positive impacts on eco-social development but also caused many adverse ones on our social and environmental conditions. The detail of the main involvement to economic development and the undesirable impacts to the environmental and social conditions of the mining sectors has been presented in Bui et al. (2011).

Measuring sustainable development using indicators is increasingly being recognized as a useful tool for policy making and public communication in terms of conveying information on countries' performance in environmental, economical, social, and technical development (Singh et al. 2009). This paper (1) employs the concept of AHP to create a specific sustainability framework of indicators, based on the three bottom-line criteria of economic, environmental, and social at a national scale; (2) utilizes fuzzy AHP to determine the importance of each indicator towards sustainability in the mining sector, using triangular and linguistic fuzzy numbers for the first time since its ability in handling vagueness in deriving the relative importance of each component to the overall goal; and (3) models up an sustainable development evaluation for the mining sectors, and demonstrates for the mining sectors of two APEC representatives, Vietnam and Japan.

MINING INDUSTRIES IN VIETNAM AND JAPAN

Vietnam

Vietnam has been known as one the countries having such rich mineral resources in the world. In 2012, Vietnam has been ranked seventh in the production of crude petroleum in the Asia and the Pacific region. Vietnam produced about 2.3%, 1.8%, and 1% of the world's tin, cement, and barite, respectively (Carlin, 2013; Miller, 2013). Other minerals produced in the country included chromium ore, coal, natural gas, lead, crude petroleum, phosphate rock, salt, and zircownium. As for major processed minerals, Vietnam produced refined copper, rolled steel, refined tin, and zinc. The mining and quarrying sector has made up to 9.57% of the country's total estimated gross domestic product (GDP) of $116.6 billion (in 2010 constant dollars) compared with about 9.62% in 2011 (USGS, 2014) (see Figure 1).

Vietnam provides a promising business opportunity for the mining companies with both domestic and international enterprises. However, environmental and social management of mining activities still remains relatively poor. There have been a number of severe occupational accidents and diseases, reported at mining sites due to the hazardous and dangerous working conditions (MOLISA, 2006). Illegal mining activities are common in certain areas. For example, gold mining is causing significant local and regional environmental impacts, due to the mercury contamination of downstream watercourses and groundwater.

Japan

The Japan Oil, Gas and Metals National Corporation (JOGMEC), established in February, 2004, integrates the functions of being in charge of securing a stable supply of oil and natural gas, and nonferrous metal and mineral resources and implementing mine pollution control measures. JOGMEG also provide financial assistance, technology development, and technical support, stockpiling, and gathering/providing information, in addition to mine pollution control and overseas field surveys.

Japan has ten underground coal mines in operation and approximately a thousand mines either inactive or abandoned. All active mines are operating under the sea, forests or waste lands. Due to huge mining damages in the past and for prevention of damages in the future, the Japanese government and mining companies have been devoting themselves to fulfilling rehabilitation plans and have spent much effort towards preventing and minimizing future damage. The remnant damages are estimated at about 590 billion yen (4.9 billion dollars); this may depend on social and political situations to a certain extent. Most of the damages are due to extraction of coal seams, that is usual surface subsidence. Discharging of mine water or used water, accumulation of abandoned stones and mineral tailing, or discharging of mining smoke have also cause damages in some districts. However, changes in mining operations, accompanied by mining under worse conditions or mine closure, have caused new complicated environmental impacts, namely: subsidence due to mining and dewatering in areas of thick alluvium, cave-in due to cavities remaining at shallow depths, and springing out of ground water at abandoned mines. However, Japan, a highly developed APEC economy, has been known as the advanced development of technologies and they have spent much effort towards preventing and minimizing the undesired impacts from the mining activities as much as possible.

