Significant	Moderate	Minor
Do nothing				
Show concerns and be alerted	32.1%		17.8%	14.3%
Conduct research to gain insight	10.7%		7.1%	3.6%
Conduct research and be prepares to take actions	32.1%	7.1%	17.8%	7.2%
Begin to take adaptation actions +(c)+(d)	25.0%	10.7%	14.3%	

Table 42 the detailed adaptation activities to the impacts of changed precipitation pattern on exploration and production infrastructure

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts and the vulnerabilities of related activities, adaptive process, and potential measures	32.1%	10.7%	32.1%	25.0%
Change the timetable of constructions	7.1%		14.3%	14.3%
Improve the construction efficiency to shorten project period		7.1%	17.8%	25.0%
Select anti-erosion material for constructions	10.7%	17.8%	28.6%	7.1%
Enhance the maintenance of various constructions	7.1%		21.4%	25.0%
Redesign the foundations and structures to adapt to changed condition		7.1%	28.6%	25.0%
Redesign pipeline systems to handle greater variability of precipitation		14.3%	25.0%	21.4%

Table 43 the perception to the impacts of changed precipitation pattern on transportation activities within exploration and production processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant		14.3%	11.1%	66.7%	13.9%
Moderate	25.0%	57.1%	83.3%	33.3%	61.1%
Minor	12.5%	14.3%	5.6%		5.5%
No impact	25.0%	14.3%			8.3%
Not sure	37.5%				8.2%
Total	100%	100%	100%	100%	100%

Table 44 the adaptation strategy to the impacts of changed precipitation pattern on transportation activities within exploration and production processes

	Number of answers	Significant	Moderate	Minor
Do nothing	10.0%		6.7%	3.3%
Show concerns and be alerted	23.3%	6.7%	16.6%	
Conduct research to gain insight	6.7%		6.7%	
Conduct research and be prepares to take actions	30.0%		30.0%	
Begin to take adaptation actions +(c)+(d)	30.0%	10.0%	13.3%	6.7%

Table 45 the detailed adaptation activities to the impacts of changed precipitation pattern on transportation activities within exploration and production processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts and vulnerabilities of related activities adaptive process, and potential measures	22.2%	7.4%	33.3%	33.3%
Select anti-erosion and anti-rupture material for pipeline	11.1%		22.2%	29.6%
Redesign pipelines routing and enhance the foundation of pipeline to improve its stability	11.1%		18.5%	22.2%
Introduce new turbine engines to increase efficiencies			7.4%	18.5%
Redesign the ways to access the underground portion for maintenance			14.8%	14.8%
Reinforce flood control system			29.6%	22.2%
Others				

Table 46 the perception to the impacts of changed precipitation pattern on cost of exploration and production

	Industry	Government	Research organization	Non-governmental organization	Total
Significant			16.7%		8.3%
Moderate	37.5%	71.4%	55.5%	66.7%	55.6%
Minor	25.0%		11.1%	33.3%	13.9%
No impact					
Not sure	37.5%	28.6%	16.7%		22.2%
Total	100%	100%	100%	100%	100%

Table 47 the adaptation strategy to the impacts of changed precipitation pattern on cost of exploration and production

	Number of answers	Significant	Moderate	Minor
Do nothing	10.7%		7.1%	3.6%
Show concerns and be alerted	32.1%	3.5%	14.3%	14.3%
Conduct research to gain insight	14.3%		143%	
Conduct research and be prepares to take actions	25.0%	7.1%	17.9%	
Begin to take adaptation actions +(c)+(d)	17.9%		17.9%	

Table 48 the detailed adaptation activities to the impacts of changed precipitation pattern on cost of exploration and production

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	32.0%	12.0%	24.0%	20.0%
Use high-pressure gas feed, which is rich in liquids and low in hydrogen sulfide, thus lower energy requirements			8.0%	8.0%
Develop new technique to increase exploration and production efficiency	20.0%		16.0%	8.0%
Find and repair leaks in facilities and processing equipment, install vapor recovery equipment		8.0%	16.0%	12.0%
Reinforce the foundation and stability of constructions to reduce the damage	8.0%	8.0%	20.0%	16.0%

Table 49 the perception to the impacts of changed precipitation pattern on petroleum refinery processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant					
Moderate		42.8%	22.2%	66.7%	25.0%
Minor	12.5%		27.8%	33.3%	19.4%
No impact	37.5%	28.6%	44.4%		36.2%
Not sure	50.0%	28.6%	5.6%		19.4%
Total	100%	100%	100%	100%	100%

