African Journal of Business Management Vol.6 (31), pp. 9040-9055, 8 August, 2012
Available online at http://www.academicjournals.org/AJBM
DOI: 10.5897/AJBM12.652
ISSN 1993-8233 ©2012 Academic Journals

Full Length Research Paper

A framework for assessing the riskiness of construction of a structural experiment project under Sino-African laboratory environment

Arnaud R. Agnantounkpatin* and Lian Ying Zhang

School of Management and Economics, Tianjin University-China.

Accepted 16 July, 2012

Every construction project, whether small size (laboratory construction experiments) or big size (real scale) project, needs a structured management framework. An experimental construction project in a laboratory can present as much risks as a real scale construction project. And as bases for theory, laboratory experiments should be carried with a careful management structure to insure the correctness of the results; therefore, risk management is an important issue during laboratory experiments. This paper investigates the state of art of laboratory experiments management through literature by exploring the existing frameworks for quality and risks management in laboratory environment. Then we evaluate and present the value of this concept by implementing the proposed framework to assess the riskiness of a construction experiment project under international (Sino-African) laboratory environment. The results show that, using the risk management framework during the laboratory experiments improves the accuracy of the obtained results therefore increases the reliability of the proposed theory. The riskiness of the case experiment project is calculated using Analytic hierarchy process (AHP) assessment tool (Expert choice) and the result shows that this case project is a low risk level project.

Key words: Framework, risk management, laboratory experiment management, international laboratory environment, reliability.

INTRODUCTION

Much of the work in management science lives at the boundary of analytical and behavioral disciplines. Laboratory experiments are a major method used in the construction industry and also in many other social science fields (economics, psychology, sociology etc.). There are three major purposes that laboratory experiments serve: (1) to test and refine existing theory, (2) to characterize new phenomena leading to new theory, (3) to test new institutional designs (Roth, 1995a). Laboratory studies complement other methods by bridging the gap between analytical models and real business problems. Analytical models are built to be parsimonious and general. These models can be tested using a variety of empirical methods, including surveys, field studies, field experiments, or laboratory experiments. All empirical methods involve a trade-off between the internal and the external validity. Surveys and field studies that use secondary data have high external validity (they are close to the real settings being studied), but may be low on internal validity because they often suffer from being confounded, or not having all the data that would ideally be required. This is because researchers cannot directly manipulate the factors or levels in the study, and have to accept the data that is available to them. Therefore, the relative advantage of laboratory experiments is control. Experiments can be designed to fully manipulate all factors at all desired

---

*Corresponding author. E-mail: ronaldenbj@yahoo.fr. Tel: +8618602219741.

levels, and to match the assumptions of the analytical model being tested. So, laboratory experiments are high on the internal validity, but because the environment is often more artificial, they are lower on the external validity. A good experiment is one that controls for the most plausible alternative hypotheses that might explain the data. It also allows the researcher to cleanly distinguish among possible explanations.

Three factors make experimental work rigorous. The first one is theoretical guidance. To interpret the results of an experiment, researchers need to be able to compare the data to theoretical benchmarks. Systematic deviations from theory can provide insights into factors missing from the analytical model, and guidance into how the model can be improved. The second factor is induced valuation. The third factor is careful control of institutional structure. Strategic options and information available to participants should match those assumed by the theoretical model. The art of designing good experiments (as well as the art of building good analytical models) is in creating simple environments that capture the essence of the real problem while abstracting away all unnecessary details. Thus, the first step in doing experimental work is to start with an interesting theory. What makes a theory interesting is that; (1) it has empirical implications, and (2) these implications are worth testing, meaning that they capture a phenomenon that is sufficiently real and interesting so that learning about it adds to our knowledge of the real world. Laboratory experiments tend to be relatively inexpensive compared for example, to experiments conducted in natural or physical sciences. Many research-oriented universities provide small grants for data collection that is often sufficient for a study with a reasonable sample size.

One of the questions often asked about laboratory experiments is about whether their results can be carried over into the real world. Smith (1982) addresses this question with the concept of parallelism. But to insure that the results of a laboratory experiment can be reliable and used in the real world, it's imperative to carry experiments under a good management system. This article investigates the state of art of laboratory experiments management through literature by exploring the existing frameworks for quality and risks management in laboratory environment, then discusses the important of risk management during laboratory experiments before proposing a framework for laboratory construction experiments projects risk management. We then evaluate and present the value of this concept by implementing the proposed framework in the management process of a construction experiment project under international (Sino-African) laboratory environment.

i. Why pay any attention to outcomes in an experiment?
ii. What more can possibly be learnt about project risk management from laboratory that are not already learned in the field?

The answers to these two questions give the importance of the work in this paper.

The main objectives of the work in this paper are to: (1) identify the sources or areas of risk and uncertainty and their sub-areas during laboratory structures experiments for Sino-African International Construction Projects, (2) develop an assessment model for the effects of these sources using Analytic hierarchy process (AHP) and (3) test the proposed model with a case study.

Laboratory experiments management

Multiple research methods applied to the same question give better results than a single method; experimental research enables one to test the impact of specific variables in repeated controlled settings, something that is never available to a scholar studying field settings. One gains external validity in doing field research and internal validity in the laboratory. But when a researcher can use both methods related to one theoretical set of questions, the scientific community can have more confidence in the results (Ostrom, 2006). The laboratory experiments project management is based on normal management system approach. This implies that identifying, understanding and managing a system of interrelated processes for a given objective improves the organization's effectiveness and efficiency. An effective management system approach should be built on the concept of continual improvement through a cycle of planning, implementing, reviewing and improving the processes and actions that an organization undertakes to meet goals. This is known as the PDCA (*Plan-Do-Check-Act*) principle:

- Plan: Planning, including identification of hazard and risk and establishing goals,
- Do: Implementing, including training and operational issues,
- Check: Checking, including monitoring and corrective action,
- Act: Reviewing, including process innovation and acting to make needed changes to the management system.

Many researchers working in a laboratory think of laboratory experiments management as additional burdensome work that is necessary only because it's required by regulatory. The College of American Pathologists first introduced Q-PROBES to acquire national laboratory performance data on selected quality performance measurements (Howanitz, 1990). Therefore it seems that a large segment of medical laboratory community has yet to understand that quality must be built into, not inspected into work processes to ensure quality and patient safety (Food and Drug Administration Department of Health and Human Services, 1987). Many laboratories miss out by focusing on their destination (that is, passing an accreditation inspection) instead of more carefully mapping out and enjoying their journey (management of day to day laboratory work). Risk management concept in the health care industries (laboratories) have matured and harmonized over the years (Martin and Perez, 2008). There are still very few considerations in the construction industry (laboratory experiments projects), but the use of risk management is now an expectation in all aspects of every business.

It should be possible to reduce or eliminate unwarranted work at all risk levels but especially on low risk areas, freeing critical resources to mitigate higher risks (Samardelis and Cappucci, 2009). Thus, focusing effort on laboratory experiments projects where theories are born and therefore insure the accuracy of those theories would help reducing risks in real scale projects. The amount of involvements (materials, equipments, human resources, etc.) in laboratory experiments projects is far smaller than real scale project but the need for risk management is as important because errors due to failure in the experiments management can generate incorrect results and have high impacts on the real scale projects risk management. Therefore applying a good risk management system to laboratory experiments project can help improving the risk management of real construction projects.

Risk assessment in laboratory experiments projects

A variety of hazards exist in the laboratory work environment and the risks associated with these hazards can be greatly reduced or eliminated if proper precautions and practices are observed during the laboratory experiments process. To manage these risks and in response to a heightened concern for safety in the workplace but mostly to the accuracy of the results of the experiments, these risks need to be assessed and managed properly. Like in real scale project risk management, the first step and the most important part of an experiment risk management is the risk assessment (See Figure 1)". Carrying out a risk assessment for an experiment requires three simple steps:

1. Indentify the hazards and problems associated with the materials, equipments and tasks,
2. Assess the risk of exposure to these hazards and problems,
3. Control the risk by implementation of procedures and precautions.

