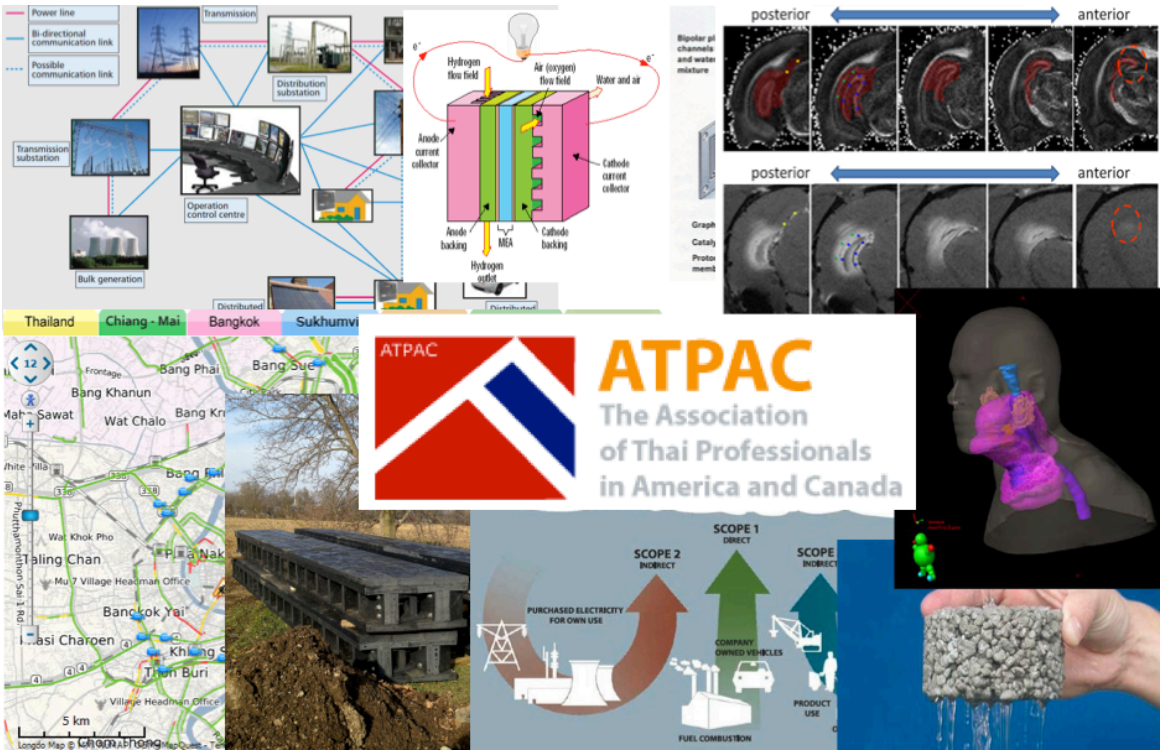
EMERGING SCIENCE AND TECHNOLOGY DEVELOPMENT IN THE US THAT CAN BE BENEFICIAL TO THAILAND



โครงการศึกษาแนวทางการพัฒนาเทคโนโลยีจากประเทศสหรัฐอเมริกาและประเทศแคนาดาของสมาคมนักวิชาชีพไทยในอเมริกาและแคนาดา (ATPAC)

January 7, 2013

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Executive Summary

This report presents 11 research ideas and proposals for Thailand through a project funded by the Office of Science and Technology Counselor (OSTC), Ministry of Science and Technology (MOST), Washington, D.C. These proposed research projects cover the following technical areas, namely, Energy, Biophysics, Biomedical, Electronic and Communications, Transportation, Environment, Water Resource and Flood Risk Management, Materials, Food Science, and Climate Change and Carbon Credit. Each of these projects was derived from the expertise, experience, and contact and connection of each ATPAC member, who provides technical contribution to this project. The followings provide a brief summary into the main substance of these 11 technical proposals.

The "Wireless Connectivity" project, proposed by Dr. Gaviphat Lekutai, is the leading emerging research area in communication for this coming year. He proposes to study smart grid wireless connectivity, Cognitive Radio with Cloud Connectivity, Device-to-device connectivity, and small cell wireless backhaul connectivity. These critical device-to-device connections are in high demand as most new electronic and communication devices and gadgets compete to do multi-tasks with flexible mobility, and be able to communicate with other devices, fixed or mobile.

In environmental area, Dr. Eakalak Khan proposes to treat wastewater with algae to remove nutrient and at the same time produce energy. The novel treatment process serves as a critical part of a biofuel production which can generate energy for communities in rural area. The research proposes a novel process based on two-step stress conditions that will enhance uptakes of organics and nutrients in wastewater by algae and produce biomass. This research could provide an energy efficient wastewater treatment process for economically challenged rural communities and in turn improve public health.

Dr. Malisa Sarntinoranont, a bio-physicist whose expertise and research are in the area of drug delivery technology, proposes an alternative novel biophysical approach to improve understanding of changes in the physiological environment in the brain, which can be used to improve drug delivery mechanism and improve patient response to therapies.

As energy continues to be a pressing global research interest, Dr. Sirivatch Shimpalee proposes a study on the feasibility for robust and low-cost fabrication of Proton Exchange Membrane Fuel Cell (PEMFC) bipolar plates by developing an innovative hybrid manufacturing process. The proposed approach could reduce process steps, reduce variation in dimensional tolerances and surface finishing, increase product quality, increase fuel cell performance, and reduce overall stack cost.

Dr. Witoon Prinyawiwatkul, a professor with the Department of Food Science at Louisiana State University, proposes a major research program for Thailand to develop sodium-reduced food and salt substitutes for Thai food industry and communities. Excessive sodium intake in daily diet is

a major source and contributor to hypertension (high blood pressure-HBP) and a major public health problem. HBP is one of the main contributors to cardiovascular diseases, which are leading cause of death, disability, and sky-rocketing healthcare cost. Sodium reduction is therefore an urgent public health priority that requires cooperation and partnership of government, food industry, educational community, and other diverse stakeholders. Researchers have an urgent task of developing sodium-reduced food and salt substitutes. This project aims at preparing Thai food industry to be ready for any forth-coming sodium reduction regulations and requirements in the global market. Furthermore, the project also intends to raise awareness and concerns to both the Thai public and the healthcare community to address this hidden life threatening time bomb.

In biomedical science and engineering, Dr. Vorakarn Chanyavanich, a leading Thai scientist in this field, suggests that Thailand launch a research project on "Knowledge-based Treatment Planning for Radiation Therapy of Head and Neck Cancers". Citing increasing cancer patients in Thailand in recent years (estimated at 120,000 new cases each year), more than a third of these patients will have to be treated using radiation therapy. For patients diagnosed with head and neck cancer, surgery and radiation therapy need to be precise as normal tissues in the affected area are critical, sensitive, and vital to life sustaining of the whole system. IMRT (Intensity Modulated Radiation Therapy) is an advanced radiation delivery technique that requires well trained and experienced oncologists and medical physicists to control the dosage of radiation. These processes are tedious, time-consuming, and often inefficient as it depends on trial and error. Dr. Vorakarn proposes to develop decision-support software for IMRT treatment planning for those required head and neck radiotherapy treatment. The software will ensure safety, reliability, and consistency of treatment planning to eliminate the unwanted cancer cells at these complex sites. Specific aims of the project include developing a knowledge-based high quality radiotherapy treatment plans, and designing and compiling case-similarity algorithm for patients with similar problems. This should help enhance the reliability of the treatment process and speed up the treatment of these cancer patients.

Dr. Kanok Boriboonsomsin and Dr. Praprut Songchitruksa, both in the area of Transportation, jointly propose a research program to develop eco-routing navigation algorithms for Thai vehicles. With serious traffic problems in Bangkok and in all other major cities in Thailand, travelling on a route that consumes the least amount of fuel, commonly known as "eco-routing", is definitely a critical energy conservation measure for Thailand and each Thai consumer driving to his/her destination. The two researchers propose to develop this research program for Thailand following the model and experience they earn working on a similar navigation system for the U.S. market. This project on "eco-routing" navigation, if successfully developed and implemented, will have significant impact to the Thai economy as it can save enormous amount of time and money, and reduce petroleum consumption and emissions.

Lessons learned from the great flood of 2011 that hit Thailand and Bangkok, causing loss of lives and significant damage to Thailand's economy, are clearly the lack of a comprehensive

water resource management and flood-risk mitigation program. Dr. Nisai Wanakule, through this proposal, suggests that ATPAC and Thai government jointly hold several workshops and roundtable meetings between US experts in water resource and flood-risk management with their Thai counterparts. The goals are: 1) to provide a platform to develop a close technical collaboration between the US and Thai experts for Water Resource and Flood Risk Reduction Management; 2) to utilize experienced technical resources in the U.S. to help review and provide assessment for the new water resource programs, to be implemented under the WFMC program of the Thai government; and 3) through bi-lateral cooperation between the U.S. and Thailand, to request support from the U.S. (to be specific, the U.S. Army Corp. of Engineers) to help advise and make recommendations to Thai government on the development of a sustainable plan on integrated water resource management for flood protection and flood risk reduction.

Global warming and climate change increasingly cause irregularity in global weather pattern. Super storm Sandy, Hurricane Katrina, the 2011 Great flood of Thailand, and the earthquake and Tsunami in Japan are among the very few recent extraordinary natural disasters. These unusual natural events have prompted the EU to launch its EU-ETS program with the goals of reducing CO_2 emissions, following the agreed upon emission reduction ratified by the Kyoto protocol. Phase III of the EU-ETS program, starting this year (2103), will include accountability of CO_2 emissions of the aviation industry. Dr. Methi Wecharatana suggests that all Thai airports develop their emission inventory in compliance with the Airport Carbon Accreditation requirements. Also, the Airport Authority of Thailand should initiate carbon projects in its airports to accrue EUAs and CERs to help strengthening its airline industry when doing business with the 27 European Union countries, and thus in turn strengthening the Thai tourism industry as well.

The great flood of 2011 of Thailand that caused so much damages to our country, has motivated many of us, in Thailand and overseas alike, to find alternative solutions to help mitigate flooding problems in Thailand. Dr. Methi Wecharatana, a professor in Civil and Environmental Engineering, suggests that pervious concrete technology be explored and research, and develop into new construction products, such as, pavement, pedestrian walkways, and parking lots in Thailand. Water can quickly flows through pervious concrete. With proper mix proportions, pervious concrete would allow stormwater to percolate into the subbase and subgrade, thus helping mitigate the flooding on roadways after heavy storm. Pervious concrete pavement can turn parking lots into temporary retention ponds and thus slow the rate of surface runoff, and help alleviate flooding. Pervious concrete can also be used as cover for many dangerous uncovered drainage and water channels in Thailand.

Plastic waste has been reclaimed and made into recycled plastic structural members, such as planks, piles, I-beams, and structural box sections. With abundant plastic waste generated by human activities these days, structural members made from recycled plastic waste provide ideal construction products that can be reused indefinitely. Furthermore, these products are water-proof, extremely durable, and can carry the needed normal service loads, and can be used in

place of conventional concrete and timbers. With shortage of landfills and depletion of natural resources, these recycled plastic structural members can be a perfect solution for the building and construction industry toward a sustainable future. This project, proposed by Dr. Methi Wecharatana, recommends that Thailand launch a research program on developing recycled plastic waste into structural members for construction. Previous studies, found in the literature, confirm that the proposed project is viable and has great potential.

In closing, the proposed research projects listed in this report provide a pool of invaluable ideas for Thailand to launch and carry out their research programs in these areas. Delightfully, all ATPAC members, who suggested these projects, will be pleased to provide any additional information if needed.

Respectfully submitted,

Dr. Methi Wecharatana, Editor

Dr. Wanpracha Chaovalitwongse, Co-Editor

Acknowledgement

The Association of Thai Professionals in America and Canada (ATPAC) was established in 1990 with the objectives of voluntarily assisting in the development of Thailand. The organization works closely with the Office of Science and Technology Counselor (OSTC), Ministry of Science and Technology (MOST), in Washington, D.C., the Reverse Brain Drain (RBD) programs of the National Science and Technology Development Agency (NSTDA), MOST, and the Office of Higher Education Commission (OHEC) of the Ministry of Education. Every year our ATPAC members will take time off from their normal work assignments and travel to Thailand to provide technology transfer, which are mostly in the form of lectures, seminars, workshops, and trainings. Some teach graduate courses and, together with Thai professors, jointly supervise research for Thai graduate students. For those who could not make the trip(s) due to workload and job responsibility here in the U.S., many contribute to the mission of ATPAC by proposing new research ideas to Thailand via technical research proposals, compiled and collected through the OSTC Office.

For 2012, during his visit to the U.S. in August, Dr. Pornchai Rujiprapa, then the Permanent Secretary of MOST, initiated a project to solicit research ideas from ATPAC members for Thailand. The project received strong support and endorsement from Mr. Alongkorn Laowngam, Minister Counselor on Science and Technology of MOST at the OSTC Office, Royal Thai Embassy in Washington, D.C. The initiation of this project and the support from both senior Thai government officials of MOST are gratefully acknowledged here. This report was made possible from the contribution of each participating ATPAC member, namely, Dr. Wonpracha Chaovalitwonge, Dr. Sirivatch Shimpalee, Dr. Malisa Sarntinoranont, Dr. Praprut Songchitruksa, Dr. Kanok Boriboonsomsin, Dr. Gaviphat Lekutai, Dr. Vorakarn Chanyavanich, Dr. Witoon Prinyawiwatkul, Dr. Eakalak Khan, Dr. Nisai Wanakule, and Dr. Methi Wecharatana. Their contributions are greatly appreciated and acknowledged here. Eleven research proposals, covering technical ideas in energy, biophysics, biomedical, electronic and communication, transportation, environment, water resource management, materials, food science, and climate change and carbon credit, are presented. The editor would like to thank Dr. Nisai Wanakule, ATPAC's Acting President, and Dr. Wanpracha Chaovalitwonge, ATPAC's Executive Vice President and Treasurer, for their support and encouragements. Special thanks are also due to Mr. Alongkorn Laowngam, who provided many ideas for this project and for his support and help in putting the report into its final form. Finally, financial support provided by MOST and OSTC for this project is gratefully acknowledged here.

Dr. Methi Wecharatana, Editor

Dr. Wanpracha Chaovalitwongse, co-Editor

Wireless Connectivity

BY *GAVIPHAT LEKUTAI*

Emerging research area in communication for the coming years would evolve around wireless connectivity of various access technologies such as LTE, UMTS, Wi-Fi, Wi-Max, ZigBee, Bluetooth, RFID, etc. and towards seamless cloud computing where users could transfer data from anywhere on any device and from one provider to another (cloud portability and interoperability interfaces) applied to specific business applications. The following sections highlight some examples of wireless connectivity of various collaborative networks with potential cutting edge and growth.

Smart Grid Wireless Connectivity

Smart grid is a concept of improved energy delivery, informed consumption and reduced environmental impact. It typically uses Internet technologies to enable bi-directional communication, coordination and control. The vision of a smart grid starts with overlaying an information network, increasingly based on IP, onto connecting elements of the existing electric grid. In the long term, it will encompass re-architecting the generation and distribution of energy to make the energy grid more decentralized, resilient, secure and responsive to consumer demand and utility supply.