Table 50 the adaptation strategy to the impacts of changed precipitation pattern on petroleum refinery processes

	Number of answers	Significant	Moderate	Minor
Do nothing				
Show concerns and be alerted	68.7%		43.7%	25.0%
Conduct research to gain insight	12.5%			12.5%
Conduct research and be prepares to take actions				
Begin to take adaptation actions +(c)+(d)	18.8%		12.5%	6.3%

Table 51 the detailed adaptation activities to the impacts of changed precipitation pattern on petroleum refinery processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	62.5%	12.5%		18.7%
Innovate the technique to prevent oil leakage, spill, and release		12.5%		12.5%
Install automatic monitor system to reduce the fire risk	12.5%			12.5%
Take anti-erosion action to decrease the rates of corrosion for the facilities	31.2%			12.5%
Find and repair the leakage				18.7%
Install oil vapor recovery system	12.5%			12.5%
Reinforce flood control system	18.7%	12.5%		12.5%

Table 52 the perception to the impacts of changed precipitation pattern on pollutant emission within refinery processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant			11.1%		5.6%
Moderate	25.5%	42.9%	38.9%	66.7%	38.9%
Minor	12.5%		5.5%	33.3%	8.3%
No impact	25.0%		16.7%		13.9%
Not sure	37.5%	57.1%	27.8%		33.3%
Total	100%	100%	100%	100%	

Table 53 the adaptation strategy to the impacts of changed precipitation pattern on pollutant emission within refinery processes

	Number of answers	Significant	Moderate	Minor
Do nothing	10.5%		10.5%	
Show concerns and be alerted	31.6%		26.3%	5.3%
Conduct research to gain insight	36.8%	10.5%	26.3%	
Conduct research and be prepares to take actions	10.5%			10.5%
Begin to take adaptation actions +(c)+(d)	10.6%		10.6%	

Table 54 the detailed adaptation activities to the impacts of changed precipitation pattern on pollutant emission within refinery processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	35.3%	41.2%	11.8%	11.8%
Innovate current techniques to reduce the pollutant emission of each process unit	11.8%	11.8%		11.8%
Increase the use of natural gas, replacing petroleum as the facility's source of energy				
Develop new technologies to convert coal into clean synthesis gas for use in making electricity, chemicals, feels and fertilizer		17.6%		
Install oil vapor recovery system	17.6%			
Enhance the maintenance, find and repair the leakage		23.5%	11.85	11.8%
Promote wider acceptance of diesel engines for offering greater fuel efficiency to lower CO2 emissions				
Improve the drainage treatment system to reduce the pollutant emission	11.8%		11.8%	11.8%

Table 55 the perception to the impacts of changed precipitation pattern on cost of refinery processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant					
Moderate	25.0%		16.7%	66.7%	19.4%
Minor	25.0%	28.6%	22.2%	33.3%	25.0%
No impact	12.5%	28.6%	27.8%		22.3%
Not sure	37.5%	42.8%	33.3%		33.3%
Total	100%	100%	100%	100%	100%

Table 56 the adaptation strategy to the impacts of changed precipitation pattern on cost of refinery processes

	Number of answers	Significant	Moderate	Minor
Do nothing	12.5%		12.5%	
Show concerns and be alerted	43.7%		6.2%	37.5%
Conduct research to gain insight	31.3%		12.5%	8.6%
Conduct research and be prepares to take actions	12.5%		12.5%	
Begin to take adaptation actions +(c)+(d)				

Table 57 the detailed adaptation activities to the impacts of changed precipitation pattern on cost of refinery processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	50.0%	35.7%	14.3%	
Improve fire alarm and prevent system to reduce the damage resulting from fire		14.3%		
Select new material for facilities and associated constructions to prevent disrupt, oil leakage		28.6%	14.3%	
Innovate current technique to reduce oil spill and release		14.3%	14.3%	
Install oil vapor recovery system			14.3%	
Reinforce flood control system to reduce the damage resulting from flood	14.3%	35.7%	14.3%	
Reinforce the maintenance of related facilities		28.6%	14.3%	

Table 58 the perception to the impacts of changed precipitation pattern on petroleum transportation and storage processes

	Industry	Government	Research organization	Non-governmental organization	Others
Significant			11.1%	66.7%	11.1%
Moderate		42.8%	38.9%		27.8%
Minor	62.5%	14.3%	38.9%	33.3%	38.9%
No impact					
Not sure	37.5%	42.9%	11.1%		22.2%
Total	100%	100%	100%	100%	100%

