ISSN 1905-9094

GMSARN INTERNATIONAL JOURNAL

Vol. 2 No. 3
September 2008

Published by the

GREATER MEKONG SUBREGION ACADEMIC AND RESEARCH NETWORK
c/o Asian Institute of Technology
P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand

GMSARN INTERNATIONAL JOURNAL

GMSARN MEMBERS

Asian Institute of Technology (AIT)	P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand. www.ait.ac.th
Hanoi University of Technology (HUT)	No. 1, Daicoviet Street, Hanoi, Vietnam S.R. www.hut.edu.vn
Ho Chi Minh City University of Technology (HCMUT)	268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam. www.hcmut.edu.vn
Institute of Technology of Cambodia (ITC)	BP 86 Blvd. Pochentong, Phnom Penh, Cambodia. www.itc.edu.kh
Khon Kaen University (KKU)	123 Mittraparb Road, Amphur Muang, Khon Kaen, Thailand. www.kku.ac.th
Kunming University of Science and Technology (KUST)	121 Street, Kunming P.O. 650093, Yunnan, China. www.kmust.edu.cn
National University of Laos (NUOL)	P.O. Box 3166, Vientiane Perfecture, Lao PDR. www.nuol.edu.la
Royal University of Phnom Penh (RUPP)	Russian Federation Blvd, PO Box 2640 Phnom Penh, Cambodia. www.rupp.edu.kh
Thammasat University (TU)	P.O. Box 22, Thamamasat Rangsit Post Office, Bangkok 12121, Thailand. www.tu.ac.th
Yangon Technological University (YTU)	Gyogone, Insein P.O. Yangon, Myanmar
Yunnan University	2 Cuihu Bei Road Kunming, 650091, Yunnan Province, China. www.ynu.edu.cn
Guangxi University	100, Daxue Road, Nanning, Guangxi, CHINA www.gxu.edu.cn

GMSARN
INTERNATIONAL JOURNAL

GREATER MEKONG SUBREGION ACADEMIC AND RESEARCH NETWORK
(http://www.gmsarn.org)

The Greater Mekong Subregion (GMS) consists of Cambodia, China (Yunnan & Guanxi Provinces), Laos, Myanmar, Thailand and Vietnam.

The Greater Mekong Subregion Academic and Research Network (GMSARN) was founded followed an agreement among the founding GMS country institutions signed on 26 January 2001, based on resolutions reached at the Greater Mekong Subregional Development Workshop held in Bangkok, Thailand, on 10 - 11 November 1999. GMSARN is composed of eleven of the region's top-ranking academic and research institutions. GMSARN carries out activities in the following areas: human resources development, joint research, and dissemination of information and intellectual assets generated in the GMS. GMSARN seeks to ensure that the holistic intellectual knowledge and assets generated, developed and maintained are shared by organizations within the region. Primary emphasis is placed on complementary linkages between technological and socio-economic development issues. Currently, GMSARN is sponsored by Royal Thai Government.

The GMSARN member institutions are the Asian Institute of Technology; the Institute of Technology of Cambodia; Kunming University of Science and Technology, Yunnan Province, China; National University of Laos; Yangon Technological University, Myanmar; Khon Kaen University, Thailand; Thammasat University, Thailand; Hanoi University of Technology, Vietnam; Ho Chi Minh City University of Technology, Vietnam; the Royal University of Phnom Penh in Cambodia; Yunnan University in Yunnan Province and Guangxi University in Guangxi province, China.

GMSARN International Journal

Volume 2, Number 3, September 2008

CONTENTS

Assessment of Waste Recycling Performance: A Study of School Garbage Banks in Thailand

Samonporn Suttibak and Vilas Nitivattananon

Abstract— *Solid waste management presents a serious challenge to most urban areas in developing countries including Thailand. An effective way to reduce this tremendous problem is to integrate waste recycling into the existing and future waste management schemes so as to conserve natural resources, save energy in production and transport of goods and materials, and reduce the risk of pollution and the demand for landfill. Understanding recycling performance is a key to achieving sustainable waste management. A study has been carried out aiming at exploring the status of existing recycling programs in Thailand, selecting recycling performance indicators, and assessing the performance. A total of 100 school garbage banks (SGBs) located in several urban areas of Thailand were observed and investigated. The results reveal that the SGBs are mostly initiated by schools and local governments and facing the inconsistency of the price of recyclable materials. The efficiency, effectiveness, and service ratio indicators were used to assess the performance, which was found to be good in terms of participation rate, recycling rate, and B/C ratio, while the diversion rate is fair if compared with national goal. Recommendations for improving performance of the recycling systems are also discussed in this paper.*

***Keywords*— Local governments, Performance indicators, School garbage bank (SGB), Waste recycling.**

1. INTRODUCTION

Solid waste management (SWM) is a major deplorable environmental problem faced by local government authorities (LGAs) in developing countries including Thailand. These countries have been confronted with rapid growing waste generation rates. The amount of solid waste generated in urban areas of Asia has been estimated to increase to 1.8 million tons per day by 2005 [1]. This massive amount of solid waste generated is beyond the capacity of most LGAs to provide even the minimum basic services. As a result, they are facing rapid depletion of landfill space and the problem in obtaining new disposal sites as most of the existing disposal sites are becoming open dump and nearly exhausted [2]. These problems are highly critical of concern to local authorities that are the centers of SWM systems and play an important role for changing the tradition to more sustainable approached of SWM.

In this regard, recycling has to be recognized and accepted as a sustainable municipal SWM. This sustainable approach attracts local governments because of its potential to reducing disposal costs, waste transport costs and prolonging the life span of the sanitary landfill site in recent years [3], [4]. Furthermore, the increase of the waste recycling level has become an indispensable environmental-policy goal for the number of countries, which have many previous models of recycling focused on recycling behavior, socio-demographic variables, and waste generation rate [5].

There are many successful recycling programs implemented in developed countries, which are now available to local governments. Some successful programs highlight curbside collection, material recovery facilities (MRFs), and composting, and others address drop-off and buy-back programs. Several involved private-sector sponsorship and others are run by private enterprises [6]. These successful recycling programs have factors influencing their performance that also depend on their capacity to manage recycling programs. Some of these programs could not be met by the needs of local governments in developing countries and surpass capacity of LGAs to implement.

In Thailand, one of recycling programs has been implemented widely in the communities that is the “School Garbage Bank” (SGB), begun in several cities in 1999. This recycling program has long played an important role in recovering recyclable materials and raising awareness of youth and community members. In recent years, however, their role has become increasingly important by the convenience and the implementation cost that is inexpensive. This tremendous role has contributed to SGB as an element of municipal SWM systems in Thailand. It is a positive sign of recycling promotion in Thailand, the percentage level of recycling has been targeted to utilize organic and recyclable wastes of 15% by 2006 [7]. The challenge now is to put it into effective practice in many different recycling programs in Thailand. Many of these SGBs are in the decision process on how best to modify this program to achieve greater overall efficiencies and high performance.

In order to cope with the increasing waste generation rates and variety of waste composition, this study is based on the case study of SGBs and aimed at improving the existing practices. The main subjects covered in this

S. Suttibak (corresponding author) is a Ph.D. candidate with the Urban Environmental Management Field of Study, Asian Institute of Technology, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand. Phone: +66-2-524-5639; Fax: +66-2-524-6380; E-mail: st102847@ait.ac.th.

V. Nitivattananon is Assistant Professor with Urban Environmental Management Field of Study, Asian Institute of Technology, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand. Email vilasn@ait.ac.th.

paper are (i) investigation of the current status of waste recycling practices related to SGB programs in Thailand, (ii) selection of recycling performance indicators, (iii) assessment of SGB performance, and (iv) recommendations for improving performance of SGB recycling systems.

2. METHODOLOGY

The present study is based on data collection and analysis from interviews, postal questionnaire surveys and on-site observations. This paper discusses only part of a more comprehensive SGB study in Thailand, and describes the relevant methodologies used to assess its performance. It mainly analyses the current SGB patterns and focuses on selection of recycling performance indicators and assessment of SGBs implementation. In addition, the key informants have been interviewed to assess the SGB situation in urban areas of Thailand. Around 180 postal questionnaire-based surveys were mailed between January and March 2007 with a response rate of 55% (100 SGBs) was achieved.

In selecting recycling performance indicators, a set of indicators is taken from various literature sources and followed by selection criteria. The indicators for recycling system should be reflected by the function and the performance of the system, relevant, showing something about the system that decision makers need to know, understandable, meaningful, reliable, and need to be collected and reported at the right time to influence many management decisions [8]. On the part of an assessment of recycling performance to obtain the result of SGB performance, selected performance indicator and existing situation of SGB implementation is assessed. The recycling performance is assessed and compared with benchmarking indicators or other available options [9].

3. OVERVIEW OF THE SGBs AND STUDY AREAS

Existing Situation of SGBs

The first essential step toward promoting SGB is to understand the current status of this program. Wongpanit recycling company has introduced the SGB since 1999. Watpunpee school is the pioneer of SGBs where is located in Phitsanulok municipality, Phitsanulok province. This SGB has been replicated throughout country. References [10], [11] report that there were 500 schools in 30 provinces of Thailand has implemented SGBs since 2001 that recycled a total of 2,500 tons of recyclables a year.

The SGB has been conceived as initiative to encourage recycling activities at the school and community level, which are currently undertaken by students and supervised by teachers. This SGB is often implemented in conjunction with the local government, which may supply building, equipment, and staff. The SGB is very typical of the buyback center, where the generators are financially compensated for recyclable materials. The SGBs' members take the recyclable materials and receive an earning in exchange, depending on the weight and the type of the recyclable materials. The amount earned at a time is recorded into the passbook, which is analogous to a commercial bank. This can function as a banking transaction, for example cash withdrawal and loaning. The SGBs activities focus on encouraging people and youth participation, as well as creating understanding among them on waste separation and the SGB operation. It is one of waste management strategies implemented by school and community. Physical layout of a SGB varies by the volume and number of recyclable materials processed, site characteristics, and level of supervision.

The general objectives are to raise awareness of youth and their parents in value of recyclable waste, to train youth on their responsibilities in environmental conservation and to encourage them to spend free time constructively, to generate income for youth and reduce family's expenditures, and to reduce amount of waste that go to dispose. Most SGBs were supported by NGOs and external agencies (e.g. GTZ, CIDA) and subsidized by the school. The recycling through implementing SGB is a good practice because of the environmental impacts from sorting and recycling recyclable material are less than the environmental impacts to provide virgin material and dispose residual solid waste safely.

Potential for Recycling

Presently, only aluminum cans, plastics, and papers, have potential high-value materials in the SGB program. The recyclable materials were sold to recycling dealers, either at the junk shop. It was observed that aluminum cans have high-value materials and can be the greatest revenue generator of SGB program. It is estimated that it takes 95 percent less energy to produce aluminum can from an existing can than from ore [12]. However, the price of aluminum varies depending on location of centralized processing plants.

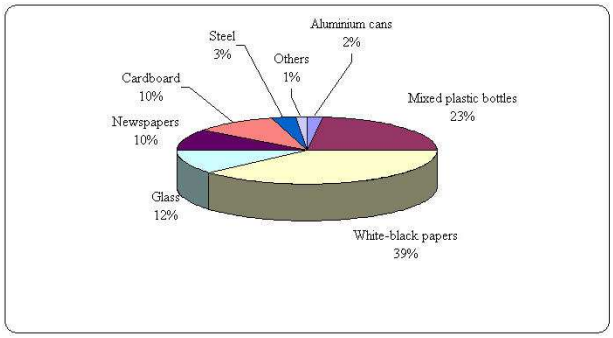


Fig. 1. Percentage of Materials Collected From 100 SGBs

The composition of recyclable materials collected from the 100 SGBs is shown in Fig. 1 based on percentage by weight. The largest component consisted of white-black papers with 38.90%, followed by mixed plastic bottles, glass, cardboard, and newspaper at 22.79%, 11.68%, 10.18%, and 9.94%, respectively. The remaining 6.51% comprised steel, aluminum cans, and others. A study by World Bank and Pollution Control Department (PCD) found that metal and paper have tremendous recycling potential and approximately two

thirds of these recyclables are currently discarded [11]. In addition, materials recovered from solid waste in Bangkok are glass bottles, paper, and plastic products [4]. The ease of taking these major recyclable materials to SGB is the reason why this portion different from others.

Table 1. The Main Characteristics of the 100 Selected SGBs

Information of 100 Schools	Primary School (N=50)	Secondary School (N=48)	College, University (N=2)	Total (N=100)
System Supervision				
LGAs	22	14	-	36
Private school	7	5	-	12
Educational service area	21	29	-	50
Commission on higher education	-	-	2	2
Investment Costs				
Private office	4	4	-	8
NGOs, external donors	10	6	-	16
LGAs, central government	17	15	1	33
School	19	23	1	43
Operation Costs				
Private office	2	2	-	4
NGOs, external donors	6	3	-	9
LGAs, central government	10	7	-	17
School	5	8	1	14
Revenue from sale of materials	24	25	1	50
Reward from the SGB competition	3	3	-	6

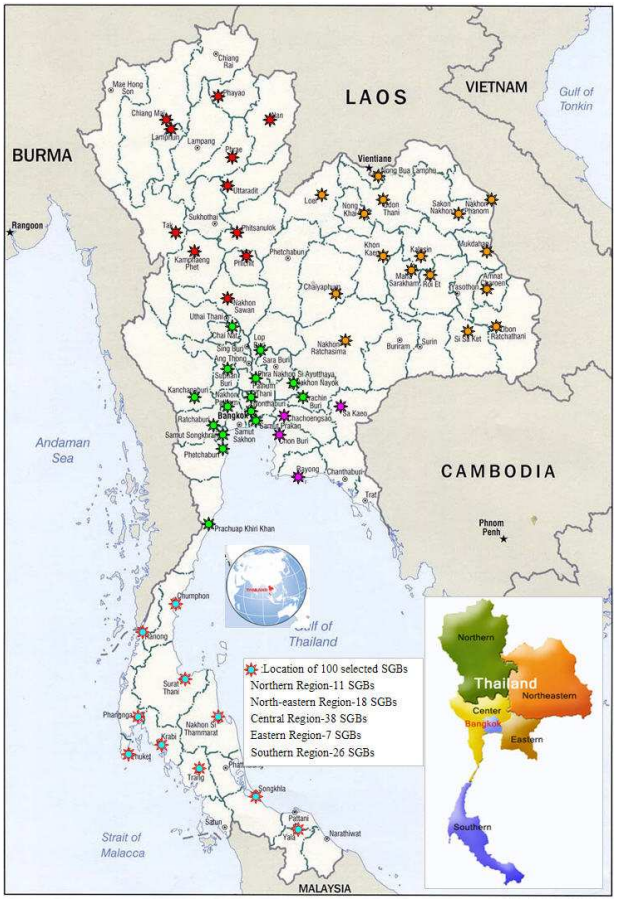


Fig. 2. Location of 100 Selected School Garbage Banks

Study Areas

How is study areas selected? This question was tackled through a recruitment of study areas from newspapers, mass media, experts' advice, and official documents and followed by utilizing selection criteria. The selection of SGBs is based on: (i) existence of SGBs located in different five regions of Thailand, (ii) various development partners such as NGOs, private sectors, or LGAs involved in such recycling program, (iii) whether were categorized into different school levels and system supervision, and (iv) the accessibility of reliable information.

As shown in Table 1, of the one hundred selected SGBs, 50 respondents were primary school, 48 were secondary school, and 2 were college. In terms of school supervision, 50 respondents were educational service area, 36 were LGAs, and 12 were private sector. One-third of investment costs are sourced from LGAs and central government, while the operation costs are obtained from revenues through the sales of materials. Their locations are given in Fig. 2. These are scattered throughout Thailand, there are 11 in Northern, 18 in North-eastern, 38 in Central, 6 in Eastern, and 26 in Southern areas.

4. PERFORMANCE INDICATORS AND ASSESSMENT RESULTS

Selecting Recycling Performance Indicators

Performance indicators are measures of project impacts, outcomes, outputs, and inputs that are monitored during project implementation to assess progress toward project objectives. They are also used later to evaluate a project's success. Indicators organize information in a way that clarifies the relationships between a project's impacts, outcomes, outputs, and inputs and help to identify problems along the way that can impede the achievement of project objectives [13]. Furthermore, the Organization for Economic Cooperation and Development (OECD) defines an indicator as *"a parameter, or a value derived from parameters, which provides information about a phenomenon. The indicator has significance that extends beyond the properties directly associated with the parameter value"* [14].

In addition, according to World Bank, performance indicators can be used for (i) strategic planning, (ii) performance accounting, (iii) forecasting and early warning during program implementation, (iv) measuring program results, (v) program marketing and public relations, (vi) benchmarking, and (vii) quality management [13].

Selecting appropriate and useful performance indicators requires careful consideration through iterative refining, collaboration, and consensus building [15]. Since there are time and resources constraints, only existing performance indicators could be reviewed rather than new indicators are developed. Each candidate indicator is discussed in more detail below together with possible calculating example.

Set-Out Rate

The set-out rate is the percentage of households, which set out their recyclables on collection days. This indicator determines the number of stops for trucks and affects the collection time, and thus is necessary for estimating the size of collection areas [16].

Participation Rate
The participation rate denotes the percent of households or business that regular set out recyclables. This indicator usually applies to participation in curbside collection, and has been applied as measure of the effectiveness of drop-off or buy-back centres [17]. The participation rate does not indicate the quantities of materials recycled or what materials were recycled, but does provide some useful measure of the extent of household or community member involvement in their recycling program [16]. Participation rate will be the same as the service ratio that was defined by Chang and Wei as the population serviced by recycling drop-off stations divided by total population in district [18].

Quantity Recovered or Recycling Rate
This denotes the quantity of recyclables collected per household per unit of time (e.g., 50 kg/ residence. month) [17]. Wang et. al. states that a very useful indicator of recycling performance is the quantity of recyclables collected, which can be expressed in terms of the average quantity of recyclable per participating household or the average quantity of recyclable per household [16]. In addition, Gies evaluated drop-off performance by using this indicator in four municipalities of Canada [19].

Diversion Rate or Recovery Rate
The success of a recycling program is measured by the diversion rate that represents the weight of total solid waste, which is not landfilled or not incinerated [17]. However, diversion rate sometime will be the same as the recycling rate that is the amount of material recovered from the generators served divided by total amount of available waste from the generators served [20], [21].

Net Cost per Ton
This indicator refers to net recycling program costs per ton recycled [21].

Ratio on Benefit to Cost
The benefit to cost ratio (B/C) has been applied as a measure of the efficiency of recycling program. This indicator represents the ratio of inputs needed per unit of output produced and examines percentage of revenue cover cost of recycling program [22]. In this paper, benefit is defined as the revenue from sale of recyclable materials over period of project and cost is defined as the investment cost and operation and maintenance cost (O&M).

Utilization rate
This defines the recyclables collected by drop-off stations divided by total capacity provided by drop-off stations in district [18].

Average walking distance
This defines the average walking distance of residents from their household to the recycling containers, that is the total service distance between node i and k of network link divided by total number of drop-off stations [18].

Value of Waste Recycled
This measures the value of recycled waste in a recycling program. The value of recycled waste is calculated by multiplying the volume of waste by the respective price, on an annual basis, in order to determine the value of recycled waste [23].

$$\text{Value of recycled waste} = \text{quantity}_{\text{type}} \times \text{price}_{\text{type}}$$

After reviewing the list of possible indicators was reviewed, appropriate indicators were selected to evaluate the performance of recycling programs that are applicable to existing recycling implementation in Thailand, which are differentiated from those implemented in developed countries. Throughout this paper, the process of selecting performance indicators was linked based on relevance to existing recycling implementation in Thailand. The set contained a total of 9 candidate indicators that were then assessed by using criteria for judging an indicator's appropriateness and utility. These criteria are related to [14]:

- policy relevance and utility for user-should be simple, easy to interpret and able to show trends over time, provide a basis for international comparisons, be either national in scope or applicable to regional environmental issues of national significance;
- analytical soundness-should be theoretically well founded in technical and scientific terms, be based on international standards and international consensus about its validity; and
- measurability-should be readily available or made available at a reasonable cost/benefit ratio, adequately documented and known quality, and updated at regular intervals in accordance with reliable procedures.

From an initial set of 9 candidate indicators identified, the following 4 indicators (Table 2) have been selected as core indicators for presenting in this paper that respond to the completed questionnaires. The selected indicators could be available in all SGBs since inter-school comparisons have a common purpose with such performance assessment.

Table 2. List of Selected Recycling Performance Indicators

Indicators category	Definitions	Units
Service ratio ▪ Participation rate	(Number of recycling program member/ total students and teachers) x 100	Percentage
Output ▪ Recycling rate or quantity of recyclables per recycler	(Total waste recycled/total recycler)	Kg/recycler.unit of time
Effectiveness ▪ Diversion rate or recovery rate	(Total waste recycled/total waste generated) x 100	Percentage
Efficiency ▪ Ratio on benefit to cost (B/C ratio)	(Revenue from sale of recyclable materials/ Investment cost+O&M cost)	-

Performance Results

Most required data is provided by the recycling coordinators that given through the postal questionnaire survey. Obtaining recycling performance results, four selected performance indicators and existing situation of 100 SGBs were assessed. The SGB performance assessment results were presented in Table 3.

By considering assessment result, it is seen that participation rate is good because the participants were

enhanced by education and economic incentive. If compared to other separation projects that have been implemented in Thailand, it was revealed that the participation rate was quite low, at less than 14% [24], [25]. In addition, if compared with drop-off recycling program such as those implemented in Taiwan [18], SGB performance reaches a satisfied level.

In terms of recycling rate, it was found that about 32.00 kg/recycler/year were recycled. This result was satisfied if compared with the performance of drop-off centers that have been implemented in four Canadian municipalities namely: the city of Calgary, township of Amabel, town of Gananoque, and city of Laval. These cities recovered recyclable materials through their drop-off programs representing 12, 60, 40, and 10 kg/recycler/year, respectively [19]. In addition, the average diversion rate of 8.25 % was lower than a national goal of 15 percent recycling of wastes in 2006 [7]. However, this diversion rate was close to the diversion rate of Thailand since only 11 percent of discarded wastes are recycled. If compared with other level it was found that the value is much lower than other cities such as Seoul, Hong Kong, Singapore, and Manila [11].

A simple benefit-cost analysis was performed to show the economic feasibility of SGB implementation. This B/C ratio was assessed by identifying benefit from sale of recyclable materials and cost from start up and operating cost. Start up costs is a one-time cost to initiate the SGB program. These include capital cost (e.g. providing recyclable material storage cost, measuring instrument and pass book), while operating costs are transportation cost and incentive cost for committee. The result showed that the B/C ration was greater than 1.00, which implies that SGB is economically feasible and also plays an important role for the improvement solid waste management within school and their communities.