Applying the risk management approach to safety in the laboratory means completing a risk assessment of any research project or experiment before work begins. Every time a new experiment is to be carried out, a risk assessment must be performed and documented by the researcher in consultation with the supervisor. A risk assessment should identify potential hazards and determine the actions or controls required to eliminate or reduce any risks to the health of workers. Risk assessment involves considering the following steps when undertaking a research project:

1. Determine the purpose of the project, where, when and how will the work be done, and will do the work (level of knowledge, skills and expertise),
2. Identify the specimens and experiment process or techniques,
3. Determine the potential risks and hazards involved by gathering information about the materials and equipments or tools to be used. Are there other possible hazards associated with the project (electrical, etc),
4. Evaluate the level of risks. This evaluation is based on the project members' knowledge of the hazards involved and what can go wrong,
5. Determine the actions and controls to be taken. This may include precautions such as personal protective equipments, specific handling procedures or any particular disposal methods required,
6. Monitor and review. The whole process should be monitored and reviewed to ensure that initial evaluation and controls were effective. Re-evaluation of the risks and control will be necessary with changes to the specimens, processes and procedures.

METHODOLOGY

The framework for risk management during construction experiments using AHP

Risk assessments begin with a well-defined problem description or risk question. When the risk in question is well defined, an appropriate risk management and the types of information needed to address the risk question will be more readily identifiable. As an aid to clearly defining the risk(s) for risk assessment purposes, three fundamental questions are often helpful:

1. What might go wrong?
2. What is the likelihood (probability) it will go wrong?
3. What are the consequences (severity)?

These questions help develop a risk matrix which is a summary of the different risks involved in any process. It considers the consequences (Table 1) and the likelihood (Table 2), and a risk score (Table 3) is calculated according to the risk matrix. AHP has been applied in different fields (Arbel and Seidman, 1984; Zahedi, 1986; Al-Bahar, 1988; Bord and Feinberg, 1989; Mustafa, 1987; Liberatore, 1987; Khorramshahgol et al., 1988). The AHP is used here to rank the sources or areas of risk and uncertainty and their sub-areas during laboratory structures experiments for Sino-African International Construction Projects. It will provide a sample methodology for risk assessment. The framework presented in this paper was developed in the following steps:

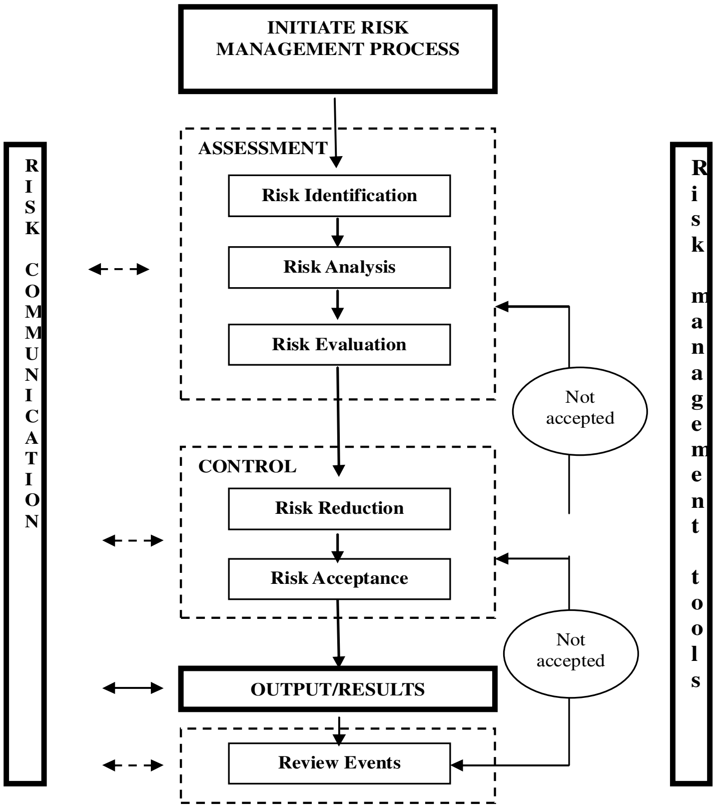


Figure 1. Typical risk management process.

Table 1. Risk consequences rating.

Scale (1-9)	Consequences	Personal damage	Cost increase ($)	Time delay	Environment
1-3	Insignificant	No treatment needed	< $ 1 K	< 1 h	Potential impact
3-5	Minor	First Aid treatment	$ 1 K - 5 K	1 h - 1 day	On site impact
5-7	Moderate	Medical treatment	$ 5 K - $ 15 K	1 day - 1 week	Off site impact
7-9	Major	Extensive injury or death	>$ 15 K	> 1 week	Community alarm

Table 2. Risk likelihood rating.

Risk Class	Percentage	Description
A (very likely)	50-100	Will occur in most circumstances
B (likely)	25-50	Could occur at some time
C (less likely)	5-25	Could occur but only rarely
D (not likely)	0-5	May occur but probably never

Table 3. Risk score classification.

Risk score class	Definition	Description
H	High	Very Likely to occur with major or moderate consequences
M	Medium	Likely or less likely to occur with moderate or minor consequences
L	Low	Less or not likely to occur with minor or insignificant consequences

Step 1

A comprehensive literature review is performed to investigate the common methods used risk assessment in construction projects.

Step 2

Surveys (questionnaires and onsite interviews) are also performed in order to collect useful data from the construction practitioners and experts in International construction Projects, more importantly Sino-African ICPs but also from experts in laboratory experiment management.

Step 3

Based on the information and data collected from steps 1 and 2, an AHP risk model is developed. Firstly, the risks involved in laboratory experiments projects are identified and classified according to their sources. Then a hierarchy is developed before the performance of the AHP analysis to obtain the risk level of the project. The survey result is summarized in Table 4.

Survey sample

At the beginning of the research investigation, the survey overall sample is presented as follows:

1. 100 experts were contacted to ask for their availability to participate in the surveys,
2. 86 experts responded favorably to be interested and questionnaires were sent to them,
3. At this stage, 72 responded to our research team but only 58 responses were valid (14 experts did not respond and 14 responses were judged to be invalid). The experts were considered from different cultural background and nationalities (Chinese, Africans, other foreign experts), different disciplines (engineers, managers, architects, government officials, etc) and different projects backgrounds (Sino-international projects, Afro-international projects and Sino-African projects).

Table 4. Construction experiments identified risk factors and risk sources.

No.	Risks	Sources
1	Earthquake	Acts of God
2	Fire	
3	Weather	
4	Flood	
5	Damage to Equipments	Physical
6	Damage to Structures	
7	Labor Injuries	
8	Subcontractors financial defaults	Financial
9	Pollution	Environmental and Political
10	Safety rules	
11	Hostility with neighbors	
12	Defective design	Design
13	Design changes	
14	Inappropriate specifications	
15	Equipments failure	Job site
16	Different site conditions	
17	Management skills	
18	Safety	
19	Languages	Cultural
20	Religions	
21	Bad quality of specimens	Quality
22	Technology transfer	Technology
23	Technology implementation	
24	Availability of special equipments	Resources
25	Delay in material supply	

CASE STUDY: APPLICATION OF THE PROPOSED FRAMEWORK TO CONSTRUCTION EXPERIMENT PROJECT

Case project background

Introduction of the case experiment

Compared with reinforced concrete (RC) structure, steel reinforced concrete (SRC) structure has characteristics of high bearing capacity and good ductility, and so has been applied in engineering widely (Busaell, 1995). However, under action of strong earthquake, plastic hinge at beam end may induce brittle fracture of welded joint between beam and column and entry joint core, which may reduce the seismic behavior of the SRC structure significantly (Chou and Uang, 2002). In this case experiment, the experimental investigation on seismic behavior of SRC frame structure with dog-bone type reduced beam section is systematically performed. A 1/3 scale model of SRC frame with reduced beam sections is designed and fabricated. From the similitude between the original frame and the specimen, the specimen different members are designed. This design includes a detailed calculation of flexural strength, shear strength and internal forces of the frame members, satisfying seismic. The results show that the SRC frame structure with “dog-bone type” reduced beam sections has good ductility, strong deformation ability, high energy dissipation and bearing capacity, so as to meet the requirement for the seismic behavior of general ductile frame. Then the use of “dog-bone type”