Table 59 the adaptation strategy to the impacts of changed precipitation pattern on petroleum transportation and storage processes

	Number of answers	Significant	Moderate	Minor
Do nothing	7.1%			7.1%
Show concerns and be alerted	42.9%		10.8%	32.1%
Conduct research to gain insight	17.9%		10.8%	7.1%
Conduct research and be prepares to take actions	10.7%		7.1%	3.6%
Begin to take adaptation actions +(c)+(d)	21.4%	14.3%	7.1%	

Table 60 the detailed adaptation activities to the impacts of changed precipitation pattern on petroleum transportation and storage processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	34.6%	15.4%	7.7%	23.1%
Invest money to construct additional roads in case of waterways dysfunctional, and road networks are destroyed	23.1%	7.7%	11.5%	7.7%
Redesign pipeline to enhance the foundation to improve the stability of pipeline	26.9%	19.2%	11.5%	15.4%
Change the timetable of pipeline installation	23.1%	15.4%	7.7%	
Improve the installation efficiency to abbreviate the installation period	15.4%		7.7%	
Select new material to prevent corrosion of pipeline	23.1%	7.7%	11.5%	7.7%
Improve the stability of pump station operation	7.7%		11.5%	7.7%
Redesign the foundation of storage tanks	15.4%	15.4%	11.5%	15.4%
Reinforce flood control system	15.4%	19.2%	7.7%	15.4%
Strengthening of land use planning regulations in damage-prone areas	15.4%		11.5%	
Use computerized devices to detect weaknesses in pipeline walls and foundation instability	7.7%	7.7%	7.7%	15.4%

Table 61 the perception to the impacts of changed precipitation pattern on cost of transportation and storage

	Industry	Government	Research organization	Non-governmental organization	Total
Significant		28.6%		66.7%	11.1%
Moderate			38.9%		19.4%
Minor	12.5%	28.6%	44.4%	33.3%	33.3%
No impact	37.5%				8.4%
Not sure	50.0%	42.8%	16.7%		27.8%
Total	100%	100%	100%	100%	100%

Table 62 the adaptation strategy to the impacts of changed precipitation pattern on cost of transportation and storage

	Number of answers	Significant	Moderate	Minor
Do nothing				
Show concerns and be alerted	30.4%			30.4%
Conduct research to gain insight	30.4%	8.7%	8.7%	13.0%
Conduct research and be prepares to take actions	17.4%		8.7%	8.7%
Begin to take adaptation actions +(c)+(d)	21.8%	8.7%	13.1%	

Table 63 the detailed adaptation activities to the impacts of changed precipitation pattern on cost of transportation and storage

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process	26.1%	17.4%	17.4%	21.7%
Use computerized devices to supply early warning to correct problems before incidents occur, preventing natural gas leaks and pipeline rupture			8.7%	17.4%
Improve the installation efficiency to abbreviate the installation period	17.4%	8.7%	8.7%	
Realize the automatic control of operation to improve the stability of transportation and storage system	13.0%	17.4%	8.7%	17.4%
Redesign tanks to reduce the spill and leakage	8.7%	17.4%	8.7%	17.4%
Reinforce flood control system	17.4%	21.7%	8.7%	17.4%
Develop new loading process for in-land mobile transportation to prevent hydrocarbon escape	8.7%	8.7%		8.7%
Change in-land mobile transportation routes	8.7%	8.7%		8.7%
Install recovery system to recycle vapors back into operations		8.7%		17.4%

Table 64 the perception to the impacts of changed precipitation pattern on environmental management activities within petroleum industries

	Industry	Government	Research organization	Non-governmental organization	Total
Significant		14.3%		66.7%	8.3%
Moderate	25.0%		77.8%		44.4%
Minor	25.0%	28.6%	22.2%	33.3%	25.0%
No impact	25.0%				5.6%
Not sure	25.0%	57.1%			16.7%
Total	100%	100%	100%	100%	100%

Table 65 the adaptation strategy to the impacts of changed precipitation pattern on environmental management activities within petroleum industries

	Number of answers	Significant	Moderate	Minor
Do nothing	7.1%			7.1%
Show concerns and be alerted	10.7%		7.1%	3.6%
Conduct research to gain insight	28.6%	3.6%	17.9%	7.1%
Conduct research and be prepares to take actions	21.4%		7.1%	14.3%
Begin to take adaptation actions +(c)+(d)	32.1%	7.1%	25.0%	