Table 3. The Performance Results of 100 SGBs

Indicators	Mean	SD	Available Benchmark	References
Participation rate	60%	35%	<10% , (Yala, Thailand)	[24], 2005
			14% , (Hatyai, Thailand)	[25], 2006
			4% to 66, (Taiwan)	[18], 1999
Recycling rate	32	38	10-60 kg/recycler/year, (Canada)	Gies , 1995
Diversion rate	8%	9%	11% , (Thailand)	World Bank , 2003
			15% , (Bangkok)	
			36% , (Hong Kong)	
			45% , (Seoul)	
			39% , (Singapore)	
			13% , (Manila)	
			<10% , (Beijing)	
B/C Ratio	3	3	1[a]	Glenn, 1988

[a] B/C ratio is based on revenue from sales of recyclable material, disposal cost saving, capital costs, operation and maintenance costs.

Constraints of SGB Implementation and Recommended Strategies

One of the initial objectives of the study was not only to quantify the recycling rate of recyclable materials and participation rates at SGBs, but also to use more qualitative methods to determine what possible factors were expected to have success in recycling implementation. These factors can be contributed to the development of strategies to enhance SGB performance in order to reduce the amount of wastes to be disposed. Using some of the results of this study as a starting point, decision maker will continue to explore this issue in the future. The performance of SGBs is high in terms of participation rate, recycling rate, and B/C ratio, while the diversion rate is moderate if compared with national goal. This result implies that the participation rate does not associate with the quantity of recyclable materials that put out by recyclers. In fact, it was found in some cases that recycling programs with high participation rates yielded few amount of recyclables [16]. The convenience to be taken and separated out in the recyclable materials from students or residents leads to both higher participation and recycling rate. In terms of cost effectiveness, labor is usually one of the most costly aspects of recycling program. However, SGB is an exception.

Findings and observations of al1 100 SGBs, the success is tentatively dependent upon good attitude of administrator to initiate the establishment of SGB, transportation cost, method to increase value added recyclable materials, students provided incentive by giving bicycle, electrical appliances, or interest for SGB's member to gain saving, or students can take a loan. In addition, the encouragement of NGOs and external donors are also potential factors in SGBs success. These factors were considered into corresponding SGBs performance results, where high performance were achieved.

In contrast, there have been some implementation constraints, which can be found from SGBs competing with many itinerant recycling buyers. Sometimes students and their parents decide selling recyclable materials to such buyers, since they are not willing to store accumulated recyclable materials for a long time in their house. The fluctuation of recyclable materials prices cause SGBs member gain less profit that expected. This problem might affect the sustainability of the recycling program. The burden of transportation cost is also a major constraint to impede SGBs performance. In addition, training and site visit of students committee and teachers were neglected which cause them missed knowledge and technique to implement SGB efficiently. Another major constraint is the limited time of teacher supervisors and students committee. Therefore, SGB implementation has not been done completely. Most schools implemented such garbage bank last for only 6-8 months per year.

As SGB implementation constraints have been occurred, some strategies to enhance SGB performance are taken into consideration. First, provision of areas for storing the accumulated amount of recyclable materials should be done in order to negotiate the price of materials with recycling dealers. Second, LGAs should contact recycling company who provides high price of recyclable materials to buy those materials in the school. Third, university or large schools should be the center to contract with recycling dealer. Recyclable materials price would be guaranteed with the exact amount of recyclable wastes and the nearby schools can take recyclable materials to that SGB's center where economies of scale can be significant. Lastly, in order to reduce the heavy load of students committee, they should be categorized into several groups and several grades and provide them

some incentive to run it smoothly despite changing conditions and personnel turnover.

5. CONCLUSIONS AND RECOMMENDATIONS

The results obtained show that the 500 schools in 30 provinces of Thailand have implemented SGBs since 2001 which recycled a total of more than 2,500 tons of recyclables a year. The composition of recyclable materials mianly consists of white-black papers followed by mixed plastic bottles, glass, cardborad, and newspaper respectively. The remaining small portions are steel, aluminum cans, and others. One-third of investment costs are sourced from LGAs and central government, while the operation costs are obtained from revenue through sale of materials. Four peformance indiactors were selected which cover efficiency, effectiveness, and service ratio indicators based in relation to policy relevance, analytical soundness, and measurability. The performance results from the assessment were found to be good in terms of participation rate, recycling rate, and B/C ratio, while the diversion rate is fair if compared with the national goal.

The strategies for improving SGB implementation that should be considered include: provision of areas for storing the accumulated amount of recyclable materials; university or large schools to be the center of the SGB implementation to contract with recycling dealer; and student committees to be categorized into several groups and grades and with provision of some incentive.

REFERENCES

[1] Terazono, A.; Moriguchi, Y.; Yamamoto, Y. S.; and Sakai, S.-i. 2005. Waste management and recycling in Asia. *International Review for Environmental Strategies* 5(2): 477-498.

[2] Suttibak, S. and Nitivattananon, V. 2005. Enhancing solid waste management capacity of local government authorities: review of current status in Thailand. In *Proceeding of International Conference on Integrated Solid Waste Management in Southeast Asia Cities*. Siem Reap, Cambodia, 5-7 July. Thailand: Southeast Asia Urban Environmental Management Applications (SEA-UEMA) Project, Asian Institute of Technology.

[3] Kaseva, M. E. And Gupta, S. K. 1996. Recycling-an environmentally friendly and income generating activity towards sustainable solid waste management : case study-Dar es Salaam City, Tanzania. *Resources Conservation and Recycling* 17: 299-309.

[4] Muttamara, S.; Visvanathan, C.; and Alwis, K. U. 1994. Solid waste recycling and reuse in Bangkok. *Waste Management & Research* 12: 151-163.

[5] Tucker, P.; Murney, G.; and Lamont, J. 1998. Predicting recycling scheme performance: a process simulation approach. *Journal of Environmental Management* 53: 31-48.

[6] U.S. EPA .1999. Recycling work: state and local solutions to solid waste management problems. EPA530-K-99-003. USA: United States Environmental Protection Agency (U.S.EPA).

[7] MONRE (1997). Thailand policy and perspective plan for enhancement and conservation of national environmental quality 1999-2006. Bangkok: Office of Environmental Policy and Planning (OEPP), Ministry of Natural Resources and Environment (MONRE).

[8] Eik, A.; Steinmo, S.; Solem, H.; Brattebo, H.; and Saugen, B. (2002). Eco-efficiency in recycling systems. Norway: Norwegian University of Science and Technology (NTNU), Industrial Ecology Programme (IndEcol).

[9] Ugwu, O. O. And Haupt, T. C. 2007. Key performance indicators and assessment methods for infrastructure sustainability-a South Africa construction industry perspective. *Building and Environment* 42: 665-680.

[10] DEQP 2003. Recycling Bank. *Nawatthakum Pamphlet* (Thai) 4(14): 21-25.

[11] World Bank (2003). Thailand environment monitor 2003. Bangkok, Thailand: Pollution Control Department, Ministry of Natural Resources and Environment (MONRE), The World Bank, Japan Bank for International Cooperation (JBIC), and United States-Asia Environmental Partnership (US-AEP).

[12] U.S. EPA (1989). Decision-makers guide to solid waste management. Washington, D.C.: Office of solid waste management programs, United States Environmental Protection Agency.

[13] World Bank (1996). Performance Monitoring Indicators: A handbook for task managers. Washington D.C.: Operation Policy Department, World Bank.

[14] OECD (2003). OECD Environmental indicators: development, measurement and use: Organization for Economic Co-Operation and Development.

[15] USAID (1996). Performance monitoring and evaluation: Selecting performance indicators. *USAID Center for Development Information and Evaluation*. Retrieved September 12, 2007 from the World Wide Web: http://pdf.dec.org/pdf_docs/pnaby214.pdf.

[16] Wang, F. S.; Richardson, A. J.; and Roddick, F. A. 1997. Relationships between set-out rate, participation rate and set-out quantity in recycling programs. *Resources, Conservation and Recycling* 20: 1-17.

[17] McMillen, A. and Skumatz, L. A. (2000). Separation, collection, and monitoring systems. In H. F. Lund (Ed.), Recycling handbook (2nd ed.). New York: The McGraw-Hill.

[18] Chang, N.-B. and Wei, Y. L. 1999. Strategic planning of recycling drop-off stations and collection network by multiobjective programming. *Environmental Management* 24(2): 247-263.

[19] Gies, G. 1995. Dropoff recycling as a low cost alternative. *Bio Cycle* 3 (March): 30-33.

[20] Thomas, C. 2001. Public understanding and its effect on recycling performance in Hampshire and Milton Keynes. *Resources and Conservation & Recycling* 32: 259-274.

[21] Folz, D. H. 2004. Service quality and benchmarking the performance of municipal services. *Public Administration Review* 64: (2).
[22] Glenn, J. 1988. Recycling economics: benefit-cost analysis. *BioCycle* 29(9): 44-47.
[23] Arendse, L. and Godfrey, L. (2006). Waste management indicators for national state of environmental reporting. Retrieved January 15, 2007 from the World Wide Web: http://www.csir.co.za/ciwm/Godfrey_Wastecon02.pdf
[24] Mongkolnchaiarunya, J. 2005. Promoting a community-based solid waste management initiative in local government: Yala municipality, Thailand. *Habitat International* 29: 27-40.
[25] Charuvichaipong, C. and Sajor, E. 2006. Promoting waste separation for recycling and local governance in Thailand. *Habitat International* 30: 579-594.

Construction Waste Management from a Gender Perspective

Ektewan Manowong and Ranjith Perera

Abstract— *Construction industry generates high volume of waste. The availability of dump sites for construction waste is decreasing and becoming a serious problem. Common waste management strategies such as Reduce, Reuse, Recycle (3Rs) can be provided for construction waste management (CWM). However, in order to be extensively implemented in construction industry, such practices need to be recognized by construction operatives and the general public whose behavior may be influenced by their attitudes and perception. A survey was carried out to investigate current situation of CWM in various regions of Thailand. Attitudes, perceptions, and roles of men and women in the construction-related sectors were analyzed. Recommendations are planners and decision-makers to improve the relevant parties' perception and attitudes towards CWM policy planning and implementation in the GMS countries.*

***Keywords*— Attitudes, Construction, Gender, Waste management.**

1. INTRODUCTION

The rapid urbanization in many developing countries over the past decades seems to have been resulted from their soaring economy. To maintain the economic boom, development of relevant facilities is essential. As such, number of construction projects including infrastructures, commercial offices and residential buildings continues to increase. However, such construction boom proceeds in an unprecedented way, resulting in higher level of construction waste generation.

Among sources of waste generated in urbanized areas, construction industry has been found to be a major generator of waste that pollutes the environment as well as a main consumer of resources and energy. It has been reported that the construction sector generated unacceptable levels of material waste [1]. Being in the period of transition economy, the countries in the Greater Mekong Subregion (GMS) experience particular problems of construction waste. Construction boom in China, Vietnam and Thailand considerably causes environmental problems. Among sources of waste generated in urbanized areas, construction industry has been found to be a major generator of waste that pollutes the environment. Construction activities and manufacturing of construction materials have created adverse environmental effects including solid and liquid wastes, dust, harmful gases, noises, blazing lights, ground movements, fallen items, and so forth.

As the environmental impacts from construction may be significant and irreversible, the interrelated problems of water, air, and land pollution must be appropriately and adequately dealt right from the sources of construction waste. Resources can then be effectively consumed. Sustainable construction can then be achievable through effective participation from construction operatives, both at management offices and construction sites, as well as the general public. In the field of solid waste management, consideration of gender differences has emerged as essential issues. As such, it is expected to apply gender initiatives into the construction waste management scheme. This paper examines the significance of roles and attitude of men and women with an objective to integrate the issue of gender into the construction waste management program. The paper reports findings of a survey carried out in the capital and regional cities of Thailand to evaluate respondents' attitudes and perceptions towards the construction waste management.

2. LITERATURE REVIEW

Gender, Environment, and Sustainable Development

Gender refers to the culturally and socially determined differences between men and women, the relationships between them, and their roles in the community at large [6]. Such relationships determine decisions and activities affected in both the management and utilization of the environment for sustainable development [7]. Rapid urbanization is inevitably associated with increased construction projects and higher generation of waste. Such development activities also cause severe pollution, depletion of natural resources, degradation of ecosystems, and loss of biodiversity.

Gender is becoming the key issue for environmental management because men and women could have

Ektewan Manowong (corresponding author) is with the SEA-UEMA Project in the Urban Environmental Management Field of the Urban Environmental Management Field of Study, School of Environmental, Resources and Development (SERD), Asian Institute of Technology, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand. Phone: +66-2-524-6106; Fax: +66-2-524-5777; E-mail: ektewan@ait.ac.th.

Ranjith Perera is Coordinator of the Alumni Demonstration Project (ADP) within the SEA-UEMA Project in the Urban Environmental Management field of the Urban Environmental Management Field of Study, School of Environmental, Resources and Development (SERD), Asian Institute of Technology, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand. Phone: +66-2-524-5619; Fax: +66-2-524-5777; E-mail: ranjithp@ait.ac.th.

contributed essentially to the conservation, use and management of natural resources [8]. Importance of gender issue has already been emphasized by the international organization as a cross-cutting priority [9]. As such, gender is incorporated in the environmental management in order to enable women and men perform their roles in the best cost effective methods, which facilitate conservation of the environment, accelerate sustainable development, and consequently improve the people's quality of life [7].

It is also revealed that [10], regarding the ordinary urban waste, the gender may have influence upon the person's judgment about the definitions of "waste". Men and women may see the value of discarded materials differently. Further, men and women differently participate in managing waste depending on their roles in the waste-related activities. The subordinate status of women frequently affects their control of resources, including re-using and recycling waste materials. Besides, different attitudes of men and women may also carry through preferences for policies or approaches which affect decisions made by women and men managers or public authorities. Moreover, as in [10], the commitment to empowerment of women is considered critical in the support of new initiatives in urban environmental protection.

In many societies such as construction industry, which is characteristically a male-dominated sector in terms of employment at all level, women are traditionally afforded a lower status than men. As the construction industry is a labour-intensive, construction operatives should have more responsible attitude towards the environment. Behavior of construction operatives may be influenced by their awareness, attitudes and perceptions towards CWM, as pointed out by [5], [11], [12], and [13]. Hence, their decision-making regarding waste handling is directly affected. As such, these attributes, as well as their CWM efforts, should be investigated and organized to maximize the probability of achieving practical and effective CWM. Altogether, diversities among men and women need to be studied to explore whether such differences have any effects on the CWM efforts.

Managing Construction Waste

Construction waste (CW) is normally disposed by land filling in private areas or municipal landfill sites. However, construction industry is facing a serious problem as the dumping sites become inadequate and unavailable to accommodate higher volume of construction waste. As such, the heavy and bulky CW is undesirable for disposal in landfills [2]. In some cases, therefore, construction waste is illegally dumped to public areas causing environmental problems to local communities. The strategies of Reduce, Reuse, Recycle (3Rs) have been recently promoted for the solid waste management practices. As the construction projects are major sources of waste generation, CW can be targets for potential 3Rs opportunities. However, the 3Rs attempts for CW are not yet widely practiced in the construction industry. Some reasons for the 3Rs not being popular options for CW include that the recycling markets are not available for some types of CW such as concrete and bricks [3] or that the use of recycled building materials is not widely practiced because it is not cost-effective [4].

It is also argued that previous research on CW in the construction industry traditionally focused only on the work practices, processes and technologies that contribute to the generation of waste while ignoring importance of people's willingness to change their attitudes and behavior [5]. As such, exploring the current situation of construction waste management (CWM) in Thailand would enable policy/decision-makers to perceive possibilities as well as the problems of CWM when preparing plans for construction.

As a good and proactive way to manage construction waste is prevent or reduce the generation of waste. Then, people working or living in or near the environment exposed to construction waste are regarded as key participants in the urban waste management activities, including collection, separation, transportation, treatment, processing, recycling, composting, and disposal of waste. Therefore, the construction operatives particularly play important role in managing waste by foreseeing possible reuse of construction materials such as woods, steel bars, and broken bricks in some types of construction works. At this point, since the construction is labour-intensive industry, the gender perspectives should enter the area of waste management. It is expected that a gender-integrated CWM plan can then have an important role in improving performance of the overall environmental management.

3. OBJECTIVES AND METHODOLOGY

This study is part of the authors' research on CWM practices in Thailand. One of the major objectives is to investigate the current attitudes, perception and expectation of the people, directly or indirectly involved with construction activities, towards the management of construction waste. Attitudinal differences among men and women towards the management of waste generated by construction activities are also examined. The study was carried out by conducting structured questionnaire surveys and interviews. Target groups of respondents include construction operatives, local government officials, and the local residents. All respondents were personally approached at the workplaces or residences. Locations of this study are limited to the Bangkok downtown, Bangkok's suburban area of Rangsit in Pathumthani province, and three regional cities of Thailand, including Chiang Mai, Udon Thani, and Hat Yai. The survey was carried out during August to October 2007.

4. FINDINGS

Survey Respondents

The total of 226 sets of returned questionnaires comprises responses from Pathumthani (44 sets: 19.5%); Chiang Mai (54 sets: 23.9%); Udon Thani (31 sets: 13.7%); Bangkok (50 sets: 22.1%); and Hat Yai (47 sets: 20.8%). It was found that there were total male

respondents approximately twice the number of female respondents. This reflects that, in general, there are more men involved in the construction in all locations under study. Figure 1 shows groupings of the respondents according to their involvement with the construction projects under study.

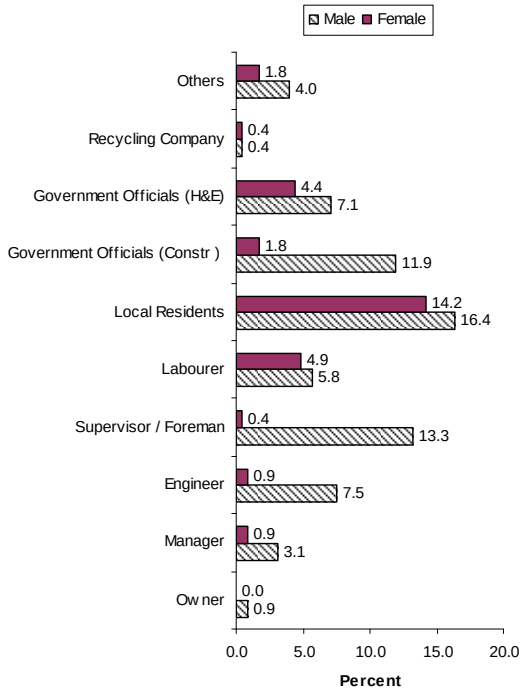


Fig.1. Respondent Involvement with Construction Projects

The survey did not find any female project owner. It can be seen that, responses from male and female in the group of local residents were slightly different. At construction sites, there were almost equal number of men and women working as labourers while the number of women who are supervisor/foremen, engineer, or manager is much less than men. In government sector, there were more female respondents from the department of health and environment (H&E) than the construction department.

Important Concerns in Construction Project

The respondents were asked to rank the factors that should be concerned as most important when executing a construction project. Results are presented in Table 1. In the group that is directly involved with the construction project, it is found that the groups who had more decision-making power (i.e. owner, manager, engineer, and supervisor/foremen) considered waste management is less important. Only the group of female engineers perceived waste management more important than profits. On the contrary, male and female labourer considered that the issue of health and safety is most important. In addition, male labourer viewed that waste management is the second most important while female labourer did not think that profits is in the top five important concerns. The group of government officials expressed that the construction quality should be most concerned while considering that the issue of health & safety is more important than waste management.

Table 1. Ranking of Important Concerns in Construction

	Respondents' ranking categorized by gender	
	Male	Female
Owner	1. Profit 2. Expenses & Quality 3. Time management 4. Health & Safety 5. Waste management	N/A
Manager	1. Expenses 2. Profits 3. Time management 4. Health & Safety 5. Quality	1. Expenses 2. Profits 3. Quality, Time management and Health & Safety 4. Waste management
Engineer	1. Quality 2. Health & Safety 3. Time management 4. Profits 5. Expenses	1. Quality 2. Time management 3. Health & Safety 4. Expenses & Waste management 5. Profits
Supervisor / Foreman	1. Quality 2. Expenses 3. Profits & Time management 4. Health and Safety 5. Waste management	1. Profits 2. Expenses 3. Quality & Time management 4. Health & Safety 5. Waste management
Labourer	1. Health & Safety 2. Waste management 3. Time management 4. Quality 5. Profits	1. Health & Safety 2. Expenses 3. Time management 4. Quality 5. Waste management
Government Officers (Constr)	1. Quality 2. Expenses 3. Health & Safety 4. Time management 5. Waste management	1. Quality 2. Health & Safety 3. Expenses 4. Waste management 5. Profits
Government Officers (H&E)	1. Quality 2. Health & Safety 3. Expenses 4. Waste management 5. Time management	1. Quality 2. Health & Safety 3. Expenses 4. Waste management 5. Time management

When the respondents were further asked to specifically indicate level of importance of the construction waste management (CWM) in construction project and how important CWM is when comparing with other works in the project, using the seven-point Likert scale ranging from "1=Not Important at all" to "7=Very Highly Important", the result is shown in Figure 2.

Considering the mean value of the question on the importance of CWM in construction project and comparing responses from men and women, the result reveals that women generally give more importance to CWM.

Table 2. Perceived Responsibility for CWM Process

Groups of Respondents	Party that should be responsible for CWM process	Percent	
		M	F
Owner	Project Owner	50.0	N/A
	Contractor	50.0	N/A
Manager	Project Owner	14.3	0.0
	Contractor	71.4	50.0
	Recycling Company	0.0	50.0
	All party	14.3	0.0
Engineer	Government	0.0	50.0
	Project Owner	17.6	0.0
	Contractor	47.1	0.0
	Sub-Contractor	11.8	0.0
	Recycling Company	17.6	0.0
	All party	5.9	50.0
Supervisor / Foreman	Government	3.3	100.0
	Project Owner	23.3	0.0
	Contractor	50.0	0.0
	Sub-Contractor	10.0	0.0
	Recycling Company	13.3	0.0
Labourer	Government	7.7	0.0
	Project Owner	23.1	27.3
	Contractor	53.8	45.5
	Sub-Contractor	15.4	0.0
	Recycling Company	0.0	9.1
	All party	0.0	18.2
Local Residents	Government	13.5	6.3
	Project Owner	40.5	37.5
	Contractor	37.8	40.6
	Sub-Contractor	5.4	3.1
	Recycling Company	2.7	12.5
Government (Construction)	Government	11.1	0.0
	Project Owner	37.0	50.0
	Contractor	40.7	25.0
	Recycling Company	11.1	25.0
Government (Health & Environment)	Government	6.3	20.1
	Project Owner	43.8	20.0
	Contractor	43.8	50.0
	Recycling Company	0.0	9.9
	All party	6.3	0.0
Recycling Company	Project Owner	100.0	0.0
	Contractor	0.0	100.0
Others (e.g. safety & procurement officers, architect)	Project Owner	33.3	75.0
	Contractor	44.4	25.0
	Recycling Company	22.2	0.0

Responsibility, Roles, and Options for the Management of Construction Waste

The respondents were also asked to indicate which party should be most responsible for arrangement of CWM process. It can be seen from Table 2 that most of the male respondents indicated that "Contractor" and "Project Owner" should be responsible for this task.
In contrast, female engineers and supervisors perceived that the government should take more responsibility for CWM process arrangement. However, most of the government officials seem to disagree although about 20% of female officers working in health and environment department pointed out that the arrangement of CWM process should be responsible by the government agencies. Female managers and labourer perceived similarly that CWM process should also be arranged by the recycling companies.