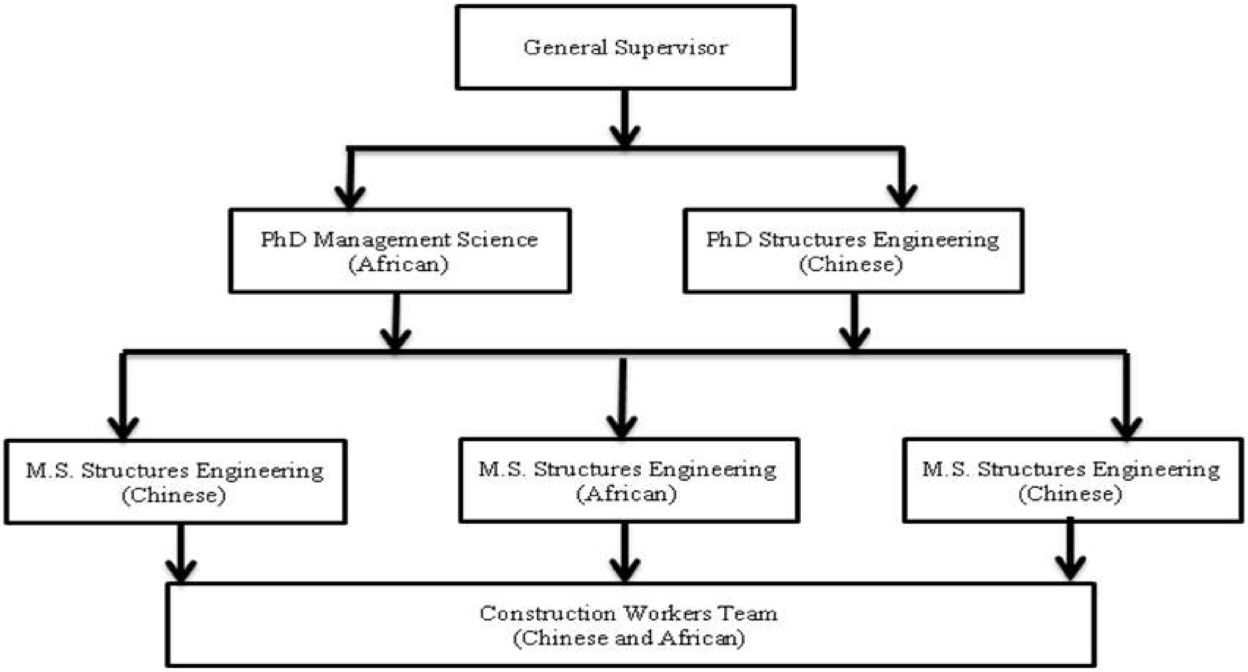


Figure 2. Laboratory experiment project members.

reduced beam section improves the seismic capacity of the SRC frame structure (Agnantounkpatin, 2007).

Experiment project members and roles

The case experiment is carried out by five engineers and one general supervisor (Figure 2). The General supervisor or Professor is considered as the Project director in this case study and his responsibility is to supervise and control the experiment project process at every stage and take important decisions; the Management Science PhD is responsible for the overall management of the experiment process from the design and construction stages to the final experiment phase. In this case, he has the duty to make sure the risk model is properly applied; the Structures engineering PhD is responsible for the design of the experiment specimens and models, he is responsible for handling all technical issues during the management of the experiment process and the M.S students (Engineering and Management) assist the PhDs in their different tasks and mainly supervise the subcontractor during the construction and installation of the experiment specimens and make sure they respect laboratory guidelines

Case experiment design basis

To perform a seismic design of a construction structure, we must first calculate the seismic action, the structure's components seismic effect, and then the internal forces and the deformation of the structure and components under the seismic action including the bending moment, the shear force, the axial force and the displacement. The second step is to combine the seismic effect and the other loads effects, check the structure and components strength and deformation in order to satisfy the "no damage under small earthquake, repairable under moderate earthquake and no collapsing under strong earthquake" design requirements (Isao and Hiroshi, 2004). This case experiment, satisfying the similarity requirements between the real scale frame and the experiment model, designs a 1/3 scale frame. Then, a push over analysis is performed to calculate the horizontal displacement of the whole frame and simultaneously analyze the position of the plastic hinges on the model frame. The SRC model frame design also satisfies the "strong column-weak beam" and "strong" seismic design requirements (Park, 1998).

Seismic performance experiment

A pushover analysis was performed in order to study the elastoplasticity of the steel reinforced concrete (SRC) frame as shown in the Figure 3a and the results of the pushover analysis are presented in the Figure 3b. After the design and pushover analysis was the seismic experiment was carried out using the loading procedure,

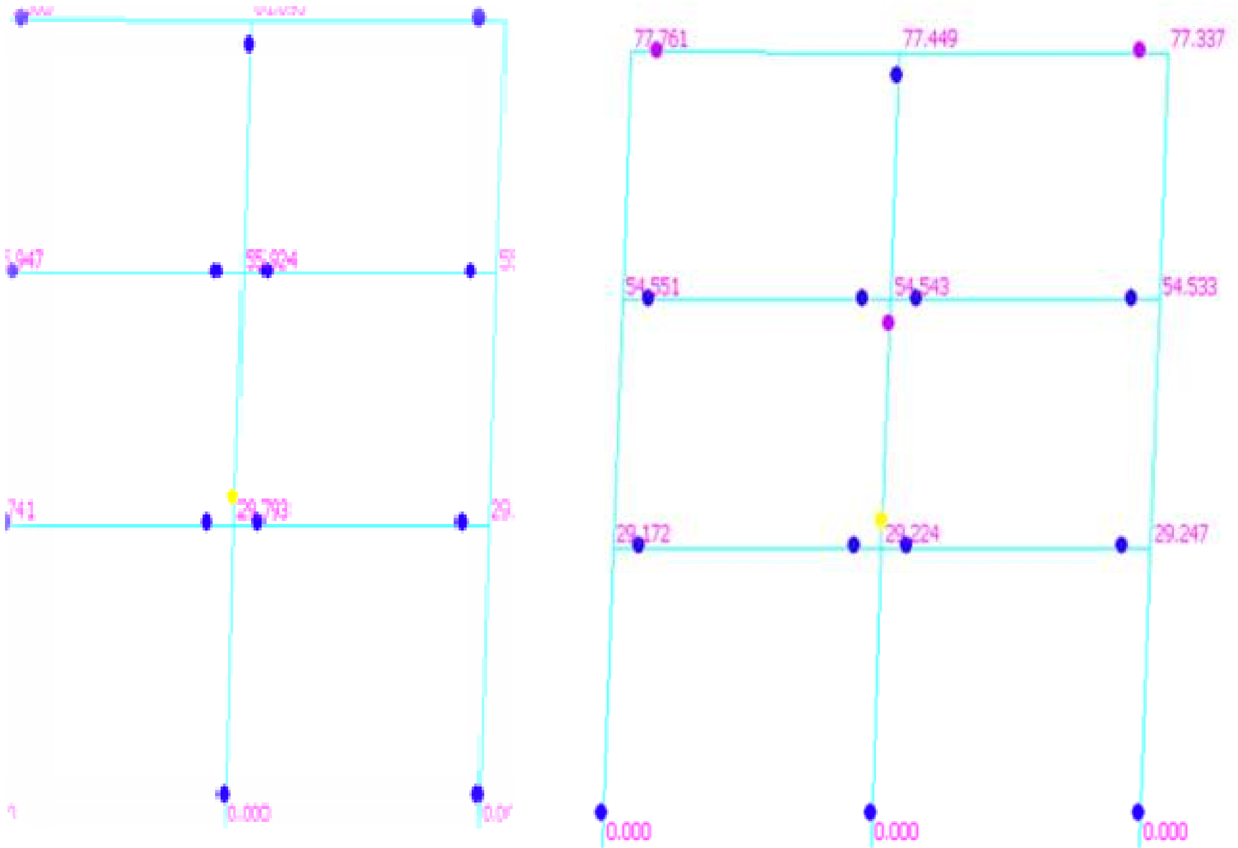


Figure 3a. Location of the plastic hinges.