The smart grid is architecturally similar to the Internet, in that it is hierarchical and has clear points of demarcation. Energy utilities run the generation and interstate links of the grid, equivalent to an ISP's backbone. Within a metro area or neighborhood, local utilities run a neighborhood area network (NAN), equivalent to a metropolitan area network (MAN). The smart grid reaches out to individual homes and businesses through the advanced metering infrastructure (AMI), which is like a local ISP's DSL network -- the last mile to the "smart meter." Inside a building or home, consumers and businesses will run a home area network (HAN) or building automation system (BAS), which is the smart grid equivalent of a LAN. The AMI smart meter also acts as the Network Termination Point or ingress router, a demarcation between the utility's network and the HAN or BAS.

The interfaces of the wireless connectivity between building automation network and the utility feed will be intelligent. This brings up tremendous opportunities for automation as well as severe management and security challenges. An example of smart grid architecture with wireless communication link is depicted in Figure 1 [1].

The power flow is no longer limited to the direction of bulk power plants but dynamically expand to/from any generation sources in the grids. The energy can be stored and released back to the girds even at household level allowing opportunities for consumers to participate in the energy demand management and reduce the cost of their energy.

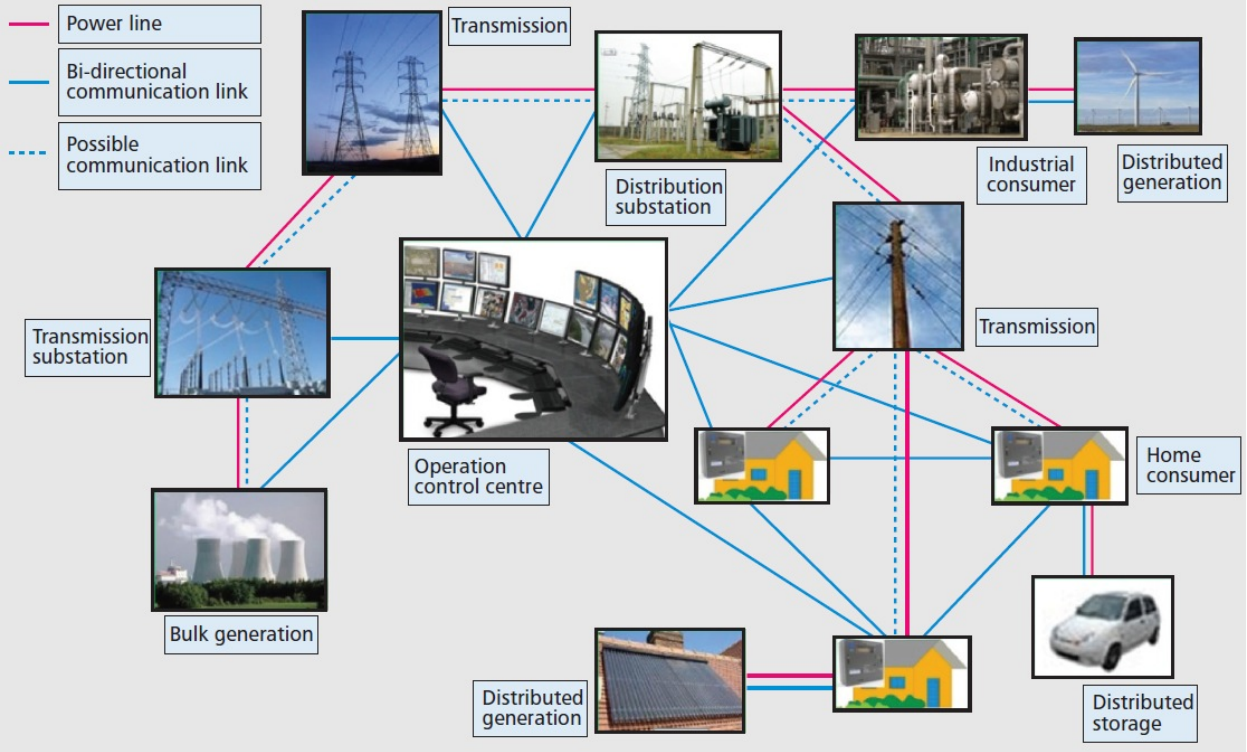

Figure 1. Smart Grid Wireless Connectivity Example

Cognitive Radio with Cloud Connectivity

Due to persistent trend of higher bandwidth to support multimedia data rates, efficient utilization of radio spectrum beyond its traditional limits is consistently sought-after, thus the concept of the cognitive radio (CR) was developed in year 1999 [2].

A CR may be defined as a technology that uses radio intelligently by recognizing its radio environment and its internal state, together with knowledge of these elements and any stored pre-defined objectives, to better implement decisions about its behavior. A tutorial is available in [3].

CR covers a wide range of real-world topics including heterogeneous radio spectrum access and sharing, coexistence mechanisms, architecture designs, geo-location databases, device platforms, TV white spaces, medical/health telemetry, connected home, vehicle telematics, a wireless smart grid, etc. Implementing **CR in combination with cloud computing services platform could potentially develop into a new paradigm of intelligent networking** (not to mention in combination of big data/datamining which could take into another step further). Cloud services platform in cognitive radio networks make a good fit due to its cloud's elastic, ubiquitous and scalable computing power; enabling collection, analysis, process and coordination of sheer massive and dynamic multiple radio communications (as seamless as) possible.

An example of a conceptual cognitive radio cloud application in medical body area networks [4] is illustrated in Figure 2.

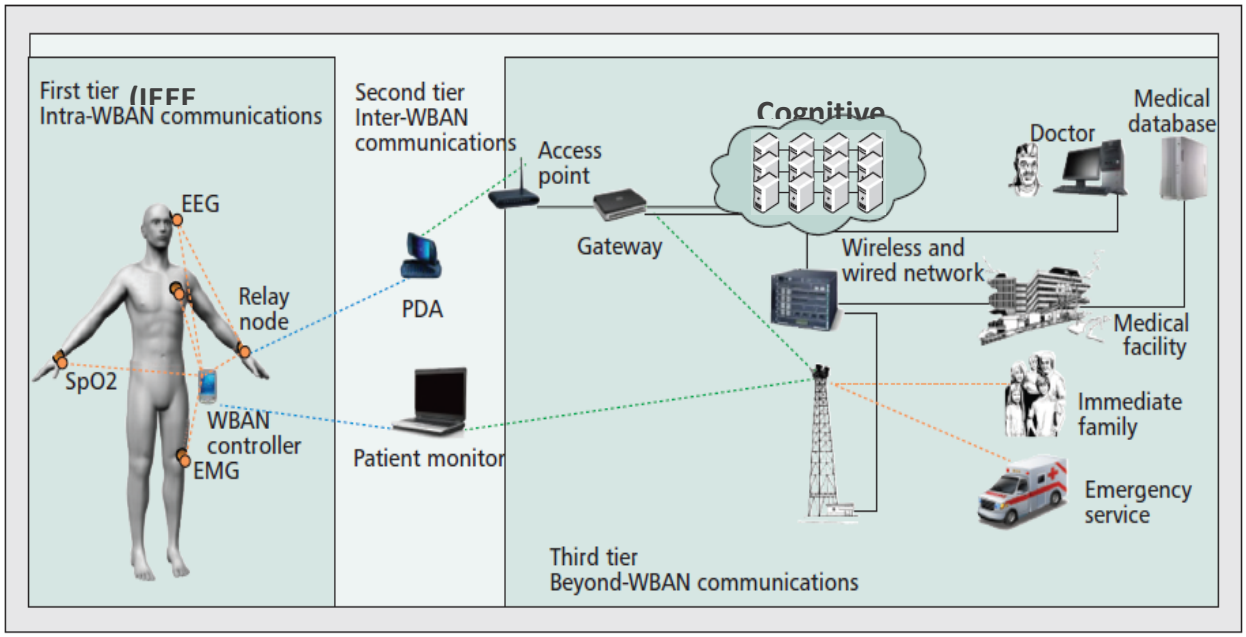

Figure 2. Medical Body Area Wireless Connectivity Example

Thailand could take an advantage of substantial used/unused radio spectrum by developing its own cognitive radios together with the rapid growth of existing cloud computing Platform as a Service (PaaS) such as Microsoft's Windows Azure or Google App Engine or Red Hat's OpenShift, et cetera. A strong integration with wireless application in medical/health services, connected home security/automation and connected car/telematics are warranted for multiple new business opportunities (Gartner forecasted $183B cloud opportunity by 2015 [5]).

Device-to-Device Connectivity

Device-to-device (D2D) communication has evolved from fixed cable connectivity without an infrastructure of access points to wireless radio connectivity where cellular phone can be the hub for other consumer electronic devices and used as the gateway to the cellular networks. The term Machine-to-Machine (M2M) and D2D is used interchangeably with an emphasis to the 4G wireless generation of mobile smartphones/tablets to the latter. The most widely known D2D technologies are Bluetooth and Wi-Fi.

An example of a D2D mobile payment application or ISIS Mobile Wallet™ is shown in Figure 3. D2D/M2M is expected to be gradually cloud based.

Figure 3. D2D Connectivity for Mobile Payment Example

Small Cell Wireless Backhaul Connectivity

Outdoor small cell is the next economical step of providing solution to alleviate 3G/4G macrocell capacity, hotspot demand and improve coverage and performance in the mobility networks. Small cell could be in the form of femtocell (250 mWatts), picocell (1-5 Watts) or microcell (5-10 Watts). It is targeted to be installed on low profile street furniture such as light poles, signs, lamp posts, etc. (i.e., below rooftop level structure) with low transmit power and in dense and busy urban environments. Providing access backhaul to these low profile structures is the most challenging the industry has to solve. Wired connectivity such as fiber, copper pairs, coaxial cable or Metro Ethernet is generally not available at these facilities or available at the high cost of construction, trenching, etc. Wireless connectivity such as traditional line-of-sight (LOS) microwave, millimeter-wave, sub-6GHz licensed and unlicensed Non Line-Of-Sight (NLOS) microwave or satellite tends to emerge as the potential solution to support small cell backhaul deployment. With small cell deployment promises from the operators worldwide [6], tremendous backhaul opportunity has sprung up many innovative, efficient and affordable wireless connectivity technologies. For example, recent **in-band full duplex communication techniques (with self interference cancellation)** have been developed to provide high capacity and low latency point-to-multipoint NLOS backhaul connectivity solutions [7] (see Figure 4).

In summary, wireless connectivity provides a class in itself for emerging research topics due to its massive demand for intricate applications and robust agility. Several examples of innovative concepts and growth opportunities were given.

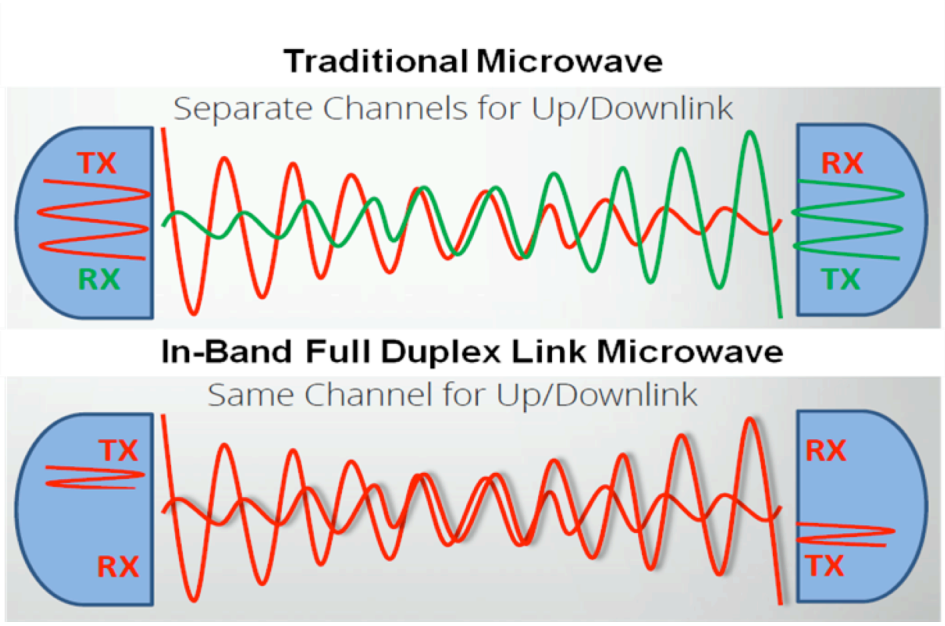

Figure 4. Wireless Backhaul Connectivity – In-Band Full Duplex Technology Example

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Algal Wastewater Treatment Process for Nutrient Removal and Energy Production

BY *EAKALAK KHAN AND TANUSH WADHAWAN*

Potential Counterpart in Thailand: Energy Research and Development Institute, Chiang Mai University

Summary

The depletion and rising cost of fossil fuel have prompted the world to rely more on alternative energy. Biofuel is one of the major types of alternative energy. Algae are a good feedstock for biofuel production. It does not suffer from social, economic, and environmental issues as some other feedstocks such as wheat and corn. Growing algae in wastewater has been practiced for energy production and removal of pollutants particularly nitrogen. Traditional algal-based wastewater treatment processes including conventional stabilization ponds and high-rate algal ponds are not very efficient in removing nutrients, require high energy and do not produce enough biomass. This research proposes a novel process based on two-step stress conditions that will enhance uptakes of organics and nutrients in wastewater by algae and produce high lipid containing biomass. Nutrient and carbon limitations will be the first stress while aeration which can activate carbon dioxide concentrating mechanism will be the second stress. The proposed research is appropriate for Thailand particularly rural areas because algal growing is more favorable under warm climate and is land intensive. The research will provide an energy efficient wastewater treatment process for economically challenged communities and in turn will improve public health. Other benefits of the research include protection of natural waters which are often used for recreational purposes and aquaculture/fishing industry.

Background and Rationale

Algae are autotrophic organisms and exist as unicellular and/or multicellular. Algae have an ability to convert and store carbon dioxide (CO_2), light and micro- and macro-nutrients in a form of lipids (up to 30% of their cell weight). When grown under controlled conditions algae can be harvested for the lipids which can be further processed for producing biofuels. Different forms of biofuels produced from algae are biodiesel, bioethanol, biobutanol, straight vegetable oil and biogas (methane) (Ellis *et al*., 2012). According to the National Renewable Energy Laboratory when grown under controlled conditions algae can produce 40 times more lipids or oil per unit area compared to oil producing plants. The ability of algae to use organic and inorganic compounds in the presence of light to produce oil can prove to be very beneficial for wastewater treatment plants (WWTPs). Using algae for treating wastewater can provide sustainable solutions for various issues associated with modern WWTPs (Christenson and Sims 2011; Zhou *et al*., 2012). Algal wastewater treatment process is very suitable for rural areas where land is not

limited and warm climate regions. Based on these criteria, the process is appropriate for Thailand which lacks wastewater treatment facilities in smaller towns and communities.

One of the major issues for WWTPs is discharge of nutrient rich wastewater effluents into surface waters. Release of nutrients such as nitrogen and phosphorus into rivers, streams and lakes can result in eutrophication or growth of unwanted and/or toxin producing algae. Eutrophication is detrimental to the aquatic ecosystem and causes aesthetic and public health concerns. Using non-toxic algae for removing nutrients from wastewater effluent before the discharge can prevent destruction of the water bodies. The second major issue related to WWTPs is the cost associated with their operation and maintenance. Growing algae on wastewater can provide biomass for producing enough biofuel to offset the cost of operating and maintaining WWTPs. The third major issue related to WWTPs is the production of large amount of greenhouse gases (GHG), which does not seem to be a problem when using algae. The fourth major issue is high sludge production and disposal of activated sludge. Algae produces less sludge and most of the biomass can be used for biofuel production. Even residual algae biomass after producing biofuel can be used as fertilizers for land application.