Table 3 contains the results of the question asking the respondents to indicate the party that should be most active in handling waste in construction project. It can be clearly seen that male respondents indicated that the project management/decision-making level (owner and manager) should have most active role for CWM followed by the supervisor/foremen who lead and control the construction works at operational level. Meanwhile, the female managers and engineers indicated that the project owner and supervisor/foremen should be most active in CWM. It can also be noticed that the group of labourers, both male and female, who are most directly exposed to construction waste, indicated that their supervisors/foremen should be most active role in managing waste generated in construction project. However, the supervisor/foremen disagreed as they think that the project owner should be most active party to deal with construction waste. This corresponds to opinion from the project's outsiders such as local residents and government officers.

The respondents were further asked to indicate their favorite options to manage the waste from construction. It was found that (result not shown here) most of the managers (55%), supervisor/foremen (48.4%) and labourers (62.5%) still prefer the landfill method while most engineers (57.9%) prefer the options of recycle and reuse. Meanwhile, the project outsiders (both male and female) such as local residents (53.6%) and government officials from health and environment department (57.7%) prefer the recycle method. Government officials from the department of construction almost similarly prefer the recycle option (42%) and the landfill (41.9%).

Awareness of Gender Issues in Construction

Figure 3 presents the result of the question regarding the issue of gender in construction industry. It was found that the recognition on differences among men and women among construction operatives (Manager, Engineer, Supervisor/Foremen, and Labourer) was averagely low (Mean=3.45/7) while the government sector seem to be slightly more recognized on the importance of gender differences (Mean=4.34/7). The result also indicates that the respondents considered that the importance of gender issue and the existing of respect to women's ability are at average level (Means are 4.11 and 4.00 respectively).

Table 3. Parties with Most Active Role for CWM

Groups of Respondents	Party that should have most active role for CWM	Percent	
		M	F
Owner	Project Owner	50.0	N/A
	Supervisor/Foreman	50.0	N/A
Manager	Project Owner	14.3	0.0
	Project Manager	28.6	0.0
	Supervisor/Foreman	28.6	50.0
	Labourers	14.3	50.0
	All party	14.3	0.0
Engineer	Project Owner	0.0	50.0
	Project Manager	35.3	0.0
	Supervisor/Foreman	29.4	50.0
	Labourers	23.5	0.0
	All party	11.8	0.0
Supervisor / Foreman	Project Owner	33.3	100.0
	Project Manager	16.7	0.0
	Supervisor/Foreman	23.3	0.0
	Engineer	10.0	0.0
	Labourers	3.3	0.0
Labourer	Project Owner	7.7	0.0
	Project Manager	15.4	0.0
	Supervisor/Foreman	61.5	63.6
	Engineer	7.7	0.0
	Labourers	7.7	36.4
Local Residents	Project Owner	35.1	50.0
	Project Manager	10.8	9.4
	Supervisor/Foreman	27.0	25.0
	Engineer	5.4	0.0
	Labourers	16.2	12.5
	All party	5.4	3.1
Government (Construction)	Project Owner	63.0	50.0
	Project Manager	22.2	25.0
	Supervisor/Foreman	11.1	0.0
	Labourers	3.7	0.0
	All party	0.0	25.0
Government (Health & Environment)	Project Owner	37.5	60.0
	Project Manager	18.8	0.0
	Supervisor/Foreman	25.0	20.0
	Engineer	12.5	0.0
Recycling Company	Project Owner	0.0	100.0
	Project Manager	100.0	0.0
Others (e.g. safety & procurement officers, architect)	Project Owner	33.3	0.0
	Project Manager	44.4	50.0
	Supervisor/Foreman	11.1	25.0
	Labourers	0.0	25.0
	All party	11.1	0.0

Table 3 contains the results of the question asking the respondents to indicate the party that should be most active in handling waste in construction project. It can be clearly seen that male respondents indicated that the project management/decision-making level (owner and manager) should have most active role for CWM followed by the supervisor/foremen who lead and control the construction works at operational level. Meanwhile, the female managers and engineers indicated that the project owner and supervisor/foremen should be most active in CWM. It can also be noticed that the group of labourers, both male and female, who are most directly exposed to construction waste, indicated that their supervisors/foremen should be most active role in managing waste generated in construction project. However, the supervisor/foremen disagreed as they think that the project owner should be most active party to deal with construction waste. This corresponds to opinion from the project's outsiders such as local residents and government officers.

The respondents were further asked to indicate their favorite options to manage the waste from construction. It was found that (result not shown here) most of the managers (55%), supervisor/foremen (48.4%) and labourers (62.5%) still prefer the landfill method while most engineers (57.9%) prefer the options of recycle and reuse. Meanwhile, the project outsiders (both male and female) such as local residents (53.6%) and government officials from health and environment department (57.7%) prefer the recycle method. Government officials from the department of construction almost similarly prefer the recycle option (42%) and the landfill (41.9%).

Awareness of Gender Issues in Construction

Figure 3 presents the result of the question regarding the issue of gender in construction industry. It was found that the recognition on differences among men and women among construction operatives (Manager, Engineer, Supervisor/Foremen, and Labourer) was averagely low (Mean=3.45/7) while the government sector seem to be slightly more recognized on the importance of gender differences (Mean=4.34/7). The result also indicates that the respondents considered that the importance of gender issue and the existing of respect to women's ability are at average level (Means are 4.11 and 4.00 respectively).

Participation of Men and Women in Construction Waste Management

Figure 4 shows the surveyed participation level of men and women in construction industry, from the respondents' perspectives. The respondents, especially the female supervisor/foremen and labourers, confirmed that there are less women working in the management level while there are more women working as labourers and handling construction waste. The graph of risk exposure shows that men and women are similarly susceptible to risks when handling waste generated from construction activities.

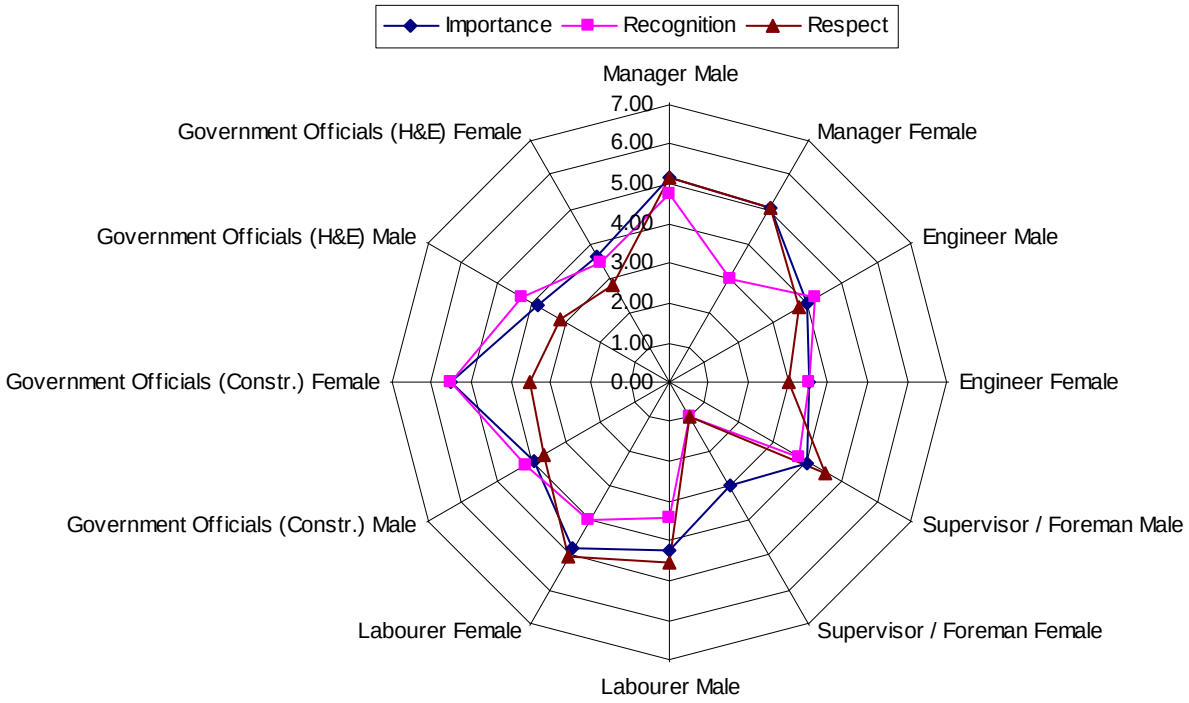


Fig.3. Level of Awareness on Gender Issues in Construction

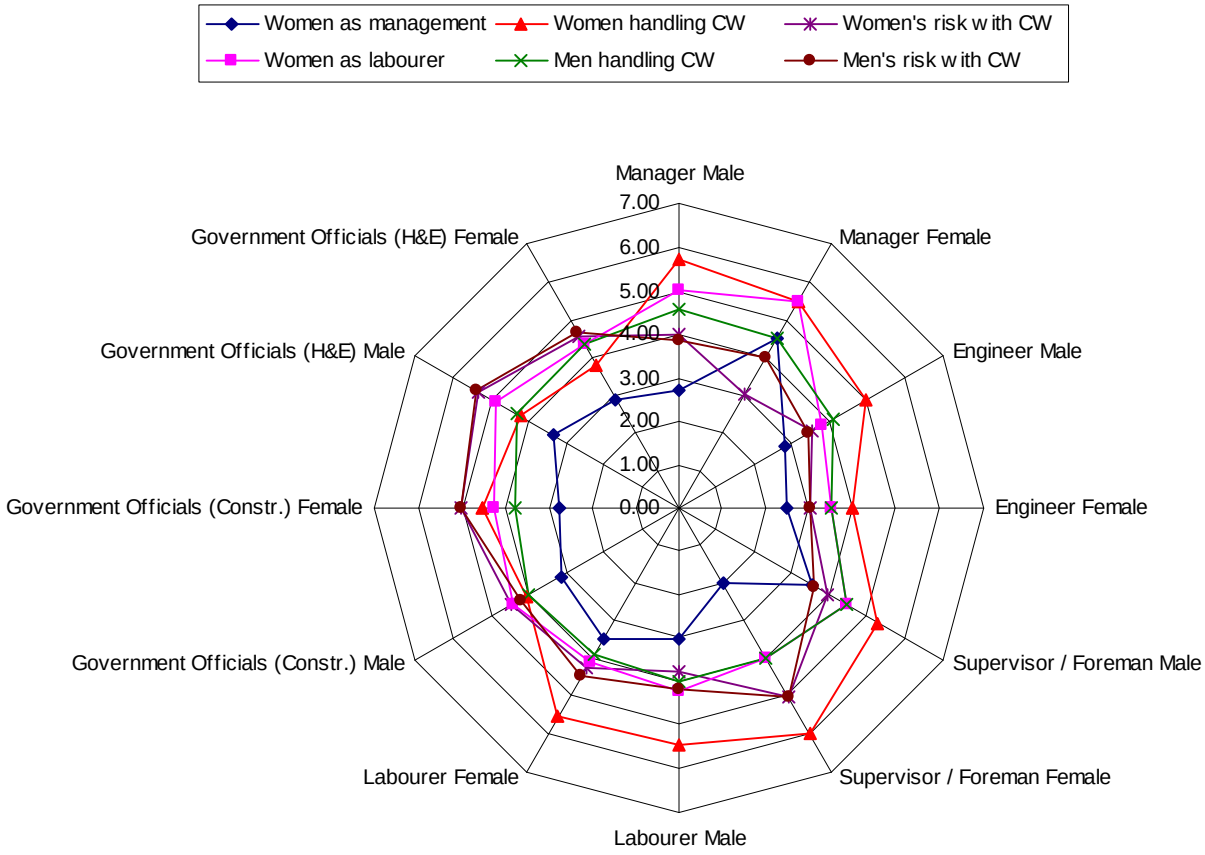


Fig.4. Participation of Men and Women in Construction Waste Management

5. DISCUSSION AND RECOMMENDATIONS

There was more survey response received from male respondents because more men were involved in the construction works. Each group of the respondent was dominated by men, except for the group of local residences which the researcher tried to balance the number of male and female respondents. However, the respondents' attitudes and perceptions were separately analyzed based on category of gender and the respondents' involvement with the construction.

The result indicates that most of the respondents perceived the waste management in construction operations as less important than other concerns such as profits and quality. It is also found that the construction operatives at management level (manager and engineer) included waste management in top-five ranking of their important concerns while male respondents in management level did not rank waste management as their top five priorities. Regarding the lower-management level (Supervisor/Foremen), they consider waste management as top concerns but still less important than other construction management issues related to cost, quality and time.

On the contrary, male and female labourers considered that the issue of health and safety was their highest concern. Male labourers considered waste management as the second most important concern. This is different from female labourers. This can be explained that women are physically more sensitive to environmental hazards related to construction waste such as dust and chemicals. Moreover, men are more likely to be engaged in skilled and dangerous jobs than women so that they are paid higher wages [14]. Women labourers assigned to take role as site cleaner and waste collector are considered as low skilled position so that they get low wages. Therefore, women labourers perceived works related to waste as less important since they had no incentives to perform such task.

As women from every group of the respondents considered CWM as important as other works with higher mean value than men's, increased participation of women at management level could better facilitate arrangement of CWM. Since the project owner and contractor were perceived as potential party to be responsible for CWM arrangement, they should take more proactive action to arrange preparation and implementation of CWM program. Then, female managers and engineer working for both project owner and contractors can be empowered and assigned to monitor this task because they are more aware of waste management. Consequently, both male and female supervisors/foremen should be equally supported to extend their on-site duties related to CWM.

At labour level, attempts should be made to encourage female workers to be happy with their jobs in handling waste at construction sites. To achieve this, more social and financial incentives are needed together with adequate healthcare. That is, the construction project management could give more importance to the CWM efforts by compromising the gap of social respect and income. Then the role of men and women in construction industry becomes more widely recognized and adequately emphasized by assigning them important and appropriate responsibilities to waste management [15].

In addition, regarding the aspect of sustainable environmental management, specific roles and positions of women in environment and development have been recognized since the accomplishment of the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. Women's extensive experiences make them an invaluable source of knowledge and expertise on environmental management and appropriate actions [8]. Incorporation of their collective perspectives, experiences and contributions to sustainable development need, therefore, to be ensured.

The study further found that roles, attitudes, and perceptions of the construction operatives have interrelated effects on the on-site practices of CWM. Although the surveyed respondents indicated that they have positive attitudes towards CWM and perceived the essence of proper environmental management associated with construction activities, their roles in the project may not permit them to carry out the CWM scheme as wished as long as the management level, particularly the construction site managers and supervisors, fail to raise CWM awareness and to provide encouragement, procedural direction, and incentives. Knowing and understanding potential roles of male and female in CWM should be emphasized accordingly to their roles.

Nevertheless, there are still challenges for application of gender issues in GMS countries since, as stated in [16], the cultural and traditional practices that discriminate against women in developing countries can be identified. Besides, it is an undeniable fact that the construction industry is still male-nominated. In addition, the labourers are usually assigned to handle construction waste differently due to their physical conditions and nature of works. As such, attempting to provide equal incentives for waste-related work remains highly challenging as the management regards this task as non-profitable activities. Such challenges can be overcome in the future when the project management becomes more recognized with the profitable value of CWM through potential of 3Rs.

However, proactive CWM action from governmental organizations seems to be insufficient. As found from this study, there is large proportion of government officials working in the department of construction works that consider dumping construction waste to landfills is still preferable options. This perception may be appropriate practice in those municipalities with large landfill areas as it may be cheaper method but it will finally face the same situation as those cities whose landfill areas already run out. As such, another challenge of CWM practices is to introduce policy, rules, regulations, and law enforcement that particularly focus on CWM. Further, government officials need to be informed and trained to change their attitudes and raise their awareness of appropriate CWM efforts. In addition, an outreach for opinions from the construction operatives and the general public can help the government sector to appropriately prepare a CWM plan suitable to the actual and current situation. It should be stressed among GMS

countries in transition economy that the economic development must be essentially integrated with social and environmental sustainability.

6. CONCLUSION

Construction waste is becoming more serious problem to urban environment as it is now undesirable for landfills. Attitude and perceptions of the stakeholders, who are those directly or indirectly involved with the construction activities, can have important role in managing construction waste. This paper investigated and examined the attitudes and perceptions of the respondents who are construction stakeholders in various urban areas of Thailand by means of questionnaire surveys, interviews, and field observation. The result mainly presents the comparison of differences among groups of respondents as well as the gaps between male and female respondents. It is reported in this paper that women are generally more concerned with management of construction waste but they are in the environment that allows less power to manage or make decision. More women participated in labourer level but they were less concerned about waste management due to less encouragement and incentives.

With more cooperation of the construction operatives, construction waste generation can be reduced, appropriately handled, and correctly disposed. Further, the active participation from the general public, either male or female who are equally the stakeholders of construction projects, can be supportive surveillance on practices of construction operators. Empowering the right gender active for CWM can then pave the way to the success of CWM via applications of 3Rs approaches. As GMS countries have similar cultures and social beliefs, application of findings from this study may be useful for improving attitudes and perception of construction stakeholders. Increased awareness and recognized responsibility play important role in driving the well-designed CWM policy and plan to be widely accepted, economically viable, and successfully implemented. With regional CWM policy formulation, the GMS communities will successfully meet the challenges of getting prolonged benefits of balanced and sustainable development in the region.

ACKNOWLEDGMENT

Authors wish to sincerely express their appreciations to all of the respondents for their kind understanding and cooperation during the survey. The study is inspired by the Southeast Asia Urban Environmental Management Applications (SEA-UEMA) Project. The project goal is to contribute to the improvement of urban environmental conditions in Southeast Asia (SEA) region. It seeks to attain improved implementation and sharing of sound Urban Environmental Management (UEM) policies and practices in the three key urban environmental sub-sectors (water and sanitation, solid waste, and air pollution) in Southeast Asian region with poverty reduction and gender equality as the two crosscutting themes.

REFERENCES

[1] Ekanayake, L.L. and Ofori, G. 2000. Construction material waste source evaluation. *Proceedings of the Conference: Strategies for sustainable built environment.* Pretoria, South Africa. 23-25 August.

[2] Peng, C.L., Scorpio, D.E., and Kibert, C.J. 1997. Strategies for successful construction and demolition waste recycling operations. *Construction Management and Economics* 28: 49-58.

[3] Duran X., Lenihan H., and O'Regan B. Duran X., Lenihan H., and O'Regan B. 2006. A model for assessing the economic viability of construction and demolition waste recycling—the case of Ireland *Resources, Conservation and Recycling* 46: 302–320.

[4] Wong E.O.W. and Yip R.C.P. 2004. Promoting sustainable construction waste management in Hong Kong. *Construction Management and Economics* 22: 563–566.

[5] Teo, M.M.M. and Loosemore, M. 2001. A theory of waste behaviour in construction industry. *Construction Management and Economics* 19: 741–751.

[6] Srinivas, H. (2007). Gender and Good Governance. *Global Development Research Center*. Retrieved October 7, 2007 from the World Wide Web: http://www.gdrc.org/gender/governance/gender-gov.html.

[7] Lwanga M. (2001). Gender, Environment and Sustainable Development. *Proceedings of the Conference: "Sustainable Development, Governance and Globalisation: An African Forum for Strategic Thinking Towards the Earth Summit 2002 and Beyond"*. Nairobi, Kenya 17 – 20 September.

[8] Dankelman I. (2004). *Women and Environment: weaving the web of life*. IRDANA advices, Radboud University Nijmegen.

[9] United Nations Environment Programme (UNEP). (2007). Gender and the environement. Retrieved July 15, 2007 from the World Wide Web: http://www.unep.org/gender_env/About/index.asp.

[10] Muller, M. and Schienberg, A. (1997). Gender and Urban Waste Management. *The Gender, Technology and Development Conference*. Amsterdam, the Netherlands. Retrieved July 15, 2007 from the World Wide Web: http://www.gdrc.org/uem/waste/swm-gender.html.

[11] Tam V.W.Y., Tam C.M., Shen L.Y., Zeng S.X., and Ho C.M., 2006. Environmental performance assessment: perceptions of project managers on the relationship between operational and environmental performance indicators. *Construction Management and Economics* 24: 287-299.

[12] Kulatunga U., Amaratunga D., Haigh R., and Rameezdeen R. 2006. Attitudes and perceptions of construction workforce on construction waste in Sri Lanka. *Management of Environmental Quality: An International Journal* 17(1): 57-72.

[13] Linggard A., Graham P., and Smithers G. 2000. Employee perceptions of the solid waste management system operating in a large Australian contracting organization: implications for company policy implementation. *Construction Management and Economics* 18: 383-393.
[14] Ogunlana S.O., Rost U., Austriaco L., Kusakabe K., and Kelkar G. 1993. *Thai Women Construction Workers*. Gender Studies, Monograph 3. Bangkok: Asian Institute of Technology.
[15] Hemmati M. and Gardiner R. (2002). Gender equity and sustainable development. (Henrich Böll Foundation's Briefing paper towards the World Summit 2002, Johannesburg)
[16] Organization for Economic Co-operation and Development (OECD). (2007). OECD work on gender equality in developing countries. Retrieved October 17, 2007 from the World Wide Web: http://www.oecd.org/dataoecd/44/56/37962700.pdf.

Would Wetland Biodiversity Conservation Improve Social Welfare? A Case Study in Vietnam's Mekong River Delta

Thang Nam Do and Jeff Bennett

Abstract— *Wetlands in the Vietnam's Mekong River Delta (MRD) have experienced losses and degradation. Plans have been drafted by government agencies to use public funding to conserve the wetlands. However, one challenge to policymakers is whether the wetland conservation proposed would improve social welfare. To provide an answer, this study conducts a cost-benefit analysis of a proposed biodiversity conservation program for Tram Chim National Park in the MRD. The cost to local farmers of changing wetland management in the form of reduced income from rice production is estimated using a production function approach. The benefit of wetland conservation is estimated using a choice modelling approach.*

It was found that the proposed conservation program of Tram Chim would generate a net social benefit in the order of USD 0.15 and 0.96 million, indicating that wetland conservation in the MRD would improve social welfare. This supports the proposed plan of using public funding for conserving the wetlands.

Keywords— **Cost-benefit analysis, Mekong, wetland biodiversity values.**

1. INTRODUCTION

Wetlands in Vietnam's Mekong River Delta (MRD) have great biodiversity. They support a large number of herons, egrets, storks and ibises and some rare species such as sarus Cranes, black necked storks, lesser adjutants and greater adjutants [1]. In particular, mature semi-natural Melaleuca forest and seasonally inundated grasslands in MRD have a large number of birds and support high numbers of globally threatened bird species [2]. Fourteen of 194 bird species recorded in the Delta are globally threatened [3].