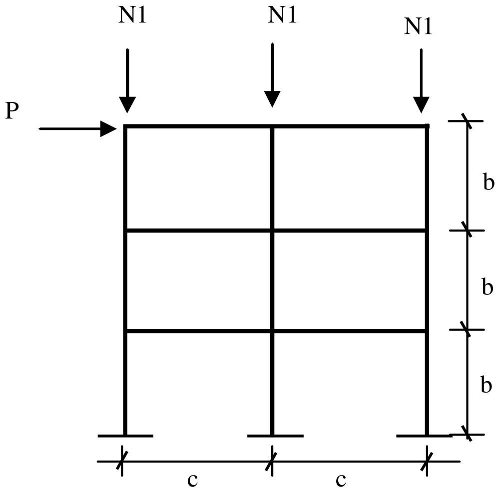


Figure 3b. Loading schematic of the SRC frame.

illustrated in the Figure 4. This experiment project is used as a model for a real scale construction project. The specimen design parameters and experiment results (seismic performance) are used for the design of the real

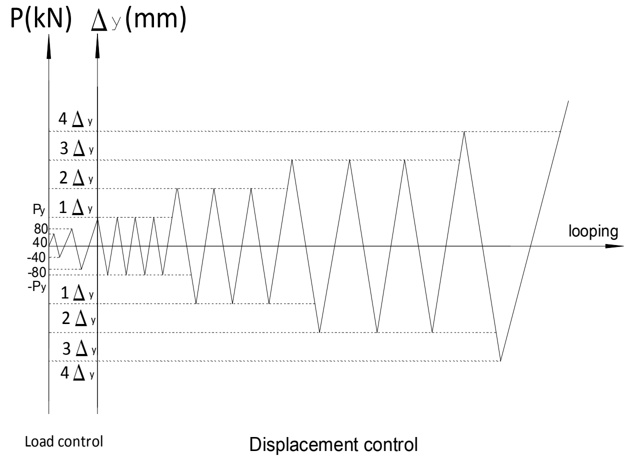


Figure 4. Loading procedure of the experiment.

scale buildings.

The AHP risk assessment model

In this part, we apply the AHP to assess the risks of the case experiment by using the following steps:

Identification of the project risks

We proceed to a classification of the various potential sources of the probable risks for this case project. Ten risk factors and 25 different risks (Table 4) that can affect the level of risk for the case experiment are identified but only the most significant risk factors are categorized to be used for this case study. The proposed classification scheme is composed of five risk categories:

Financial risks: This case study is a laboratory experiment, therefore the project is not very complex and there are few complications associated with involving international equipment but it is still important to identify the financial risks that could be faced in the project, as the model can be used for real scale more complex projects. The financial consideration is: Subcontractor financial default; this can result in serious financial problems and time delays for the experiment. This experiment project hired a subcontractor for the construction and the installation of the specimens. The qualifications of the subcontractor should be reviewed carefully. Negligence by the subcontractor could result in delays and consequently higher costs.

Act of God risks: The experiment is carried out outdoors to meet the natural conditions as the real scale building. Therefore, the materials and equipments used and the resulting structure are subject to loss or damage during their transportation to the site and during construction because of these types of risks:

Earthquakes: The location of the experiment site is in a moderately active seismic region (reason why we are conduction a seismic performance experiment). The experiment team is aware of the possible impact of an earthquake on the experiment (but not likely).
Water damage and floods: The experiment site is subject to flooding.
Soil subsidence and collapse: The site is considered to be vulnerable to subsidence and collapse.
Weather: Severe weather conditions can affect the experiment process.

Cultural risks: The experiment team members have different cultural backgrounds; decision making can suffer of some cultural issues such as linguistic and religious issues:

Languages: The laboratory experiment team is composed by Chinese and African (French speakers) researchers, therefore there is a difference of languages as the Chinese engineers are fluent only in Chinese language with some English speaking level. The African engineers are French speakers but can also speak English, thus, the official communication language for this project is English. But as English is only a second language for the two parts, this can create some issues during communication and influences negatively on the project execution.

Religion: Religion and religious beliefs are very developed in the African culture. In African countries the most important religions are Christianity and Islam. Christians and Muslims have the culture of resting at least one day per week for going to church or mosque, but as the Chinese intend to work seven days a week, this also is considered as an issue during the interaction between Chinese and African workers.

Physical risks: Some physical related risks can affect the process of the experiments:

Damage to equipments: The equipment to be used for the experiment and other related tasks are exposed to physical damage.
Damage to structure: The frame structure (experiment specimens) can be damaged during its displacements or installation.
Labor injuries: The experiments team members are likely to exposed corporal injuries due to the interaction with materials or equipments.

Design risks: Design risks are being considered also:

Defective design: Human factor such as errors in the

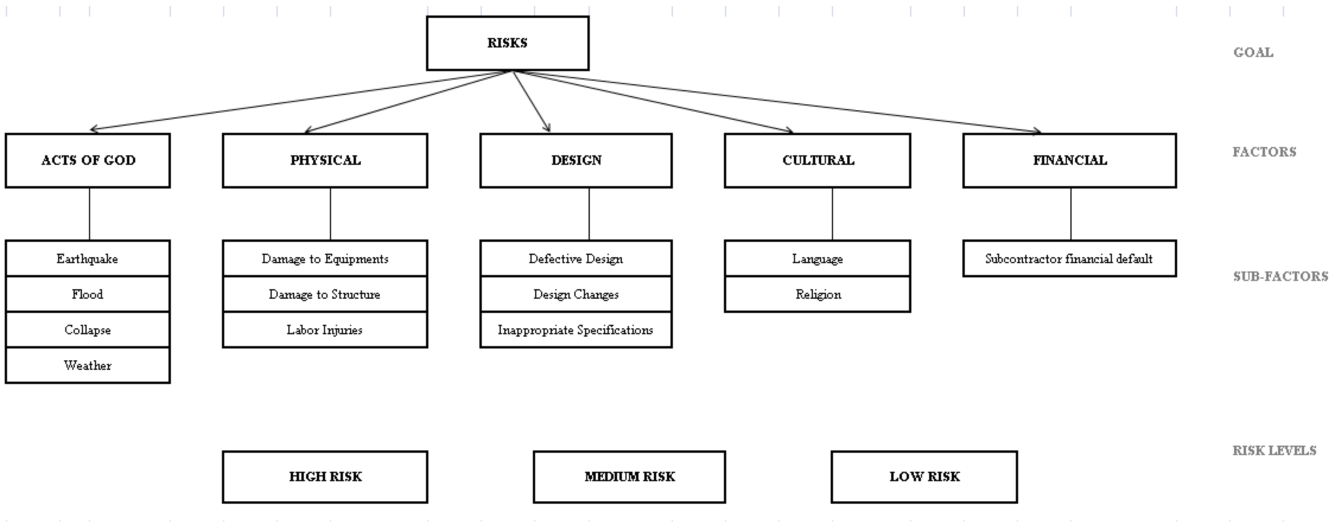


Figure 5. Proposed risks hierarchy for the case study.

design calculation can conduct to a defective design.
Design changes: Possible design changes due to probable changes in the experiment objective can occur.
Inappropriate specification: Due to the fact that the designers are Chinese and the project is being carried in Africa, there could be some differences in design requirements. The design team has to check the local specifications to make sure the design satisfy them.

While the list of potential risks in every category is neither complete nor exhaustive, it represents most of the typical risks associated with this kind of experiment project. Describing every possible risk is impractical; therefore we focus our attention on the details of the general categories of risks.