Table 66 the detailed adaptation activities to the impacts of changed precipitation pattern on environmental management activities within petroleum industries

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, update criteria of environmental management	11.5%	23.1%	23.1%	34.6%
Innovate current remediation technology, develop new technology		19.2%	23.1%	15.4%
Take actions to reduce the oil leakage, spill, increase the treatment efficiency to lower the cost for pollution abatement	7.7%	23.1%	7.7%	26.9%
Establish new environmental management policy to increase the pollution control efficiency		19.2%	7.7%	23.1%
Establish special environmental management system for petroleum industry		7.7%	7.7%	15.4%
Install recovery system to recycle, leakage oil, vapors back into operations		15.4%	7.7%	23.1%
Improve drainage system to prevent the pollutant directly moving into ambient		23.1%	11.5%	15.4%
Implement an on-line energy monitoring system, maximize energy efficiency		7.7%	7.7%	7.7%
Install a flare-reduction and emissions-recovery program			7.7%	
Develop new technologies to convert coal into clean synthesis gas for use in making electricity, chemicals, fuels and fertilizer			7.7%	7.7%

Table 67 the perception to the impacts of changed humidity and cloud pattern on exploration processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant					
Moderate	12.5%	28.6%	22.2%		19.4%
Minor	37.5%	14.2%	61.1%	33.3%	44.4%
No impact	12.5%	28.6%	16.7%	66.7%	22.2%
Not sure	37.5%	28.6%			13.9%
Total	100%	100%	100%	100%	100%

Table 68 the adaptation strategy to the impacts of changed humidity and cloud pattern on exploration processes

	Number of answers	Significant	Moderate	Minor
Do nothing	4.3%			4.3%
Show concerns and be alerted	31.8%			31.8%
Conduct research to gain insight	26.1%		4.3%	21.8%
Conduct research and be prepares to take actions	17.4%		8.7%	8.7%
Begin to take adaptation actions +(c)+(d)	17.4%		17.4%	

Table 69 the detailed adaptation activities to the impacts of changed humidity and cloud pattern on exploration processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate the changed condition of related field works	27.3%	18.2%	18.2%	9.1%
Change the timetable of field survey		9.1%		
Increase the efficiency of field works to shorten the survey period		18.2%	9.1%	18.2%
Take actions to prevent operation instruments from erosion as possible	18.2%	22.7%	13.6%	9.1%

Table 70 the perception to the impacts of changed humidity and cloud pattern on drilling and production processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant			11.1%		5.6%
Moderate		28.6%	44.5%		27.8%
Minor	50.0%		22.2%	33.3%	25.0%
No impact		57.1%	22.2%	66.7%	27.8%
Not sure	50.0%	14.3%			13.9%
Total	100%	100%	100%	100%	100%

Table 71 the adaptation strategy to the impacts of changed humidity and cloud pattern on drilling and production processes

	Number of answers	Significant	Moderate	Minor
Do nothing				
Show concerns and be alerted	14.3%			14.3%
Conduct research to gain insight	32.4%		33.3%	19.1%
Conduct research and be prepares to take actions	23.8%		14.3%	9.5%
Begin to take adaptation actions +(c)+(d)	9.5%	9.5%		

Table 72 the detailed adaptation activities to the impacts of changed humidity and cloud pattern on drilling and production processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts	14.3%	47.6%	19.1%	9.5%
Select anti-erosion steel for drilling equipment		28.6%	9.5%	
Use high-efficiency compressors and motors in drilling operations			14.3%	
Install a clean-bum compressor and emission controls on a dehydrator unit and use compressed air-activated, rather than gas-activated, valves				9.5%

Table 73 the perception to the impacts of changed humidity and cloud pattern on petroleum refinery processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant					
Moderate	25.0%	28.6%	11.1%		16.7%
Minor	12.5%	14.2%	61.1%	33.3%	38.9%
No impact	12.5%	28.6%	16.7%	66.7%	22.2%
Not sure	50.0%	28.6%	11.1%		22.2%
Total	100%	100%	100%	100%	100%

Table 74 the adaptation strategy to the impacts of changed humidity and cloud pattern on petroleum refinery processes

	Number of answers	Significant	Moderate	Minor
Do nothing	5.0%			5.0%
Show concerns and be alerted	45.0%		20.0%	25.0%
Conduct research to gain insight	10.0%			10.0%
Conduct research and be prepares to take actions	20.0%		10.0%	10.0%
Begin to take adaptation actions +(c)+(d)	20.0%			20.0%