Some other benefits of using algae for treating wastewater is that growth of algae causes rise in pH and can lead to disinfection of pathogenic microorganisms. Algae can provide improved and faster treatment. Biofuel produced can provide GHG abatement and a saving of about $6 and 15 kWh per gallon of oil produced. However, there is no commercially available technology which allows sustainable growth of algae in wastewater for biofuel production to its full potential. Currently available technologies using algae for wastewater treatment are conventional stabilization ponds and high-rate algal ponds (Arauzo *et al*., 2000; Park *et al*., 2011; Christenson and Sims 2012). Conventional ponds have very little or no mechanical mixing and have a high residence time of 20-100 days while high-rate ponds have paddle wheel mixing and a residence time of 4-10 days. Both of these processes are not very efficient in removing nutrients, require high energy and do not produce enough biomass. Hence both of the technologies are not very efficient in using algae to its ability.

Algae cultures offer solutions to tertiary and quandary treatments due to their ability to use nitrogen and phosphorus for growth (Kang *et al*., 2009; Wang and Lan, 2011). A number of different studies have identified that nutrient limiting conditions can cause higher biomass and lipid production. Xin *et al.* (2010) identified that under nutrient limiting conditions *Scenedesmus sp*. LX1 accumulated 30% (N = 2.5 mg/L) and 53% (P = 0.1 mg/L) more lipids than their biomass. Li *et al.* (2011) showed that growing *Chlorella sp*. in the raw concentrate of municipal wastewater (TN = 116.1 mg/L, TP = 212.0 mg/L) removed total nitrogen and total phosphorus by 89.1% and 80.9% respectively, while accumulating the fatty acid methyl ester up to 11% of its dry biomass which produced 0.12 g-biodiesel/L-algae culture solution.

This research presents a new process for achieving high concentrations of algae for biofuel production while treating wastewater for high quality. The growth rate of algae directly affects

the nutrient removal rate and requires proper N/P ratio in wastewater for optimum nutrient uptake and removal. Both the algal growth rate and nutrient concentration of algae also influence the lipid accumulation rate, the lipid productivity and lipid content per algal biomass. Nutrient limitation has shown to increase lipid accumulation. Nitrogen limitation decreases the cellular content of thylakoid membrane, activates acyl hydrolase and stimulates the phospholipid hydrolysis which results in the increase of the intracellular fatty acid acyl-CoA which is converted to triglyceride (lipids) (Li *et al*., 2008). This proposed process will apply a two-step stress condition for improving growth of high lipid containing algal biomass. Higher lipid contents of the biomass provide higher methane production during anaerobic digestion (Cirne *et al*., 2007).

Research Justification/Proposed Study for Thailand

This research proposes an innovative technology which will create two-step stress conditions that will increase the ability of algae to uptake organics and nutrients in the wastewater and produce high lipid containing biomass. Figure 1 presents the process diagram. The anoxic-aerobic activated sludge (Anx-AerAS or phase 1) tanks will treat wastewater to nutrient and carbon limiting conditions (first stress) for the algal growth in the anaerobic-aerobic algae sludge (AnA-AerA or phase 2) tanks. The continuous circulation of algal sludge between the AnA and AerA causes the second stress due to aeration (O_2). The aeration causes stress on algal biomass which activates the CO_2 concentrating mechanism responsible for high CO_2 uptake (for higher uptake under anaerobic conditions). So both of the stress causing conditions will result in higher removal of substrates (nutrients and organics) and provide a higher lipid producing biomass. The uptake or oxidation of substrate by algal and activated sludge will result in production of biomass which will produce total suspended solids that can be separated in the respective clarifiers. The first clarifier prevents a large amount of activated sludge from getting into the phase two. The amount of solids from both the clarifiers will be mixed and transferred to the anaerobic digester for methane production.

This process is a design for a brand new wastewater treatment plant. However, the process can also be used to retrofit some of the existing plants. Not all wastewater plants use a similar technology for treating their wastewater. Non-nitrified, completely nitrified, and denitrified effluents are the three distinct types of wastewater effluents that are produced by typical wastewater treatment plants. The proposed technology can be modified to adapt to different types of existing wastewater treatment processes. For wastewater plants producing non-nitrified effluent, both phases 1 and 2 can be used. For nitrified effluents, only the anaerobic tank from the phase 1 plus the entire phase 2 can be added to the existing plant. However, plants already achieving denitrification will require only phase 2.

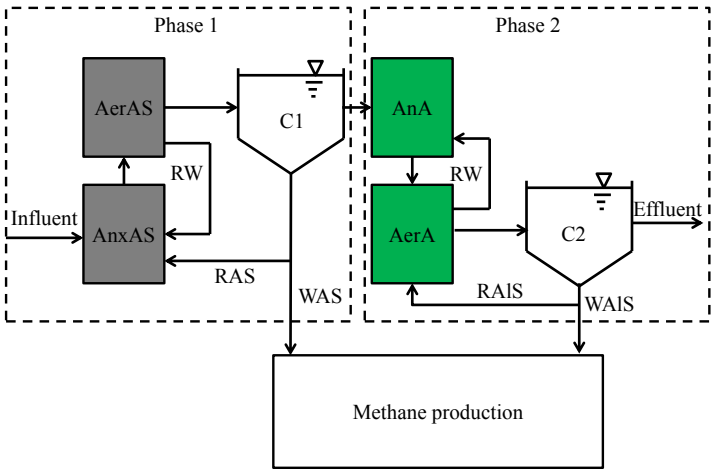

Figure 1: Where Aer is aerobic, Anx is anoxic, An is anaerobic, C is clarifier, WAS is waste activated sludge, RAS is recycle activated sludge, RAlS is recycle algae sludge, AlS is algae sludge, RW is recycled wastewater.

Goal, Objectives and Hypotheses

The major goal of this research is to optimize the growth of high lipid containing algal biomass for achieving low nutrient levels in the wastewater effluent and increased methane production. This research presents a promising process that can be immediately laboratory and rapidly field tested for treating wastewater using algae while simultaneously producing enough biomass for biofuel production. The process will allow wastewater treatment plants to achieve low nutrient concentrations in their effluents and to produce enough biofuel for offsetting their operation and maintenance costs. The objectives and hypotheses are as follows.

Objectives:

1. Investigate algal growth kinetics under aerobic and anaerobic conditions with varying concentrations and types of carbon, nitrogen and phosphorus.
2. Set up a bench scale multi-stage tank (described below) for treating wastewater and methane production. Determine the effect of different combinations of solids retention time (SRT) and hydraulic retention time (HRT) on the growth and lipid content of the algae in continuous flow anaerobic-aerobic zoned algae reactor.
3. Evaluate the effect of intermediate CO_2 sparging during the anaerobic incubation period of objective 2.
4. Set up a pilot-scale multi-stage tank for treating wastewater and methane production.
5. Identify an appropriate ratio of activated sludge and algal sludge for methane production.

Hypotheses:

1. Wastewater containing different ratios of different forms of carbon, nitrogen and phosphorus can result in different growth kinetics of high lipid containing algae. High carbon (in a form of CO_2), low nitrogen (nitrate) and phosphorus containing wastewater will result in higher lipid rich biomass for methane production.
2. Growing algae under anaerobic conditions with a brief period of aerobic condition allows it to accumulate more than desired inorganic carbon and nitrogen in its biomass. These conditions result in the production of high lipid containing biomass. The anaerobic conditions will also allow fermentation products which will enhance methane production.
3. Two-step stress condition will increase the production of lipid containing algal biomass.
4. Different ratios of activate sludge and algae sludge can result in different amount of methane production. The ratio which gives the highest C:N ratio will result in highest methane production.

Brief Research Tasks

A mixed algae culture will be obtained from a local lake or a reservoir and enriched continuously on wastewater effluent until a stable growing culture is achieved. The growth rate of the culture will be determined and the major species present will also be identified using microscopy and molecular techniques. For most of the batch experiments the composition of synthetic wastewater will be as follows unless stated: 400 mg/L of glucose, 20 mg/L of calcium chloride, 100 mg/L of protein, 25 mg/L of magnesium sulfate, 25 mg/L of sodium bicarbonate, 300 mg/L of chemical oxygen demand (COD), 15 mg/L of potassium phosphate, 60 mg/L of ammonium chloride. To study the effect of different ratios of C:N:P the concentrations of glucose, ammonium chloride and potassium phosphate will be varied. For studying the effect of different forms of inorganic nitrogen instead of ammonium chloride, sodium nitrate and sodium nitrite will be used. The growth rate will be determined by cell counting using microscopy and measuring chlorophyll over a period of incubation. The batch experiments for treating synthetic wastewater will be carried out in both aerobic and anaerobic conditions. The lipid content of the algae will be determined using a solvent extraction procedure. The Philip-Bird Jar test equipment will be used to quantify the amount of sludge produced during batch the experiments.

For a continuous flow bench-scale study, two conical reactors (for clarifier) with a volume of 2.5 cubic feet and four 1′ x 2′ x 1′ (height x length x width) reactors (anoxic, anaerobic and aerobic tanks) will be made using plexiglass acrylic sheets. The reactors will have a working volume of approximately 56 L. The reactors will be set up as presented in Figure 1. PVC tubing will be used to circulate the wastewater using peristaltic pumps. The process will be run under different SRTs (1 to 10 days) and HRTs (1 to 24 hours) and will be evaluated for treatment of synthetic wastewater, raw wastewater from a treatment plant and simultaneous production of high lipid containing algal biomass. Diffusers will be placed in the AnA reactor for sparging CO_2. Different

sparging times (5, 10 and 25 min) at different time intervals (10, 20 and 30 min) will be used to evaluate the effect on treatment of wastewater and production of high lipid containing biomass. Nitrogen, phosphorous, CO_2, total organic carbon, total suspended solids, and volatile suspended solids will be measured during most of the wastewater treatment experiments. This study will also make an effort to differentiate between bacteria biodegradable COD and algae biodegradable COD for the purpose of determining the removal of different organic substrates in wastewater. The essential growth kinetic coefficients that will be determined in this study are as follows: algal biomass yield (Y; g/g), rate of substrate concentration change due to utilization (R_{su}; g/m^3*d); maximum specific substrate utilization rate (k; g substrate/g algae*d), half-velocity constant (Ks; g/m^3), rate of oxygen uptake (R_o; g O_2/m^3*d), rate of carbon dioxide uptake (R_o; g CO_2/m^3*d). These bio-kinetic parameters are essential to understand and design a working wastewater treatment plant (Aslan and Kapdan 2006). All the essential parameters for designing a pilot plant will be determined from the bench scale studies. Different ratios of activated sludge and algae sludge (1:0, 1:1, and 0:1) will be evaluated for lipid content and methane production.

Project Benefits

The proposed research will benefit Thailand particularly rural areas. It will provide a way to treat wastewater with a simple and environmental friendly technology. In addition, methane generated from algae sludge digestion can be used to offset energy needed to operate the treatment plant. Methane generated beyond the need of the plant could be used for household applications such as water heating and cooking. Having efficient wastewater treatment in rural Thailand will benefit environment and quality of life. It will reduce water pollution which would not only reduce nuisance but also improve public health. Outbreaks of waterborne diseases such as chlorella, typhoid fever, cyclosporiasis, and amoebiasis are often linked to wastewater sources. Water quality in natural waterways which could be degraded by untreated or inadequately treated wastewater is very critical to recreational activities such as fishing, swimming, and boating as well as aquaculture/fishing industry. The proposed research is the first step to a sustainable solution to wastewater problems in rural Thailand. Although the research does not provide direct monetary benefit, better quality of life and public health for Thai people are invaluable and could save the country on costs for wastewater treatment and medical care related to waterborne illnesses. Reducing loss of workforce due to waterborne illnesses and protecting aquaculture/fishing industry are other indirect economic benefits of the research.

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A Biophysical Approach for Drug Delivery to the Brain

BY *MALISA SARNTINORANONT*

Drug delivery to the brain and spinal cord is challenging due to the presence of the blood brain barrier which consists of tight cell junctions that can block drug passage across blood vessels. This effectively limits brain uptake of most large drug compounds following oral or intravenous delivery. Because of this barrier, many alternative delivery methods have been developed to provide local delivery including implanted drug pumps, drug-releasing wafers or particles that slowly release drugs, or direct tissue infusions. In these cases, there is always a question of where exactly does the drug go and how long does it reside in tissue? Certain drugs like chemotherapeutic agents can be toxic and limited exposure to targeted tumor tissues, in this case, is desired. Implantation of engineered drug delivery systems can also alter the environment of the brain, changing normal transport processes. While there are many research initiatives to develop new therapeutic agents, to develop new delivery systems, and to manipulate the blood brain barrier, an alternative biophysical approach is also important to consider. Improved understanding of changes in the physiological environment may also be used to improve drug delivery and improve patient response to therapies.

Fluid flows exist throughout the brain. Blood flows through blood vessels and the brain is also buoyed and surrounded by a cushion of cerebrospinal fluid (CSF) Central nervous tissue is densely packed with neurons and support cells that are interspersed with vasculature. Within these tissues, fluid exists in the spaces between cells and blood vessels, and this extracellular space has been estimated to be approximately 20% of the tissue volume. Fluid also flows in these spaces but at much slower velocities than either vessel or CSF flows. These flows can have a direct influence on drug delivery and clearance, especially for large engineered therapeutic compounds associated with nanomedicine and gene therapy. Often times these compounds will be stuck in place once introduced into tissues; however, it is possible to design them to move with tissue flows, allowing them to penetrate much further into tissues and reach their target cells. Since these flows are slow, direct measurement on a patient-by-patient basis is currently not possible. In this case, computational models based on engineering flow models can be used to predict underlying physiological fluid flows and their effect on drug transport. Drug delivery to the CNS and tumors has defied simple solutions and there is increasing need for improved understanding of complex transport processes. Computational models are increasingly needed to predict this environment. Three-dimensional, anatomically-realistic computational models are currently being developed using individual patient imaging data. While predictive simulations need to be further validated, these models show great promise as a drug delivery tool.

Drug Infusions into the Brain

An example of using computational models to improve targeted delivery is **convection-enhanced delivery (CED).** CED is one of the few options available for CNS delivery of promising engineered compounds. It relies on slow and controlled infusion from a needle that is inserted directly into the brain. In this way, infused agents are carried along by enhanced tissue flow, and drug distributions can cover much larger volumes than can be attained normally. CED has been shown to be reproducible and clinically safe, and research has progressed to clinical trials for treatment of brain tumors. However, poor targeting and non-uniform distributions have been identified as major problems hindering the success of these trials. This is not surprising given the complex anatomical structure of the brain and the greatly increased fluid flows that can divert infusate into unexpected places, see Figure 1. There is a critical gap in knowledge about tissue flow patterns based on local microarchitecture, composition, and physiology – without this knowledge it is difficult to control the outcome of CED.