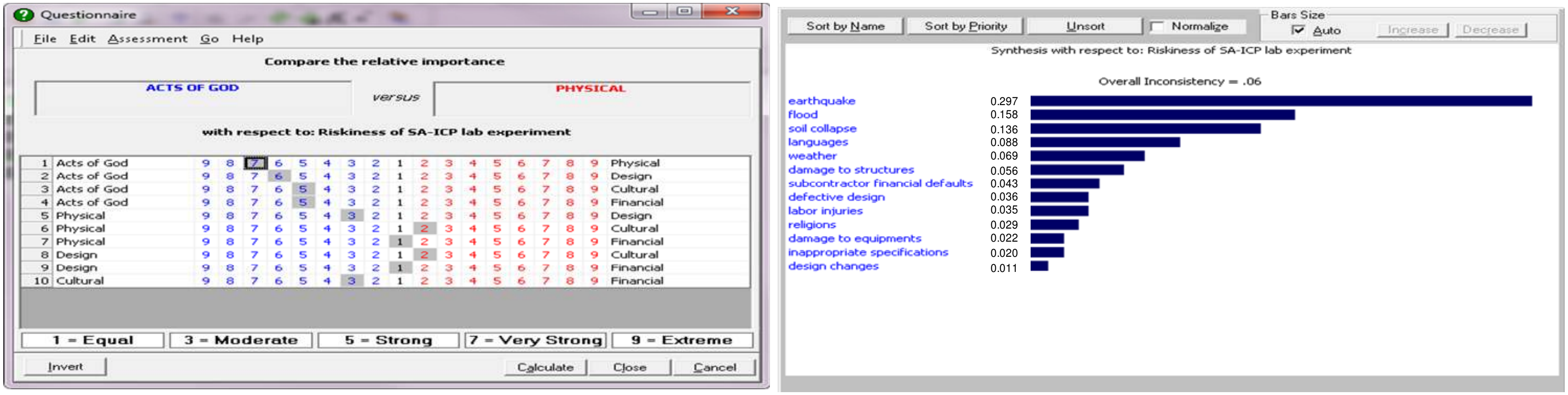
The risk assessment model

Hierarchical structuring of the project risks: Only the five most relevant risks factors as introduced in the precedent part are selected for consideration. These factors are incorporated in levels 2 (factors) and 3 (sub-factors) of the hierarchy (Figure 5). Level 1 is the representation of the research goal, the risk level of the experiment project taking in consideration both the likelihood and the consequences of the pre-identified risks. Level 4 contains the alternatives (three possible levels or intensities of the total risk of the case project).

Relative Weights of the various risks factors: The importance of the factors and sub-factors and the likelihood of the levels of risk are determined. Judgments are elicited from the research team members and laboratory experts. In order to obtain the relative importance of the five factors of the second level, this model uses Expert choice to conduct an assessment based on the results of the investigations questionnaires (Figures 6 to 11). The judgments of the experts are based on the AHP rating scale (Table 5). The relative weights of importance are calculated using Expert choice software. Figures 6 to 11 show the relative importance of the risk factors at every level of hierarchy and according to the overall goal of the assessment but also according to each risk source. Therefore, according to the overall riskiness of the experiment, Figure 4 shows that the risk factor earthquake (from the Act of God risk source) has the highest score, while the design changes risk factor has the lowest score. The risk levels assessment are shown by Figures 12 to 17. Figure 17 shows that the “medium risk level” has the highest score on the graph, meaning that the case study project is a medium risk level project.

Conclusion

The model uses the Analytic hierarchy process (AHP) to analyze the hierarchy of the identified risks within each level and to determine the relative importance of the risks sources/factors by establishing priority among the risk sources, risk factors and risks level. The analysis was important because all the elements in a specific level might not have the same degree of significance with respect to the goal. The hierarchy of risks is systematically evaluated using the “Expert choice” software and the results show that the case experiment project is a “medium risk level” project. Future research works focus on the SA-ICPs risk sources and risk factors



Compare the relative importance

ACTS OF GOD versus PHYSICAL

with respect to: Riskiness of SA-ICP lab experiment

1	Acts of God	9	8	**7**	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Physical
2	Acts of God	9	8	7	**6**	5	4	3	2	1	2	3	4	5	6	7	8	9	Design
3	Acts of God	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	Cultural
4	Acts of God	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	Financial
5	Physical	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	Design
6	Physical	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	Cultural
7	Physical	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	Financial
8	Design	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	Cultural
9	Design	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	Financial
10	Cultural	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	Financial

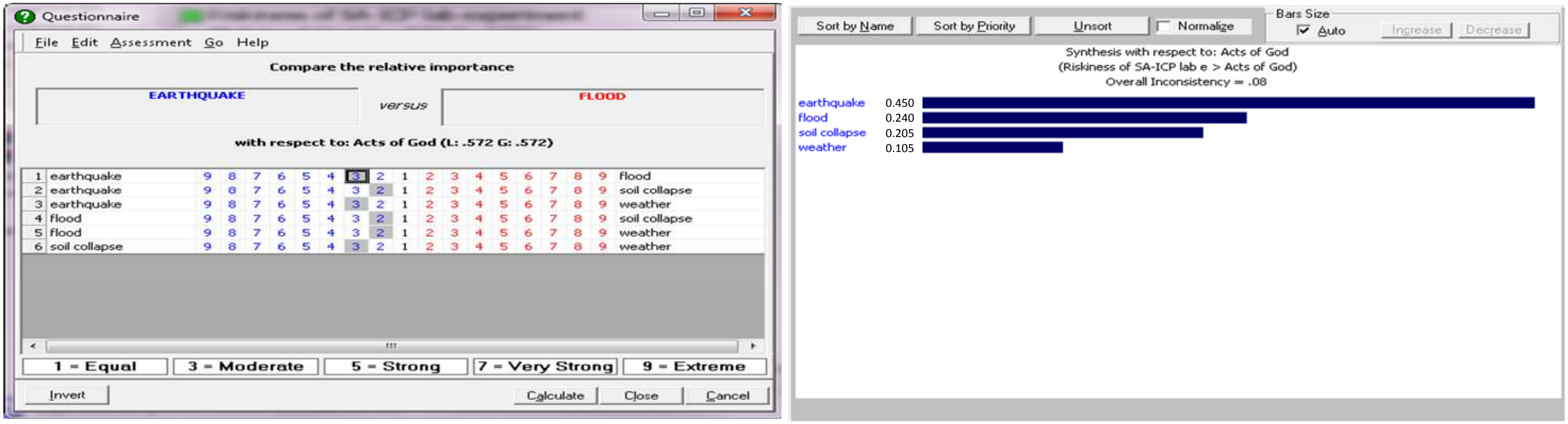
1 = Equal | 3 = Moderate | 5 = Strong | 7 = Very Strong | 9 = Extreme

Synthesis with respect to: Riskiness of SA-ICP lab experiment

Overall Inconsistency = .06

earthquake	0.297
flood	0.158
soil collapse	0.136
languages	0.088
weather	0.069
damage to structures	0.056
subcontractor financial defaults	0.043
defective design	0.036
labor injuries	0.035
religions	0.029
damage to equipments	0.022
inappropriate specifications	0.020
design changes	0.011

Figure 6. Relative Importance of risk sources and risk factors with respect to the overall riskiness of the project.



Compare the relative importance

EARTHQUAKE versus FLOOD

with respect to: Acts of God (L: .572 G: .572)

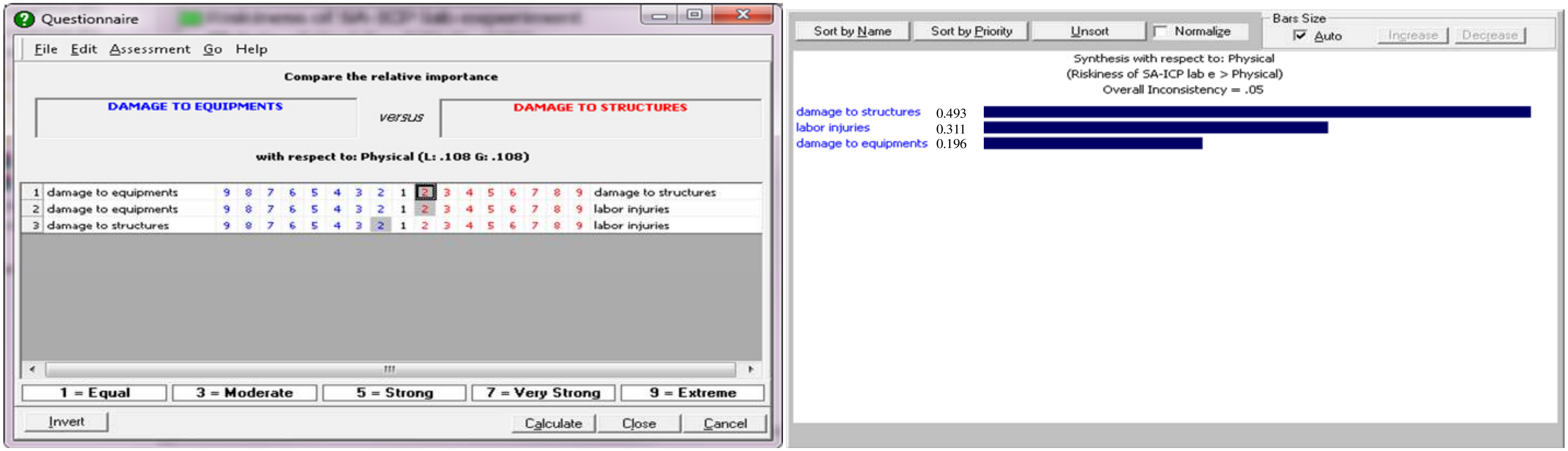
1	earthquake	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	flood
2	earthquake	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	soil collapse
3	earthquake	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	weather
4	flood	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	soil collapse
5	flood	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	weather
6	soil collapse	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	weather