However, the wetlands have experienced serious loss and degradation. The area of mangrove forest has decreased by about 80 per cent over the last 50 years [4]. The increase in shrimp farming is the leading cause of this loss. Other causes include the conversion of wetlands to agriculture and construction land, war destruction and excessive fuel wood collection. In addition, the *ad hoc* development of dykes in the MRD has altered hydrologic conditions and hence wetland health [5].

To address the wetland loss and degradation, plans have been drafted by government agencies to use public funding to improve the protection of the wetlands. However, at present, there is a lack of information on the impact of alternative management strategies on values of wetlands in the MRD [5]. In particular, there is limited information on the impact on local farmers' livelihoods as well as benefits of improved wetland biodiversity. Due to this information gap, it is unclear to policymakers whether the change in current wetland management practices would generate a net social benefit.

This study helps to fill this information gap by conducting a cost-benefit analysis (CBA) of a proposed wetland conservation program for Tram Chim National Park in the MRD. CBA of wetland alternative management strategies is aimed at calculating the net impact of a project on the economic welfare of society by measuring all the costs and benefits of the project relative to some base case or status quo [6]. In CBA, environmental impacts are evaluated and measured in monetary units. This process not only has a sound theoretical framework but also provides wetland managers with unambiguously quantitative data on which to make informed decisions [7].

The case study reported here was carried out in the Tram Chim National Park and its adjacent areas in the Plain of Reeds in the Mekong River Delta (Figure 1). Established as a national park in 1994, Tram Chim is a 9,000 ha wetland located in the Tam Nong District of Dong Thap Province. Tram Chim is a habitat for 127 plant species. It supports a large number of rare birds. Most notably, Tram Chim provides a habitat for the Sarus Cranes, the endangered bird species listed in the World Conservation Union (IUCN) Red Book [8]. Due to its biodiversity value, Tram Chim was the first wetland national park declared in Vietnam and has been nominated by the Vietnamese government to be a Ramsar wetland site [3].

Tram Chim is enclosed by a 53-km dyke built in 1985 to retain water in the national park during the dry season. This helped restore the wetland ecological systems damaged during the Vietnam war [10]. Evidence of ecological restoration came with the return of the Sarus crane. However, in 1996, to prevent fire, the local authorities raised the height of the dyke so that the water

Thang Nam Do (corresponding author) is a PhD candidate in the Environmental Management and Development Program, Crawford School of Economics and Government, Australian National University, Canberra ACT 0200, Australia. Email: donamthang18@gmail.com.

Jeff Bennett is Professor and Director, Environmental Management and Development Program, Crawford School of Economics and Government, Australian National University, Canberra ACT 0200, Australia. Email: jeff.bennett@anu.edu.au.

This study was funded by the Economy and Environment Program for Southeast Asia (EEPSEA).

level is now constantly higher than the ecological optimal level of 0.5m [8].

Fig. 1. Location of Tram Chim National Park.
Source: Adapted from [9]

The current park dyke system has affected Tram Chim's ecological system [11]. While the long inundation supports some deepwater aquatic species, overall, it has negative impacts on the ecological system. Native plants have been replaced by invasive mimosa pigra while eleocharis or 'nang' grasses, the favourite food of the Sarus crane, have been destroyed. The latter has led to reduced numbers of this endangered bird species visiting the park. The dyke has also hindered fish migration and hence reduced the number of fish species living in the wetlands.

To improve wetland biodiversity, the Park Management Board has proposed to change the current park dyke system and wetland management practices [12]. The changes involve lowering the dyke, controlling the invasive species, increasing hydrological and biological monitoring and enforcing against illegal encroachments. The main impact on local farmers is reduced rice profit due to prolonged flood duration in adjacent farms [5]. In the present study, this cost was calculated using a production function approach. The benefit of wetland conservation was estimated using a choice modelling approach.

This paper comprises five sections. Following this introduction, Section 2 details the estimation of cost associated with the proposed program in the form of reduced rice profit of local farmers. Section 3 reports the process of valuing benefits derived from improved wetland biodiversity. Section 4 discusses the results of the cost-benefit analysis of the proposed program. The paper ends with the conclusion that the wetland conservation program would generate a net social benefit.

2. ESTIMATING THE COST OF REDUCED RICE PROFIT

Rice production function approach

The production function (PF) approach is used to estimate market values forgone as a result of government intervention to improve environmental qualities [13]. The complexity of the PF approach can range from simply examining the PF for single use systems to examining input and output market effects associated with multiple use systems [14]. In general, there are three types of models used in the PF approach: a traditional model, an optimal model and an econometric model [15].

The main algebraic forms of PF estimations are translog, which include quadratic polynomial and square-root quadratic polynomial, and Cobb-Douglas [16]. When there are three or more independent variables, it is generally best to use the Cobb-Douglas function [16]. This is particularly true for rice production in the MRD [17]-[18].

In this study, a static PF approach was used to estimate changes in rice producer surplus as a result of lowering the dyke surrounding Tram Chim. Current market prices for rice were used under the assumption that any changes in rice output in the Plain of Reeds would be insufficiently large to affect the market prices of inputs and rice. That is, it was assumed that resource use and prices, and thus consumer surplus remained constant. By using this approach, the effects of changes in flood duration resulting from the changes in wetland management on rice profits were estimated.

A literature search on the relationship between rice production and water management regimes was conducted to make sure that all relevant variables would be included in the farm survey questionnaire and to examine the suitability of using existing rice production models for this research. It was found that there has been considerable research on this topic. However, none of the existing models of rice production included a flood duration variable that could be used in this study [5].

Among the rice production function models available in the literature, the model reported in [17] was deemed to be the most relevant to this research because it had been recently developed based on Vietnam's Mekong Delta data. For this research, this model was extended to include a flood duration variable. The model takes the basic form:

$$Y = f(L, K, I, F, E) \quad (1)$$

where

Y is the output of rice of a household in the studied year of 2005 (tones/ha)

L is labour input (human working hours/ha)

K is capital input (machine working hours/ha)

I is a vector of material inputs such as seeds (kg/ha), fertilizers (kg/ha) and pesticides (100ml/ha)

F is flood duration in rice farms (days)

E is the vector of other factors such as household characteristics, farming conditions and environmental factors.

A Cobb-Douglas functional form [17]-[18] was applied as follows:

$$\ln(Y) = \alpha 0 + \alpha 1 \ln(A) + \alpha 2 \ln(L) + \alpha 3 \ln(K) + \alpha 4 \ln(I) + \beta 0 F + \beta 1 E1 + \beta 2 E2 + \beta 3 E3 + \beta 4 E4 + \beta 5 E5 + \beta 6 E6 + \beta 7 E7 \quad (2)$$

where

Y, A, L, K, I, F are the same as in the above equation and

$\alpha 1$ is the model constant

$\alpha 2$ is the coefficient of labour,

$\alpha 3$ is the coefficient of capital

$\alpha 4$ is the coefficient of material inputs

$\beta 0$ is the coefficient of dykes

E1 is farming experience (years)

$\beta 1$ is the coefficient of farming experience

E2 is training on rice production (yes =1, no=0)

$\beta 2$ is the coefficient of training on rice production

E3 is the soil conditions (fertile soil=1, other soil=0)

$\beta 3$ is the coefficient of soil conditions

E4 is the farm fragmentation, represented by the number of farm plots

$\beta 4$ is the coefficient of farm fragmentation

E5 is irrigation conditions, represented by the distance to water sources (m)

$\beta 5$ is the coefficient of irrigation conditions

E6 is disasters during studied year of 2005 (yes=1, no=0)

$\beta 6$ is the coefficient of disasters

E7 is the relative location of farms (upstream of the Mekong River=1, downstream of Mekong River=0)

$\beta 7$ is the coefficient of the relative location of farms

Based on these models, the effect of flood duration on rice output was estimated.

Farm survey

A draft PF farm survey questionnaire was developed based on previous studies on rice production in the MRD [17]-[18]. A pre-test was conducted in 27 households in three villages in Dong Thap Province.

The two main objectives of selecting the sites studied were representativeness and heterogeneity. Representativeness means that the studied sites need to represent rice production and flood duration in the MRD. Heterogeneity means that the studied sites need to have sufficient variation in rice production input and output conditions under different flood duration to produce a meaningful production function estimate.

To achieve these objectives, a mixture of probability sampling techniques was adopted. The use of this mixture of sampling techniques aimed to maximise the advantages and minimise the disadvantages of each of the sampling techniques. It involved three stages. First, four districts were selected from the list of 29 districts in the Plain of Reeds, using a simple random sampling technique. Second, each selected district was stratified into two strata: high dyke and low dyke. Third, 34 households in each stratum were selected using a systematic sampling technique. Using this technique, enumerators approached every 50^{th} households in the stratum. Households were the sample units with a member of the household who was over 18 years old being the unit of inquiry.

Using this sampling strategy, the following four districts were selected: Tam Nong and Thap Muoi in Dong Thap Province, Thu Thua in Long An Province and Cai Be in Tien Giang Province. The survey was conducted in June and July 2006. A total of 241 usable questionnaires were collected. The farm survey was conducted across 272 households. Socio-demographic characteristics of the sample were checked against those of the population of the Plain of Reeds. It was found that there were no significant differences between the sample and the population. Therefore, the sample could be considered to be representative of the population.

Results

The correlation matrix method was used to check for multicollinearity problems. No correlation of more than 70 per cent between the independent variables was found. That is, there was no multicollinearity in the independent variables. Definitions and descriptive statistics of the variables are presented in Appendixes 1 and 2 respectively.

The Cobb-Douglas functional form was estimated[1]. Heteroscedasticity was detected using the Breusch-Pagan method and corrected using feasible generalised least squares [19]. The model has an acceptable explanatory power with the adjusted R^2 being 0.42. The significant variables have a priori expected signs.

It was found that an increase by one day of flooding reduces rice productivity by 0.06 per cent, significant at the five per cent level (Table 1). The model also shows that the increase by one working hour per hectare per year increases rice productivity by six per cent. An additional one year of rice farming experience increases rice productivity by 0.3 per cent. Using the method for interpreting coefficients of the dummy variables in semilogarithmic equations [20], it was found that fertile soil increases rice productivity by 12.7 per cent. Similarly, rice productivity in upstream areas is 17.4

[1] Both Cobb-Douglas and translog functional forms were estimated. Following the method proposed in [17], the null hypothesis of a Cobb-Douglas functional form of the production function was tested against the translog functions. The resulting test statistics was $\chi^2_{20} = 29.3$ compared to a critical value of 31.4. This suggests that the Cobb-Douglas is preferred to the translog form.

higher than in downstream areas. Disasters reduce rice productivity by 5.1 per cent.

Based on findings reported in Table 1, the following equation was used to calculate impacts of changes in flood duration due to lowering park dykes on rice productivity.

$$\text{Ln (rice)} = 1.37 + 0.06*\ln(\text{labour}) - 0.0006*\text{flood} + 0.12*\text{soil} - 0.05*\text{disaster} + 0.003*\text{experience} + 0.16*\text{location} \quad (3)$$

It was predicted that the lowering of Tram Chim park dykes would prolong flood duration in adjacent areas by 16.2 days [5]. Using equation 3, it was estimated that the lowering of the park dyke would decrease the rice productivity on average by 0.06 tonne per ha per annum. With the average rice profit forgone being VND 1.24 million per tonne [5], it was estimated that the lowering of the Tram Chim park dykes would reduce rice profit on average by VND 0.07 million per ha per annum.

Table 1. Impacts of Flood Duration on Rice Productivity

Variable	**Coefficient (Standard error)**
Constant	1.37*** (0.24)
Labour	0.06*** (0.01)
Capital	0.003 (0.014)
Fertilizer	0.03 (0.02)
Seed	0.04 (0.03)
Pesticide	0.028 (0.018)
Herbicide	0.019 (0.02)
Flood	-0.0006** (0.0003)
Soil	0.12*** (0.02)
Plot	-0.009 (0.008)
Disaster	-0.05*** (0.01)
Irrigation	-0.0008 (0.0007)
Experience	0.003*** (0.0008)
Training	-0.04 (0.03)
Location	0.16*** (0.04)
Statistic summary	
R-square	0.45
Adjusted R-square	0.42
Std error of regression	0.18
Included observations	227

Note: *** denotes statistical significance at 1% level, ** denotes statistical significance at 5% level and * denotes significance at 10% level.

3. ESTIMATING BENEFITS OF IMPROVED WETLAND BIODIVERSITY

Choice Modelling

Choice Modeling (CM) is a stated preference technique used to estimate non-market values. CM involves asking survey respondents to choose their most preferred resource use option from a number of alternatives [21]. In CM, samples of choice sets or choice scenarios are drawn from all combinations of possible choice sets and presented to respondents. The objective of CM is to quantify a person's willingness to bear a financial cost to achieve some potential environmental improvement or to avoid some environmental harm. Using CM, not only the value of changes in individual attributes but also the value of aggregate changes in environmental quality are estimated [22].

CM is based on the Lancastrian consumer theory that utility or value is derived from attributes of a particular good or situation [13]. Under this theory, preferences are not based on single attributes but are based jointly on several attributes. In addition, CM is based on the theory of information processing in decision making [23]. This theory indicates how individuals trade-off different levels of attributes and form preferences over different alternatives. CM is also consistent with random utility theory [23]. In RUT, utility is a latent construct that exists in the mind of the consumer but cannot be observed directly. By using CM, some of this unobservable consumer utility can be explained, while some proportion remains unexplained.

To estimate the choice probabilities using Conditional Logit (CL), it is assumed that the random components are independently and identically distributed (IID). When the data do not support IID, CL estimates might be biased. This triggers the use of other models that allow heterogeneity across respondents, for example, random parameter logit (RPL). Discussions of the CL and RPL are detailed in [24].

Research Design and Survey Implementation

Detailed discussions of the questionnaire development and survey implementation are reported in [9]. Briefly, the questionnaire has the following five sections. First, it introduced Tram Chim National Park and its biodiversity loss due to poor wetland management. Second, it described the proposed plan for wetland improvement and the outcomes of different management options. Third, it explained that to implement the plan, the government would need to raise funds to cover the costs of lowering the dyke, remove invasive species, improve hydrological and biological monitoring and pay compensation to local farmers who would suffer from subsequent changes in flood levels. Fourth, it asked respondents to select their preferred options presented in the choice sets. Each option presented several wetland and social attributes associated with a cost in the form of a one-off increase in electricity bill. Example of a choice set is in Appendix 3. Last, it collected information about the demographic characteristics of the respondents.

Personal interviews were conducted in three sub-samples of respondents: Cao Lanh, Ho Chi Minh City

and Ha Noi. These sub-samples represented three zones: inside the MRD, on the edge of the MRD, and outside the MRD respectively. The number of useable questionnaires collected was 917. The samples were found to have bias toward younger and better-educated males [9].

Results

LIMDEP was used to run CL and RPL models of the choice data. The RPL was preferred to CL for two reasons [9]. First, the RPL showed heterogeneity in respondents' preference. Second, it had a better model fit, with a higher pseudo-R square and significantly lower log-likelihood estimates, as opposed to the CL model. Therefore, the RPL (Appendix 4) was used for further analysis. Details of the model and its variables are reported in [9].

The willingness to pay (WTP) or compensating surplus for a specific management change scenario was calculated for each sub-sample. The status quo and the change scenario in three years' time predicted by wetland managers were:

- Status quo scenario: 50% healthy vegetation, 150 Sarus Cranes, 40 fish species and no farmers affected.
- Change scenario: 55% healthy vegetation, 250 Sarus Cranes, 40 fish species and 400 households to be affected.

The WTP were estimated using the following formula:

$$WTP = - (1/\beta monetary)*(V1 - V2)$$

where

V1 is the value of the indirect utility associated with the status quo,

V2 is the indirect utility associated with the specific levels of the attributes describing the changed resource allocation, and

βmonetary is the coefficient of the variable cost [21].

The indirect utility of the average respondent was calculated using the coefficients and the sample means of the significant variables. As shown in Table 2, the average WTPs for the proposed program in Ha Noi and Ho Chi Minh City were VND 93,910 (USD 5.9), VND 78,178 (USD 4.9) respectively. On the other hand, respondents in Cao Lanh were not willing to pay for the program[2]. This is because for respondents in Cao Lanh, the marginal values for the wetland attributes were not large enough to compensate for the marginal values of reducing the number of local farmers who would be negatively affected [5].

Hence, it can be surmised that the inverse distance decay function arose because although the local people in Cao Lanh desire the benefits of wetland improvement, they also know that they will be most affected by the costs of such a program. The costs include not only increased electricity bills but also potential increased prices of rice and other agricultural products due to farmers' losses after the change in current wetland management practices. Because Cao Lanh is closer to the affected areas than Ho Chi Minh and Hanoi, the respondents in Cao Lanh would bear these costs more directly. The inclusion of these costs in respondents' minds when making their choice would have reduced the WTP of local respondents.

Table 2. Willingness to Pay for Wetland Conservation

	Cao Lanh	Ho Chi Minh	Ha Noi
Distance from Tram Chim	40 km	250 km	2,000 km
Compensating surplus (VND)	-13,304 (7,254 to -34,691)	78,178 (42,836 to 131,997)	93,910 (47,541 to 152,469)
Compensating surplus (USD)	-0.8 (0.5~-2.1)	4.9 (2.7 to 8.3)	5.9 (3 to 9.5)

Note: Confidence intervals at 95%, calculated using Krinsky and Robb (1986) bootstrapping procedure, are given in brackets.
'_' denotes the WTPs that are not significantly different from zero at the 95% level.

4. DISCUSSIONS

Based on findings in Sections 2 and 3, a cost-benefit analysis for the proposed wetland conservation program was conducted. As discussed in Section 2, the rice profit would reduce by VND 0.07 million per ha per annum under the proposed program. With 30,000 ha that would be affected, the total loss in rice profit would be VND 2,100 million or about USD 131,250 per year, assuming that input choices and costs do not change. Other costs would include biological and hydrological monitoring expenses and engineering costs for dyke reconstruction. The total estimated cost for a five-year program would be about USD 1.9 million [12]. Using the discount rates of 5 and 15 per cent, the higher bound and lower bound present costs were estimated at USD 1.65 and USD 1.27 million respectively.

The benefits of the program were calculated based on the assumption that the benefits would be enjoyed by 0.3 million households living on the edge of the MRD and 0.3 million households living outside the MRD. The aggregation was conducted using two approaches. In the first approach, it was assumed that 30 per cent of non-respondents had the same WTP of the respondents, following the method proposed by [25]. In the second approach, non-respondents were assumed to have zero WTP, following [26]. The two approaches provided higher and lower bounds of aggregate willingness to pay values. The higher and lower bound WTPs for the populations were about USD 2.23 million and USD 1.8 million respectively. These WTP estimates are the

[2] The confidence intervals at 95% of WTP of Cao Lanh respondents included zero, indicating that the WTP of the two sub-samples were not significantly different from zero.

present values of benefits of the wetland conservation, because being asked to state values for wetland improvement in three years, the respondents had already discounted the values when selecting choices.

The lower bound net social benefit was calculated using the lower bound WTP and higher bound cost. Similarly, the higher bound net benefit was estimated by subtracting the lower bound cost from the higher bound WTP. The net social benefit of the program, therefore, ranged from USD 0.15 million to USD 0.96 million. This suggests that the proposed wetland conservation program would improve social welfare. It should be noted that the results of the CBA for the same proposed program varying the assumptions about the predicted outcomes, the number of beneficiaries and discount rates also showed positive net social benefits [9]. This suggests a robust finding about a potential net social benefit generated from wetland conservation.

5. CONCLUSION

This study investigates the changes in social welfare resulting from changes in current wetland management practices by conducting a case study of cost-benefit analysis of the proposed plan for wetland conservation of Tram Chim National Park in the MRD. To this end, two main aspects were assessed. First, the costs that the change in the wetland management would impose on local farmers due to lost rice production; and secondly, the benefits that would result from the wetland biodiversity improvements. The impact of changes in the wetland management on rice profits was assessed using a production function model. Estimates of the benefits of improved wetland biodiversity were carried out using a choice modelling technique.

It was found that the benefits of the plan under review would outweigh its costs. The biodiversity benefits of the changes outweigh the costs of reduced rice production. More specifically, the estimated net social benefit of the program ranged from USD 0.15 million to USD 0.96 million. This indicates that society as a whole would benefit from the proposed changes. However, individual farmers will suffer a loss of income. These individual farmers should be compensated. Information presented in this study can be used for determining the level of compensation paid to the local farmers.

The positive net social benefit of the proposed wetland improvement program indicates that wetland biodiversity conservation would improve social welfare. This supports the proposed plan of using public funding for conserving the wetlands. Indeed, the funding for implementing the wetland conservation program can be mobilised from urban populations on the edge of and outside the MRD, as they indicated their positive WTP for the program. This is in line with the Government of Vietnam's policy of socialising environmental protection, which involves mobilising funding for environmental protection from all sources including individuals.

The provision method of an increase in the electricity bill can be used, although further studies on alternative provision methods such as donations or taxes would provide more insights into this issue. The funding will be used for compensating the local farmers for their forgone incomes as calculated in this study. However, in the long run, the farmers may benefit from the wetland conservation conversion due to improved fish stock, reduced invasive mimosa pigra and eco-tourism [5]. These potential benefits can be used as incentives for farmers to accept the changes in the current wetland management practices but have not been evaluated in this study.

In conclusion, this study has showed that the proposed wetland biodiversity conservation strategy for Tram Chim would improve social welfare. Similar studies investigating environmental benefits and costs associated with changes in current environmental practice would be helpful in assisting policymaking so that better-informed decisions can be made to improve the wellbeing in the region.

ACKNOWLEDGMENT

The authors thank Vic Adamowicz, University of Alberta and David Glover, former director of EEPSEA for their helpful comments and suggestions about study designs and data analyses. Assistances of Vietnamese colleagues in data collection are fully acknowledged.

REFERENCES

[1] Vietnam Environmental Protection Agency, International Conservation Union and Mekong Wetland Biodiversity Program (2005). Overview of Wetland Status in Vietnam Following 15 Years of RAMSAR Convention Implementation, Vietnam 2005.

[2] Torell, M. and Salamanca, A.M 2003. Wetlands Management in Vietnam's Mekong Delta: an overview of pressures and responses. In M. Torell, A.M. Salamanca, B.D. Ratner (eds.), *Wetlands Management in Vietnam: issues and perspectives*, Penang: World Fish Centre, pp. 1-8.

[3] Buckton, S.T.; Cu, N.; Quynh, H.Q.; and Tu, N.D. (1999). The conservation of key wetlands site in the Mekong Delta. Birdlife International Vietnam Conservation Program Report No. 12, Birdlife International Vietnam Program, Hanoi, Vietnam.

[4] World Bank 2002. *Vietnam Environment Monitor 2002*, the World Bank Groups, Washington D.C.

[5] Do, N.T. (2007). Impacts of dykes on wetland values: a case study in the Plain of Reeds, Vietnam's Mekong River Delta. Research Report, Economy and Environment Program for Southeast Asia (EEPSEA), Singapore.