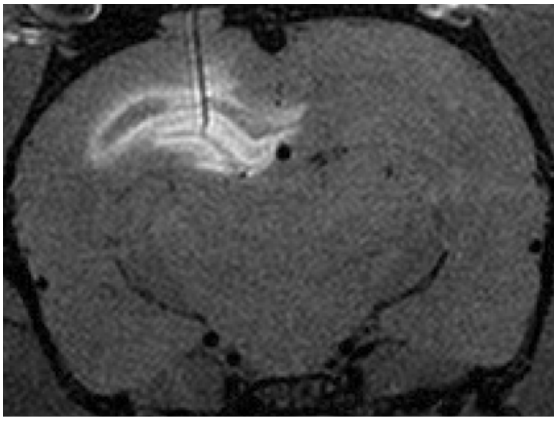
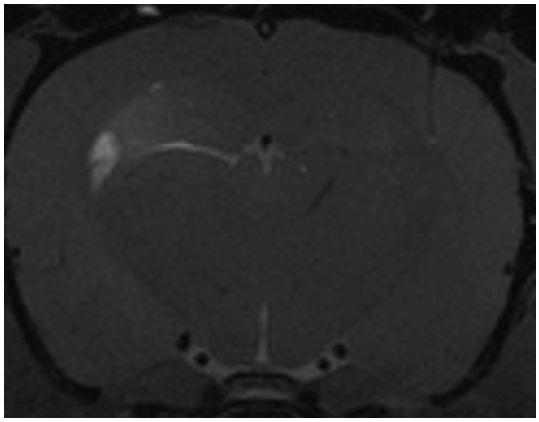
(a)  (b) 

Figure 1. MR of CED into rat brain tissues. Shown is the diversion of injected tracers (a) back along the needle track and (b) into fluid space between target tissue regions.

Research groups have taken different approaches towards improving CED targeting. Rules of thumb have been established by neurosurgeons to avoid undesirable distributions into neighboring CSF spaces and tissue regions. These guidelines include infusing at depths 1-3 cm from tissue surfaces and using controlled flow rates. Even with such rules in place, tissue coverage can be inadequate, especially when treating tumors which have a non-uniform and abnormal structure. Increasingly, co-infusion of a MRI-visible compound has gained popularity as it allows monitoring of spread within tissues and confirmation of targeting. However, computational tools that can predict distributions before the start of infusion are more desirable.

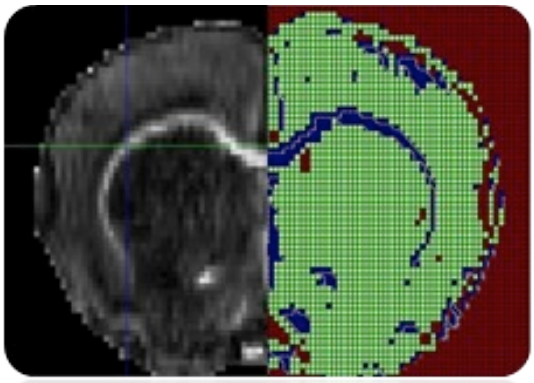
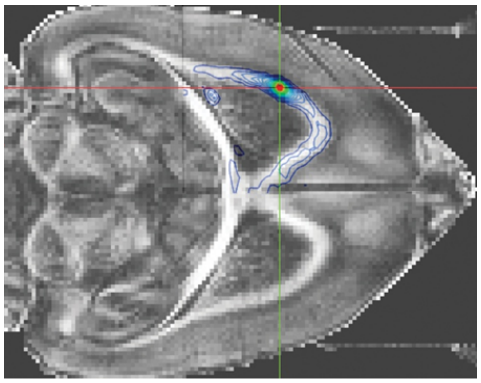
(a)  (b) 

Figure 2. MRI-based computational model of the rat brain that predicts flows: (a) realistic anatomical boundaries and (b) velocity contours around an injection site [1].

Computational CED models are powerful complements to real-time MRI. They can account for underlying flow fields that are otherwise difficult to measure. Validated biophysical models will ultimately allow for greater treatment flexibility and optimized surgical planning. Transport of molecules that are not MR-visible may be predicted as well as the effect of different infusion sites or multiple infusion sites. They can provide information about simple failure to treat the target and undesired drug spread which can lead to toxicity or secondary effects in untargeted regions. MRI is commonly used for diagnosis and treatment of CNS diseases, and this data can be used to generate patient-specific models of the brain. CED computational models need to account for fluid flows. Computational fluid dynamic models have been developed to simulate flow patterns and the effect of these flow patterns on local delivery by multiple research groups. These models account for realistic anatomical boundaries, different tissue types (white vs. gray matter) and the effects of aligned fibrous tissues (neuronal axons) on tissue flow, see Figure 2. A more difficult objective is to understand changes in tissue flow patterns due to specific disease progression to achieve optimal therapeutic effect. Our research group has undertaken a comprehensive study to measure and model CED tissue penetration for the treatment of epilepsy for which changes with vasogenic edema, long-term clearance, and improved targeting are also fundamental considerations. Again, use of an image-based is advantageous, since changes in anatomical structure can be accounted for by using patient imaging data. Such physiologically based models are necessary foundations to control of CED to the CNS. This is especially true for successful treatment of epilepsy in which the physiological factors effecting CED transport in tissues is multi-factored and complex.

MR-based models are able to uniquely account for 3D non-uniform distribution patterns in the specific brain structures. Overall, CED transport models are able to capture certain major transport characteristics: (1) Tracers were confined by anatomical boundaries. Gray matter structures which consist of densely packed cell bodies may serve as effective boundaries while white matter regions behave as preferential fluid pathways. (2) Similarity of transport predictions between different brains showed the consistency of the modeling approach. (3) Infusate entered

into CSF spaces depending on the site of infusion. Thus, infusion distribution patterns were sensitive to the location of the needle tip and overall access to interconnected fluids spaces.

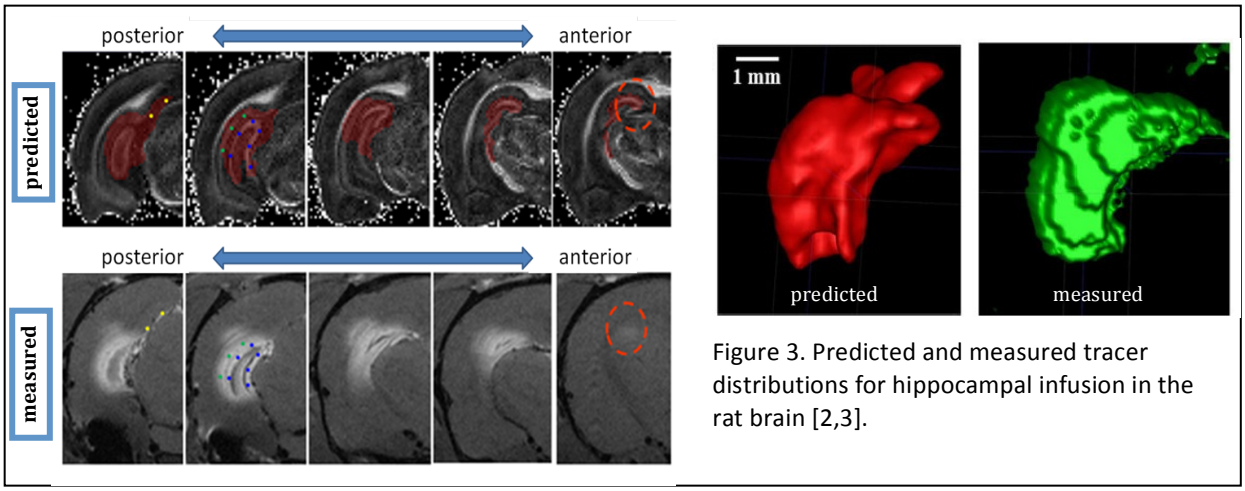
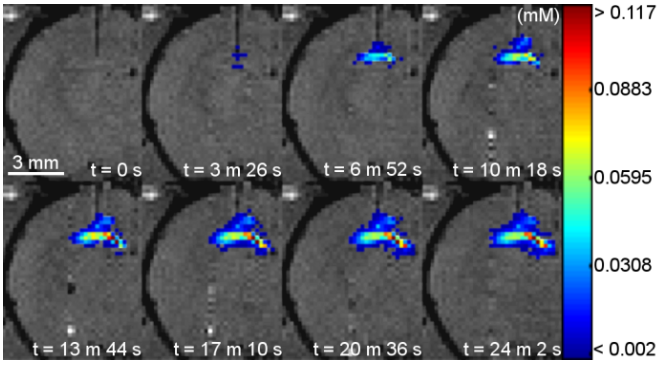


Figure 3. Predicted and measured tracer distributions for hippocampal infusion in the rat brain [2,3].

Since models require multiple input variables, computational models need to be rigorously validated. Tracer distribution studies allow for such validation of predicted flow patterns. MR-measured distributions following and during CED infusions can be compared with simulations, see Figure 3. Our group is active in developing MR imaging techniques to monitor and quantify CED transport. We have developed methods to estimate tracer concentrations directly from MR scans, allowing for more accurate in vivo biodistribution study, see Figure 4.



[4]

Figure 4. *In vivo* concentration contours (mM) in the rat hippocampus based on MRI scans [4].

Capturing patterns of injury

Treatment strategies regions also require an improved understanding of the disease-specific transport environment and knowledge of changes that may occur with progression of the disease. A new modeling approach which combines dynamic contrast enhanced MRI (DCE-MRI) information of BBB breakdown can also quantify abnormal extracellular flows that result from blood vessel injury. DCE-MRI scans capture local tissue uptake of a MR-visible tracer following intravenous infusion. Data from these scans can be used to measure spatial variation in blood vessel leakiness that increase with injury or disease, for example with vascular injury following seizures or due to leaky tumor blood vessels. Incorporation of DCE-MRI information of BBB spatially varying vessel leakiness into biotransport models accounts for injury-specific

edema with enhanced flows and increases in vascular exchange, see Figure 5. The contribution of edematous flows to drug spread is also largely unknown and, again, computational models can be used as a tool to quantify this physiological effect. Such a quantitative and predictable approach is required for treatment of sensitive injured tissue regions.

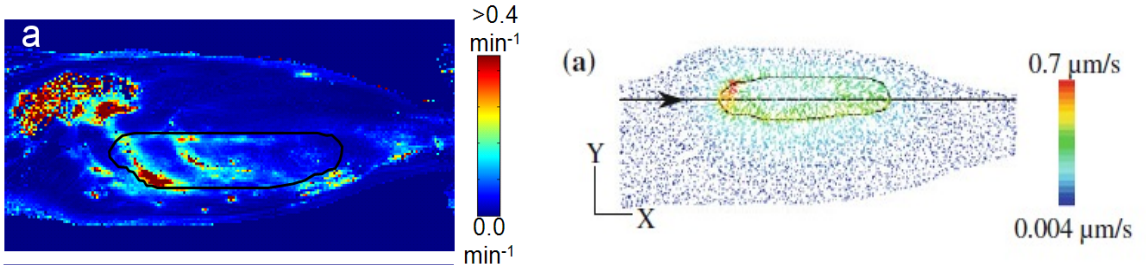


Figure 5. DCE-MRI model of a tumor in a mouse leg: (a) vascular leakiness map and (b) tissue flow patterns due to leaky vessels [5, 6].

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Investigation for robust and low-cost fabrication of PEMFC bipolar plates

BY *SIRIVATCH SHIMPALEE*

Introduction, Motivation and Objectives

The objective of this collaborative research proposal is to investigate the feasibility for robust and low-cost fabrication of Proton Exchange Membrane Fuel Cell (PEMFC) bipolar plates by developing an innovative hybrid manufacturing process. The premise of the proposed method stems from the use of internal pressure assisted embossing process (cold or warm) combined with mechanical bonding of double bipolar plates in a single-die and single-step operation. Such combined use of hydraulic and mechanical forming forces and in-process bonding will (a) enable integrated forming of micro-channels on both surfaces (as anode and cathode flow fields) and at the middle (as cooling channels), (b) reduce the process steps, (c) reduce variation in dimensional tolerances and surface finish, (d) increase the product quality, (e) increase the performance of fuel cell by optimizing flow field designs and ensuring consistent contact resistance, and (f) reduce the overall stack cost.

Despite various proven advantages such as high efficiency, quiet and reliable operations, near-zero emission, etc., fuel cells are not yet cost competitive with the existing power generation technologies especially in the transportation applications. Compared to internal combustion engines, fuel cell power is 4-10 times more expensive ($30-$50/kW vs. $200-$300/kW). Extensive research and development efforts are necessary to address the materials and manufacturing related technical issues to bring the cost of fuel cells down to competitive levels since around 60-70% of the fuel cell cost is in materials and manufacturing.

Among different components of the fuel cells, the bipolar plates stand as the high cost-, high weight-, and high volume-component with complicated micro-channels (in the range of 100-500 microns in depth and width) on both sides for effective distribution of hydrogen and oxygen gases, and inside cooling channels to sustain the operation temperature within 80-90^{o}C for efficient performance (i.e., 0.6-0.7 V per cell), Figure 1. The bipolar plates have also stringent requirements for electrical connectivity, corrosion resistance, weight, thickness, handling, etc. All these operational and functional requirements make the cost-effective design and manufacturing of bipolar plates a challenging research topic in addition to other research issues in fuel cells such as membrane, coating, catalyst, sealing, etc. developments. Basically, the bipolar plate needs to meet the following requirements: (1) Thin (<1mm), (2) Light-weight (<0.2-1kg/kW), (3) Corrosion resistant (1e10^{-6} A/cm^2), (4) Channels inside for cooling water passage, (5) Channels on both sides for H_2 and O_2 distribution, (6) Low gas permeation, (7) Low electrical resistance (ohmic loss, <10mΩ-cm^2), (8) High heat conductivity, (9) Tough and flexible to reduce handling damage, (10) Durable (good electrochemical stability, min. 5000

hours for automotive use), (11) Low cost ($5/kW), and (12) High dimensional accuracy for uniform contact resistance.

The proposed collaborative study is an interdisciplinary approach aimed to address the fundamental technical and scientific issues for achieving a feasible, cost-effective and applicable hybrid manufacturing method. Namely, these issues and barriers to be addressed are:

- Understanding of the deformation mechanics involved in the forming of micro-scale features (channels, grooves) under combined and complex loading conditions,
- Characterization of material and tribological behavior under the above deformation conditions particularly for micro-feature forming where the overall part/product size is still in macro scales,
- In-depth understanding of the micro-mechanical bonding/joining that will be created during the proposed method, and its characterization (effect of processing conditions on the final bond strength and quality),
- Optimal design of micro-channel form and size considering both fluid flow/distribution and manufacturability aspects,
- Predictive process models for evaluation of producibility and optimization of process parameters and their synchronization incorporating the micro-manufacturing related issues such as size effects (i.e., grain size/feature size, material modeling, ram speed and stroke, internal pressure, temperature distribution in case of warm forming and friction conditions), and
- Characterization of dimensional tolerance and surface quality capability of the proposed method. Process repeatability and potential to achieve minimum variations in dimensional tolerances and surface quality (roughness).

The scope of the proposed project encompasses both experimental and computational investigations on (a) material behavior and deformation mechanics under micro-forming conditions where feature and grain size ratios are very small (i.e. size effects), (b) solid state bonding at micro-scales, (c) optimal design of micro-channel shapes and size considering both manufacturability and fluid/gas flow aspects, (d) development and optimization of a hybrid and integrated manufacturing process, (e) prototyping of bipolar plates and validation of the process capability, and (f) evaluation of the part performance using single cell or short stack tests. The broader impacts of the proposed method will be realized with the remarkable cost reductions and power density improvements in PEMFCs with the use of integrated bipolar plates contributing to the wide use of near-zero emission, efficient and hydrogen based fuel economy for a sustainable mobility and society. Fundamental understanding micro-manufacturing related issues such as size effects, deformation mechanics, interface interactions, etc. will contribute to towards improvements for enhanced heat and mass transfer products such as micro-reformers, microfluidics, micro-arrays, heat pipes, etc.