Table 75 the detailed adaptation activities to the impacts of changed humidity and cloud pattern on petroleum refinery processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	42.1%	10.5%	10.5%	
Innovate the technique to prevent oil leakage, spill, and release	10.5%	10.5%		10.5%
Take anti-erosion action to decrease the rates of corrosion for the facilities	15.8%	10.5%	21.0%	
Find and repair the leakage		10.5%	10.5%	

Table 76 the perception to the impacts of changed humidity and cloud pattern on petroleum transportation and storage processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant			11.1%		5.6%
Moderate			11.1%		5.6%
Minor	50.0%	57.1%	33.3%		38.9%
No impact	12.5%	28.6%	16.7%	66.7%	22.1%
Not sure	37.5%	14.3%	27.8%	33.3%	27.8%
Total	100%	100%	100%	100%	100%

Table 77 the adaptation strategy to the impacts of changed humidity and cloud pattern on petroleum transportation processes

	Number of answers	Significant	Moderate	Minor
Do nothing				
Show concerns and be alerted	50.0%		11.1%	38.9%
Conduct research to gain insight	33.3%	11.1%		22.2%
Conduct research and be prepares to take actions	16.7%			16.7%
Begin to take adaptation actions +(c)+(d)				

Table 78 the detailed adaptation activities to the impacts of changed humidity and cloud pattern on petroleum transportation and storage processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	38.9%	33.3%	22.2%	
Take action to prevent measurement instruments from erosion	33.3%	22.2%	11.1%	
Select new material to prevent corrosion of pipeline	22.2%	22.2%	16.7%	
Install fire alarm and prevention system	11.1%	22.2%		
Redesign tanks to reduce the spill and leakage		22.2%	11.1%	

Table 79 the perception to the impacts of increased natural hazards on oil exploration processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant	12.5%	42.8%	61.1%	33.3%	44.4%
Moderate	25.0%	28.6%	33.3%		27.8%
Minor	25.0%	28.6%	5.6%	66.7%	13.9%
No impact		2			5.6%
Not sure	37.5%				8.3%
Total	100%	100%	100%	100%	100%

Table 80 the adaptation strategy to the impacts of increased natural hazards on oil exploration processes

	Number of answers	Significant	Moderate	Minor
Do nothing	9.7%		3.2%	6.5%
Show concerns and be alerted	16.1%		6.4%	9.7%
Conduct research to gain insight	19.3%	12.9%	6.4%	
Conduct research and be prepares to take actions	25.8%	16.1%	9.7%	
Begin to take adaptation actions +(c)+(d)	29.0%	22.6%	6.4%	

Table 81 the detailed adaptation activities to the impacts of increased natural hazards on oil exploration processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate the possible extreme events	7.1%	14.3%	28.6%	32.1%
Change the timetable of field survey				14.3%
Introduce new instruments which can work under extreme conditions			28.6%	28.6%
Enhance the maintenance of various instruments			14.3%	14.35

Table 82 the perception to the impacts of increased natural hazards on drilling and production processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant	25.0%	14.2%	50.0%		33.3%
Moderate	37.5%	28.6%	44.4%	33.3%	38.9%
Minor	25.0%	28.6%	5.6%	66.7%	19.5%
No impact					
Not sure	12.5%	28.6%			8.3%
Total	100%	100%	100%	100%	100%

Table 83 the adaptation strategy to the impacts of increased natural hazards on drilling and production processes

	Number of answers	Significant	Moderate	Minor
Do nothing	3.0%		3.0%	
Show concerns and be alerted	39.4%	6.1%	12.1%	21.2
Conduct research to gain insight	6.1%		6.1%	
Conduct research and be prepares to take actions	36.4%	15.2%	21.2%	
Begin to take adaptation actions +(c)+(d)	15.2%	15.2%		

Table 84 the detailed adaptation activities to the impacts of increased natural hazards on drilling and production processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible extreme events and their possible impacts	40.6%	6.2%	25.0%	12.5%
Change the timetable of drilling and production	6.2%		12.5%	6.2%
Enhance the maintenance of various instruments	9.4%		9.4%	5
Upgrade and/or move of facilities and structures, strengthen land use planning regulations, particularly in damage-prone areas, redesign related infrastructures		6.2%	25.0%	6.2%
Reinforce flood control system	12.5%		31.2%	
Develop storm forecasting system to decrease the storms detriment to drilling and production activities			31.2%	6.2%
Take measures to prevent drilling casing from damage due to permafrost-melting under extreme high temperature			25.0%	9.4%