[6] Barbier, E.B.; Acreman, M.; and Knowler, D. 1997. *Economic Valuation of Wetlands: a guide for policy makers and planners*, Gland, Switzerland: Ramsar Convention Bureau.

[7] Emerton, L. and Bos, E. 2004. *Counting Ecosystems as an Economic Part of Water Infrastructure*, Gland, Switzerland: IUCN.

[8] United Nations Development Program; International Conservation Union; Mekong River Commission; and Global Environment Facility

(2005), Integrated water and fire management strategy Tram Chim National Park, unpublished report, Vietnam.
[9] Do, N.T. and Bennett, J.; (submitted for publication). Estimating Wetland Biodiversity Values: A choice modelling application in Vietnam's Mekong River Delta.
[10] Pacovsky, J. (2005), 'Restoration of wetlands in the Tram Chim nature reserve', retrieved on May 13, 2005 from the world wide web: http://horticulture.coafes.umn.edu/vd/h5015/01papers/pacovsky2.htm.
[11] Hung, N.V. (2004). Tram Chim needs Cranes. Vietnam Environmental Protection Agency. Vietnamese Environmental Protection Journal. Retrieved December 12, 2005 on the world wide web: http://www.nea.gov.vn/tapchi/Toanvan/05-2k5-24.htm.
[12] Tram Chim Management Board (2005). Tram Chim National Park Five Year Work Plan. Unpublished report. 75 pp.
[13] Garrod, G. and Willis, K. 1999. *Economic Valuation of the Environment*. Cheltenham: Edward Elgar.
[14] Grafton, R.Q.; Adamowicz, W.; Dupont, D.; Nelson, H.; Hill, R.; and Renzetti, S. 2004. *The Economics of the Environment and Natural Resources*. Massachuset: Blackwell Publishing.
[15] Hanley, N. and Spash, C.L. 1993. *Cost and Benefit Analysis and the Environment*. London: Edgar Publisher.
[16] Dillon, J. L. and Hardaker, J.B. 1993. *Farm management research for small farmer development.* Rome: Food and Agriculture Organisation of the United Nations.
[17] Kompas, T. (2004). Market reform, productivity and efficiency in Vietnamese rice production. International and Development Economics Program. Crawford School of Economics and Government, Australian National University Working papers No 04-4. 36 pp.
[18] Nguyen, Q.H. 2006. Production frontier for rice production in Vietnam. Crawford School of Economics and Government, Australian National University, Canberra, Australia. PhD thesis.
[19] Greene, W.H. 2003. *Econometric Analysis*. Prentice Hall: Upper Saddle River.
[20] Halvorsen, R. and Palmquist R. 1980. The interpretation of dummy variables in semi-logarithmic equations. *American Economic Review* 70(3): 474-475.
[21] Bennett, J.W. and Adamowicz, W. 2001. Some fundamentals of environmental choice modelling. In J. Bennett and R. Blamey (ed.), *the Choice Modelling Approach to Environmental Valuation*. Cheltenham, UK: E. Elgar. 37-69.
[22] Morrison, M.; Bennett, J; and Blamey, R. 1999. Valuing improved wetland quality using choice modelling. *Water Resources Research* 35: 2805-2814.
[23] Adamowicz, V.; Louviere, J; and Swait, J. (1998). Introduction to attribute-based stated choice methods. Report to Resource Valuation Branch, Damage Assessment Centre, National Oceanic and Atmospheric Administration- US Department of Commerce, January 1998.
[24] Hensher, D.A.; Rose, J.M and Green, W.H. 2005. *Applied Choice Analysis: a primer*. Cambridge: Cambridge University Press.
[25] Morrison, M. 2000. Aggregation biases in stated preferences. *Australian Economic Paper* 39: 215-230.
[26] Boyle, K.J. and Bishop, R.C. 1987. Valuing wildlife in benefit-cost analysis: a case study involving endangered species. *Water Resources Research* 23: 943-950.

APPENDIXES

Appendix 1. Definitions of Variables in Rice Production Function

Variable	Definition
Rice	Rice yield per hectare per year
Capital	The operating duration of machines in all stages of rice production
Labour	The number of man-hours for rice production
Fertilizer	Amount of fertilizer used
Seed	Amount of seed used
Pesticide	Amount of pesticide used per year
Herbicide	Amount of herbicide used per year
Experience	The household's experience in rice cultivation
Training	Have attended training on rice production
Soil	Soil quality
Plot	Number of plots, representing farm fragmentation
Irrigation	Distance to irrigation sources
Disaster	Disasters that happened during the year, including pests, droughts and floods
Location	Location of the farms (used for capturing all other factors that might have impact on rice productivity)
Flood	Duration of floods per year

Appendix 2. Descriptive Statistics of Variables in Rice Production Function

Variable (unit)	Mean	Max	Min	S.D
Rice (tonnes/ha/year)	14.5	26.7	4.3	3.1
Land (ha)	2.3	12	0.5	2.1
Capital (hours/ha/year	58.7	330	6	56.4
Labour (hours/ha/year)	1,024	5,238	82.4	699.1
Fertilizer (kg/ha/year)	1126	4,680	107.1	539.4
Seed (kg/ha/year)	373.3	900	25.7	157.5
Pesticide (100ml/ha/year)	60.9	360	8	67.8
Herbicide (100ml/ha/year)	54.3	272	3	50
Experience (years)	25.4	66	5	13.2
Training (yes=1, no=0)	0.7	1	0	0.5
Soil (fertile soil=1, other soil=0)	0.75	1	0	0.4
Plot (number of plots)	2.2	20	1	1.8
Irrigation (m)	12.6	50	1	14.7
Disaster (yes=1, no=0)	0.37	1	0	0.5
Location (upstream=1, downstream=0)	0.57	1	0	0.49
Flood (days)	33.6	120	0	38.8

Appendix 3. An Example of a Choice Set

Scenario 1: Suppose options A, B and C are the ONLY ones available.

The following factors will vary under different management options	**Option A (status quo - no change)**	**Option B**	**Option C**
Percentage of area having healthy vegetation	50%	60%	80%
Number of Sarus Cranes visiting the wetlands per year	150 birds	300 birds	450 birds
Number of fish species	40 species	50 species	70 species
Number of local households worse-off	0	900	900
One-off change in your current monthly electricity bill	No change	Increase by VND 10,000	Increase by VND 50,000

If there were a vote (in which if the majority votes for the option you choose, then that option will be selected), you would vote for:
TICK ONE BOX ONLY

Option A ☐
Option B ☐
Option C ☐

Appendix 4. Random Parameter Logit Model

	Ha Noi	Ho Chi Minh	Cao Lanh
Random parameter			
Vegetation (mean)	0.143E-01*** (0.453E-02)	0.137E-01*** (0.508E-02)	0.404E-01*** (0.116E-01)
Birds (mean)	0.200E-02*** (0.416E-03)	0.116E-02** (0.483E-03)	-0.109E-02 (0.130E-02)
Fish (mean)	0.289E-02 (0.624E-02)	0.301E-03 (0.720E-02)	0.160E-01 (0.133E-01)
Farmers (mean)	-0.162E-02*** (0.286E-03)	-0.111E-02*** (0.268E-03)	-0.377E-02*** (0.961E-03)
Non-random parameter			
Alternative Specific Constant (ASC)	0.12 (0.6)	0.862E-01 (0.580)	-0.896 (1.027)
Cost	-0.157E-04*** (0.281E-05)	-0.171E-04*** (0.245E-05)	-0.313*** (0.623)
ASC*age	0.400E-01*** (0.118E-01)	0.231E-01** (0.958E-02)	0.244E-01 (0.160E-01)
ASC*gender	-0.5** (0.238)	0.682*** (0.228)	0.948 (0.365)
ASC*education	3.112*** (0. 506)	0.324E-01 (0.275)	1.106* (0.594)
ASC*income	0.923E-04*** (0.441E-04)	-0.427E-04 (0.289E-04)	0.449E-03*** (0.157E-03)
ASC*knowledge	0.759** (0.251)	0.277 (0.231)	0.262 (0.505)
ASC*visit	1.072 (0.917)	0.127 (0.573)	-0.524 (0.441)
ASC*option	0.237 (0.252)	0.989*** (0.256)	0.072* (0.396)
ASC*bequest	-0.171 (0.269)	1.12*** (0.256)	1.989*** (0.652)
Cost*education	-0.275E-02 (0.286E-02)	-0.622E-02* (0.358E-02)	-0.501E-02 (0.689E-02)
ASC*cheaptalk	-0.913*** (0.275)	-0.109 (0.220)	n.a.
Standard deviation			
Vegetation	0.45E-01*** (0.131E-01)	0.150E-01 (0.166E-01)	0.381E-02 (0.185E-01)
Birds	0.213E-02* (0.191E-02)	0.105E-03 (0.360E-02)	0.724E-02*** (0.238E-02)
Fish	0.419E-01* (0.225E-01)	0.124E-01 (0.273E-01)	0.191E-01 (0.381E-01)
Farmers	0.361E-03 (0.533E-03)	0.354E-04 (0.506E-03)	0.139E-02 (0.115E-02)
Model statistics			
Log likelihood	-1216.700	-648.145	-454.502
Pseudo-R2	0.22	0.21	0.22
Observations	1430	765	540

Note: Standard deviations are in parentheses. *** denotes statistical significance at 1% level, ** denotes statistical significance at 5% level and * denotes significance at 10% level.

Indian Trade Policies and Performance of Nepalese Agriculture

B.N. Acharya

Abstract— *This paper infers that Indian trade policy plays a crucial role for Nepalese producers and farmers. Due to the geographic proximity and socio-political relationship with India, Nepalese economy remains indo-centric. Trade intensity of Nepal with India is about 20 times higher with other South Asian Association of Regional Cooperation (SAARC) countries. The long porous border has been accepted by the people of both the countries as a measure of free flow of goods and people. The hurdle of the soft boarder for a small country like Nepal is to price the goods independently because of the age old illegal cross boarder trading. Highly protected Indian agriculture sector makes Nepalese product expensive and raises the issue of competitiveness in price. It is very difficult for Nepal to have independent output price policy and the market has not been able to function independently. Custom union could be one viable option to promote agricultural market. Replicating the success stories of other small-big country partnership could be another alternative. Since Nepal has been importing majority of primary and secondary products, consumer price could stabilize with appropriate reform and consumer get benefit to some extent. Nepalese trade sector is, hitherto, dependent upon Indian policies and market situation than its own production and economy. The massive reform in Indian agriculture sector provides space for hope. Nepal should more liberalize its trade not roll back as an alternative back to subsidy regime to compete with Indian, regional or international products.*

Keywords— **Agricultural trade, informal trade, liberalization, subsidy, tariff, trade policy.**

1. INTRODUCTION

Nepal, a heavily trade dependent economy, is also one of the most open economies of South Asia. Trade to GDP ratio is 50%, an average tariff rate is about 8% and there is virtually no quantitative restriction of import trade in Nepal [3]. Despite its geographical constraints and the dependence of three-fifth population in agriculture, Nepal has comparative advantage in agricultural products and in a few other manufacturing segments and sectors.

A country remains competitive in global markets as long as it continues harnessing the resources of comparative advantage in producing and exporting its products to other countries, even if the country has lower productivity in producing those goods. The gains from trade and global integration of a country depend largely on competitiveness of that country's economy. Competitiveness is a key concern for Nepalese real sector. Nepal's low labor wage places the country in a comfortable position in manufacturing labor intensive products even in a condition of lower labor productivity. This essentially includes the cost of production to cost of marketing and processing.

With the advent of periodic development planning in 1956, Nepal followed restrictive and import substitution policies with the rest of the world while it had open trade relation with its large neighbor India. Nepal's trade performance over recent years has been highly inconsistent, reflecting the unnerving constraints to realization of its potential. Even with structural change in its merchandise exports, Nepal remains dependent on a relatively small basket of exports and a few destination markets. A significant share of its exports has been encountering the pressure of gradually decreasing world demand. This poses challenge for restructuring of its export basket.

More than a decade long conflict affected Nepal's economic performance through different channels. Economic growth slowed, thousands of people have been killed, physical infrastructure has destroyed, thousands of people have been displaced, economic disruptions have increased and development expenditures have declined sharply. Private investment has also declined significantly. Ra, Sungsup and Bipul Singh [9] found that the economic growth loss attributed to the decline in development expenditure ranges from 1.7% to 2.1% per annum. These all has adversely affected the agricultural sector as well. However, various conflicts related studies[1] have not specified about the agricultural sector and its impact on agricultural production.

With regard to trade policy, Nepal has significantly opened up trade in the past decade and present trade policy is guided by its regional free trade arrangements and basically by WTO. In addition, the high transaction costs associated with formal cross-border trade with

B.N. Acharya is currently student at The University of Tokyo, Department of Agriculture and Resource Economics, Yayoi 1-1-1, Bunkyo-ku, Tokyo 113-8657. Email: aa57402@mail.ecc.u-tokyo.ac.jp.

Research funding from Fuji Xerox Setsutaro Kobayashi Memorial Fund is gratefully acknowledged. Expressions are entirely those of author and any error too.

[1] For details, please see Deraniyagala, Sonali (2005), Political Economy of Civil conflict in Nepal; Parwez, Md. Shahid (2006), An Empirical Analysis of the Conflict in Nepal; and Morshed, S. Moansoob and Scott Gates (2003), Spatical-Horizontal inequalities and the Maoist Insurgency in Nepal.

India is diverting towards informal and unaccounted trade significantly over the years. Reduction of these costs at the border will be an important part of trade facilitation between the two countries. Strengthening Nepal's capacity to administer and implement trade policy will require institutional strengthening across a range of public and private agencies. Emphasis should also be given on improving the process of trade policy formulation.

Competitiveness of Nepalese agriculture sector largely depends on price effect of all tradable inputs like fertilizer, insecticides and non-price effect of non-tradable like credit, irrigation, and knowledge also equally affect the competitiveness. Nepal largely depends on Indian market for major agricultural as well as merchandise trade due to its geography, culture and social affinity. Since India is the convenient market for Nepal, the relevant measure (effective rate of protection) affects competitiveness of Nepalese agricultural products. Nepal's productivity and competitiveness had shown some increment over the 1990s but these improvements were not sustained by the end of the decade.

The paper reviews the trade situations especially agricultural trade in response to the Indian trade policy vis-à-vis liberalization in Nepal. Section 2 discusses about trade policy reform in Nepal. Section 3 explains the trade situation and determinants of trade. Section 4 depicts the agricultural sector reform. Section 5 briefly talks about the agricultural trade situation in Nepal. Section 6 and 7 discuss about the Indian trade policies ant its implication to Nepalese agriculture sector and the paper concludes with concluding remarks in section 8.

2. INITIATION OF TRADE POLICY REFORM

Nepal's major trade reform took place in the early 1990s after the restoration of multi party democracy and India's economic reform, although structural adjustment program was launched in 1986. In 1990, Nepal kicked off market oriented trade policy reform that opened a new vista on economic integration and trade. The reforms unleashed the barriers of restricted trade and decontrolled pricing. The other salient features were the end of licensing and advent of deregulation. The foreign exchange regime was also liberalized and currency trading was made open.

Nepal is *de facto* integrated with India for trade. High cost of access to the third country markets and India as the only transit point, the country took no pain to diversify its trade. Moreover, conventional trading by petty merchants were benefitted by the long, porous and easy boarder. The nearest port for access to the world economy is about 900 km, which is far expensive and time consuming due to poor infrastructure in neighboring India. Moreover, Nepal has granted almost free access to Indian goods ever since its first agreement with British India in 1923. The treaties with independent India were first signed in 1950, which has been subsequently renewed with the latest one in March 2007. These all affect Nepal's initiation of trade liberalization and reform by compelling it to adopt protection and design incentive structure similar to that of India [5]. Lower tariff structure in Nepal provide incentive for trade deflection to India of the goods imported by it from the rest of the world causing drain in its foreign exchange reserves. If Nepal provides export incentives, Indian goods will be re-exported causing fiscal imbalances.

On the process of tariff reform, custom tariff has been reduced, rationalized and simplified since the early 1990. The tariff rates fell from 245 % in fiscal year 1980s to 110 % in July 1994 then further down to 80 % in 1997/98. The number of tariffs categories also fell from more than 100 in 1980s to only 5 in the fiscal year 1995/96 and then to 7 in 1998/99. The prevailing tariff structure include five basic standard rates (5, 10, 15, 25, 40), with the larger number of import items within the custom duty of 10 – 20 % and having a significant number of tariff lines with zero duty. These measures led to decline in tariff protection. Both the trade weighted nominal rate of protection (NRP) as well as effective rate of protection (ERP) fell substantially. The trade weighted NRP fells from about 80 % in the early 1980s to about 9 % in 1996.The distribution of tariff rates in 1990 and 2002 are presented in Table 1, which shows that the recent tariff rates close to 14 %.

Table 1. Distribution of Tariff Rates

Tariff Rates	No. of tariff items 2002	1990 (% in each category)	2002 (% in each category)
0 - 5	1,288	7.4	0.8
5-10	1,731	8.4	22.1
10-15	1,729	2.8	32.2
15-25	1,582	2.7	29.4
25-40	543	37.1	10.1
40-50		0	4.4
50-80		38.8	0.5
80 plus	52	2.9	0.04
Total	5,374	100	100
Average		**39.8**	**13.8**

Source: World Bank, Trade and competitiveness study, 2003.

There has also been substantial liberalization in non-tariff barriers. These include elimination of quantitative restrictions on imports and phasing out import license auction and replacing them with appropriate tariffs. In an attempt to reduce anti-export bias, the export duty drawback scheme and the bonded warehouse facilities were introduced. The export service fee was also reduced to 0.5 % of the export value from 2 % in 1993/4. The government has also gradually reformed the export floor price system.

3. DETERMINANTS AND TREND

Nepal's trade-to-GDP ratio increased over the last two decades, from 23% during the 1980s to more than 50% by the end of 1990s. The improved business environment greatly augmented rapid exports growth (by 30% annually from 1991 to 1995), driven mainly by

manufacturing exports, especially carpets and garments. In the case of garments, export growth came initially from the spillover of Indian exports, due to quota limitations for India. Additionally, improved profitability and increased willingness of domestic producers to enter the industry also stimulated the growth of Nepalese garments exports.

Within manufacturing, Nepal's export basket is narrowly concentrated in a few products: garments, carpets, and *pashmina*[2]. These accounted for more than 50% of total exports in the late 1990s. Furthermore, they depend on limited external markets. Carpets are exported primarily to Germany and garments to the U.S. Just after trade liberalization, in 1992, export of textile and clothing was increased by 80 and 60 % respectively. Following the signing of a renewed bilateral Trade Treaty in 1996, Nepal has been exporting new manufacturing products, all destined for India. These include vegetable ghee, toothpaste, toilet soap, acrylic yarn, copper rod, zinc oxide, MS pipe, *Hazmola*[3], *Chyawanprash*[4], noodles and biscuits. Other exports comprise a basket of about 20 agricultural products and consumer goods, which route primarily to India. After trade policy reform and implementation of the 8th five years plan in 1997, foot ware and textiles were the largest exportable products and their export increased by average 20 %. Petroleum and other non-specified manufacturing products are the major imported items. The structure of export was same in 2003 as well.

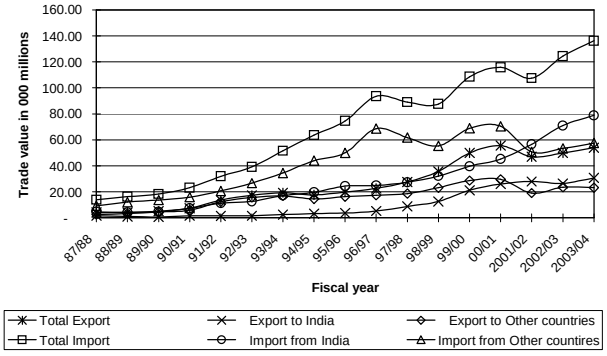


Fig 1: Nepal's Trend of Export before and after its trade liberalization

Note: Export is on a F.O.B basis and Import is on C.I.F. basis

Source: Central Bureau of Statistics, 2005

In the last decade, Nepal's dependence on the same few markets has also increased. At present, 90% of its total goods are exported to India, Germany, and the U.S.; of the three, India is the most important. Long porous borders, free movement of people and capital, and the special regime of trade and payments between two countries are the major factors responsible for export enhancement. Nepal's dependence on exports to India has recently increased sharply (more than 50%) due to the preferential trade treaty, and a sharp slowdown in exports has been observed to other key markets due to elimination of the multi fiber arrangement (MFA) quota. Also the country has not been able to proliferate businesses in regional markets. As seen in Fig.1, both export and import to and from India increased after trade policy reform and the case is similar to the other countries as well. According to the least developed countries report of UNCTAD [11], types of commodity export from Nepal remain the same as manufactured products (MAN) in the period 1980-1983 and 2000-2003. Similarly, number of commodities exported increased from 37 to 63 during the same period.

No significant changes have occurred in Nepal's import structure over time. Manufacturing constitutes the largest share of Nepal's total imports, with machinery and transport equipment the most important product. These imports underpin much of Nepal's manufacturing export capacity. Intermediate goods constitute the second largest share of Nepal's total imports, followed by food and fuels. The almost stagnant structure of imports reflects the slow and narrow growth of manufacturing activities during these periods. If industrial deepening had occurred, marked increase in imports of capital goods would have been evident. On the import front, markets are relatively more diversified. More than 10 countries supply 90 % of Nepal's imports.

4. AGRICULTURAL SECTOR REFORM

Agriculture sector is central to the livelihood of Nepalese, contributing to around 40% of the country's GDP and employing 76% of its labor force. For 90% of the poor, which comprises households in the bottom 25% of the consumption scale, agriculture is the only income-generating activity. The importance of agriculture as the single most important provider of livelihood for 90% of Nepal's population implies that the commercialization of agriculture will have a decisive effect on poverty reduction. This sector remains the focal point of overall development and it is likely to continue being the same in the immediate future. So, this sector is at the root of country's overall development. As seen from this prospective, agricultural modernizations need to be emphasized by commercialization and competitiveness.

Agriculture value added grew at an annual average rate of 2.8% during the 1990–2001 periods, slightly exceeding the average annual population growth rate of 2.3%. Agriculture growth accelerated during the second half of the 1990s to about 3.6%, with implementation of the Agriculture Perspective Plan (APP) and increased presence of the private sector in trade. The growth of agriculture sector and its composition are presented in Table 2.

[2] Pashmina refers to a type of fine cashmere wool and the textiles made from it. This wool comes from a pashimna goat, which is a special breed of goat indigenous to high altitude of Himalaya.

[3] Hazmola is a herbal medicine for digestive disorder

[4] Chyawanprash is an ancient Ayurvedic herbal preparation, widely used in India as well as in Nepal, as a rejuvenative, energizer and immunity booster. It is often called "the elixir of life" due to its alleged nutritional properties.