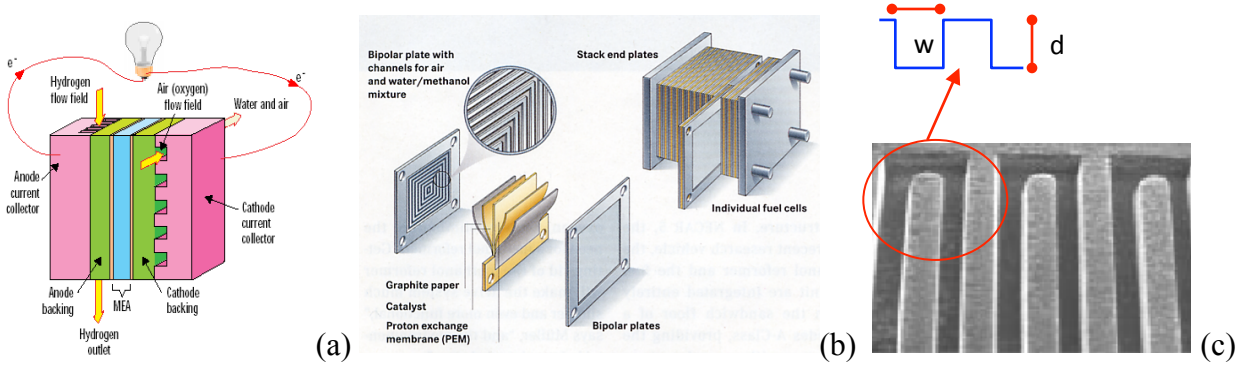


Figure 1: (a) Schematic of a PEMFC operation principle, (b) fuel cell components, and (c) details of micro-channels on bipolar plate

Existing Bipolar Plate Manufacturing vs. Proposed Hybrid Process

The selection of material and geometry, and development of fabrication methods for bipolar plate are ongoing research activities at various institutes and companies all around the world. In the past few years, the fabrication methods and material selection for bipolar plates in PEMFCs for vehicle applications has gradually evolved/narrowed to the following candidates:

- Machined graphite plates,
- Stamped and joined stainless steel sheets, Figure 2,
- Photo etched stainless steel and titanium plates],
- Molded, machined, and joined polymer-carbon composite (a GM proprietary technology),
- Molded and joined carbon-carbon material (developed at Oak Ridge National Lab and licensed to Porvair).

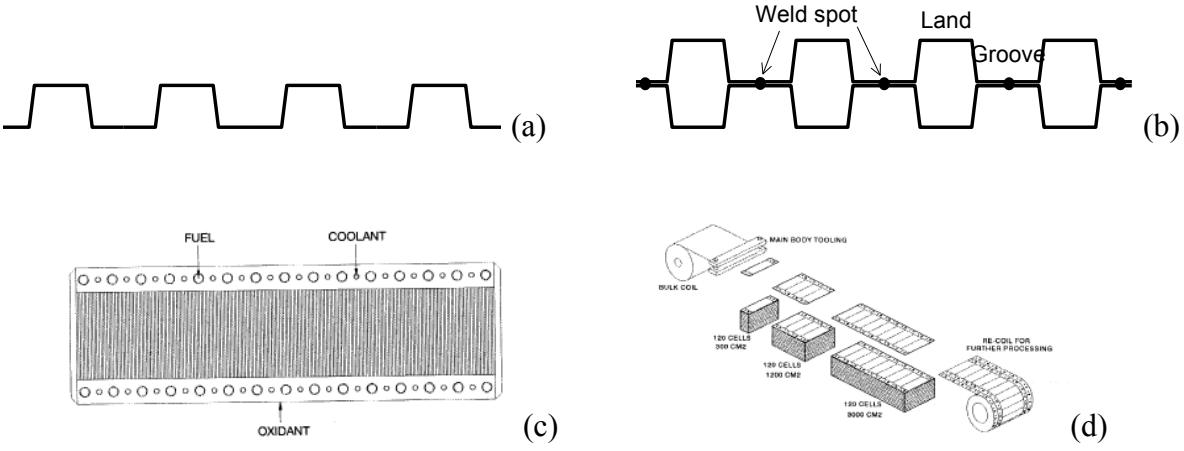


Figure 2: Stainless steel bipolar plate, (a) stamped stainless steel sheet, (b) welded bipolar plate sheet, and (c, d) continuously stamped bipolar plate and operation set-up developed by Allen Eng Co.

Graphite bipolar plates have been the choice of earlier tests and use. However due to (a) high material cost, (b) high manufacturing (machining) cost, (c) low mechanical properties (strength and flexibility), and (d) porosity (leads to high permeability), the extensive commercial use of graphite materials in fuel cells is limited and questionable. Use of metallic and composite components for bipolar plates has several advantages over the conventional graphite plates. Materials such as stainless steel, aluminum alloys and composites, with or without coatings are viable options for bipolar plates in PEMFCs].

Metallic and carbon-polymeric materials are two competing technologies for the bipolar plate of PEMFCs. Stainless steel is a low-cost material that is easy to shape. Thin sheet forms of stainless steel are commercially available, and can be used to achieve low volume and weight bipolar plates. The stainless steel bipolar plate uses two stamped stainless steel sheets, which are joined together, to create the cooling water channel inside the plate and H_2 and O_2 groove on both sides of the plate. Figure 2a shows a stamped stainless steel sheet. Two of these sheets are welded together, as shown in Figure 2b, and become a bipolar plate. The weld spot, as indicated in Figure 2b, is the bridge for electrical connection between the lands on each of the two stainless steel sheets.

Stainless steel covered with a thin coating (such as Ni coatings) is another choice of material for bipolar plates in PEMFCs. However, the cost of coating and coating process has to be considered in addition to the material and fabrication cost. A large number of stainless steel grades are commercially available, among them 316, 316L, 317L, 304, 349, and 904L found a wide acceptance for bipolar plates due to their high corrosion resistance and relatively low cost. The chromium content is found to have an important influence on the anodic behavior.

Another vital issue is the interfacial contact resistance (ohmic losses) between the metallic bipolar plate and the carbon paper. This resistance is increased due to the formation of the passive film that reduces the overall power output. Alternative grades of stainless steel have been tested in terms of the electrical resistance of their surface oxide film. Results of these studies showed that ohmic losses exhibited in fuel cell performance varied depending on the elemental composition of the stainless steel alloy. Plate-to-plate and in-plate dimensional variation also adversely affect the contact mechanics, and increase performance losses (i.e., obtained voltage per area). In order to meet the fuel cell stack volumetric power density target of 2 kW/L for viable vehicle applications, the bipolar plate area specific resistance of less than 10 $m\Omega\text{-}cm^2$ and thickness of less than 1 mm is required. Remarkable improvements in the performance can be also gained through optimization of the channel dimensions and shape in the flow-field of bipolar plates. Initial studies indicate that channels with triangular and hemispherical shaped cross-sections resulted in an increase in hydrogen consumption at the anode side contributing to the improved fuel cell efficiency.

The polymer-carbon composites were used to fabricate bipolar plates using (a) low loading (60 to 90 v/o) of high-aspect-ratio conductive particle (such as carbon fibers, flakes, etc.), (b) an alignment process, and (c) a conductive-tier layer (CTL) to meet plate conductive, thickness, and toughness requirements. On a molded plate with a rib, the fiber is aligned to enhance the electrical conductivity of the bipolar plate. Two of these plates are joined and sealed together to assemble a complete bipolar plate. Micro-channels between two plates become the cooling water channel. Micro-channels on both sides of joined plate are the grooves for H_2 and O_2, respectively. With high loadings, the plate materials are inherently brittle and result in high scrap rates and the inability to mold thin plates (less than 1 mm) required for high stack volumetric power densities. Low loadings of high-aspect-ratio conductive fillers, a fiber/flake alignment process, and a conductive layer (CTL) were used to simultaneously increase the plate conductivity and toughness. The alignment process reduces the bulk resistance in the current-flow direction, and the CTL reduces the contact resistance at the plate-to-diffusion medium interface. Although a significant reduction in plate resistance is realized, high filler loadings are still required to meet conductivity targets. Moreover, this method requires additional operations to join and seal two plates into a bipolar plate form. Hence, high cost and quality variation issues remain to be addressed.

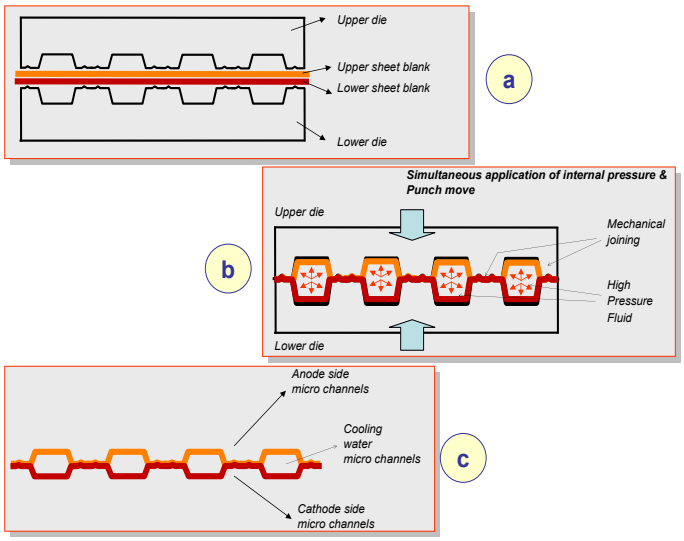
Carbon composite bipolar plates have been developed at Oak Ridge National Lab. They are reported to have high electrical conductivity, high strength, lightweight and low permeability. The carbon composite bipolar plate is produced by slurry molding short carbon fibers into preform structures, molding features into the green body, and using chemical vapor infiltration to strengthen the material, give it high conductivity, and densify the surface to make it impermeable. Current efforts on the carbon composite bipolar plate manufacturing have focused on optimizing the fabrication process and characterizing prototyped components. This manufacturing method requires subsequent joining and sealing operations to assemble the bipolar plates together to obtain the necessary cooling channels at the middle and gas distribution channels on both sides.

In contrast to the existing methods of bipolar plate manufacturing, the proposed hybrid process will result in thin, lightweight, flexible bipolar plates with internal cooling channels, and flow fields (micro-channels) net-shape formed on both sides (anode and cathode) in one step and one die, thus eliminating handling, welding, assembly and sealing processes. Hence, the dimensional tolerances and surface quality will be improved leading to superior advantages and performance due to reduced variations in eventual assembly of the stacks and consistent contact resistance properties. The closest technology to the proposed one has been developed by GenCell, where additional stamping steps are taken to form channels at both sides and middle as explained in their various publications and patents. A brief description of the proposed method is as follows:

As shown in Figure 3a, two sheet metal blanks are placed between the upper and lower die halves. Upper and lower dies have the intricate shape of micro-channels to be imprinted on the bipolar plate. The shape, distribution and dimensions of these micro-channels can vary, and they are also necessary research topics in bipolar plate design and manufacturing. Upper and lower dies are pushed against each other at the edges of the sheet metal to provide sealing. Then, upper die is moved down while high pressure fluid (or gas) is supplied between two sheet blanks. Lower die may be also moved up to obtain additional forces, if necessary. Both die movements and the internal pressure forces the sheet blanks to deform into the shape of the upper and lower dies, Figure 3b. Upper and lower dies will be moved further, simultaneously or sequentially with the application of fluid pressure, to make the deformation easier, evenly and defect free. Once the forming into complex micro-channels is completed, upper and lower dies are further pressed each other to generate a mechanical joint between two contacting surfaces of the sheet blanks to form the final shape of the bipolar plate, Figure 3b. A finished bipolar plate with precisely formed internal cooling channels as well as micro-channels on anode and cathode sides is illustrated in Figure 3c. Such an assembled and honeycomb–like plate would not only reduce and facilitate the eventual assembly operations but also make the handling easier and safer. Finally, for effective fabrication of bipolar plates, warm or hot conditions can be also considered by heating all or some of the blanks and dies to designed elevated temperatures.

With this method, efficient material utilization can be achieved resulting in thinner bipolar plates with integrated cooling channels, sealing and manifolds. Total thickness of the bipolar plates in the existing methods can go up to 4mm. With the proposed method, thin blank sheet materials can be formed into integrated bipolar plates with a total thickness of less than 1 mm. As a result, it will be possible to improve the power density up to the required levels of 0.2-1 kW/kg, while reducing the stack cost and increasing the service life. Figure 4 depicts the results of a two dimensional, representative finite element analysis sequence of the proposed method. In this case stainless steel 304 sheet metal blanks of 0.5 mm thickness were formed into 0.5 x 0.5 mm channels using the hybrid forming and mechanical joining. The sequence or coordination of die stroke with the application of internal pressure would results in different material flow and filling characteristics, bonding between two plates and loading requirements. Thus, it is a subject of further optimization as part of the proposed research in this project.

Figure 3: Proposed novel method of fabricating bipolar plates using internal pressure assisted embossing and mechanical joining process; (a) two sheet blanks are clamped between upper and lower dies having the intricate shape with micro-channels, (b) Simultaneous (or sequential) application of internal hydraulic pressure between the sheet blanks and die movement enable the deformation of sheet blanks into upper and lower dies completely and defect free, (c) the resulting bipolar plate with the micro-channels on both sides serving as anode and cathode in the fuel cell and closed channels for water cooling at the middle.



Due to their low cost, high strength, proven ease of shaping, excellent corrosion resistance, and vast availability in various thin sheet blanks, stainless steels and nickel will be used in this study for prototype purposes. However, titanium and other commercially available materials with different coatings will be also tested whenever available and justified. Desired overall size of the prototype bipolar plate will be in the range of ~25-100 cm^2 in order to be able to fit into the existing experimental equipment capabilities. In addition to the design of micro-channels and other process parameters, we will also pay attention to the sealing design for successful injection and build up of fluid pressure between the plates around the perimeter. We plan to develop mechanical sealing method similar to bonding of upper and lower channels by plastically deforming the plates around the perimeter since this sealing will be also functionally important during the performance of the bipolar plates. Similarly, manifolds for air and fuel supply, and heat and water removal will be also incorporated into same forming tooling.