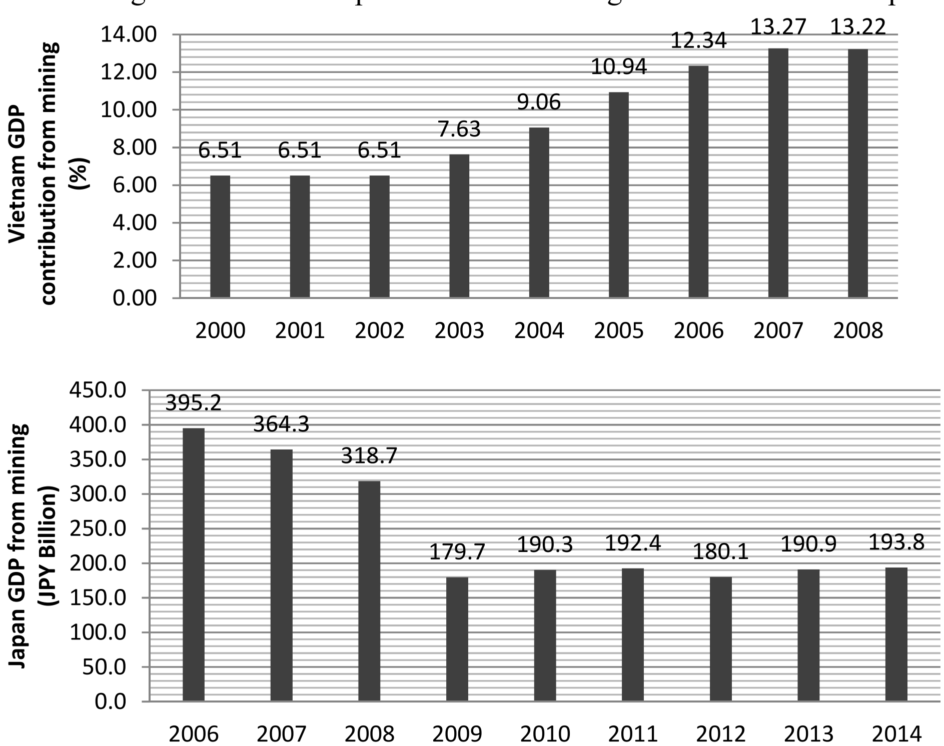

Figure 1. GDP contribution from mining sectors in Japan and Vietnam.
(Data source from http://www.tradingeconomics.com/)

METHODOLOGY

Established by Saaty (1977), Analytic Hierarchy Process (AHP) is one of the most popular and powerful methods in multi-criteria decision making (Saaty 2001). However, the serious criticism of AHP is capturing vagueness associated with the experts' judgments based on crisp judgment (Boender et al. 1989). In order to deal with vagueness of human thoughts, Zadeh (1965) firstly introduced the fuzzy theory, which was oriented to the rationality of uncertainty. The fuzzy AHP proposed by Chang (1996), has been utilized in the various applications. This fuzzy AHP has been developed by Calabrese et al. (2013) to overcome the situation of zero-weights of the indicators and criteria. The method for consistency analysis has been presented in Saaty (2000) and updated by Fang (2009).

SUSTAINABLE DEVELOPMENT ASSESSMENT FOR THE MINING SECTORS (SDMI) OF VIETNAM AND JAPAN

Data collection and normalization

To evaluate their contributions, the judgments on pairs of elements are made with respect to a controlling element by using the expert's opinion survey. The survey was conducted within the Workshop of "*Balancing competing demands of mining community and environment to achieve sustainable development in mining sector*" September, 2010 in Seoul, Korea. There were 24 experts from a various members of APEC countries such as Australia, Japan, China, Peru, Vietnam, Thailand, Malaysia, Philippines, Taiwan, Chile, and Mexico. The experts have the highly experienced years working in mining companies, mine reclamation and rehabilitation, mine closed, and mining government policies in both researches and practices.

The actual input data in this evaluation are the series of values for the indicators for the mining sectors from 2000 to 2008. The suitable normalization process follows the equation (1):

$$Nor_{ijt} = \left(\frac{\mathrm{Re}_{ijt}}{AR_{ij0}} \right)^k \qquad (1)$$

Nor_{ijt}: is the normalization value of quantitative datum ij at the year t; Re_{ijt}: is the quantitative datum ij at the year t; AR_{ij0}: is the algebraic mean of quantitative datum ij in the five previous years from 2004 to 2008; and k is the impact index.

Sustainable development evaluations model for mining sector (SDMI)

The basic steps of SDMI model are present in Figure 1.

$$Sub-index(it) = \sum_{j=1}^{n} Nor_{ijt} * W_{ij}. \qquad (2)$$

Sustainability sub-indices evaluated by equation (2); where *Sub-index(it)* is the sustainability index for the criterion i and the year t, W_{ij} is the weight of the indicator j of criterion i. *Comp-index(t)* is the composite sustainability index in the year t; Nor_{ijt} and W_{ij} are defined as in the equation (1), and CW_i are the weights of three main criteria.

$$Comp-index(t) = \sum_{i=eco}^{soci}\sum_{j=1}^{n} Nor_{ijt} * CW_i * W_{ij}. \qquad (3)$$

Table 1. Acceptable range of consistency ratio (CR) values.