Table 2. Growth of Agriculture Sector in Nepal and Composition

	Growth Rates 1990/1 to 1994/5	Growth Rates 1995/6 to 1999/0	Share of Value added 1995/6 to 1999/0
Agriculture, Fishery and Forestry	1.75	2.97	100.00
Food grains	-0.88	2.32	34.70
Cash Crops	3.44	5.55	7.56
Other Crops	5.41	3.02	18.73
Livestock	1.62	3.57	28.97
Forestry	3.33	9.66	1.35
Fishery	2.51	0.26	8.70

Source: Central Bureau of Statistics of Nepal occasional paper 1/01

Nepal's agriculture-sector policies were liberalized relatively late in the second half of the 1990s; since then, however, there has been significant progress. A more comprehensive reform of agriculture sector was started in 1998-2001. Liberalization of both agriculture inputs and outputs was done by allowing them to be priced according to the market forces. Institutional reform of state-owned Agricultural Input Corporation (AIC) and Nepal Food Corporation (NFC) took place. Until 1997, the Nepal Food Corporation and the Agricultural Inputs Corporation dominated agricultural inputs trade and, to a lesser extent, food procurement, which adversely affected food supply and utilization. In 1998, government removed the monopoly of AIC allowing the private sector to import and distribute the fertilizers. Government has also removed the subsidy on fertilizer from the same time. Similarly, the role of state-owned NFC is modified to promote competitive agricultural produce markets by eliminating unnecessary market distortion including the withdrawal of subsidies in food grain distribution. Other reforms are the removal of irrigation subsidy and strengthening agriculture research, extension and training system. All price interventions have been withdrawn, with the exception of deep-tube wells in agriculture. Nepal has greatly liberalized its external trade regime for both agricultural and nonagricultural products, with average tariffs currently falling below 11%.

5. AGRICULTURAL TRADE

Nepal's exports of agricultural products also showed greater dynamism in the second half of the 1990s. Indeed, the late 1990s witnessed rapid growth in agricultural exports of items such as foods and feeds at an annual average rate of 11%, compared with 7% growth in agricultural imports. India remained the most important partner in agricultural trade, accounting for 80% of Nepal's agricultural exports and; 36% of its agricultural imports. Exports to India have been the major source of growth in agricultural exports during the second half of 1990s.

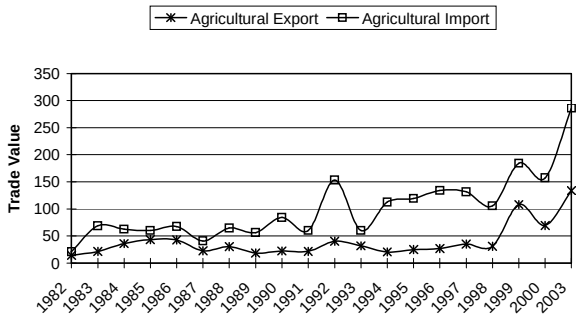


Fig. 2. Nepal's Agricultural Export and Import

Agricultural export has grown at 21 % on average during 1995- 2003, much higher than the overall towards high-value crops. This is further illustrated by data relating to growth of agro industries. Farmers are increasingly producing crops and livestock for sale to agro based industries. Agro-Industries, which have benefited from the liberalization of agriculture markets and private sector participation during 1990s, now comprise more than half of the manufacturing GDP and about 4.5% of Nepal's overall GDP. There has been strong growth in agro industrial products. Growth of agro products with strong external demand such as vegetable ghee, tea, noodles, and processed milk are the strongest. According to UNCTAD [11], the dynamic agricultural goods as percentage of total primary exports increases from 27.6 to 61.2 in the period 1980-1983 to 2000-2003. Agricultural export and import pattern is presented in Fig.2.

Despite stronger performance of exports relative to imports in recent years, Nepal suffers from chronic deficit in its agricultural trade, with exports receipts accounting for less than half of import payments. In contrast to formal agricultural trade, informal imports from India have been dominated by agricultural products (mainly food items), while Nepal exports some spices and vegetables. The extent of informal trading in agricultural produce is estimated to be much higher than that of formal trade between Nepal and India [1]. The share of formal and informal fertilizer imports from India is presented in fig. 3.

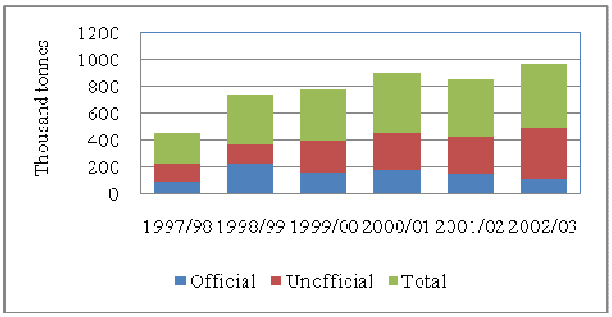
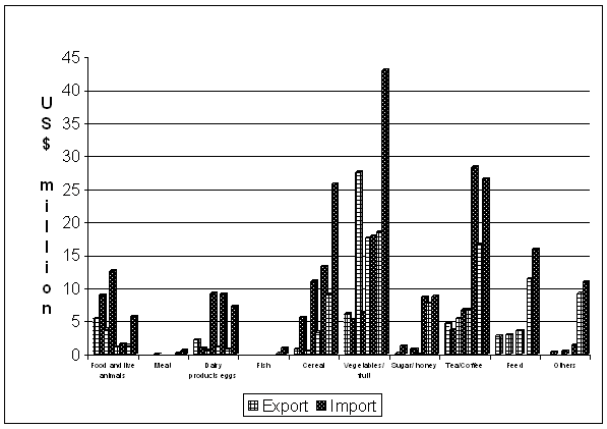


Fig.3. Share of formal and informal fertilizer trade with India

In 1987, before economic policy reform, fruits and vegetables were the major exportable commodities but it turns major importable items in 2003. Live animals are

exported and imported in the same proportion during that period. Just after trade policy reform, in 1992, fruits and vegetable, and spice crops are major exports and export value is increased by 300 and 15 % respectively compare to 1987. During the same time the import commodities did not change. In 1997, export items remained the same but the import items changed to spices and coffee, and vegetables, which used to be the exportable commodities in 1992. So, major export and import items were vegetables and fruits, and coffee and spices during the 90s and early 2000. Export and import of agricultural commodities based on standard international trade classification (SITC) Rev. 2 of the years 1987, 1992, 1997 and 2003 are presented in the bar chart Fig. 4.



Agricultural commodities (SITC Rev. 2)

Fig. 4. Agricultural trade (in the year 1987, 1992, 1997 and 2003 respectively)

From the data there is an irregularity in the commodities traded and trade value. It is not clear that such a variation is due to the trade policy or other factors related to trade.

Several factors constrain the competitiveness of agricultural products. First, the productivity of Nepalese agriculture is low. Nepal's labor productivity is about half that of India, while yields of most crops are also low compared with its South Asian neighbors (e.g., some 33% less than neighboring Bangladesh). Crop agriculture is characterized by little diversification, with cereal crops accounting for more than 80% of gross cropped area.

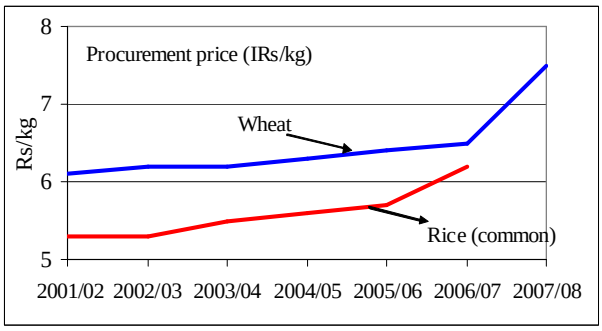
Underdevelopment of markets and lack of commercialization are key factors underlying this weak performance. Currently, only half of Nepali households sell any agricultural produce in the market, while nearly all households in Bangladesh sell some of their produce. Such low levels of commercialization and productivity of agriculture stand in sharp contrast with the country's significant potential, arising from its inherently favorable agro-climatic conditions and regional diversity. Domestic policies affecting agriculture that restricted trade and distorted prices until a few years ago, competition from Indian producers who are supported by large subsidies and the poor state of Nepal's infrastructure are the key factors behind the country's low labor productivity and lack of market development.

Analysis from the various experts about Nepal reveals that access to market and road infrastructure is a major constraint to commercialization, diversification, and technology adoption in Nepal's agriculture. In addition, Nepal has a low productive processing sector (e.g., the costs of rice milling are twice that of Uttar Pradesh, India). Similarly, product losses during transport, as well as transport margins, are extremely high. Nepal also ranks low in both rural electrification and telecommunications.

To improve the competitiveness of Nepalese agriculture and stimulate non-farm activities in rural areas, significant investments in rural roads, electrification, and communications will be essential. Other requirements include mechanisms to test and verify quality according to international standards, disseminating marketing information in order to link domestic producers to foreign markets, developing mechanisms to enforce sanitary and phytosanitary standards, and establishing facilities to test and handle chemical residue restrictions. Nepal will also need to develop a research and extension infrastructure to provide technical services to the farmers on appropriate farming, harvesting, processing, and preservation techniques. An important way to gain market access and access to technical knowledge will be to attract foreign investment in these areas, which will require simplifying regulatory procedures to facilitate foreign investment.

6. INDIAN AGRICULTURAL AND TRADE POLICIES

Liberalization reforms in India over the past decade clearly mark a significant departure from the country's protectionist past. India has been gradually but palpably shifting from its inward-oriented, state-led development strategy to a policy of active integration with the world economy. The first round of trade reforms (1991–95) was largely confined to the manufacturing sector. But recently steps have been taken to broaden trade liberalization to cover trade in consumer goods and agricultural products. By 2002, almost all quantitative restrictions on agricultural imports had been abolished. Tariffs are now the principal means by which India protects its domestic industries and agriculture.

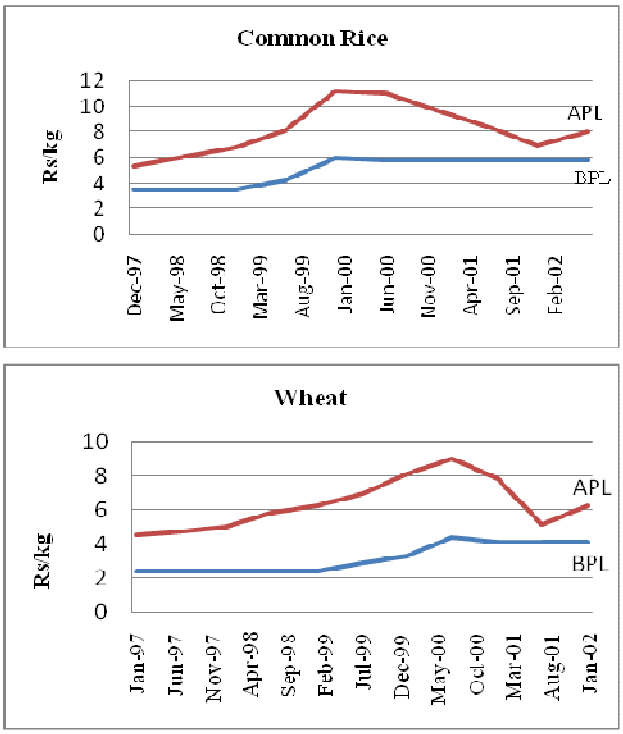


Source: Trade and Export Promotion Center, Nepal, 2006

Fig.5. Procurement price of wheat and rice in India

The focus of these reforms has been on liberalization; openness, transparency and globalization with a basic

trust on outward orientation focusing on export promotion activity and improving competitiveness of Indian industry to meet global market requirements. In early 2002, the Indian Government presented a Medium Term Export Strategy (MTES) for 2002-07 providing a vision for creating a stable policy environment with indicative sector-wise targets, with a mission to achieve one per cent of global trade by 2007. The new Export and Import (EXIM) Policy framed for the period 2002-07 also seeks to usher in an environment free of restrictions and controls. Synergy between these policies and strategies is expected to realize India's strong export potential and enhance the overall competitiveness of its exports.



Source: ADB, 2005

Fig.6. Subsidy and sale price of rice and wheat in India

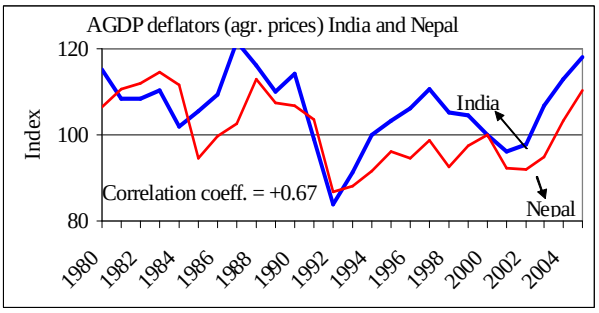
India's net food import dependence has fallen and total imports had declined. The strong net food export position of India is, however not a reflection of agricultural transition along the line of country's comparative advantage but it is due to interventionist agricultural development policy regime that includes domestic price support, insulation from world markets, trade restrictions and subsidization of inputs [2]. Trade opening has started to the intermediate and capital goods only and all consumer goods and agricultural products were kept on protected. The protections on agricultural goods were still continuing even after the market access commitment of World Trade Organization (WTO) in 1995. India has been subsidizing export of excess storks of wheat and rice by violating the market access provision of Agreement on Agriculture of WTO. Domestic price stability is a key objective for India; so, Indian agriculture sector is still highly protected and subsidized. Fig.5 shows the minimum support price of wheat and rice in India, which are in increasing trend. Similarly, fig.6 shows the regulated market price of wheat and rice for people above poverty line (APL) and below poverty line (BPL).

Undoubtedly, the reform initiatives undertaken in Nepal and India have provided new impetus to trade activities of both the countries. More significantly the treaties of Trade and Transit as well as the agreement to control unauthorized trade have changed the trade composition, in particular of the Nepalese trade.

7. INDIAN POLICY AND NEPALESE AGRICULTURE

Most of the agricultural products prices of Nepal are influenced heavily by Indian prices. Although India liberalized its agricultural trade regime during the second half of the 1990s, it still applies quantitative restrictions on agricultural imports. Several price interventions and subsidies also distort producer incentives in agriculture. Because of open boarder and informal trade, it will be hard to regulate by policy measures and restrictions. India's agricultural policies, which heavily protect their farmers, have been major issues for Nepal. While the overall domestic policy environment for agriculture in Nepal currently presents only few distortions and anomalies, India still applies high tariff, quantitative restrictions and tariff rate quotas on imports. Several price interventions and subsidies also distort producer incentives in agriculture. The Central Government of India provides subsidies to all major purchased inputs (fertilizer, seed, and pesticides). Irrigation water from surface schemes is heavily subsidized, along with power subsidies for irrigation pumps. State governments also provide additional support. The farm gate prices for major commodities are influenced by State trading agencies at fixed procurement prices. The large subsidies and price support programs accorded to major agricultural produce in India provide important cost advantage to Indian farmers (accounting for some 25-50% of purchased input costs). This situation caused high cost of production to the Nepalese farmers as compare with Indian farmer. Private sectors in fertilizer trading could not grow due to the same reason.

Given the reality that Nepal has a long and virtually open border with India, competitiveness of Nepal's agricultural products have been constrained by Indian agriculture policies. The large subsides and farm support programs accorded to major agricultural produce in India provided important cost advantage to Indian farmers. While some of the Indian subsidies on traded inputs (e.g., fertilizer) tend to benefit Nepalese farmers located in close proximity to Indian borders, most interior input markets are not well integrated into Indian markets, limiting such spillover benefits. On the other hand, output markets appear to be better integrated, exposing Nepalese farmers to artificially low border prices, due to heavy subsidization of Indian agriculture. Despite better performance of exports relative to imports in recent years, Nepal suffers from chronic deficit in both formal and informal agricultural trade.



Source: Graph based on World Bank WDI data.

Fig.7. Prices in Nepal and India

8. CONCLUSION

This paper has focused on the Indian trade policy, Nepalese trade sector and situation of Nepalese agriculture trade. Since Nepal has de facto economic integration with India, it is clear that India's trade policy will greatly affect Nepalese agriculture. It is very difficult for Nepal to have independent output price policy such as support price and price band defend stock. High tariff rate, subsidy and price support in India make Nepalese produce expensive and less competitive. Due to the open boarder and informal trade Nepal cannot regulate its market. Price is determined on cost of production and market situation in India. Basically, producers in Nepal are greatly affected by subsidized cheap price in Indian side. However, some positive effect has also been observed, pesticide and fertilizer price in the boarder area has benefited Nepali farmers. Those along the Nepal-India boarder have been procuring fertilizer at cheaper rate, but supply and quality is never guaranteed. Similarly consumers have also benefited by relatively cheaper price of illegally imported goods.

Nepal is becoming net importer in many products; so Nepalese price will be higher. Nepal can assure some price stability but hard to do much. Independent pricing is not appropriate as well. Some regulation and administrative arrangement for informal trade could be useful. Custom union could be a solution so implementation of South Asian Free Trade Agreement (SAFTA) might be an answer. Cases from other small-big partner such as Uruguay-Brazil; Paraguay-Argentina; Niger-Nigeria, Botswana-South Africa will be useful to get some concrete idea and apply some success case if possible.

The value of trade is simply enhanced; however, further analysis is needed to conclude on policy impact on trade. Exports and import of agricultural products have increased after trade liberalization in Nepal. Various manufactured as well as agricultural commodities have comparative advantage for Nepal. Focusing on these items with liberalized policy will boost both productions and trade. Due to very limited destination market and few products, Nepal should focus equally on the other aspects of trade along with policies in India.

ACKNOWLEDGEMENT

Author is grateful to the participants of second GMSARN International Conference for their comments and the responses from anonymous referees to on an earlier version of this paper.

REFERENCES

[1] Adhikari, Ratnakar. 2005. Market Access Barriers to Selected Nepalese Agricultural Exports, SWATEE, Kathmandu, Nepal.

[2] Athukorala, Prema Chandra. 2005. Agricultural Trade Policy Reforms in India, South Asia Economic Journal 6(1): 23-36

[3] Central Bureau of Statistics (CBS). 2005. Kathmandu, Nepal

[4] Government of Nepal. 1992. Nepal: Foreign Direct Investment and one Window Policy.

[5] Government of Nepal. 1992, Nepal Trade Policy

[6] Karmacharya, B.K. and Sharma, K. 2003. Trade policy regimes, growth and poverty: Nepalese experiences. Trade policy growth and poverty in Asian developing countries, Editor Kishor Sharma, Routledge, London

[7] Nepal Rastra Bank. 2004. Trend of Nepal Import Duties: Implication with Trade Liberalization, Economic Review 16: 152-176.

[8] Pant, Bhubanesh. 2005. Nepal's Trade Sector: Review, Repercussions and Recommendations, Economic Review 17: 89 – 115.

[9] Ra, Sungsup and Bipul Singh. 2005. Measuring the Economic Cost of Conflict, Asian Development Bank Working Paper Series No. 2, Nepal Resident Mission, Kathmandu, Nepal.

[10] Sharma, Kishor. 2005. Trade Policy, poverty and inequality in Nepal, South Asia Economic Journal 6(2): 241-250.

[11] UNCTAD. 2006. The least developed countries report, Developing Productive Capacities.

[12] Van Den Berg, H. 1997. The relationship between international trade and economic growth in Mexico, North American Journal of Economic and Finance 8(1): 1-21.

Analysis of Pipe Breaks in Urban Water Distribution Network

Mofid Gorji-Bandpy and Majid Shateri

Abstract— *The goal of this paper is to present a descriptive analysis of the water pipe breakage data to predict the evolution of the annual number of pipe breaks and the application of the modeling strategy to the cities. To make a general diagnosis, one must collect and analyses data on the characteristics of water pipes and on their breakage histories. Since many city water authorities have only a few breakage histories, a modeling strategy, inspired by Survival analysis and using the annual number of water pipe breaks as an indicator of the structural state of a network, was applied to three cities in Mazandaran province, north of Iran, characterized by their brief recorded pipe break histories. The results show that the annual pipe breaks increase, but the rate of increasing of the annual pipe breaks can be reduced by replacement of the old pipes.*

Keywords— **Pipe break, Weibull distribution, Survival function, Deterioration.**

1. INTRODUCTION

Nowadays, managing the city water infrastructure systems often means managing critical situations, when unhappy consumers report water leaking in the streets due to a water pipe break and flooding of their houses due to a sewer overflow or even the collapse of the street pavement due to foundation washout.

Tools are needed to assess the present and future structural state of water pipes from readily obtainable data. A mathematical model can help water authorities in the diagnosis and planning of repair, rehabilitation, and replacement of water pipes. To model the overall structural state of water pipes, it is necessary to choose an indicator of their structural state. The average annual number of pipe breaks on a water pipe networks is the most commonly used indication. The number of pipe breaks is the most readily available data correlated to the structural state.

In this paper, a pipe breaks is defined as a failure resulting in water leaking to the surface, thus necessitating an immediate intervention on the network. Of course, water leaking from a failed pipe may reach the surface days after the initial break or it might not even reach the surface if, for example, sewer infiltration is possible in the vicinity. The main difficulty in developing mathematical models for this type of problem is the lack of data on both the water pipe network and the pipe breakage history. For a thorough analysis of pipe breakage, information must be known on the physical and environmental characteristics that have an impact on pipe failure. Most city water authorities have little information on their water pipes, such as pipe diameter, pipe material, and date of installation, but few have been maintaining thorough records of pipe breaks for longer than a decade.

Mofid Gorji-Bandpy is with Department of Mechanical Engineering, Noushirvani Industrial University, P.O. Box 484, Babol, Iran. Fax: 00981113234205; E-mail: gorji@nit.ac.ir.

A survey of water authorities in the province of Mazandaran in the north of Iran has helped us to identify a few cities that maintain pipe break records. We present here the results obtained in three cities, Behshahr, Sari and Ramsar. Of these three cities Sari has the longest pipe break history available in a usable format.

The main purpose of this paper is to apply an operational pipe break model to estimate present and future structural states of water pipe networks, and verify the performance in the above three mentioned urban waters networks. The modeling strategy is designed to require minimal data and take into account the fact that the number of previous break is a key factor. The model is designed to answer a global but important practical question: What is the replacement effort a city has to make in order to limit the number of annual pipe breaks over a given period? The development of a model dealing with the average annual number of pipe breaks is the first step in the diagnosis of the overall structural state of a network. By incorporating all of the data in a database for model development, one can obtain specific information on all pipe segments. It is necessary to identify the factors that are important in the degradation of water pipes and at the development of methods to help urban water managers in assessing the structural state of their water networks. Using elaborate sets of data, when coupled with an economic assessment model, will ultimately serve as a powerful decision making tool for water managers [1-4].

Research efforts on water pipe degradation generally fall in the following categories; physical analysis, descriptive analysis, and predictive analysis.