1 = Equal | 3 = Moderate | 5 = Strong | 7 = Very Strong | 9 = Extreme

Synthesis with respect to: Acts of God
(Riskiness of SA-ICP lab e > Acts of God)
Overall Inconsistency = .08

earthquake	0.450
flood	0.240
soil collapse	0.205
weather	0.105

Figure 7. Relative importance of risk factors with respect to “Acts of God source”.



Compare the relative importance

DAMAGE TO EQUIPMENTS *versus* DAMAGE TO STRUCTURES

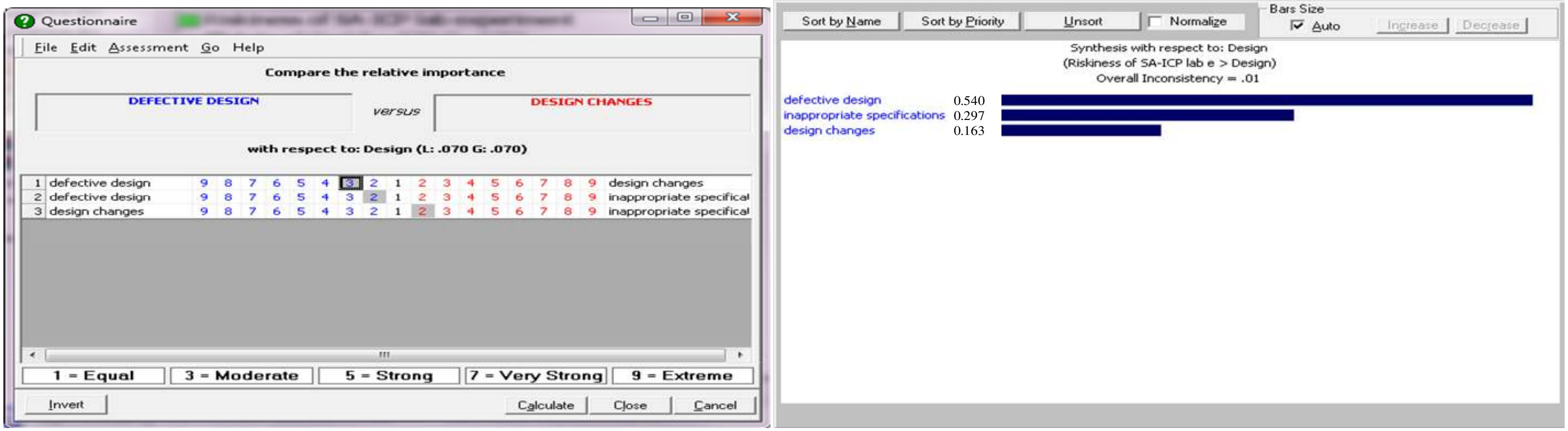
with respect to: Physical (L: .108 G: .108)

1	damage to equipments	9 8 7 6 5 4 3 2 1 [✓ 2] 3 4 5 6 7 8 9	damage to structures
2	damage to equipments	9 8 7 6 5 4 3 2 1 [✓ 2] 3 4 5 6 7 8 9	labor injuries
3	damage to structures	9 8 7 6 5 4 3 [✓ 2] 1 2 3 4 5 6 7 8 9	labor injuries

Synthesis with respect to: Physical
(Riskiness of SA-ICP lab e > Physical)
Overall Inconsistency = .05

damage to structures	0.493
labor injuries	0.311
damage to equipments	0.196

Figure 8. Relative importance of risk factors with respect to “Physical source”.



Compare the relative importance

DEFECTIVE DESIGN *versus* DESIGN CHANGES

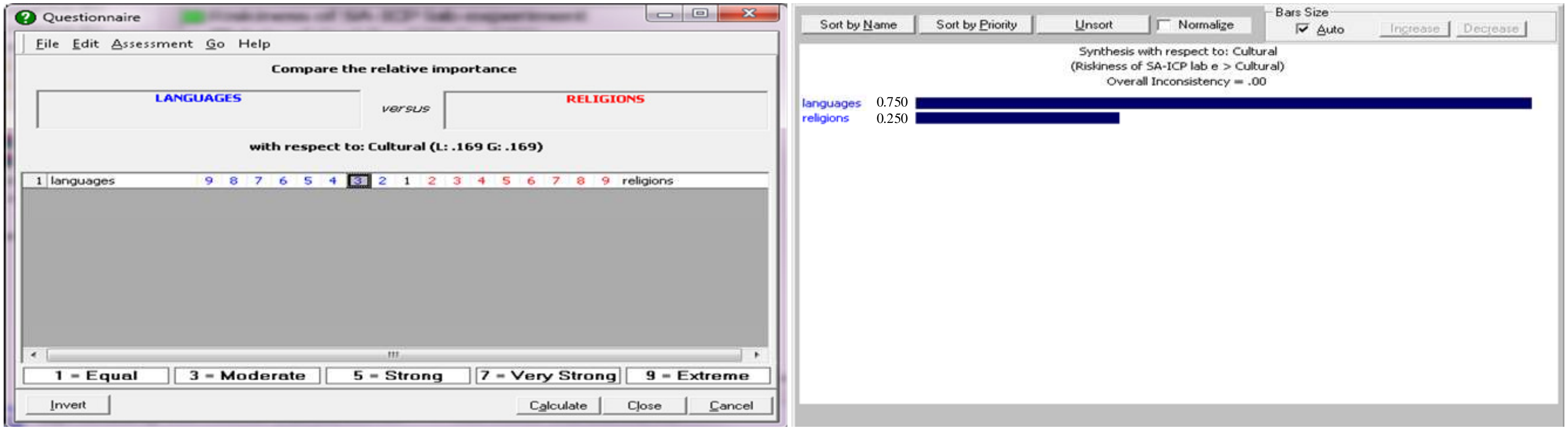
with respect to: Design (L: .070 G: .070)

1	defective design	9 8 7 6 5 4 [✓ 3] 2 1 2 3 4 5 6 7 8 9	design changes
2	defective design	9 8 7 6 5 4 3 [✓ 2] 1 2 3 4 5 6 7 8 9	inappropriate specifical
3	design changes	9 8 7 6 5 4 3 2 1 [✓ 2] 3 4 5 6 7 8 9	inappropriate specifical

Synthesis with respect to: Design
(Riskiness of SA-ICP lab e > Design)
Overall Inconsistency = .01

defective design	0.540
inappropriate specifications	0.297
design changes	0.163

Figure 9. Relative importance of risk factors with respect to “Design source”.