The order of matrix	3	4	Higher than 4
Acceptable range of CR values	(0.0-0.05)	(0-0.08)	(0-0.1)

Adapted from Fang (2008)

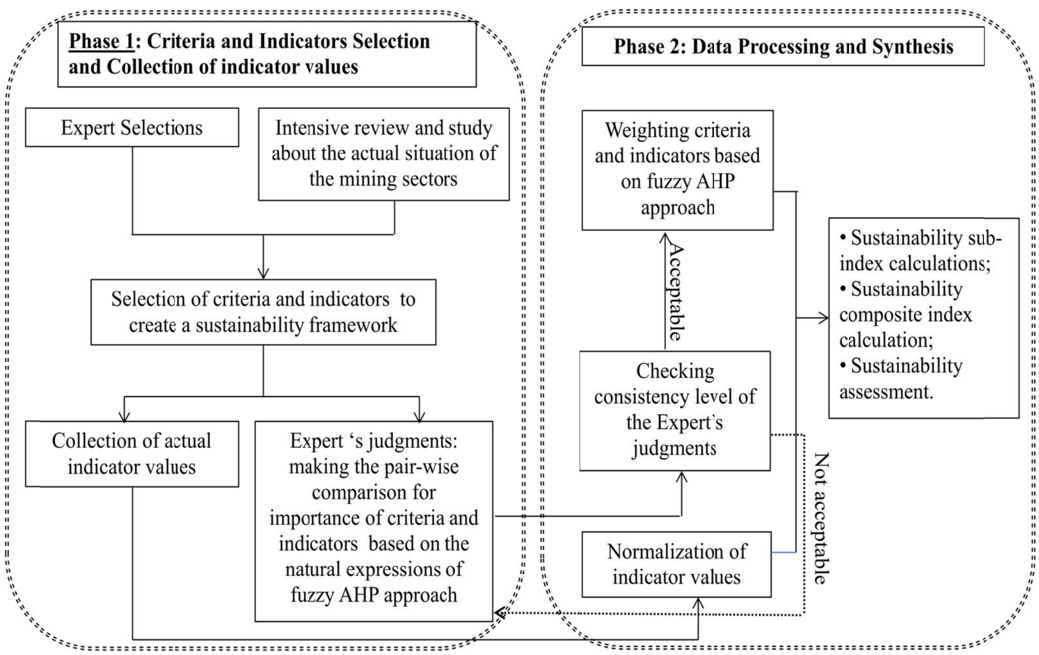

Figure 2. Sustainable development assessment model for mining sectors(SDMI).

Table 2. Consistency ratio (CR) calculations.

	The matrix A of three criteria	The matrix A_1 of group C_1 (n= 9)	The matrix A_2 of group C_2 (n= 8)	The matrix A_3 of group C_3 (n= 3)
Matrix B and B_i (i= 1, 2, 3)	0.000	0.04	0.07	0.04
Matrix C and C_i (i= 1, 2, 3)	0.003	0.04	0.02	0.02
Consistency Assessments	Strongly acceptable	Strongly acceptable	Strongly acceptable	Acceptable

Table 3. List of 20-core sustainability indicators for the mining industries

Names	Indicators	Explanations(Units)
C_{11}	Total import payments	Total payment for importing mining products/year (Million USD/year)
C_{12}	Total export earnings	Total earning from exporting mining products per year (Million USD/year)
C_{13}	Allocation of Fiscal Year Budget	Allocation of Fiscal Year Budget to mining sector (Million USD/year)
C_{14}	GDP Contribution	Contribution of mining industry to GDP per year (at constant price) (%)
C_{15}	Total investment	Total investment per year for mining industry (Million USD/year)
C_{16}	The training investment	The amount of training investment per year for mining workers (Million USD/year)
C_{17}	Community resettlement investments	Investments per year for resettlement communities (Million USD/year)
C_{18}	Mine closure and mine rehabilitation fund	Total fund for mine closure and mine rehabilitation (Million USD/year)
C_{19}	Foreign direct investment	Total foreign direct investment per year for mining sector (Million USD/year)
C_{21}	Total energy consumption	Total amount of energy consumption for mining sector per year (TOE/year)
C_{22}	Total waste disposal	Total waste disposal per year (Tones/year)
C_{23}	Greenhouse gas emission	The amount of greenhouse gas emission from mining operation per year (Mt CO_2/year)
C_{24}	Acid gas emissions (NO_x, SO_2, etc)	The amount of acid gas emissions (NO_x, SO_2, etc) from mining operation per year
C_{25}	Particle emissions	Emissions of particles from mining operation per year (%)
C_{26}	Noise pollution exceeding national standard	Percent of noise pollution exceeding national standard from mining activities (%)
C_{27}	Total closed and/or habilitated mining sites	Total number of mining sites closed and/or habilitated per year
C_{28}	Complaints from local residents	Total number of complaints related to living condition form residents per year
C_{31}	Mining employees	Number of mining employees per year
C_{32}	Mining fatalities	Number of fatalities at work in mining industry per year
C_{33}	Compensated occupational problems	Number of compensated occupational problems caused by mining activities per year

Adopted from Azapagic 2004; Singh et al. 2007; Boggia &Cortina 2010; Si et al. 2010.