Physical analysis consists of evaluating of the scope and severity of corrosion on the internal and external pipe walls, and the estimation of resulting stresses from the loads applied to the water pipe [5-10]. Descriptive analysis consists of calculating descriptive statistics to provide insight on breakage patterns and trends. This kind of analysis can only be performed in the cities that have comprehensive databases on the characteristics of the pipe and on the pipe breaks. Due to the lack of data

in the urban water breakage, there are very few case studies in Iran. This type of analysis is limited by the challenges faced for constructing databases and as a matter of fact, building such databases has been a concern for many researchers [11-13].

Predictive analysis is done by modeling past pipe breakage behavior in order to project it in the future. Different types of modeling strategies have been developed to evaluate the structural state of water pipe networks [14-16].

There are three main types of models namely:

1) Aggregate models, which are exponential or linear models of the number of breaks versus the age of pipes [17].
2) Regression models, which considers factors that influence the degradation of pipe [18,19], and;
3) Probabilistic models, of which survival analysis is the most widely used approach.

Survival analysis has been used successfully to predict pipe breakage behavior by many researchers in the past two decades, and most frequently used in the biomedical fields, to water pipe failure problems [20,21]. This kind of analysis is a statistical technique that deals with time to failure data, and incorporate the fact that, while some pipes breaks, other do not, and this information has a strong impact on the analysis.

Many researchers have shown that the breakage pattern strongly depends on the number of previous breaks that pipes have experienced [22]. As a matter of fact, the number of previous breaks is often reported as the most important factor for predicting future breaks. Survival analysis is particularly useful in this field when pipe break records have been maintained for a good portion of the water pipe network history. This kind of analysis cannot, however, be used in this study because the recorded pipe histories in our case studies are not long enough to provide adequate information on the pipe breakage behavior. To our knowledge, we have found a few studies that addressed the problem of brief recorded pipe breakage history [23,24]. A methodology is used in the present study to estimate parameter values of the water pipe breaks model. The method on a statistical basis is the relative performance of a Weibull distribution compared to an exponential distribution for a given break order.

2. GENERAL CHARATERISTICS OF THREE CITIES

Table 1 presented some general characteristics for the three cities. Water pipe loosely follows street patterns in the cities, so pipe segments are usually defined from one street corner to the next. The average length of a pipe segment is highly variable and depends mainly on the discretization of the water pipe network adopted by the city.

In terms of break history, Sari has the longest recorded pipe break history and the highest ratio of pipe breaks per 100 km, while Behshahr has the lowest recorded pipe break history. Based on the reported ratios of pipe breaks per 100 km and the perception of water managers on the global state of their water pipe networks, ratios of 40 breaks per 100 km and up are considered high and indicate a network in poor condition.

Table 1. Some characteristics of Three Cities

Characteristics		Cities		
		Behshahr	Sari	Ramsar
Approximate population		73696	205146	34038
Pipe network length (km)		185.82	485.06	139.4
Ratio of pipe length (m) per habitant		2.52	2.36	4.10
Percentage of water losses	2000	38.8%	40.7%	34.1%
	2001	23.6%	32.3%	29.3%
Year of installation of first pipes		1956	1952	1954
Number of years of recorded pipe breaks		5	7	6
Number of pipe breaks per 100 km in 2002		393	424	292

Table 2. Percent of breakage in different years

Name of cities	Year	Percentage of breakage	
		Network	Branch
Behshahr	2000	36	64
	2001	19	81
	2002	36	64
Sari	2000	23	77
	2001	22	78
	2002	24	76
Ramsar	2000	36	64
	2001	39	61
	2002	31	69

Networks with ratios between 20 and 39 are considered in acceptable condition, while the ratios less than 20 indicate that the network is in good condition [25]. Overall, this represents well the perception of the three water manager's interviewed in this study. Table2 presents the percentage of breakage in the year 2000, 2001 and 2002. We can see that the percentages of breakage in branch are higher than in network. In terms of the tendency in the annual number of pipe breaks for the duration of the recorded history, there is a strong

increase in the annual number of pipe breaks with time in all three urban water cities. These will be presented along with the modeling results.

Because of degradation of networks we have an increase in annual number of pipe breaks with time in all cities. Information gathered on all pipe segments are as follows:

1) Pipe diameter
2) Pipe length
3) Pipe type of material
4) Year of installation
5) Type of soil; and
6) Land use above the pipe

3. DESCRIPTIVE STATISTICS

Basic descriptive statistics are presented to give insight on the impact of different risk factors on the structural deterioration of water pipes. Statistics on pipe diameter, installation period, and pipe material are presented herein. These are calculated based on the total pipe length in 2001, and with only the pipe breaks that could be associated with a single pipe segment. Statistics on breakage rates are estimated by taking the ratio of the number of breaks on pipes in a given category and the total pipe length in that category in 2001. This gives an indication of the breakage behavior in a given category.

Fig.1 presents the length of pipes versus different pipe materials for three cities. The asbestos pipes are widely used in these cities, while steel pipes are used in one city and much less than asbestos pipes.

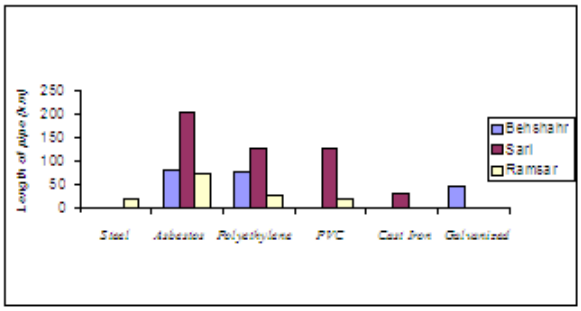


Fig.1. Pipe length versus different materials for three municipalities in 2001

Fig.2 presents the breakage percentage in both network (NT) and branch (EN). Breakage percentages are higher for branches.

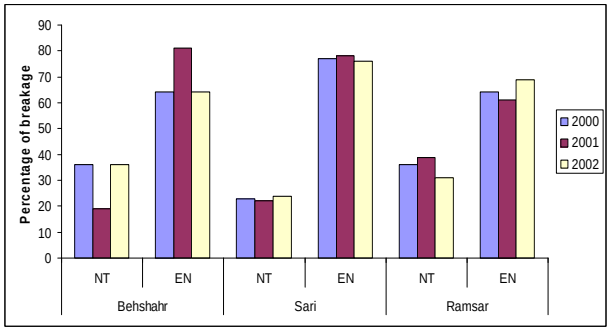


Fig.2 . Percentage of pipe breakage for three cities in three successive years

Fig.3 presents the number of pipe breaks versus different pipe diameters for just asbestos pipes. The most number of pipe breaks is related to smaller diameters. It is because of their thinner pipe walls and smaller moment of inertia [8,10].

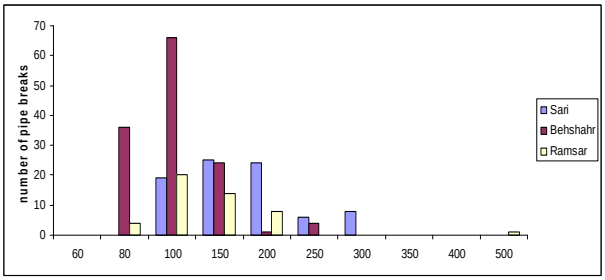


Fig.3 . Number of pipe breaks versus different pipe diameters for just asbestos pipes

Sari can be considered as having the “oldest” water pipe network, which has been developing the least rapidly in recent years, where as Behshahr can be considered as having the “youngest” water pipe network, which has been developing the most rapidly in recent years.

Fig.4 presents the breakage rates of pipes in 1996 to 2002. There is an increase in breakage rate for the above mentioned cities, which is the expected behavior for a deterioration process.

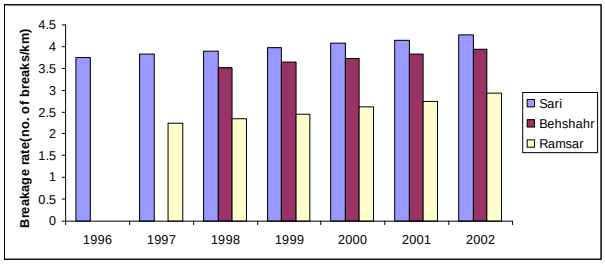


Fig.4 . The breakage rates of pipes in 7 successive years

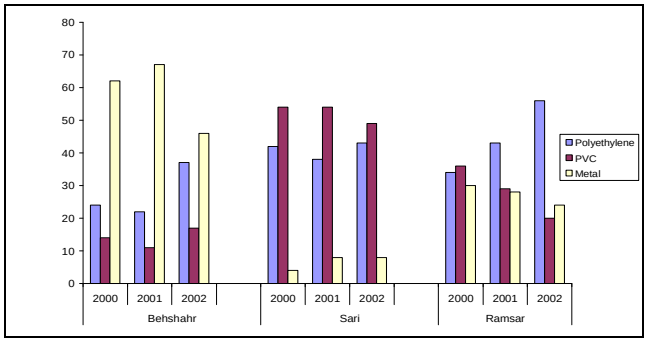


Fig.5 . Percentage of pipe breaks for the three types of materials in 2000, 2001 and 2002

Fig.5 presents the percentage of pipe breaks for the three types of materials in 2000, 2001 and 2002. It is obvious that polyethylene and PVC has the most percentage of pipe breaks in Ramsar and Sari while metal and polyethylene has the most percentage of pipe breaks in Behshahr.

Table 3. Causes of breakage in percent

City	Year	Causes of breakage											
		Vertical Impact on pipe		Pipe Corrosion		Pipe material with poor quality		Different Institution*		High pressure		Unknown	
		EN	NT	EN	NT	EN	NT	EN	NT	EN	NT	EN	NT
Behshahr	2000	6.8	5.1	41	52	33.5	26	3.3	4	1.4	4.5	14	8.4
	2001	7	3.7	36	56	18	18.5	3	7.5	9	3	27	11.3
	2002	7.5	4.3	34	64	15.5	13	4.5	7.8	12	4	26.5	6.9
Sari	2000	37	36	7.5	5.4	30.5	26.6	13.	18	3	3.2	9	10.8
	2001	37	37	3	7.5	22.5	30.5	10.5	13	19	3	8	9
	2002	34	35	6	7	26	32	9	12	14	4	11	10
Ramsar	2000	6.7	7.5	21.4	23.5	11.5	4.3	17.5	19	39	41	3.9	4.7
	2001	7.4	10.5	22.5	22.5	12.4	3	16.5	21	38	40	3.2	3
	2002	6.3	11.3	21.2	21.5	14.9	2.9	17.3	20.4	37.5	41.2	2.8	2.7

* Careless drilling operations done by different institutions such as gas and oil, etc. companies

Table 3 represents the causes of breakage in three cities in the year 2000, 2001 and 2002.

4. MATHEMATICAL MODEL FOR WATER PIPE BREAKS

As mentioned previously, the goal of modeling is to predict adequately the annual number of pipe breaks in the future in order to apply more effective strategy to reduce the rate of breakage. The modeling strategy must take into account the installation of new pipes, the impact of pipe replacement, and the fact that the pipe segments exhibit a different pipe breakage behavior, depending on their break history.

The time step chosen for modeling is one year, which was commanded by the time scale of pipe degradation and the uncertainty on the date of occurrence of breaks compared to their date of recording. The occurrence of a first break will likely result in other breaks in the vicinity, and that breakage behavior strongly depends on break order. To distinguish between the different orders of breaks, one must identify the time to failure between the installation and the first break, between the first and second break, and so on. This is called data stratification in survival analysis [26]. Times to failure can be modeled by different distributions, depending on the breakage behavior associated with that break order. Since records of pipe breaks rarely exist for the entire history of the networks, the real order of pipe breaks is often unknown for all pipe segments laid before the year when pipe breaks started to be rigorously recorded. This makes the use of textbook survival analysis impractical. In this study the modeling strategy uses two distributions to model the different break orders:

1- Weibull distribution

2- Exponential distribution.

The first one is associated with the first break order (time to failure from installation to first break), while the second distribution is used to describe the behavior of subsequent breaks (time to failure from first to second break, second to third, and so forth). This model is referred to as the Weibull/exponential model.

The Weibull distribution is defined by two distinct parameters, β and $\frac{1}{\eta}$. The exponential distribution is a special case of the Weibull distribution when $\beta = 1$, with only one parameter, β_2. Then the three statistical functions can be used to represent a given distribution and can be defined as, the hazard function, the survival function and probability density function. The hazard function $\lambda(t)$ corresponds to the instantaneous probability of having a break between t and $t + \Delta t$ conditional to survival up to time t. The hazard function is defined, for the Weibull and exponential distribution, respectively, as [26];

$$\lambda(t) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1} \quad (1)$$

$$\lambda(t) = \beta_2 \quad (2)$$

For the Weibull distribution, the shape of hazard function depends on parameter β and is monotonously increasing for $\beta > 1$, decreasing for $\beta < 1$, and

independent of time when β=1 (exponential distribution).

Considering the Weibull/exponential model, the average number of breaks, $n(T_1,T_2)$ on a given pipe segment during the time interval (T_1,T_2) can be computed as follows [27]:

$$n(T_1,T_2)=[F(T_1)-F(T_2)]+\beta_2\{T_2[1-F(T_2)]-T_1[1-F(T_1)]-\int_{T_1}^{T_2} dt.f(t)\} \quad (3)$$

where $F(T_i)$ the survival function is associated with the Weibull distribution at time T_i and $f(t)$ is the probability density function associated with the Weibull distribution and are as follows;

$$F(T_i)=e^{-(\frac{T_i}{\eta})^{\beta}} \quad (4)$$

$$f(t)=\frac{\beta}{\eta}(\frac{t}{\eta})^{\beta-1}e^{-(\frac{t}{\eta})^{\beta}} \quad (5)$$

The reference time=0 corresponds to the year of installation of the pipe. The development of Eq.3 can be found in Ref.27. It has been shown by Mailhot et al. [23] that complex models other than three simple modeling strategies do not necessarily yield more exact results. Exponential distribution was used to describe the time to failure between first and second, the second and third, etc. breaks and between breaks up to 20th order [20] and a unique parameter value for cities where it is impossible to estimate different parameter values for different break orders with some degree of certainty. So, we used an average parameter value representative of the overall aging process associated with subsequent breaks. This modeling strategy cannot take into account the variability in the annual number of pipe breaks due to factors other than deterioration resulting from the natural aging of pipes. Severe winters, flooding, soil properties, water chemistry and traffic disturbances can cause higher breakage rates in a given year.

5. RESULTS AND DISCUSSION

The obtained calibration parameters are presented in Table 4 for the three cities. Pipe segments in Behshahr are at the highest risk for subsequent failures, as indicated by its value for β_2. After that Ramsar and then Sari have lower risk but not much.

As we can see the parameter β of Weibull distribution is larger than 1 for all groups of pipes. Survival functions associated with the Weibull distribution (time to failure from installation to first break) are shown in Fig.6 for Sari, Ramsar and Behshahr. The value of the survival function gives the proportion of pipes that have not failed at time t. Therefore, the higher the curve, the longer it takes for the first break to occur. At time=0 (year of installation) none of pipe segments have failed. As time increases the risk of first breaks increases because of degradation.

Table 4. Calibration Parameters for Weibull-Exponential distribution for Sari, Behshahr and Ramsar

Parameters	Sari	Behshahr	Ramsar
β	2.559	2.271	2.088
$\frac{1}{\eta}$	0.020	0.023	0.021
β_2	0.021	0.023	0.022

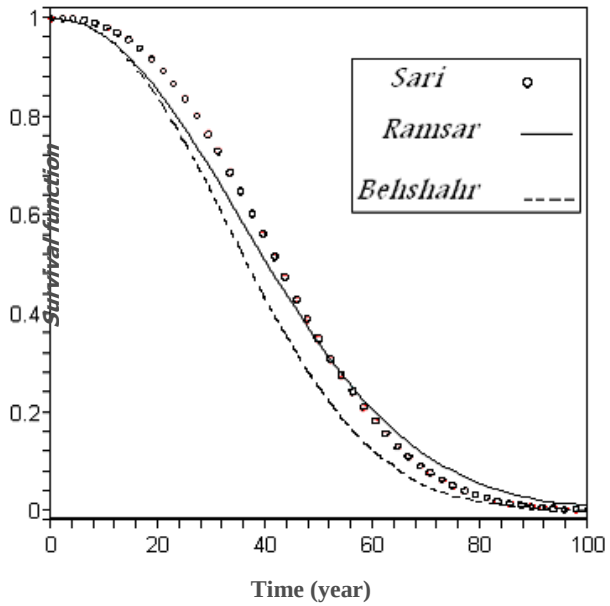


Fig.6 . Survival function associated with the first break for three cities

The following input data are required for each pipe segment to run the model; the pipe segment number, the year of installation, number of recorded breaks, year of first recorded break, year when recording began, and year of analysis.

Figs.7-9 present the observed average number of breaks and those estimated by the model in each city. In all cases, the sets of parameters obtained using the calibration strategy have permitted the adequate reproduction of the overall tendency of pipe breakage, especially considering that the pipe break histories used for calibration were quite brief. As have previously mentioned the risk of failure associated with the exponential distribution is independent of time. These values and β_2 are presented in Table 4.

6. CONCLUSION

In this paper a descriptive analysis of the water pipe breakage was presented to predict the evolution of the annual number of pipe breaks and the application of the modeling strategy to the cities. To make a general diagnosis, it is necessary to collect the data on the characteristics of water pipes and the breakage histories. A simple three parameter model, based on the estimation

of the probability of break occurrence depending on the break order (first and subsequent breaks), for three cities that have recorded their break repairs for a relatively short period compared to the history of their networks, was successfully used to reproduce average tendencies and predict tends in the annual number of pipe breaks in those cities. In ten years, the cities of Behshahr, Sari and Ramsar would see their annual pipe breaks increase by 10.81 %, 6.9% and 47.4 %, respectively. But the rate of increasing annual pipe breaks can be reduced by replacement of old pipes.

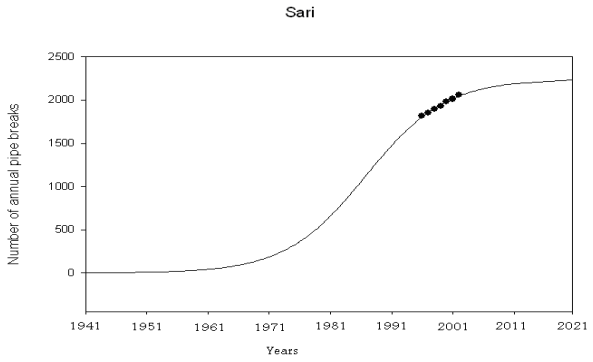


Fig.7 . Observed and simulated annual pipe breaks in Sari

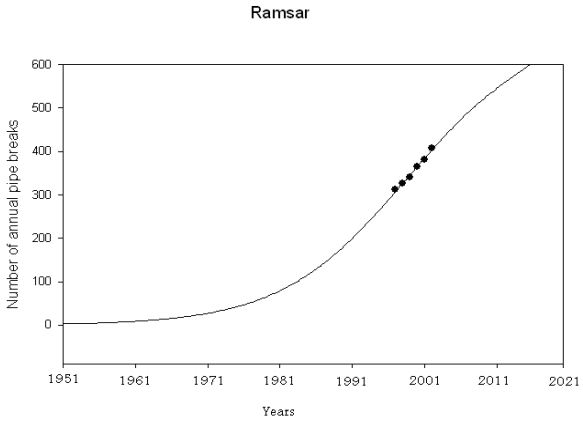


Fig.8. Observed and simulated annual pipe breaks in Ramsar

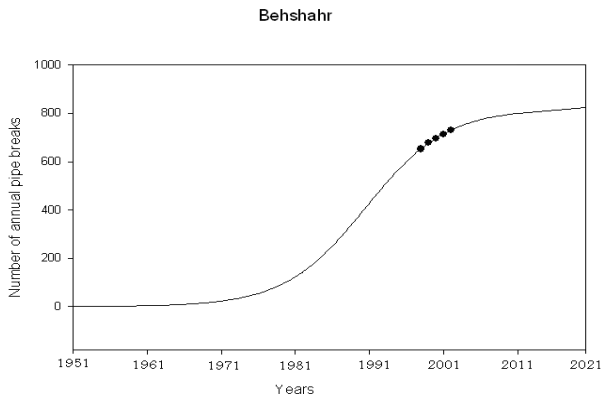


Fig.9. Observed and simulated annual pipe breaks in Behshahr

ACKNOWLEDGMENT

This investigation is being conducted under the sponsorship of Mazandaran Water and Waste Water Company, Contract number 2564-1382.

NOMENCLATURE

β	Parameter of Weibull distribution
$\frac{1}{\eta}$	Parameter of Weibull or exponential distribution
$\lambda(t)$	Hazard function
$F(t)$	Survival function
$f(t)$	Probability density function
$n(T_1, T_2)$	Average number of pipe breaks on a given pipe segment during interval $[T_1, T_2]$.

REFERENCES

[1] Kleiner, Y., Adams, B. J., and Rogers, J. S. "Long-term planning methodology for water distribution system rehabilitation." Water Resour. Res., 34(8), 2039-2051. (1998a).

[2] Kleiner, Y., Adams, B. J., and Rogers, J. S. "Selection and scheduling of rehabilitation alternatives for water distribution systems." Water Resour. Res., 34(8), 2053-2061. (1998b).

[3] Kleiner, A. J. and Rajani, B. B. "Using limited data to assess future needs." J. Am. Water Works Assn., 91(7), 47- 62. (1999).

[4] Rajani, B. B., and Kleiner, Y. "WARP-Water mains renewal planner." Proc., Int. Conf. on Underground Infrastructure Research, 1-6. (2001).

[5] Doleac, M. L., Lackey, S. L., and Bratton, G. "Prediction of time-to-failure for buried cast –iron pipe." Proc., AWWA 1980 Annual Conf., American Water Works Association, Denver. (1980).

[6] Kumar, A., Meronkly, E., and Segan, E. "Development of concepts for corrosion assessment and evaluation of underground pipelines." Rep., Construction Engineering Research Laboratory, U.S.Army Corps of Engineers, Champaign, III. (1984).

[7] Philadelphia Water Department. "Water main pipe sample physical testing program." Rep., Philadelphia. (1985).

[8] Makar, J. M., "Failure analysis for grey cast-iron water pipes." Proc., AWWA Distribution System Symp., American Water Work Association, Denver. (1999).

[9] Rajani, B., and Makar, J. "A methodology to estimate remaining service life of grey cast-iron water mains." Can. J. Civ. Eng., 27, 1259-1272. (2000).

[10] Makar, J. M., Desnoyers, R., and McDonald, S. E. "Failure model and mechanisms in grey cast- iron pipes." Proc., Int. Conf. on Underground Infrastructure Research. (2001).