Proposed Research Tasks and Schedule

The proposed effort as a whole is a fundamental study addressing several scientific challenges related to the physics and modeling of micro-forming and micro-bonding processes. Yet, it is oriented towards a specific and highly critical application (fuel cells) with strong and broader impacts (low-cost, near-zero emissions, fuel efficiency, healthy society). It requires an interdisciplinary approach to bring about solutions and basic understanding of material behavior at micro-scale deformation under complex loading conditions, design of micro-channels considering both manufacturability and mass/heat transportation aspects. In order to accomplish the objectives of this project and advance the fundamental understanding of micro-forming using the combined loading schemes as well as the micro-mechanical bonding of thin sheet metals, the required research steps can be divided into the following tasks:

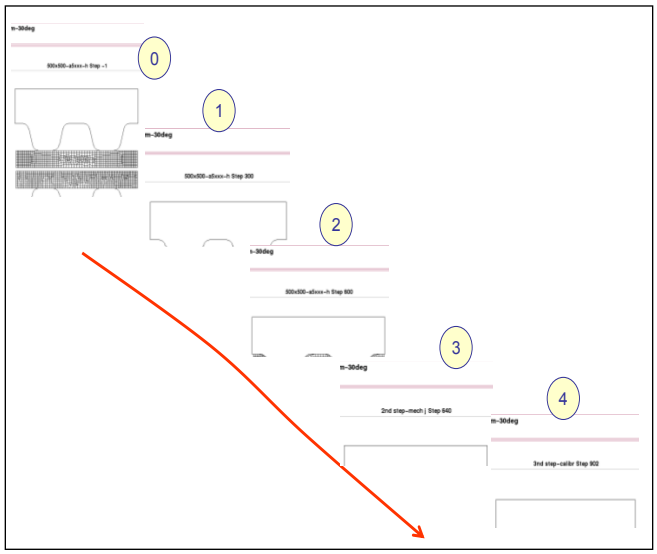


Figure 4: Finite element analysis (FEA) results of a computer simulation modeling the fabrication of bipolar plates using the proposed hybrid internal pressure assisted embossing and mechanical joining process; (0) sheet blanks are placed between upper and lower dies, edges are clamped, (1, 2) Simultaneous (or sequential) application of hydraulic pressure between two sheet blanks and die movement deform the sheet blanks into the die shapes, (3, 4) Upper and lower dies are further moved against each other to generate the mechanical joint between contacting surfaces of sheet blanks to form the final shape of the bipolar plate. Sequence

Task 1: Material characterization and deformation mechanics in micro feature fabrication under complex loading conditions using thin sheet metals

Material characterization of selected thin sheet blanks of interest (stainless steel 304, 316; 405, Ni and Ti, etc.) will be conducted to study the key material properties such as flow stress, anisotropy, and yielding using the hydraulic bulge test apparatus which has already been built up during the SGER phase. However, we will enhance it to include temperature effect investigations. The "size effects" (grain size vs. feature size) will be investigated in order to understand its effect on the forming limits in micro-scale fabrication of thin sheet blanks. A new material model will be developed to incorporate the size effect parameters (i.e. thickness to grain size ratio, feature size to thickness ratio, etc.) into a constitutive model to be validated and used in further numerical simulations. Such new material behavior models accounting the size effects will enable us and other researchers in this area to accurately model and find out optimal the process conditions using the existing continuum mechanics based finite element analysis (FEA) tools. In this task, we plan to extend these findings into thin material applications. Specifically, the sub-tasks for the size effects study can be listed as follows:

- The grain size effect will be studied by hydraulic bulge testing of small size specimens with different sheet thickness to material grain size ratios, t/d. The effect will be observed through the final shape/profile of the bulged specimens. In order to accomplish this sub-task, thin sheet blanks of several thicknesses will be heat treated to obtain different initial grain size. For grain size measurements, each specimen will need to be specially etched and examined under SEM and optical microscope.
- The feature size effect will be studied by hydroforming thin sheet specimens into different micro-channels geometries. By varying the ratio between the channel width and

depth, and the sheet thickness (W/t, H/t, W/H), the feature size vs. grain size effect will be understood and modeled accurately. To accomplish this task, special tooling with different feature/channel dimensions will be designed and manufactured. Their profiles, surface conditions and variation will be measured and compared to those of each thin micro-formed parts. This will reveal the relation and interaction, if any, between grain size and feature size during microforming. It will also constitute a basis for optimal design of micro-features from manufacturability point of view.

- Using the results of these material tests and the new material model, a finite element model will be constructed for a bipolar plate to study the deformation mechanics of micro-feature (channels, grooves) fabrication numerically. Effects of loading, geometry, and friction conditions will be investigated to gain an in-depth understanding under complex part and tooling shapes.
- Finally, we will conduct similar tests on coated (Nitrided) thin blanks since coating is required for corrosion resistance during performance of fuel cells under humid and relative high temperatures. Our experimental work will reveal first of all whether coated thin blanks can be formed into micro-channels without any additional needs and concerns (such as scratching, galling, etc.). Secondly, it will lead us to enhance the constitutive material models including the effect of very thin layer of coating (i.e., ~1 μm).

Task 2: Development of design principles for micro-channel bipolar plate fabrication

Although the effect of micro-channel dimension, land width, shape, and flow field designs on the PEMFC performance and uniformity in distributions have been studied, the channel width and depth, and the land width were limited to 0.5-4 mm range and the shape of the channels were assumed to be perfectly rectangular, triangular, and hemispheric. However, as outlined in the previous sections of this proposal, channel sizes down to 100 micrometer have been considered for further increased surface area in the next generation PEMFC applications. However, the change in pressure drop and heat transfer rate can be impacted from those designs significantly as shown in Figure 5. Those changes will affect performance, uniformity in distribution, cell degradation, and overall efficiency. Furthermore, due to the limitations and capabilities of the manufacturing processes, channel shapes may not be guaranteed to be perfectly hemispherical or rectangular.

case (0.9 mm/0.9 mm), ——: channel narrow (0.7 mm/1.0 mm),: channel wide (1.0 mm/0.7mm).

In this task, we will perform a series of computational fluid dynamics (CFD) analyses to study the effect of micro-channel dimension below 400 micrometers down to 100 micrometer under specific reactive area and operating conditions on the distributions, reactant flow behavior, pressure drop, and flow-field designs. Moreover, the interaction between gas diffusion layer (GDL) permeability and flow-field design will be taken into account especially around the bend areas. Furthermore, the shape of the channels being investigated in this task will be designed with assumed variations as can be expected in a typical stamping and micro-hydroforming

application. We may for instance simply introduce draft angles to account for the manufacturability. Numerical tools, such as Star-CD, incorporated with a PEMFC module called es-pemfc will be employed. Based on the CFD results, design guidelines for micro-channels geometries (i.e. dimension, shape, draft angles, radii, flow field pattern, and surface finish) will be developed. The optimum micro-channel geometry will be selected and built for the experimental test. It is believed that such design rules will also be most useful and applicable for design and manufacturability of micro-features in many other applications for design and manufacturing engineers.

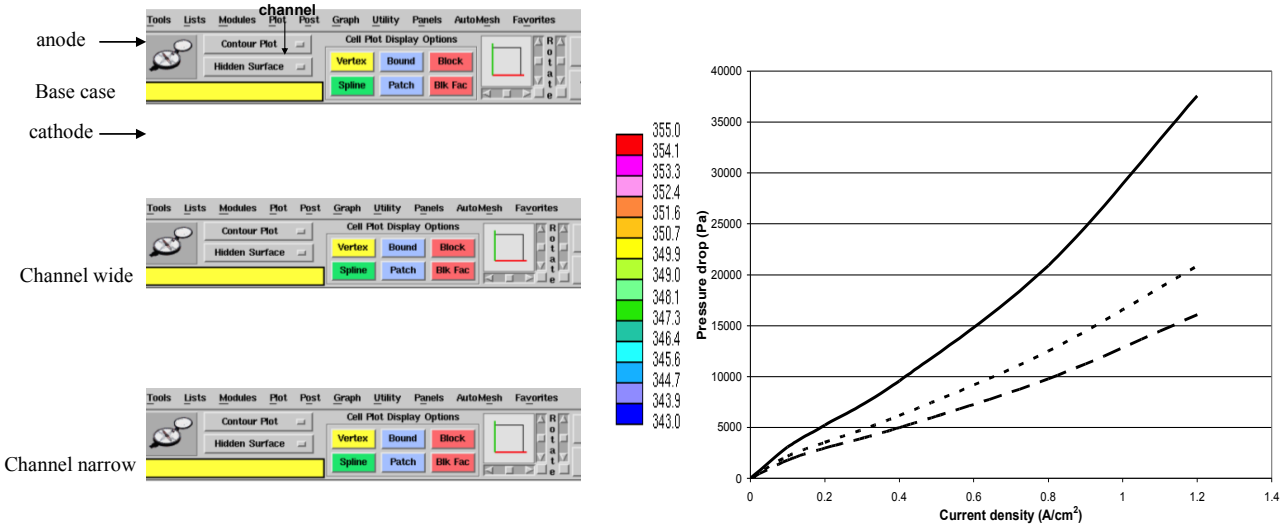


Figure 5:CFD results show the effect of channel/land width on; (a) temperature (K) distribution at the cross flow plan (x-y plane) located in the middle of flow-fields, (b) pressure drop(Pa): base

Task 3: Characterization of mechanical joining

Based on the preliminary results from the simple off-line tests in the previous study, we plan to continue on investigating the effect of material type, thickness, surface conditions, and process parameters on the bond formation and strength. We will focus our experimentation on stainless and nickel alloys as these materials are seen as the likely bipolar plate and interconnect plate materials for both PEMFC and SOFCs. We will focus on developing a predictive model, and incorporating it into FE analyses to be used for future and further optimization studies. In the previous study, the sheet thickness was found to have a significant impact on the bond formation especially when the sheet thickness is reduced below 100 micrometers. Thus, the effect of the sheet thickness will be one of the focused studies and will be included into the model for the bond formation mechanism. In addition, stainless steel was found not to be pressure-welded at cold conditions. But, at warm temperature conditions (~ 200-300 ^{o}C), sound and repeatable pressure welds were obtained. Hence, we will first investigate the bonding mechanism and physics at different temperature levels. Secondly, the factors that prevent stainless steel from being cold pressure-welded will be studied in depth. Then, we plan to focus on the use of

localized heating on the die, and hence on the stainless steel thin blanks, to achieve metal-to-metal bonding. We expect to develop guidelines to optimally design or select temperature levels, surface conditions and tool features for sound bonding results.

Task 4: Design and manufacturing of an experimental tooling, design of experiments and development of predictive process models

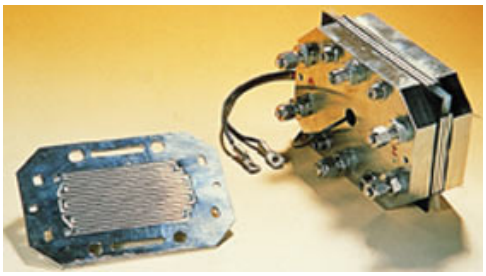
Based on the findings of the previous tool design study, an experimental apparatus will be designed and fabricated for the hybrid process evaluation. The proposed experimental apparatus will mainly consist of the following components: (1) and (2) Upper and Lower dies, (3) and (4) Die holders (bolsters), (5) Hydraulic pressure system (pump, piping, relief and control valves, discharge an filtering, etc.), (6) DAQ and control system (force, pressure, displacement, temperature sensors, software (LabView), computer, etc). Tooling will be designed in a way to accommodate a simultaneously and automated process in single step operation with one die in both cold and warm condition. We plan to use a 2200 kN Instron material testing equipment to use this tooling.

After preliminary trial experiments to test the limits of the experimental tooling and set up, a set of design of experiments will be performed. We will consider the variations in factors such as material, coating, surface condition, thickness, internal pressure level, loading, heating level, etc. We plan to use commercial FEA software such as MSC/MARC and/or ABAQUS enhanced with user subroutines, design of experiments (DOE), and adaptive control strategies along with experimental validations to develop the predictive process models. Upon successful completion of this task, predictive process models, which enable optimal or acceptable process conditions, will be obtained for any given bipolar plate design (overall dimensions, micro-channel dimensions, flow field design) and material case. Experimental results will establish a guideline and basis for the development of predictive process models for rapid and reliable evaluation of producibility. Optimization of process parameters (i.e., ram speed and stroke, internal pressure, temperature distribution and their synchronization will be conducted to achieve successful and repeatable process conditions for bipolar plate manufacturing. Basically, the movement of the upper and lower dies for embossing, and their synchronization with the application of the internal pressure, selection of stroke and speed for strong mechanical joints will be predicted accurately.

Task 5: Testing, evaluation and characterization of bipolar plates in single and/or short stack fuel cell tests

In this task, we will conduct four types of testing and evaluation: (a) dimensional measurements (optical and/or CMM) to characterize the variation (micro-channel dimensions as well as thickness, flatness, etc.), (b) optical and/or SEM measurements to characterize the surface quality variation (roughness on anode and cathode sides), (c) strength and durability tests to characterize the strength of manufactured bipolar plates under assumed loading/stress conditions; (d) single- and short-stack fuel cell operation tests (Figure 6) to characterize the functionality, durability and

performance of the bipolar plates. Thus, we will have an opportunity to compare and validate our evaluations with industry-desired or practiced thresholds. Specific sub-tasks will be as follows:



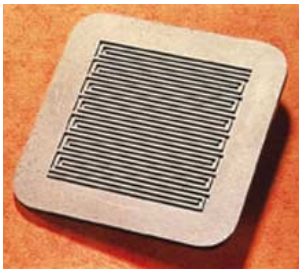


Figure 6: Single and small batch stack configurations for performance testing of bipolar plates

Process repeatability and capability to achieve minimum variations in dimensional tolerances will be investigated using optical measurement and CMM techniques. As for the optical measurement, we plan to use non-contact surface measurement techniques (such laser scanning, holography or 3D optical measurement system). We will first use the laser scanning method available in our lab. We, then, plan to use another non-contact measurement system for comparison. Figure 7 illustrates preliminary bipolar plate measurements using the CogniTens system. As a result, basic understanding on effects of process, tooling and material parameters on the dimensional repeatability will be gained. Similarly, SEM measurements will be performed on selected cases to characterize the surface topography of micro-channels on the bipolar plates. Variation of surface quality between plate-to-plate and in-plate will be evaluated. As a result of these tests, not only will we characterize the process capability but also expect to develop a cost effective quality control or measurement scheme for bipolar plate manufacturing by identifying important measurement points, features and thresholds. In order to characterize the mechanical integrity and strength of the in-die bonded bipolar plate assemblies, basic three-point bending tests will be conducted. We think that the mechanical loading modes in real life circumstances can be simply and cost-effectively emulated in three-point bending experiments. These experiments will enable us to assess the capabilities of in-die bonding mechanisms. Finally, bipolar plates, with and without coatings, will be tested in single and short-stack fuel cell tests under both stationery and automotive operating conditions (Figure 7). The optimum designs of both operating conditions will be different. The optimization of compression pressure during assembly processes will be

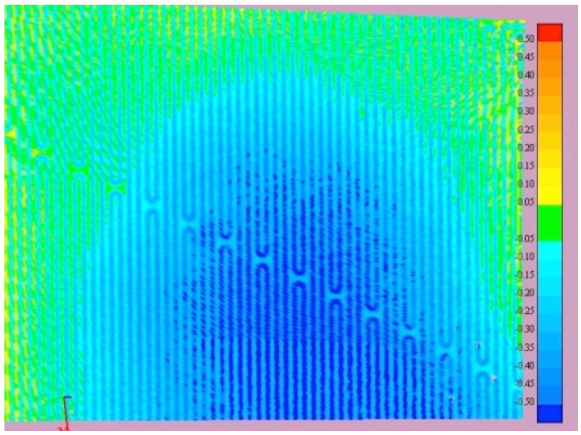


Figure 7: Preliminary depth measurements on a

performed for both carbon cloth and carbon paper GDLs. These experiments will enable us to characterize the performance of bipolar plates manufactured at different loading conditions and compare to existing bulk molding compound (graphite/resin) cells and stack. We can investigate, if necessary, the corrosion behavior of coated and non-coated bipolar plates using N_2/N_2 system baseline and corrosion techniques. We would then look at these phenomena as a function of operating hours.

Schedule

The proposed research activity will be executed over a three-year period according to the proposed schedule below.