Table 85 the perception to the impacts of increased natural hazards on exploration and production infrastructures

	Industry	Government	Research organization	Non-governmental organization	Total
Significant	37.5%	28.6%	38.9%		33.3%
Moderate	25.0%	42.8%	44.4%	33.3%	38.9%
Minor	12.5%	28.6%	11.1%	66.7%	19.4%
No impact					
Not sure	25.0%		5.6%		8.4%
Total	100%	100%	100%	100%	100%

Table 86 the adaptation strategy to the impacts of increased natural hazards on exploration and production infrastructures

	Number of answers Significant		Moderate	Minor
Do nothing	3.0%		3.0%	
Show concerns and be alerted	21.2%		9.1%	12.1%
Conduct research to gain insight	18.3%	6.1%	6.1%	6.1%
Conduct research and be prepares to take actions	33.3%	15.1%	18.2%	
Begin to take adaptation actions +(c)+(d)	24.2%	15.1%	6.1%	3.0%

Table 87 the detailed adaptation activities to the impacts of increased natural hazards on exploration and production infrastructures

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts and the vulnerabilities of related activities adaptive process, and potential measures	21.9%	18.75%	34.4%	25.0%
Redesign the construction of infrastructures for weather extremes	18.75%	6.2%	18.75%	25.0%
Enhance the building security/integrity	18.75%	6.2%	12.5%	25.05
Select anti-erosion material for constructions	6.2%		12.5%	15.6%
Enhance the maintenance of various constructions	12.5%		9.4%	18.75%
Redesign pipeline system to handle extreme events	12.5%	6.2%	6.2%	25.0%

Table 88 the perception to the impacts of increased natural hazards on transportation activities within exploration and production processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant	25.0%	28.6%	16.7%		19.4%
Moderate	25.0%	57.1%	77.8%	33.3%	58.3%
Minor	12.5%	14.3%	5.5%	66.7%	13.9%
No impact					
Not sure	37.5%				8.4%
Total	100%	100%	100%	100%	100%

Table 89 the adaptation strategy to the impacts of increased natural hazards on transportation activities within exploration and production processes

	Number of answers	Significant	Moderate	Minor
Do nothing				
Show concerns and be alerted	30.3%		27.3%	3.0%
Conduct research to gain insight	24.2%		18.1%	6.1%
Conduct research and be prepares to take actions	24.3%	9.1%	15.2%	
Begin to take adaptation actions +(c)+(d)	21.2%	12.1%	3.0%	6.1%

Table 90 the detailed adaptation activities to the impacts of increased natural hazards on transportation activities within exploration and production processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts and vulnerabilities of related activities adaptive process, and potential measures	24.2%	18.2%	24.2%	21.2%
Select anti-erosion and anti-rupture material for pipeline	18.2%	15.2%	6.1%	6.1%
Redesign pipelines routing and enhance the foundation of pipeline to improve its stability to handler the extreme events	6.1%	24.2%	12.1%	12.1%
Redesign the ways to access the underground portion for maintenance		18.2%	9.1%	12.1%

Table 91 the perception to the impacts of increased natural hazards on cost of exploration and production

	Industry	Government	Research organization	Non-governmental organization	Total
Significant	25.0%	42.9%	38.9%		33.3%
Moderate		57.1%	50.0%	33.3%	38.9%
Minor	37.5%		11.1%	66.7%	19.4%
No impact					
Not sure	37.5%				8.4%
Total	100%	100%	100%	100%	100%

Table 92 the adaptation strategy to the impacts of increased natural hazards on cost of exploration and production

	Number of answers	Significant	Moderate	Minor
Do nothing	6.1%			6.1%
Show concerns and be alerted	33.3%	6.1%	21.1%	6.1%
Conduct research to gain insight	9.1%			9.1%
Conduct research and be prepares to take actions	30.3%	15.2%	15.1%	
Begin to take adaptation actions +(c)+(d)	21.2%	15.1%	6.1%	

Table 93 the detailed adaptation activities to the impacts of increased natural hazards on cost of exploration and production

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	32.2%	9.4%	22.6%	19.3%
Use high-pressure gas feed, which is rich in liquids and low in hydrogen sulfide, thus lower energy requirements	6.4%		6.4%	
Develop new technique to increase exploration and production efficiency	16.1%		19.3%	
Find and repair leaks in facilities and processing equipment, install vapor recovery equipment			6.4%	
Reinforce the foundation and stability of constructions to reduce the damage	12.9%	9.4%	19.3%	12.9%