RESULTS AND DISCUSSION

About the fuzzy AHP evaluations

This paper, for the first time, investigates the sustainability evaluation of the mining sectors at national scale by utilizing fuzzy operations and AHP approach since the approaches have been considered as the powerful tool for sustainability assessment, in order to provide meaningful information assisting the decision makers in determining which actions should or should not be taken in an attempt to effectively improve the sustainability development of the mining sectors. The fuzzy AHP evaluations find out the important factors for improvement of sustainable development of the mining sectors. The key factors for economic sustainability are listed as export earning, the contribution of the mining sectors to GDP, foreign direct investment (FDI) inflows, and the funds for mine close and mine reclamation, community resettlement investments. The small differences among the global weights for the environmental indicators demonstrate that the environmental indicators are main factors and equally important to sustainability. The social sustainability mainly depends on the number of fatalities at work. Moreover, compared to the acceptable level provided by the previous studies in Table 2, the proposed fuzzy scale is appropriate in handling the vagueness of human judgments. The consistency ratio values are mostly placed at the smallest range of (0-0.1) interval; thus obviously the pair-wise judgments are strongly acceptable consistency.

About the sustainable development evaluations

Japanese mining has been gradually toward sustainable development with the various positive rates. JOGMEC generally provides a priority financial support for mine pollution control which covers three categories such as restoration of abandoned mine sites, wastewater treatment for mine drainage, and disbursements. The sector also focuses on safety issue for workers. The general sustainability has mainly depended on the development of environmental and social performances with the around percentage of 40% (see Figure 3). The mining sector in Japan is one of the good case studies regarding to sustainable development in APEC Group because the great benefits from economic development has been really powerful for implementation of environment protection and social satisfactions.

Benefit from the rich natural resources, the industry has contributed a big proportion to economic development of Vietnam. The mining activities of Vietnam are medium and small scales in the certain areas, thus it is difficult for the government in management and law enforcement. While the economic and the environmental aspects have been toward, the social aspect of has been backward sustainable development. The main contribution of economic performance leads the industry has been gradually toward sustainable development, however, well management and balancing between economic benefit and the effects on environment and society are still challenging for Vietnam (see Figure 4).

Table 4. The weights of the criteria.

Weights of Criteria	Indicators	Local weights (LW_{ij})	Global weights ($GW_{ij}= LW_{ij} \times CW_i$)
Economic performance (CW_1)	C_{11}	0.095	0.040
0.42	C_{12}	0.116	0.049
	C_{13}	0.101	0.042
	C_{14}	0.120	0.050
	C_{15}	0.100	0.042
	C_{16}	0.107	0.045
	C_{17}	0.119	0.050
	C_{18}	0.128	0.054
	C_{19}	0.112	0.047
Environmental performance (CW_2)	C_{21}	0.143	0.042
0.29	C_{22}	0.133	0.039
	C_{23}	0.124	0.036
	C_{24}	0.132	0.038
	C_{25}	0.113	0.033
	C_{26}	0.117	0.034
	C_{27}	0.120	0.035
	C_{28}	0.119	0.034
Social performance (CW_3)	C_{31}	0.203	0.059
0.29	C_{32}	0.512	0.148
	C_{33}	0.285	0.083

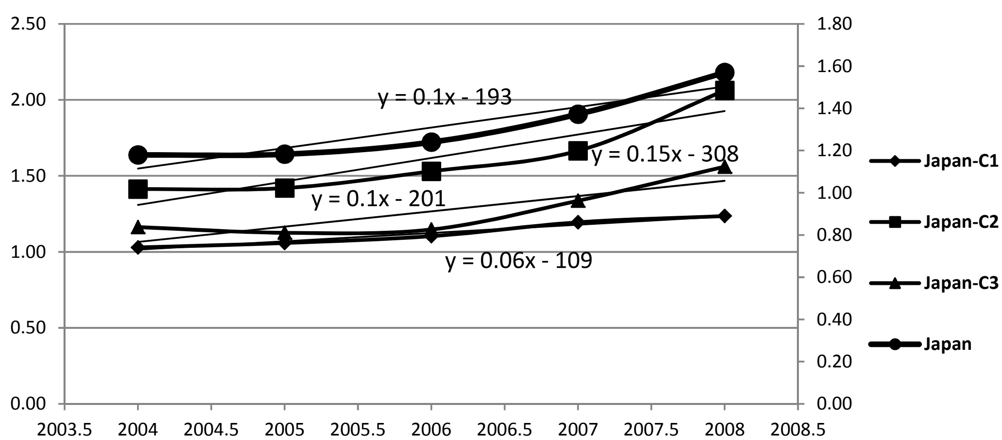

Figure 3. Sustainable development evaluation for Japan.