Compare the relative importance

LANGUAGES versus RELIGIONS

with respect to: Cultural (L: .169 G: .169)

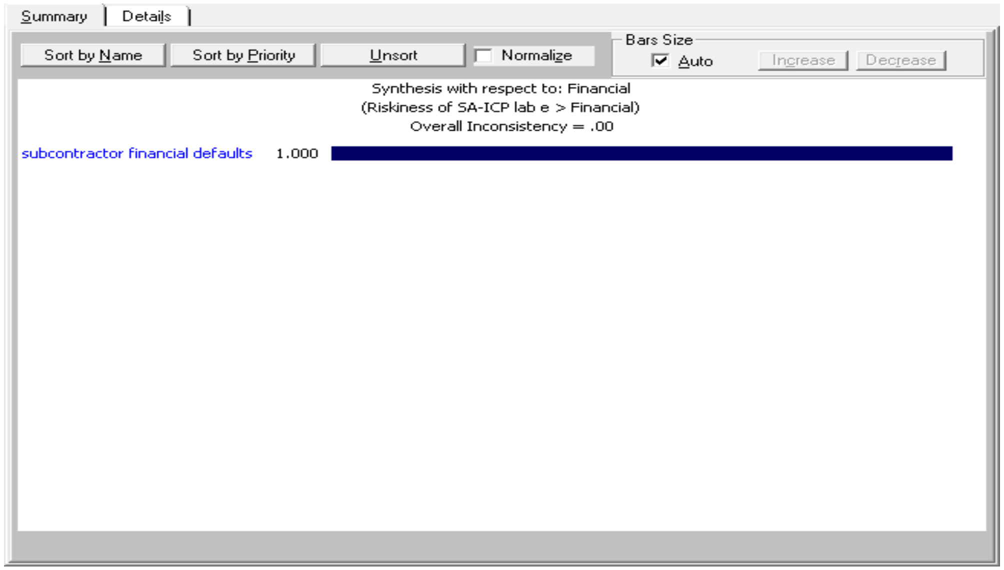
1 languages 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 religions

1 = Equal | 3 = Moderate | 5 = Strong | 7 = Very Strong | 9 = Extreme

Synthesis with respect to: Cultural
(Riskiness of SA-ICP lab e > Cultural)
Overall Inconsistency = .00

languages	0.750
religions	0.250

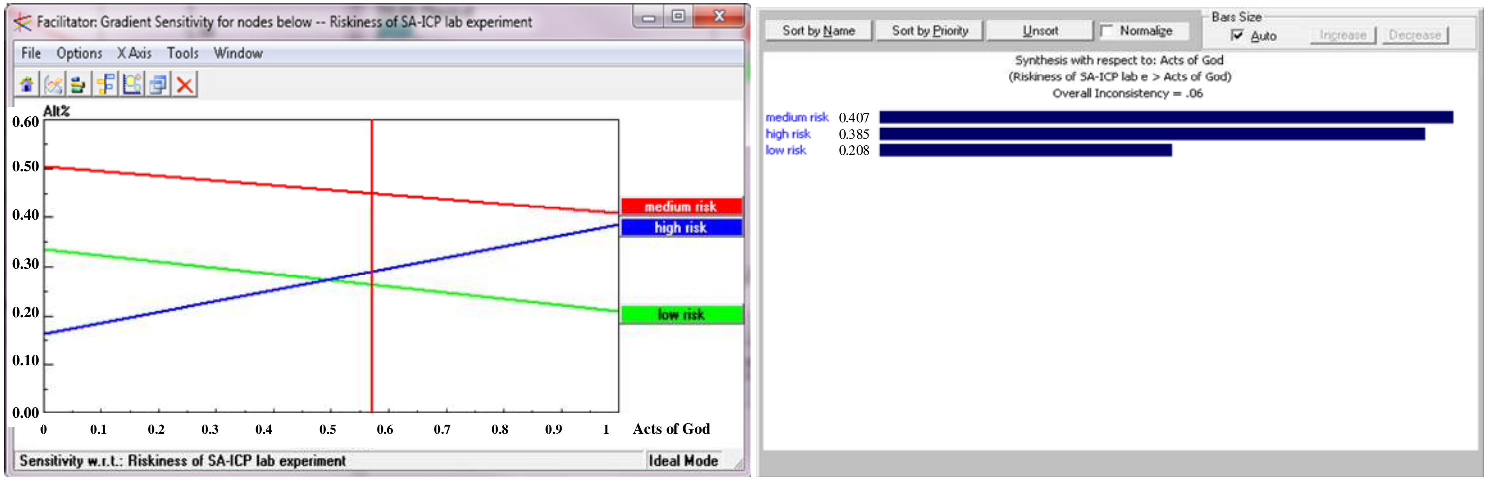
Figure 10. Relative importance of risk factors with respect to “Cultural source”.



Synthesis with respect to: Financial
(Riskiness of SA-ICP lab e > Financial)
Overall Inconsistency = .00

subcontractor financial defaults	1.000

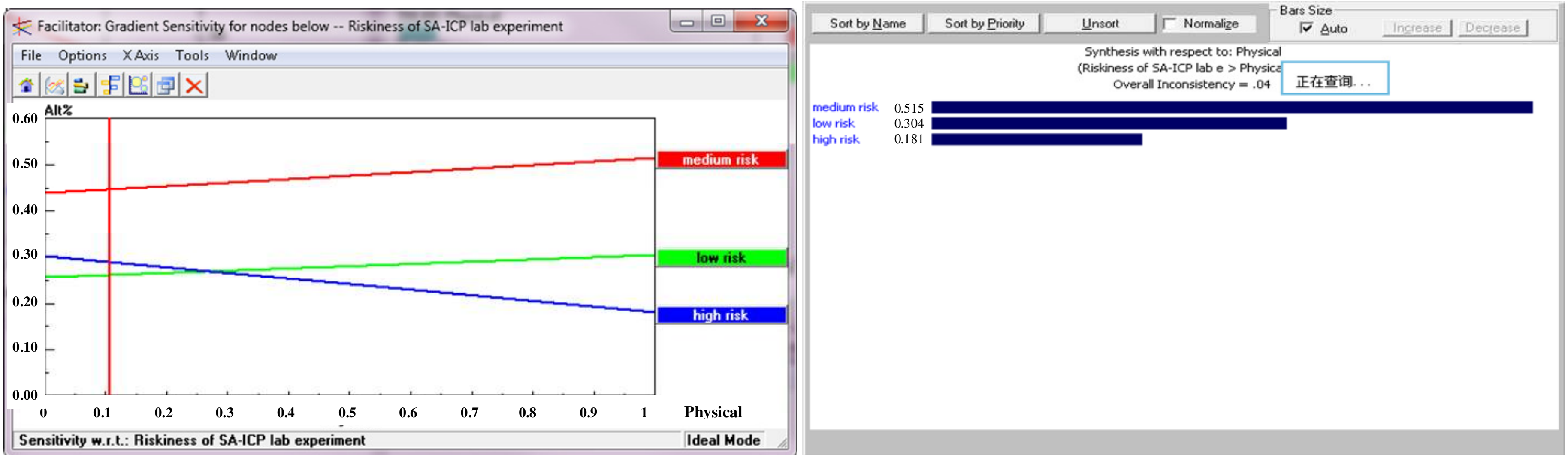
Figure 11. Relative Importance of risk factors with respect to “financial source”.



Synthesis with respect to: Acts of God
(Riskiness of SA-ICP lab e > Acts of God)
Overall Inconsistency = .06

medium risk	0.407
high risk	0.385
low risk	0.208

Figure 12. Project risk level with respect to "Acts of God source".