Table 94 the perception to the impacts of increased natural hazards on petroleum refinery processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant	25.0%	28.6%	27.8%		25.0%
Moderate	37.5%	14.2%	38.9%	33.3%	33.3%
Minor			16.7%	66.7%	13.9%
No impact	12.5%	28.6%	11.1%		13.9%
Not sure	25.0%	28.6%	5.5%		13.9%
Total	100%	100%	100%	100%	100%

Table 95 the adaptation strategy to the impacts of increased natural hazards on petroleum refinery processes

	Number of answers	Significant	Moderate	Minor
Do nothing	19.2%		11.5%	7.7%
Show concerns and be alerted	15.4%	3.8%	11.6%	
Conduct research to gain insight	19.2%	7.7%	7.7%	3.8%
Conduct research and be prepares to take actions	15.4%	15.4%		
Begin to take adaptation actions +(c)+(d)	30.8%	7.7%	15.4%	7.7%

Table 96 the detailed adaptation activities to the impacts of increased natural hazards on petroleum refinery processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	19.0%	19.0%	19.0%	38.1%
Innovate the technique to prevent oil leakage, spill, and release			9.5%	9.5%
Install automatic monitor system to reduce the fire risk		19.0%	14.3%	14.3%
Redesign the associated facilities to handle the extreme events		9.5%	9.5%	28.6%
Take anti-erosion action to decrease the rates of corrosion for the facilities		19.0%	9.5%	
Enhance the maintenance, find and repair the leakage		9.5%	9.5%	
Reinforce flood control system		9.5%	14.3%	19.0%

Table 97 the perception to the impacts of increased natural hazards on pollution emission within oil refinery processes

	Industry	Government	Research organization	Non-governmental organization	Total
Significant		18.6%	16.7%		13.9%
Moderate	37.5%	14.2%	61.1%	33.3%	44.4%
Minor			5.5%	66.75	8.3%
No impact		28.6%			5.6%
Not sure	62.5%	28.6%	16.7%		27.8%
Total	100%	100%	100%	100%	100%

Table 98 the adaptation strategy to the impacts of increased natural hazards on pollution emission within oil refinery processes

	Number of answers	Significant	Moderate	Minor
Do nothing	8.4%		8.4%	
Show concerns and be alerted	20.8%		20.8%	
Conduct research to gain insight	33.3%	12.5%	16.7%	4.1%
Conduct research and be prepares to take actions	8.3%		8.3%	
Begin to take adaptation actions +(c)+(d)	29.2%	8.4%	12.5%	8.3%

Table 99 the detailed adaptation activities to the impacts of increased natural hazards on pollution emission within oil refinery processes

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	22.7%	36.4%	9.1%	31.8%
Redesign associated facilities to handle the extreme events, prevent facilities disrupt, crack resulting in pollutant emission	9.1%	9.1%	9.1%	27.3%
Redesign pipeline and other auxiliary equipment to prevent leakage		18.2%	9.1%	9.1%
Change plant location, facilities location to avoid extreme events				27.3%
Improve fire alarm and prevent system		13.6%	9.1%	18.2%
Enhance flood control system		18.2%	9.1%	22.7%

Table 100 the perception to the impacts of increased natural hazards on petroleum transportation and storage

	Industry	Government	Research organization	Non-governmental organization	Total
Significant	12.5%		38.9%		22.2%
Moderate	62.5%	71.4%	44.4%	66.7%	55.6%
Minor		28.6%	5.6%		8.3%
No impact					
Not sure	25.0%		11.1%	33.3%	13.9%
Total	100%	100%	100%	100%	100%

Table 101 the adaptation strategy to the impacts of increased natural hazards on petroleum transportation and storage

	Number of answers	Significant	Moderate	Minor
Do nothing				
Show concerns and be alerted	6.4%		6.4%	
Conduct research to gain insight	6.5%		6.5%	
Conduct research and be prepares to take actions	45.2%	16.1%	22.6%	6.5%
Begin to take adaptation actions +(c)+(d)	41.9%	9.7%	29.0%	3.2%

Table 102 the detailed adaptation activities to the impacts of increased natural hazards on petroleum transportation and storage