	Months						
Tasks	0	6	12	18	24	30	36
1:	>----------<						
2:	>----------<						
3:	>----------<						
4:			>----------<				

Development of Healthier Sodium-Reduced Foods and Salt Substitutes Targeting Thai Population

BY *WITOON PRINYAWIWATKUL*

Potential investigators:

1. ATPAC Food & Agro-Team led by Dr. Witoon Prinyawiwatkul
2. Dr. Sujinda Sriwattana, Faculty of Agro-Industry, CMU, Thailand
3. Dr. Penkwan Chompreeda, Faculty of Agro-Industry, KU, Thailand
4. National Science and Technology Development Agency, MOST, Thailand
5. Thailand Institute of Scientific and Technological Research

Summary

Worldwide, sodium reduction efforts remain on the top priority of the food industry, but these efforts are more complex and challenging than simply discovering and using a new version of table salt, so-called salt substitutes. While many are quick to blame high sodium levels on the Western diets, the problem appears to be prevalent worldwide. For example, the Thai News Agency recently reported a government survey revealing that Thais consume about twice the maximum amount (2,400 mg) of sodium required each day. The Thailand Deputy Permanent Secretary for Public Health attributed this fact to 21.4% of the population with high blood pressure (HBP), 17.5% with kidney diseases, and 1.4% with constricted heart arteries and 1.1% with cerebrovascular diseases. In the U.S., average daily sodium intake for adults is more than double the dietary limit recommended for the majority of this population, hence leading to adverse health outcomes and economic impacts (i.e., health care and medical expenses). The majority of U.S. adults recognize the health consequences of a high-sodium diet and are interested in reducing their daily sodium intake. However, retailed, packaged and restaurant foods often contain excessive amounts of salt, which limits the choices of U.S. consumers in reducing sodium in foods they consume. Unlike the US population, Thai adults with HBP may or may not be aware of the relationship between excessive sodium intake and its adverse health risk. These adults may be unaware of alternative non-sodium salts (known as salt substitutes), which are not widely sold in Thailand. In addition, retailed, packaged and restaurant foods that are low in sodium are not common in Thailand. Without enforced regulations, the Thai food industries may not be interested on a voluntary basis in reducing sodium in their retailed food products. Sodium reduction is an urgent public health priority that should be addressed by coordinated effort at multiple levels of government authorities, food industries, educational entities (schools, colleges and Universities) and other diverse stakeholders. Reducing sodium in

the food supply will increase consumer choices, has been shown to be feasible for the food industry, and will save thousands of lives and billions of health-care dollars each year.

Background Information and Rationale

Excessive dietary sodium is a major contributor to hypertension (high blood pressure; HBP) and a critical public health issue in the United States and elsewhere. Regardless of age or sex, sodium intake by most U.S. residents considerably exceeds recommended levels. Nearly 1/3 U.S. adults or 68 million people has hypertension, but nearly half of those do not have their condition under control. HBP is a major contributor to cardiovascular diseases, which are a leading cause of death, disability, and health-care costs in the U.S. According to the German Federal Institute for Risk Assessment (BfR), the majority of German population, especially young men, children, and adolescents, consume too much salt, and almost half of German adults (44% of women and 51% of men) have elevated blood pressure.

Current dietary guidelines recommend that consumption of sodium be reduced to <2,300 mg/day. For those of any ages with HBP, diabetes or chronic kidney disease, they should further reduce sodium intake to 1,500 mg/day. Reducing sodium intake to 2,300 mg/day could potentially prevent 11 million cases of HBP and save guesstimated 26 billions of health-care dollars. To achieve those reductions and help consumers make healthful choices, expanded educational efforts and monitoring of the sodium content of the food supply are needed. One single most challenge to sodium intake reduction efforts is the ubiquity of sodium in processed and prepared foods, leaving little to no opportunity for average consumers to adjust their intake. Increased availability of reduced- or low-sodium retailed food products in the marketplace, and reductions in the amount of sodium in foods served or sold in the restaurants are also needed. Despite the good intentions of U.S. adults, the widespread use of sodium in the U.S. food supply chain makes it difficult for them to control their own sodium intake. Therefore, interventions that involve food industry participation hold promise to solutions to address this public health concern.

Globally, the food industry has a renewed interest in reducing the sodium levels in processed foods. In Germany, the German Federal Institute for Risk Assessment (BfR) recommends that salt in processed foods be reduced. In the US, part of the push to partially take salt out of foods comes from a recent report ("Strategies to Reduce Sodium Intake in the United States") of the Institute of Medicine (IOM). IOM recommended that FDA remove or modify the GRAS (Generally Recognized As Safe) status of salt and regulate the amount to be added to each food category. Removing the GRAS status of salt and regulating what amount can be added in foods will undoubtedly have enormous consequences on food and food trade globally. Taking salt out of foods and maintaining consumer satisfaction is challenging. Salt plays multiple roles in flavoring, food processing, and safety at a relatively low cost. Salt reduction will tremendously and negatively affect taste, aroma and flavor of processed foods.

In the USA, proposed reductions in sodium range from 10-40% within 61 classes of packaged foods and 25 classes of restaurant foods. On a voluntary basis, some major food manufacturers have already implemented a step-wise reduction in the sodium level of processed foods. A scan of new product launches from around the world with a low-sodium claim indicates that the trend is already well underway. Nearly 3,000 global food and drink launches were marketed on a low-sodium platform in 2009.

In Thailand, besides the heart disease related issues, diabetes is a large and growing public health concern. The estimated national prevalence of diabetes in Thai adults is approximately 9.6%. Hypertension (high blood pressure) is very common in patients with diabetes. Control of hypertension in diabetic patients usually requires multiple drugs. However, diagnosed diabetes in its early stage is likely to be treated with proven, low-cost, preventative therapies such as strict diets with low sodium to control blood pressure. However, prepared, processed, retailed and restaurant foods with low sodium (salt) are uncommon in Thailand. Commercial salt substitutes intended for home cooking are rare and even unfamiliar to Thai population. Without law reinforcement, Thai Food Industries may not be willing to participate in the step-wise salt reduction.

In the US, the majority (>85%) of sodium intake derives from salt added to processed or prepared foods during production. However, this level is not known but is expected to be similar for the Thai population. Choosing foods with less sodium content requires that foods available to the Thai population contain less sodium. An approach toward reducing sodium intakes is critical to reducing the prevalence of hypertension and its associated disease risk of the Thai adult population.

There are various alternative non-sodium healthy salts (known as salt substitutes). Potassium chloride (KCl) can be used as a substitute for ordinary salt (sodium chloride) but it imparts undesirable bitterness and metallic aftertaste. There are at least 20 bitterness blockers that can be incorporated to improve the taste of KCl. Our previous collaborative work conducted at LSU Food Science Department by Dr. Witoon Prinyawiwatkul and Chiang Mai University by Dr. Sujinda Sriwattana revealed that some compounds could partially mask the undesirable bitterness and enhance saltiness perception of KCl. Physical properties and the form of salt and the end products potentially affect saltiness and bitterness perception. This type of research has not been extensively explored. In addition, use of Thai spices and herbs to enhance aroma and flavor of low-sodium processed foods is a promising approach, thus should prompt future research.

Related Previous and Current Activities

During January 16-17, 2012, Dr. Witoon Prinyawiwatkul (ATPAC), MOST, TIRST, DSS and CMU met in order to กำหนดแนวทางความร่วมมือในการวิจัยและพัฒนา “สารทดแทนเกลือและการประยุกต์ใช้ใน อุตสาหกรรมอาหาร.” As a result, a series of activities (seminars and research) has been proposed. During August 7-8, 2012, a seminar “Non-Sodium

Healthy Salt and its Food Applications" supported by OSTC/MOST was held at the Century Park Hotel, Bangkok, Thailand. The main objectives were to make public aware of the known health risk of high consumption of sodium via table salt (sodium chloride); to update and educate Thai food industry the followings: current regulatory status of salt per US FDA Code of Federal Regulation guidelines; the impact of potential regulatory changes on food exportation; alternative & most common salt substitute (potassium chloride), its characteristics, challenges facing salt substitution; current research on salt substitution in food formulations; to preliminarily assess Thai food industry's willingness to voluntarily participate in a stepwise salt reduction program, and identify obstacles & challenges in achieving this.

From a series of seminars during August 7-8, 2012 delivered by 8 invited speakers and a brain storming session, it was very clear that a strategic plan to reduce sodium consumption in Thailand requires coordinated efforts at multiple levels including government authorities, food industries, educational entities (schools, colleges and Universities) and other diverse stakeholders. During the brain-storming session, the top 5 critical factors that will affect the stepwise sodium reduction in Thailand were identified. In the order of their significance, these are consumer awareness, food safety and quality of reduced sodium foods, know-how on salt substitutes and their availability, food labeling and regulations, production cost of reduced sodium foods.

During the August 7-8 meeting, discussion was focused on submission of a mega project for funding consideration to National Research Council of Thailand for 2014 fiscal year. The team (LSU, CMU, KU, and TIRST) was assembled and submitted a proposal "กลยุทธ์การลดเกลือโซเดียม ในอาหารเพื่อการรักษา สุขภาพเชิงป้องกัน/ Strategic approach to reduce sodium salt in foods for preventive healthcare" for funding consideration to NRTC สำนักงานคณะกรรมการวิจัยแห่งชาติ, วช).

Dr. Witoon Prinyawiwatkul indicated that this proposal submitted to NRTC may or may not go through. In order to get the research project started, seed money is necessarily needed. Therefore, the ATPAC Agro-Industry team led by Dr. Witoon Prinyawiwatkul requested research fund from MOST via OSTC for a one-year project under the 2013 fiscal year. The proposed 1-year research project is a collaborative effort between ATPAC Food Agro-Industry team (led by Dr. Witoon Prinyawiwatkul) and Chiang Mai University (CMU, led by Dr. Sujinda Sriwattana). The goal is to demonstrate that a salt level can be reduced by at least 35% in food formulations without compromising sensory acceptability and its market potential. One commonly consumed food product (i.e., Vienna pork sausage) is being used as a demonstration model to showcase this project. Dissemination of the findings will be done upon completion of this project, and technology transfer is possible upon request and available funding.

Overall Goal and Recommendation for Research during 2013-2016 fiscal years

1. There are various alternative non-sodium healthy salts (known as salt substitutes). Potassium chloride (KCl) is the most common one, but it imparts undesirable bitterness and metallic aftertaste. There are at least 20 bitterness blockers that can be incorporated to improve the taste of KCl. Further research is needed to identify some inexpensive and effective compounds that can potentially suppress the undesirable bitterness and enhance saltiness perception of KCl.

2. Physical properties and the form of salt and the end products potentially affect saltiness and bitterness perception. In particular, particle size distribution and surface area of NaCl and KCl salts can be modified, thus potentially modify saltiness and bitterness perception. The form (solid, liquid, emulsion, etc.) of the end products (e.g., potato chips, salad dressing, mayonnaise, etc.) may affect sensory perception of saltiness and bitterness. Even more importantly, solubility of salts in the mouth and time release of the saltiness perception/detection will likely help cut down the amount of salts in food formulation. This type of research work has not been fully investigated, and needs further investigation.

3. Use of Thai spices and herbs to enhance aroma and flavor of low-sodium processed foods is a promising approach, thus should prompt future research.

Project benefits

1. Short-term and near future: to allow the Thai food industry to comply with a possibly modified regulated amount of salt added in food products per US FDA for food exportation purpose.

2. Long-term: reducing sodium in daily foods will help reduce HBP which is a major contributor to cardiovascular diseases, a leading cause of death, disability, and health-care costs in Thailand, and to save thousands of lives each year.

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Knowledge-Based Treatment Planning for Radiation Therapy of Head and Neck Cancers

BY *VORAKARN CHANYAVANICH*

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Summary

The increasing cancer burden in Thailand is well established, with estimates of 120,000 new cancer cases of all disease sites projected annually. The leading disease sites include lung, liver, breast, cervix and colon-rectum. Approximately a third of all cancer diseases are treated using radiation therapy, often in conjunction with surgery and chemotherapy. This increase in recently led to increasing investments in radiation therapy infrastructure by the National Cancer Institute as well as expansions in many academic university hospitals. Presently in Thailand, there are currently only 25 radiation therapy facilities, with roughly 35 linear accelerators available to provide radiation therapy treatments for cancer patients. Moreover, there is a substantial workforce shortage of radiation oncology professionals, with insufficient numbers of trained radiation oncologists and medical physicists necessary to address the needs of present and future cancer patient population.

One of the leading cancer disease sites among the Thai population is head & neck cancer, and most patients undergo surgery and radiation therapy, which uses multiple radiation beams to deliver therapeutic dose to the cancer while sparing normal tissue, i.e. oral cavity, parotid gland and spinal cord. Intensity Modulated Radiation Therapy (IMRT) is a modern radiation delivery technique that provides effective treatment to maximize patient survival and quality of life. Currently, IMRT treatment plans are designed by radiation oncologists and medical physicists and customized for each individual patient, with patient-specific consideration of the dose delivery to tumor planning target volume (PTV) and dose sparing to adjacent normal tissues. This treatment planning process is technically complex and requires the expertise of highly trained clinical professionals. Due to the challenge of maximizing therapeutic dose to the tumor while minimizing dose to organs at risk, IMRT treatment planning often proceeds in a very inefficient manner of trial and error, and can be very time consuming and subjective. We will address this problem by developing software tools to provide a semi-automated and optimized approach to IMRT treatment planning.

Specifically, we propose to develop decision-support software for IMRT treatment planning to address the challenges of head & neck radiotherapy treatment planning. The software tool will ensure safety, reliability, and consistency of treatment planning for this complex disease site. The specific aims of the project include developing a knowledge-base of high quality radiotherapy treatment plans, and designing a case-similarity algorithm to identify similar patient based on anatomy. Radiation dose parameters from the identified similar patient will be adapted to design new plans, thereby reducing trial and error effort and improve planning efficiency. Lastly, we will evaluate the resulting treatment plan quality and assess clinical workflow improvements based on quantitative clinical metrics.

By using a knowledge-based treatment planning approach, the planner benefits from a decision support system that leverages prior cases to quickly develop new, high quality radiation therapy plans. Since treatment planning is a complex, time consuming process, and is highly dependent on the expertise level of the planner, a knowledge-based approach to adapt prior plans has the potential to reduce treatment planning time and improve plan quality across institutions.

Background

Cancer is an increasing public health problem in Thailand. The increasing cancer incidence in Thailand is well established, with estimates of 125,000 new cancer cases of all disease sites projected annually in 2008 [1]. The leading disease sites include lung, liver, breast, cervix and colon-rectum.

Refer to Figure 1. The top five leading cancer disease sites treated by radiation therapy for Thai men and women include head & neck, breast, lung, colorectal and cervix [2]. Refer to Figure 2. Radiation therapy, in conjunction with surgery and chemotherapy, plays a primary role in the treatment of these cancers. Medical physicists are highly technical professionals who work closely with radiation oncologist physicians to design treatment plans to deliver safe and effective radiotherapy treatments. In addition, medical physicists also have a broad range of technical responsibilities, including developing treatment protocols, quality assurance, and the implementation of various medical imaging modalities (i.e. x-ray, CT, MRI, ultrasound, and PET) to improve the precision and accuracy of radiotherapy treatments. The increasing integration of these imaging tools in the radiotherapy treatment process has led to substantial improvements in tumor delineation, management of tumor motion, and increased sparing of dose to normal tissue – which potentially leads to more effective radiotherapy outcomes for cancer patients [3].