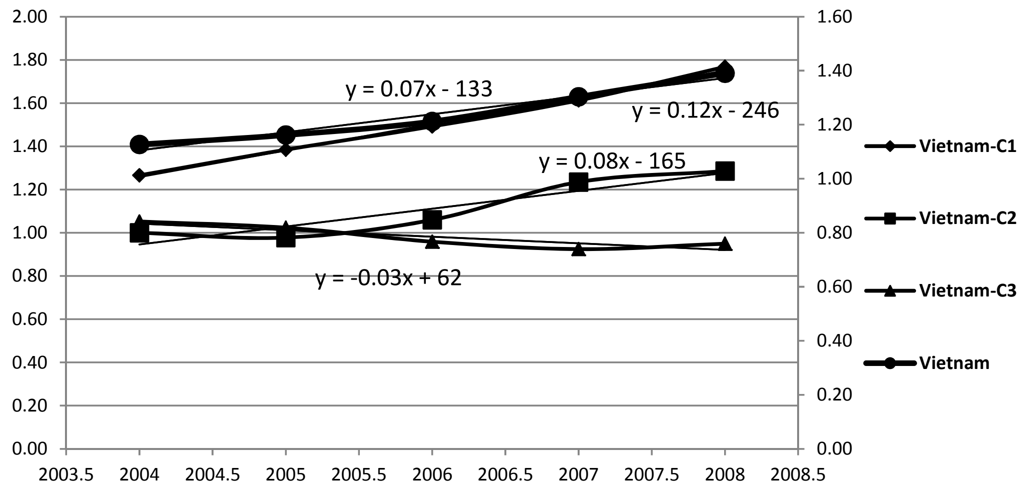

Figure 4. Sustainable development evaluation for Vietnam.

CONCLUSION

The paper demonstrates and confirms that fuzzy AHP are appropriate in deriving the priorities of the sustainability components for the mining industries in handling the vagueness of the pair-wise judgments. This paper, for the first time, investigates the evaluation by utilizing fuzzy AHP approach since the approach have been considered as the powerful tool for sustainability assessment, in order to provide meaningful information assisting the decision makers. Basically, the results from SDMI model appropriately reflect the real situations of the mining sectors in the Japan and Vietnam case studies. The paper, therefore, is fundamental for further research on sustainable development evaluation of the mining industries at national scale and provides a useful tool for not only enterprises but also government in better making their sustainability assessment for the mining industries in particular.

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Interdisciplinary Projects Require an Adaptive and Agile Management Approach: South Florida Water, Sustainability, and Climate Project Experience

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Abstract

The South Florida Water, Sustainability, and Climate Project is a $5M interdisciplinary research project funded by the National Science Foundation to explore development of a decision-making framework for South Florida water management decision-makers. The project is in year four of a five-year duration, with a geographically distributed team representing 10 universities across the U.S. and collaborators including the South Florida Water Management District. The team is developing a hydro-economic optimization model and basic science and economic inputs to evaluate management scenarios and decision-making for South Florida water and environmental resources. Management of this complex interdisciplinary project requires strategies, approaches, and tools beyond conventional approaches, and specifically those that support high levels of communication, collaboration, and transparency. Team science skills in facilitation, dialogue, and conflict resolution are required, as relationships and interactions are as important to success as technical competency. Adaptive management approaches ensure iterative and adaptive development, frequent communication, and collaborative planning, and along with team science skills, build critical trust. The SFWSC adaptive management strategy, using a 'people over process' philosophy, incorporates agile management frameworks, team science understanding, and collaborative communication and planning tools. The effectiveness on integration and productivity is continuously analyzed through in-depth interviews, retrospectives, and surveys of team members and stakeholders. Team members rate effectiveness on integration favorably, and have received praise from external advisors on the level of integration thus far achieved compared to similar interdisciplinary research projects.

BACKGROUND

The South Florida Water, Sustainability, and Climate project (SFWSC) was funded by the National Science Foundation (NSF) in 2013. The primary goal of this $5M interdisciplinary research project is to explore development of a decision-making framework for South Florida water management decision-makers. Drivers