Synthesis with respect to: Physical
(Riskiness of SA-ICP lab e > Physica
Overall Inconsistency = .04

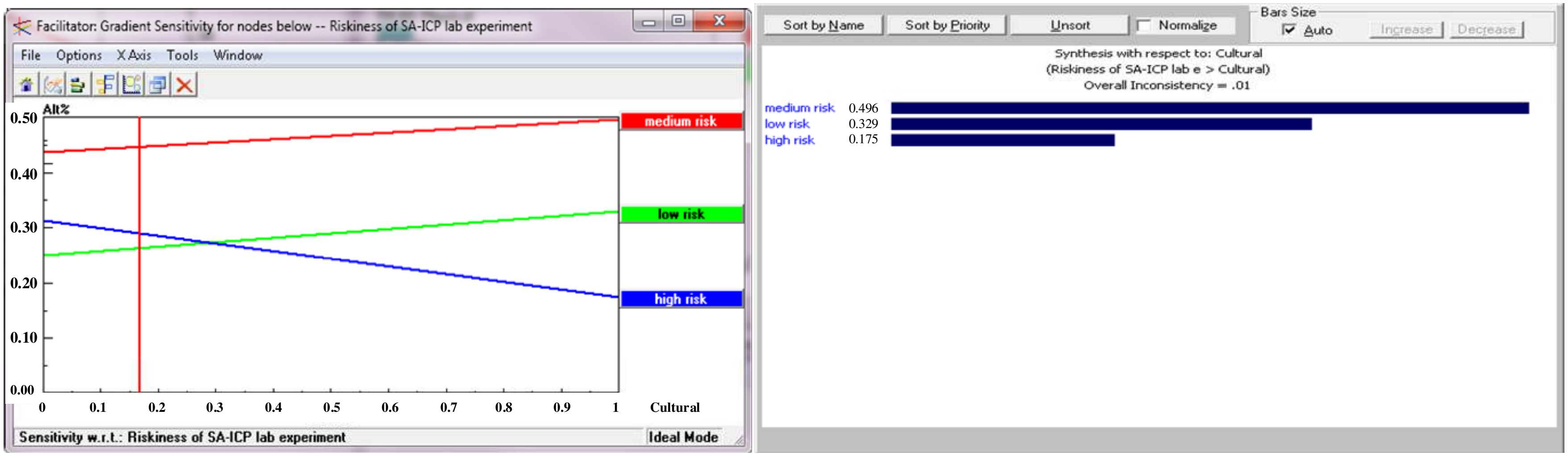
medium risk	0.515
low risk	0.304
high risk	0.181

Figure 13. Project risk level with respect to "Physical source".

```
Synthesis with respect to: Design
(Riskiness of SA-ICP lab e > Design)
Overall Inconsistency = .01

medium risk   0.433
low risk      0.375
high risk     0.191
```

Figure 14. Project risk level with respect to “Design source”.



```
Synthesis with respect to: Cultural
(Riskiness of SA-ICP lab e > Cultural)
Overall Inconsistency = .01

medium risk   0.496
low risk      0.329
high risk     0.175
```

Figure 15. Project risk level with respect to “Cultural source”.

Synthesis with respect to: Financial
(Riskiness of SA-ICP lab e > Financial)
Overall Inconsistency = .01

medium risk	0.540
low risk	0.297
high risk	0.163

Figure 16. Project risk level with respect to “Financial source”.

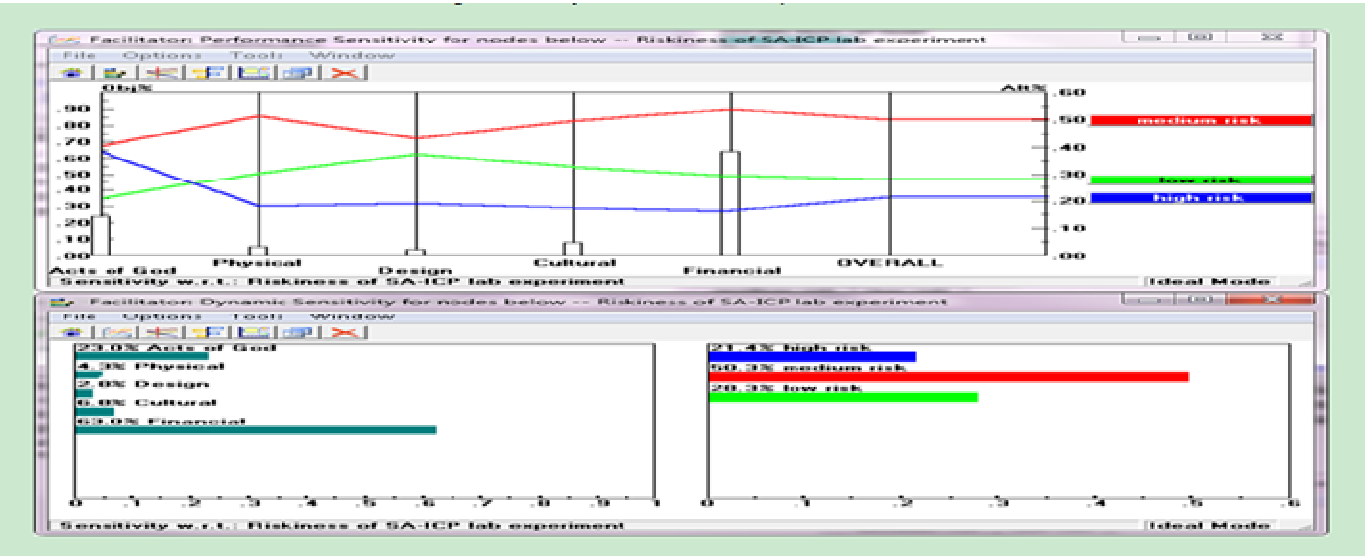


Figure 17. Project risk level with respect to “overall” risk sources.

ranking according to the likelihood and severity of the involved risks. Risk response and risk treatment with their application to ongoing and future projects are the next steps of this research.

REFERENCES

Agnantounkpatin AR (2007). Experiment on Seismic Behavior of Steel Reinforced Concrete Frames with Reduced Beam Sections, MS. Dissertation, School of Civil Eng, Tianjin University, China, (in Chinese).

Al-Bahar JF (1988). Risk management in construction projects: A systematic analytical approach for contractors, Ph.D. dissertation, Department of Civil Engineering, University of California, Berkeley.

Arbel A, Seidman A (1984). Performance evaluation of flexible manufacturing systems," IEEE Trans. Syst. Man. Cybern. SMC. 14:4.

Bord JF, Feinberg A (1989). A two-phase method for technology selection and system design," IEEE Trans. Eng. Manag. 36(1):28

Busaell R (1995). Composite structure. London and New York: the construction press.

Chou CC, Uang CM (2002). Cyclic performance of a type of steel beam to steel －encased reinforced concrete column moment connection. J. Constructional Steel Res. 58(2):63-663.

Food and Drug Administration Department of Health and Human Services (1987). Guideline on general principles of process validation. Bethesda (MD). http://www.fda.gov/cder/guidance/pv.htm

Howanitz PJ (1990). Quality assurance measurements in departments of pathology and laboratory medicine. Arch. Pathol. Lab. Med. 114:112-115.

Isao N, Hiroshi K (2004). Seismic design of composite reinforced concrete and steel buildings. J. Struct. Eng. 130(2):336-342.

Khorramshahgol R, Azani H, Gousty Y (1988). Integrated approach to project evaluation and selection IEEE Trans. Eng. Manag. 35(4):265-270.

Liberatore M (1987). An Extension of the analytic hierarchy process for industrial R&D project selection and resource allocation," IEEE Trans. Eng. Manag. EM-34(1):12-18.

Martin KM, Perez AR (2008). "GAMP 5 Quality Management Approach," May/June. Pharmaceut. Eng. 28(3):24-34.

Mustafa MA (1987). Microcomputer-based expert support system for engineering project selection and resource allocation. Proc. Annual Meeting of ASEM, St. Louis, MO.

Ostrom E (2006). The value-added of laboratory experiments for the study of institutions and common-pool resources. J. Econ. Behav. Organ. 61:149-163.

Park R (1998). Design and construction of structural concrete for seismic resistance, challenges concrete. The Next Millennium, Netherlands.

Roth AE (1995a). Bargaining Experiments, the Handbook of Experimental Economics 1. J.H. Kagel and A.E. Roth, editors, Princeton University Press pp. 253–248.

Samardelis J, Cappucci W (2009). Apply quality risk management: case study-laboratory computerized systems, Pharmaceut. Eng. 29: 5.

Smith VL (1982). Microeconomic Systems as an Experimental Science. Am. Econ. Rev. 72:923–955.

University of Wollongong, school of chemistry (2003) "Laboratory work risk assessment". CHEM Laboratory Work Risk Assessment_v4. www.uow.edu.au/science/chem/ohs/UOW016874.html

Zahedi F (1986). The analytic hierarchy process: A survey of the method and its applications," Interfaces 16:96-108.