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process, and potential measures	6.4%	6.4%	41.9%	38.7%
Redesign pipeline to enhance the foundation to improve the stability of pipeline			38.7%	19.4%
Change the timetable of pipeline installation			6.4%	6.4%
Improve the installation efficiency to abbreviate the installation period			19.4%	12.9%
Improve the stability of pump station operation			32.2%	29.0%
Redesign the foundation of storage tanks			35.5%	25.8%
Strengthen land use planning regulations in damage-prone areas			25.8%	19.4%
Install fire alarm and prevention system	6.4%		29.0%	19.4%
Redesign tanks to reduce the spill and leakage	6.4%		25.8%	22.6%
Reinforce flood control system	6.4%		25.8%	32.2%
Change in-land mobile transportation routes	6.4%		12.9%	16.1%

Table 103 the perception to the impacts of increased natural hazards on cost of transportation and storage

	Industry	Government	Research organization	Non-governmental organization	Total
Significant			16.7%		8.3%
Moderate	12.5%	71.4%	66.7%	66.7%	55.6%
Minor	50.0%	28.6%	5.5%	33.3%	22.2%
No impact					
Not sure	37.5%		11.1%		13.9%
Total	100%	100%	100%	100%	100%

Table 104 the adaptation strategy to the impacts of increased natural hazards on cost of transportation and storage

	Number of answers	Significant	Moderate	Minor
Do nothing	3.2%			3.2%
Show concerns and be alerted	22.6%		12.9%	9.7%
Conduct research to gain insight	22.6%	6.5%	9.7%	6.4%
Conduct research and be prepares to take actions	25.8%		19.4%	6.4%
Begin to take adaptation actions +(c)+(d)	25.8%	3.2%	22.6%	

Table 105 the detailed adaptation activities to the impacts of increased natural hazards on cost of transportation and storage

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, adaptive process	23.3%	23.3%	26.7%	26.7%
Use computerized devices to supply early warning to correct problems before incidents occur, preventing natural gas leaks and pipeline rupture	6.7%	13.3%	20.0%	13.3%
Install fire alarm and prevention system	6.7%	6.7%	13.3%	20.0%
Redesign tanks to reduce the spill and leakage		10.0%	13.3%	6.7%
Reinforce flood control system	6.7%	6.7%	23.3%	23.3%
Change in-land mobile transportation routes			13.3%	6.7%
Install recovery system to recycle vapors back into operations		6.7%	20.0%	6.7%
Redesign the foundation of pipelines and storage tanks to handle extreme events	10.0%	6.7%	20.0%	23.3%

Table 106 the perception to the impacts of increased natural hazards on environmental activities within petroleum industries

	Industry	Government	Research organization	Non-governmental organization	Total
Significant	12.5%		38.9%		22.2%
Moderate	50.0%	71.4%	50.0%	66.7%	55.6%
Minor			11.1%		5.5%
No impact					
Not sure	37.5%	28.6%		33.3%	16.7%
Total	100%	100%	100%	100%	100%

Table 107 the adaptation strategy to the impacts of increased natural hazards on environmental activities within petroleum industries

	Number of answers	Significant	Moderate	Minor
Do nothing				
Show concerns and be alerted	23.3%		16.7%	6.6%
Conduct research to gain insight	6.7%		6.7%	
Conduct research and be prepares to take actions	26.7%	23.4%	3.3%	
Begin to take adaptation actions +(c)+(d)	43.3%	3.3%	40.0%	

Table 108 the detailed adaptation activities to the impacts of increased natural hazards on environmental activities within petroleum industries

	Show concerns and be alerted	Conduct research to gain insight	Conduct research and be prepares to take actions	Begin to take adaptation actions +(c)+(d)
Investigate all possible impacts, update criteria of environmental management	23.3%	6.7%	26.7%	40.0%
Take actions to reduce the oil leakage, spill, increase the treatment efficiency to lower the cost for pollution abatement	20.0%	6.7%	16.7%	13.3%
Establish special environmental management system for petroleum industry	6.7%	6.7%	13.3%	26.7%
Install recovery system to recycle, leakage oil, vapors back into operations	6.7%		20.0%	6.7%
Improve drainage system to prevent the pollutant directly moving into ambient	13.3%		10.0%	20.0%
Implement an on-line energy monitoring system, maximize energy efficiency	6.7%		6.7%	13.3%
Install a flare-reduction and emissions-recovery program				6.7%
Develop new technologies to convert coal into clean synthesis gas for use	6.7%		6.7%	
Reinforce fire alarm and prevention system	10.0%		13.3%	23.3%
Develop new technologies to convert coal into clean synthesis gas for use in making electricity, chemicals, fuels and fertilizer	6.7%		6.7%	