[11] O'Day, D. K. "Organizing and analyzing leak and break data for making main replacement decisions." J. Am. Water Work Assn., 74(11), 589- 594. (1982).
[12] Clark, R. M., and Goodrich, J. A. "Developing a data base on infrastructure needs." J. Am. Water Work Assn., 81(7), 81-87. (1989).
[13] Habibian, A. "Developing and utilizing data bases for water main rehabilitation." J. Am. Water Work Assn., 84(7), 75-79, (1992).
[14] O'Day, D. K., Weiss, R., Chiavari, S., and Blair, D. "Water main evaluation for rehabilitation/ replacement." Rep., American Water Work Association Research Foundation, Denver, and U.S. Environmental Protection Agency, Cincinnati. (1986).
[15] Elnaboulsi, J., and Alexandre, O. "Le renouvellement des reseaux d'eau potable: Une revue critique." Can. Water Resour. J., 21(4), 341-354 (in French). (1996).
[16] Karaa, F. A., and Marks, D. H. "Performance of water distribution network: Integrated approach." J.Perform.Constr.Facil., 4(1), 51-67. (1990).
[17] Shamir, U., and Howard, C. "Analytic approach to scheduling pipe replacement." J.Am.Water Works Assn., 71(5), 248-258. (1979).
[18] Clark, R. M., Stafford, C. L., and Goodrich, J. A. "Water distribution systems: A spatial and cost evaluation." J.Water Resour. Plann. Manage., 108(3), 243-256. (1982).
[19] Clark, R. M., Eiler, R. G., and Goodrich, J. A. "Distribution system: Cost of repair and replacement." Proc., Conf. on Pipeline Infrastructure, B. A. Bennett, ed. ASCE, New York, 428-440. (1988).
[20] Gustafson, J. M., and Clancy, D. V. "Modeling the occurrence of breaks in cast-iron water mains using methods of survival analysis." Proc., AWWA Annual Conf., American Water Works Association, Denver. (1999).
[21] Eisenbeis, P. "Modelisation statistique de la prevision des defaillances sur les conduites d'eau potable." Serie Equioements pour l'eau et l' environnement No. 17, Etudes du CEMAGREF (in French). (1994).
[22] Anderou, S. A., Marks, D. H., and Clark, R. M. "A new methodology for modeling break failure patterns in deteriorating water distribution systems: Theory." Adv. Water Resour., 10(1), 2-10. (1987).
[23] Mailhot, A., Pelletier, G., Noel J-F., and Villeneuve, J-P. 2000. "Modeling the evolution of the structural state of water pipe network with brief recorded pipe break history: methodology and application" Water Resources Research, Vol. 36, No. 10.
[24] Le Gat Y and Eisenbeis, P. 2000. "Using maintenance records to forecast failure in water networks" Urban Water, Vol. 2, 173-181.
[25] McDonald, S., Daigle, L., and Felio, G. "Reseaux d'aqueduce et systemes d'egouts." Rep., Infrastructure Laboratory, Institue for Research in Construction, National Research Council of Canada, Ottawa (in French). (1994).
[26] Kalbfleisch, J. D., and Prentice, R. L. "The statistical analysis of failure time data" Wiley,Inc ,New York. (1980).
[27] Pelletier, G. "Impact du replacement des conduites d'aqueduc sur le nombre de bris." PhD thesis, Institute National de la Recherche Scientifique, Sainte-foy, Que. Canada (in French). (2000).

Studies on Morphological Variation of Localized Wild Populations of Black Tiger Shrimp (*Penaeus Monodon*) and Giant Freshwater Prawn (*Macrobrachium Rosenbergii*)

Aye Aye Naing

***Abstract*—** *This research was done to identify morphometric variations in localized wild populations of the giant tiger shrimp (Penaeus monodon) and the giant freshwater prawn (Macrobrachium rosenbergii). The number of each sex of the two species is 500. The prawns were collected from Thanlwin river near Hpa-an township and the shrimps from Indian Ocean shoreline near Thantwe township. Six morphometric parameters consisting total length (TL), standard length (SL), orbital length (OL), abdominal length (AL), carapace length (CL), second pereiopod (sp) length in prawn and third pereiopod length (tp) in shrimp were measured in live and wet specimens after weighing. The measurements were subjected to statistical methods of variance, ANOVA and linear regression by SPSS version 14.0 software to find out the most variable as well as stable characteristics in relation to body weight classes in the two species. The abdominal length (AL) was less variable in adult M.rosenbergii compared to adult P.monodon in both sexes among body weight classes. AL had larger significant difference ($P \leq 0.01$) in P.monodon relative to M.rosenbergii in both sexes. Linear regression revealed that jump growths occur in both sexes of M.rosenbergii, but only in females of P.monodon. Overall, regarding all six morphometric parameters, variation was lower, AL increment was slower and growth had jumps in both sexes of the wild adult M.rosenbergii, compared to the wild adult P.monodon. The data of this research could form the basis for development of high quality broodstocks and could be useful for improvement of growth in pond cultures of shrimps and prawns.*

***Keywords*— Black tiger shrimp, giant freshwater prawn, morphological variation, wild populations.**

1. INTRODUCTION

Myanmar has fairly large fishery resources and shrimps occupy a significant commercial position in the coastal fisheries. It is important to gain further knowledge about penaeids and palaemonids to understand their fisheries and effects of commercial exploitation [1], [2].

M. rosenbergii (the largest palaemonid prawn) and *P.monodon* (the largest penaeid shirmp) are of commercial importance not only in Myanmar but also in other Southeast Asian countries. They are needed to be cultured for export market because of their bigger size, good taste, faster growth, high price, high protein content and high demand in market [1], [2].

In Myanmar, regarding the systematic study on the freshwater prawn collected from Yangon markets, Tin Tin Soe (1970) described nine species of freshwater prawn [10]. Similarly, Khin Nwe Mu (1980) reported 10 species of freshwater prawn found in the mouth of Nga Wun River, Pathein Township [6]. Htay Aung (1982) recorded twenty eight species of penaeid shrimp occurring in Mon state and Tanintharyi Division coastal water [5]. Also, Myint Thein (1984) described thirteen species of freshwater prawn under the genus *Macrobrachium* found in Ayeyarwaddy Delta Regions [8]. Win Win Myint (1988) classified and described sixteen species of freshwater prawns from estuarine water of Mon state [11]. Sann Aung and Hla Htay (1987), presented a field guide to identification of commercially important marine prawns of Myanmar [9].

However, study on morphological character variations and their correlationships in the wild species of shrimp and prawns has not yet been done in Myanmar. Hence, it is necessary to study the quality and morphological variations in the natural wild populations of the shrimps and prawns so that the data could be applied to more effective genetic and quality control of the cultured shrimps and prawns to meet the export quality standards, and to develop genetically superior broodstocks for commercial applications.

2. MATERIALS AND METHODS

2.1 Study areas and study period

M.rosenbergii adults were studied from Thanlwin River near Hpa-an township in Kayin State during 2005, and *P.monodon* adults were studied from near shore catches around Thantwe township in Rakhine state during 2006-2007.

2.2 Sampling

Five hundred specimens each of adult males and females of both species were collected from local wholesale dealers in the respective study areas.

2.3 Identification of specimens

Identification, classification and sexing of both species were done using keys and methods [3], [4], [7] and [9].

Aye Aye Naing is with Department of Biotechnology, Yangon Technological University, Myanmar. E-mail: ayeayenaing7@gmail.com.

2.4 Morphometric study

After collection, identification and sexing, each specimen of the prawns and shrimps were weighed for wet body weight in grams (gm) and various respective body and appendage lengths (i.e. total length, standard length, orbital length, abdominal length, carapace length, 2nd perepiod length in prawn and 3rd perepiod length in shrimp) were measured in centimeter (cm). All data were recorded on data sheets and specimens were photographed were ever necessary.

2.5 Preservation of specimens

Specimens collected fresh from the natural wild catches were preserved in a solution of 5% formalin or 5% alcohol in labelled glass bottles with caps for future reference.

2.6 Statistical analysis of morphometric parameters

Specimens from natural wild catches were studied and measured for key characters. The results recorded were compared to that of standard parameters for the key characters of the male and female in each species.

Data for the key measurements of the morphological characteristics were subjected to suitable statistical methods by using SPSS version 14.0 to identify the most variable characters as well as stable traits within each weight class of males and females of both species.

3. RESULTS

Seven body measurement parameters consisting body weight, total length (TL), standard length (SL), orbital length (OL), abdominal length (AL), carapace length (CL), pereiopod length (sp or tp) were measured and subjected to statistical analysis, and the following results were obtained.

3.1 Variance

In male *M.rosenbergii*, the abdominal length, which is important for marketing, had very low total variance (1.842).

In female *M.rosenbergii*, the abdominal length had low total variance of 1.217.

In male *P.monodon*, AL had low variance in most weight classes with total variance of 4.662.

In female *P.monodon*, AL had total variance of 7.432.

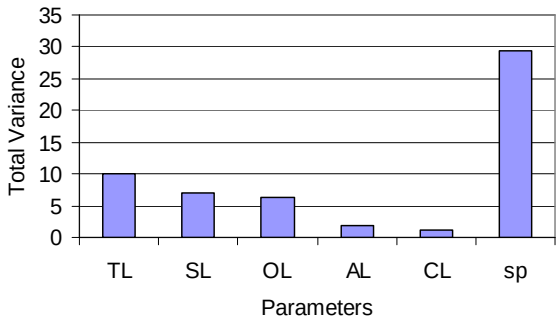


Fig .1. Total variance of six morphometric parameters based on body weight classes in adult male *M.rosenbergii*

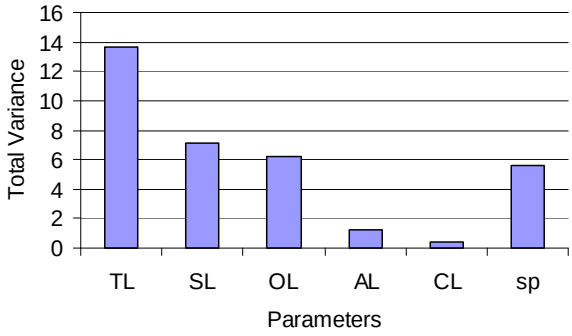


Fig .2.Total variance of six morphometric parameters based on body weight Classes in adult female *M. rosenbergii*

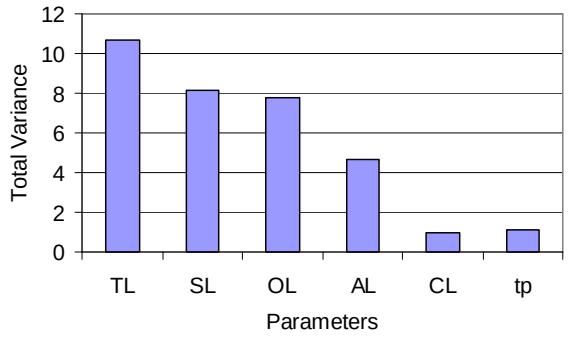


Fig .3.Total variance of six morphometric parameters based on body weight classes in adult male *P.monodon*

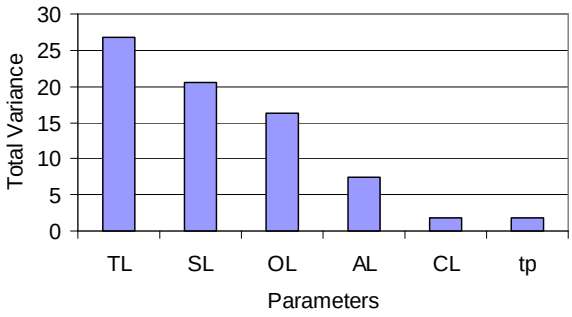


Fig .4.Total variance of six morphometric parameters based on body weight classes in adult female *P.monodon*

3.2 Analysis of variance (ANOVA)

M.rosenbergii females had larger significant difference than males for AL between weight classes (i.e. F = 175.56 and F = 44.79; $P \leq 0.01$).

Regarding *P.monodon*, females had larger significant difference in AL between weight classes compared to males (i.e. f = 785.47 and f = 347.25; $P \leq 0.01$).

3.3 Linear Regression

In *M.rosenbergii*, female had stronger relationship in Al to body weight compared to male. Females have greater AL increments than males (i.e. 0.0247 cm/gm versus 0.0127 cm/gm).

In *P.monodon* male had stronger relationships between AL and body weight compared to female. Males have

greater AL increments than females (i.e. 0.0908 cm/gm versus 0.0777 cm/gm).

M. rosenbergi wild adult males have jump or "leapfrog" growth between 250gm and 300gm body weight classes; but wild females have a spurt of "divergent" growth between 50gm and 75gm weight classes after which the growth levels off more linearly.

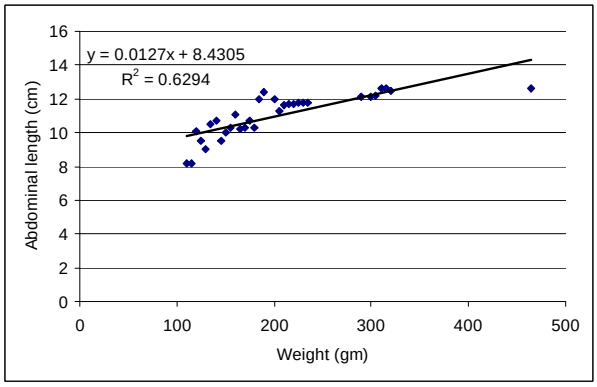


Fig .5.Relationship between body weight and abdominal length of adult male *M. rosenbergii*

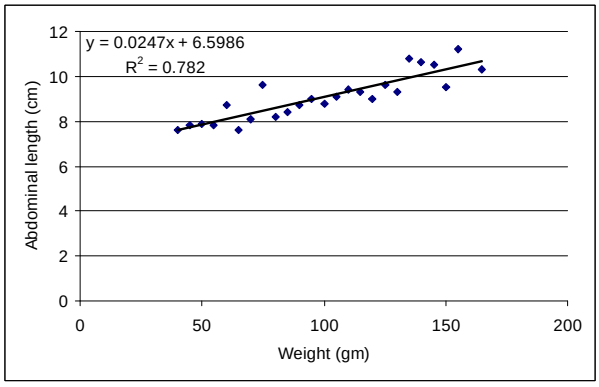


Fig .6.Relationship between body weight and abdominal length of adult female *M. rosenbergii*

P.monodon wild adult males have a more or less continuous and linear growth pattern, but females have a "jump" growth between 60gm and 80gm body weight classes for 5 parameters of TL, SL, OL, AL and CL but was slight for tp growth.

4. CONCLUSION

This research was carried out to study morphometric variations of the localized wild populations of *P.monodon* and *M.rosenbergii*, with the aim to assess the stability or variation of the morphometric characteristics of genetic and economic importance.

Abdominal length (AL), which is important for headless export, is less variable in wild adult *M.rosenbergii* compared to wild adult *P.monodon* among both sexes and body weight classes. The study through variance method showed that AL variance is the lowest in 110gm and 310gm weight classes and the highest in 185gm and 230gm body weight classes in males; but the lowest in 55gm and 150gm weight classes and the highest in 130gm and 165gm weight classes in females for *M.rosenbergii*. For *P.monodon*, variance method showed that AL variance is the lowest in 70gm and 80gm body weight classes and the highest in 50gm and 100gm weight classes in males; but the lowest in 95gm weight classes and the highest in 60gm and 100gm weight classes in wild adult female.

Females have larger significant difference ($P \leq 0.01$) than males in AL between body weight classes in both wild species.

In wild adult *M.rosenbergii* females have greater AL increments than males, whereas adult *P.monodon* wild females have slower AL increment than males.

According to linear regression analysis, males have jump or "leapfrog" growth; but females have a spurt of "divergent" growth in *M.rosenbergii*. In *P.monodon*, males have a more or less continuous and linear growth pattern, but females have a "jump" growth for 5 parameters of TL, SL, OL, AL and CL but was slight for tp growth.

RECOMMENDATIONS

Specimens with good AL increment and low variance could be selected from among the body weight classes, and cross to obtain progeny with stable and improved AL increment for grow-out farming leading to higher quality headless category export.

Moreover, individual with shorter second or third walking leg could be selected and bred for progeny with less leg weight contribution to total body weight, improving net meat weight yield.

Furthermore, through selective breeding improved broodstocks with good qualities such as stable and faster growing TL and AL with low variance, small walking legs could be developed for genetic upgrading in shrimp and prawn hatcheries. The data generated, in this research work, could form the basis for development of high quality broodstocks and for improvement of growth in pond cultures of shrimps and prawns.

ACKNOWLEDGMENT

The author is indebted to Dr. Khin Maung Saing, Visiting Professor, Ministry of Science and Technology and Dr, Mya Mya Oo, Rector, Yangon Technological University for their guidance, suggestions and supports in preparing this work. Special thanks go to His Excellency U Thaung, Minister, Ministry of Science and Technology, Myanmar for his kind permission to do this study.

REFERENCES

[1] Aung Kyi 1997. *Guide to giant freshwater prawn culture scientific and practical approach* (In Myanmar). Yangon: Sarpaebeikman.

[2] Aung Kyi 2000. *Handbook of penaeid shrimp culture* (In Myanmar). Yangon: Sarpaebeikman.

[3] Escritor. G.L. 1980. Life History of *Macrobrachium rosenbergii* de Man. In Report of the training course on prawn farming for Asia and the Pacific. Scs/ GEN/ 81/ 28.

[4] Holthuis , L.B. 1950. Key to the Indo-West species of the genus *Macrobrachium.* Cited in Nyan Taw. 1982. A brief account on the giant freshwater prawn (*M rosenbergii* de Man) in Burma. *Giant Prawn Farming.* Amsterdam: Elsevier.

[5] Htay Aung. 1982. The Taxonomy of Some Penaeidae (Crustacea, Decapoda) from Mon State and Tanasserim Division Coastal Waters. *M.Sc. Thesis*, Department of Marine Biology, Moulmein Degree College, Myanmar.

[6] Khin Nwe Mu. 1980. A Taxonomic Study of Some Prawns found from Ngawun River Mouth, Bassein. *M.Sc. Thesis*, Arts and Science University, Rangoon.

[7] Motoh, H. 1981. Studies on the fisheries biology of the giant tiger shrimp, *Penaeus monodon* (Philippine Techincal Report 7). Aquaculture Department, SEAFDEC, Tigbauan, Iloilo, Philippine.

[8] Myint Thein. 1984. Some Aspects on the Systematics and Reproductive Biology of *Macrobrachium* Species found in Irrawaddy Delta, Burma. *M.Sc. Thesis*, Department of Zoology, University of Yangon.

[9] Sann Aung. and Hla Htay. 1987. A Field Guide to Identification of Commercially Important Marine Prawns of Burma.

[10] Tin Tin Soe. 1970. Taxonomy of Prawns Found in Rangoon Markets. *M.Sc Thesis,* Zoology Department, Arts and Science University, Rangoon.

[11] Win Win Myint. 1988. Classification and Description of Some Freshwater and Estuarine Prawns of Mon State. *M.Sc. Thesis*, Department of Zoology, University of Rangoon.

GMSARN International Journal
NOTES FOR AUTHORS

Editorial Policy

In the Greater Mekong Subregion, home to about 250 million people, environmental degradation - including the decline of natural resources and ecosystems will definitely impact on the marginalized groups in society - the poor, the border communities especially women and children and indigenous peoples. The complexity of the challenges are revealed in the current trends in land and forest degradation and desertification, the numerous demands made on the Mekong river - to provide water for industrial and agricultural development, to sustain subsistence fishing, for transport, to maintain delicate ecological and hydrological balance, etc., the widespread loss of biological diversity due to economic activities, climate change and its impacts on the agricultural and river basin systems, and other forms of crises owning to conflicts over access to shared resources. The *GMSARN International Journal* is dedicated to advance knowledge in energy, environment, natural resource management and economical development by the vigorous examination and analysis of theories and good practices, and to encourage innovations needed to establish a successful approach to solve an identified problem.

The *GMSARN International Journal* is a biannual journal published by GMSARN in June and December of each year. Papers related to energy, environment, natural resource management, and economical development are published. The papers are reviewed by world renowned referees.

Preparation Guidelines

1. The manuscript should be written in English and the desired of contents is: Title, Author's name, affiliation, and address; Abstract, complete in itself and not exceeding 200 words; Text, divided into sections, each with a separate heading; Acknowledgments; References; and Appendices. The standard International System of Units (SI) should be used.

2. Illustrations (i.e., graphs, charts, drawings, sketches, and diagrams) should be submitted on separate sheets ready for direct reproduction. All illustrations should be numbered consecutively and given proper legends. A list of illustrations should be included in the manuscript. The font of the captions, legends, and other text in the illustrations should be Times New Roman. Legends should use capital letters for the first letter of the first word only and use lower case for the rest of the words. All symbols must be italicized, e.g., α, θ, Q_{wt}. Photographs should be black and white glossy prints; but good color photographs are acceptable.

3. Each reference should be numbered sequentially and these numbers should appear in square brackets in the text, e.g. [1], [2, 3], [4]–[6]. All publications cited in the text should be presented in a list of full references in the Reference section as they appear in the text (not in alphabetical order). Typical examples of references are as follows:

   - **Book references** should contain: name of author(s); year of publication; title; edition; location and publisher. Typical example: [2] Baker, P.R. 1978. Biogas for Cooking Stoves. London: Chapman and Hall.
   - **Journal references** should contains: name of author(s); year of publication; article title; journal name; volume; issue number; and page numbers. For example: Mayer, B.A.; Mitchell, J.W.; and El-Wakil, M.M. 1982. Convective heat transfer in veetrough liner concentrators. Solar Energy 28 (1): 33-40.
   - **Proceedings reference** example: [3] Mayer, A. and Biscaglia, S. 1989. Modelling and analysis of lead acid battery operation. Proceedings of the Ninth EC PV Solar Conference. Reiburg, Germany, 25-29 September. London: Kluwer Academic Publishers.
   - **Technical paper** reference example: [4] Mead, J.V. 1992. Looking at old photographs: Investigating the teacher tales that novice teachers bring with them. Report No. NCRTL-RR-92-4. East Lansing, MI: National Center for Research on Teacher Learning. (ERIC Document Reproduction Service No. ED346082).
   - **Online journal** reference example: [5] Tung, F. Y.-T., and Bowen, S. W. 1998. Targeted inhibition of hepatitis B virus gene expression: A gene therapy approach. Frontiers in Bioscience [On-line serial], 3. Retrieved February 14, 2005 from http://www.bioscience.org/1998/v3/a/tung/a11-15.htm.

4. Manuscript can be uploaded to the website or sent by email. In case of hard copy, three copies of the manuscript should be initially submitted for review. The results of the review along with the referees' comments will be sent to the corresponding author in due course. At the time of final submission, one copy of the manuscript and illustrations (original) should be submitted with the diskette. Please look at the author guide for detail.

GMSARN Members

Asian Institute of Technology

Hanoi University of Technology

Ho Chi Minh City University of Technology

Institute of Technology of Cambodia

Khon Kaen University

Kunming University of Science and Technology

National University of Laos

Royal University of Phnom Penh

Thammasat University

Yangon Technological University

Yunnan University

Guangxi University

Published by the **Greater Mekong Subregion Academic and Research Network (GMSARN)**
c/o Asian Institute of Technology (AIT)
P.O. Box 4, Klong Luang
Pathumthani 12120, Thailand
Tel: (66-2) 524-5437; Fax: (66-2) 524-6589
E-mail: gmsarn@ait.ac.th
Website: http://www.gmsarn.org