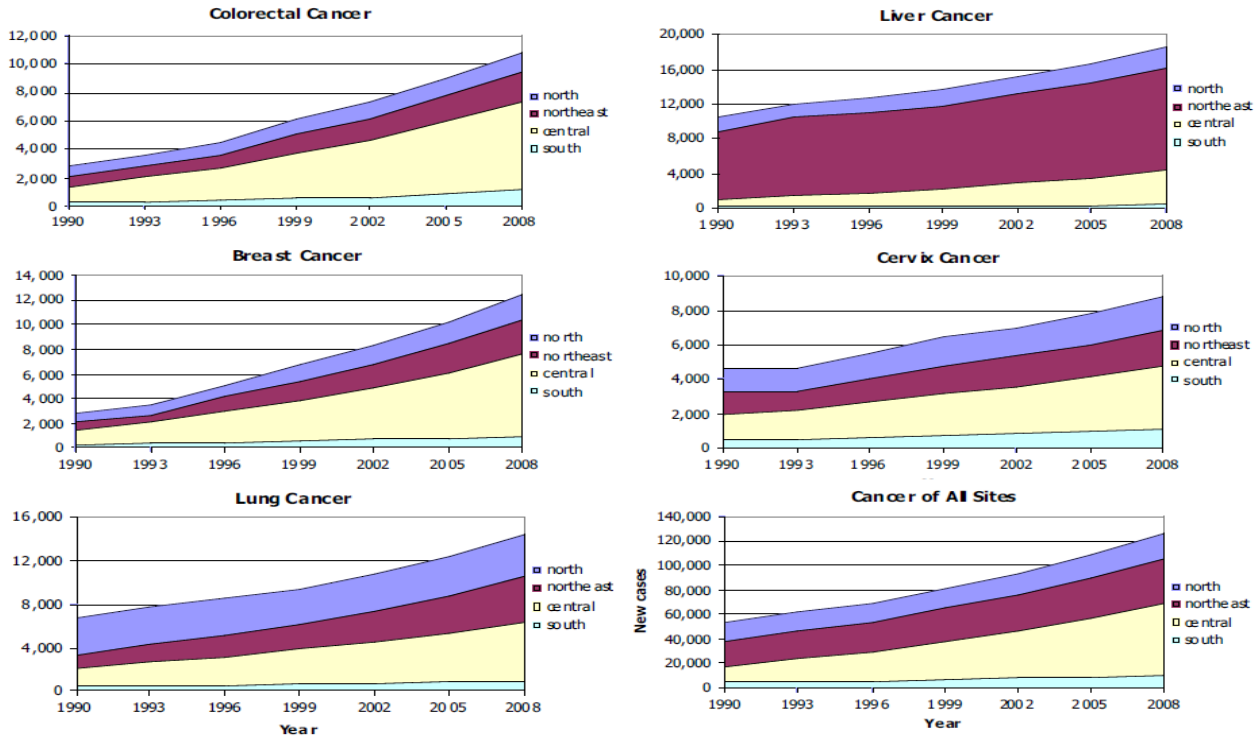

Figure 1. Trends in number of cancer cases for colorectal, liver, lung, cervix and breast cancers and cancers of all sites. Source: Sriplung, H et al., "Cancer incidence trends in Thailand," Asian Pacific J Cancer Prev, 7, 239-244, 2006.

Currently, there are only 25 cancer centers throughout Thailand, both public and private centers that provide radiotherapy treatment, with a total of 35 linear accelerators used to treat various kinds of cancers [4]. In such a highly technical field of radiation medicine, the quality of radiotherapy treatment is highly dependent on the quantity and quality of the existing infrastructure, both in terms of available equipment as well as the human resource, with due consideration for numbers, capacity and quality of the technical staff, including radiation oncologists, medical physicists and technologists [5]. In recent years, Thailand has recognized the rising cancer burden and is addressing the need of the population through investments in the purchase of multi-million dollar linear accelerators and the construction of radiation oncology facilities.

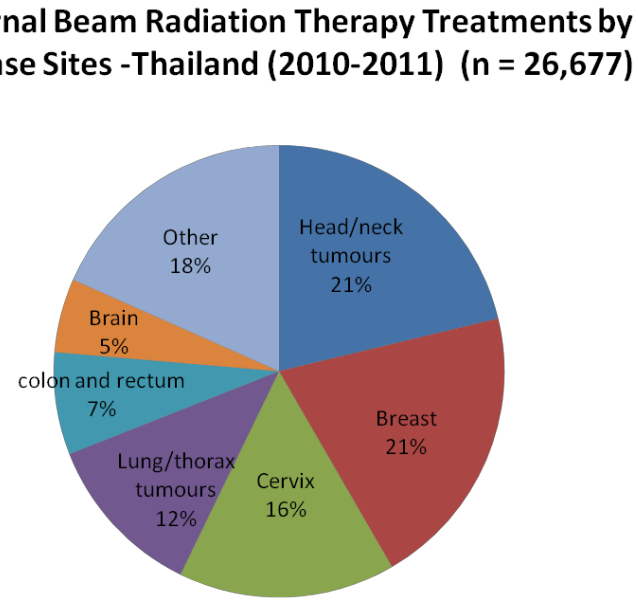

Figure 2. External beam radiation therapy treatments by disease sites – Thailand (2010-2011), Source: Ramathibodi Hospital Cancer Registry 2010-2011.

While the capital investment has been summoned and used to expand radiation medicine infrastructure, there has unfortunately been a substantial lack of investment in time and resources to address the human resource needs required to staff and provide the technical delivery of radiation therapy treatments in many newly constructed facilities. In fact, a study by Prakongsai et al. of the International Health Policy Program at the Thai Ministry of Public Health reported on the significant workforce shortages across most National Cancer Institute radiation oncology facilities in Thailand [6].

Presently, there are five academic medical centers (Siriraj, Ramathibodi, Chulalongkorn, Chiang Mai and Khon Kaen) that educate and train the nation's radiation oncologists and medical physicists, which currently total only 100 and 75, respectively [7]. In a study of the nation's radiation medicine infrastructure and factors that affect patient access, Prakongsai et al. reported severe workforce shortages for the given patient workload, with only 10% of the centers staffed with adequate numbers of radiation oncology physicians, and only 44% of the centers staffed with adequate numbers of medical physicists. The safe delivery of high quality radiation therapy treatments is dependent on adequate numbers of highly trained radiation oncologists and medical physicists. The motivation of this proposal seeks to address these needs and to develop curricula and software tools to provide training and professional development for Thailand's radiation oncologists and medical physicists.

Clinical Motivation

Within the Thai population, the five leading cancer disease sites treated by radiation therapy include head & neck, breast, lung, colorectal and cervix. Of these leading disease sites, the most technically challenging disease site to treat with radiation therapy is the head & neck cancers,

which include regions of the nasopharynx, oropharynx, larynx, esophagus, oral cavity, base of tongue, and the sinuses. Significant head & neck (H&N) cancers, specifically of the nasopharynx, exist amongst Thai population, presenting itself as a challenging and complex disease site for radiation oncologist and medical physicists. Fortunately, most H&N cancers are highly curable with radiotherapy, often in conjunction with surgery and chemotherapy.

Intensity Modulated Radiation Therapy (IMRT) is a technique that delivers highly conformal dose distribution to tumor target volumes, while sparing critical normal tissue including the parotid glands responsible for salivary function, as well as the spinal cord. Refer to Figure 3. Radiotherapy treatment planning for H&N cancer is more time consuming than for breast, lung or cervical cancers because of the intrinsic functional complexity of the region's anatomy and organs at risk, with substantial risk of potential complications of radiation injury to adjacent radiosensitive normal tissue. Radiation injury to parotid glands can lead to impaired salivary function, which greatly diminish the quality of life associated with difficulty in swallowing, eating and speech. Not surprisingly, substantial radiation dose exceeding radiobiological thresholds for spinal cord, optic nerve and optic chiasm can lead to substantial permanent morbidity.

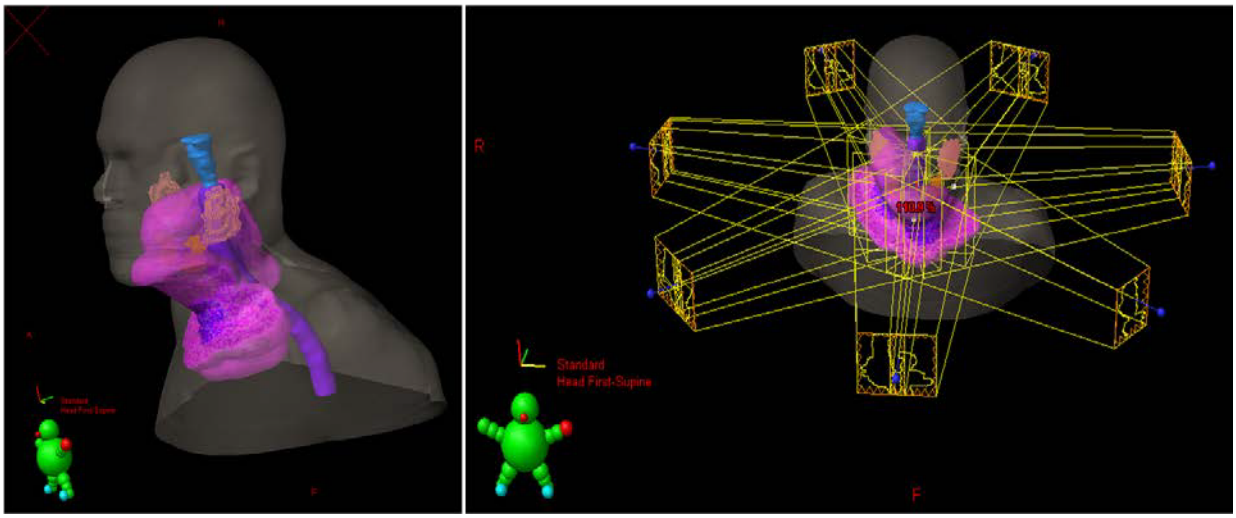

Figure 3. Radiotherapy treatment planning for H&N involves rendering of 3D contour volumes of tumor volume and adjacent normal structures, and the placement of coplanar IMRT beams.

IMRT treatment planning is a highly complex process, and depends on the level of experience and close coordination of planning strategy between the radiation oncologist and the medical physicist [8]. The radiation oncologist reviews the patient CT and delineates the contours of tumor volume and various organs and risk within a treatment planning computer system. These contours take into account the microscopic disease spread patterns, as well as nodal involvement information obtained from biopsy- established pathology reports and/or positron emission tomography (PET) diagnostic findings. Additionally, these contours often include a treatment margin of 0.5-1cm to compensate potential setup errors, tumor motion. These contours are

rendered as 3D models superimposed on CT scans, and are used by the physicist to design a patient-specific radiation therapy treatment plan. Medical physicists are then responsible for placing beam arrangements to deliver therapeutic radiation dose to the defined tumor volumes, and to calculate the radiation dosimetry models of the delivered dose to the target and to the adjacent normal tissues. The design of each patient's treatment plan for H&N cancers can often take up to 6-10 hours to develop and optimize, since the complexity lies in balancing the tradeoff between high dose delivery to the tumor and avoidance/reduction of collateral dose to adjacent organs at risk.

The process of IMRT treatment planning is thus a highly complex process requiring substantial expertise to ensure high quality and safe delivery [9]. Subsequently, IMRT treatment planning can be extremely time consuming, and the final plan quality is highly dependent on the experience and skill of the physicist designing the treatment plan.

Objectives

We seek to improve quality of radiation therapy treatment planning, to address clinical workflow needs, and to advance scientific understanding of the radiotherapy treatment of head & neck cancers. Specifically, we propose to develop decision-support software for radiation therapy treatment planning to address the challenges of head & neck radiotherapy treatment planning. The software tool will ensure safety, reliability, and consistency of treatment planning for this complex disease site. To accomplish this goal, the team draws upon interdisciplinary expertise from biomedical engineering, radiology, radiation oncology, and medical physics with the following specific aims:

Specific Aim #1: To construct a knowledge database of high quality radiotherapy treatment plans for head & neck cancers.

Specific Aim #2: To develop a case-similarity algorithm to identify and match similar patient cases based on CT datasets, and physician-delineated anatomical contours.

Specific Aim #3: To implement knowledge-based treatment planning to generate new IMRT plans by adapting the radiation fluence from matched similar plans.

Specific Aim #4: To evaluate treatment plan quality and clinical workflow improvements based on quantitative clinical metrics.

Proposed study

Specific Aim #1: To construct a knowledge database of high quality radiotherapy treatment plans for head & neck cancers.

After obtaining institutional review board (IRB) approval for use of patient data from each participating institution, we will assemble a database of 200 retrospective head and neck IMRT treatment plans to populate an information-theoretic system. Structure contours of interest will

include gross tumor volume, planning target volume, parotid glands, spinal cord, oral cavity and adjacent organs at risk. Additional imaging datasets will include the simulation CT, and any available MR/PET images. The cases will be stratified into subset disease types, including nasopharynx, oropharynx, oral cavity, esophagus, larynx, hypopharynx and thyroid. Dosimetric parameters will also be extracted from each treatment plan, to include prescription dose, boost dose, fractionation scheme, isocenter location, and organ at risk dose-volume constraints. If available, staging of gross disease and presence and extent of nodal involvement information will be extracted from associated pathology reports. Lastly, important treatment parameters from each of the optimized and clinically approved plan will include radiation beam angles, beam's eye view apertures, and intensity fluence patterns. These parameters will be anonym zed to remove patient identifiers, and then exported and maintained as DICOM format, and viewable in an open-source visualization browser platform, such as OSIRIX.

Specific Aim #2: To develop a case-similarity algorithm to identify and match similar patient cases based on CT datasets, and physician-delineated anatomical contours.

The author's prior work with prostate IMRT treatment planning optimization utilized an image similarity algorithm to identify similar patient cases [10]. We intend to adapt this algorithm to extend the mutual information technique to identify the similar cases (BEV) projections of head & neck anatomical contours. Most IMRT plans for head & neck utilize upwards of 7-11 beam angles, depending on the anatomical complexity of the treatment target. We will set aside a subset of randomly selected patient cases of each disease sub-type to serve as query cases for validation purposes. Each of these query cases will be matched against the knowledge-base by a weighted-feature prioritization scheme, and a ranking of the similar cases from the database will be generated. The case similarity comparisons will be repeated using a leave-one-out approach, matching each query case against the remaining cases in the database. A scoring method will be used to analyze the case similarity of mutual information ranking to assess heterogeneity and case variability within each disease sub-types and across sub-types.

Specific Aim #3: To implement knowledge-based treatment planning to generate new IMRT plans by adapting the radiation fluence from matched similar plans.

Treatment parameters from the matched cases, including beam geometry, fluences, and optimization criteria will be used to develop new treatment plans in a commercial treatment planning system (i.e. Eclipse) The fluence from each angle of the matched case will be adapted using deformable registration to conform to the query case planning target volume. Prior optimization constraints from the matched similar case will also be adapted and used as a new optimization starting point. This strategy provides the optimizer an 'intelligent' optimization starting point, thereby allowing the optimizer to bypass the earlier trial/error guessing phase of manual treatment planning, and to adapt prior matched fluences directly towards a 'closer' final optimal solution.

Specific Aim #4: To evaluate treatment plan quality and clinical workflow improvements based on quantitative clinical metrics.

Each newly generated plan is normalized to deliver the prescription dose to approximately 97 - 98% of the planning target volume. We will review each plan for any potential hot-spot regions where dose exceeds 115% of the prescription dose, and will assess the dose-volume histograms to evaluate the dose to normal structures, i.e. parotid and spinal cord. Also, a comparison of the differences in dose-volume histograms (DVH) between the knowledge-base plans and the original manually generated treatment plans will be conducted. Specifically, we will consider PTV coverage and dose to 20%, 30%, and 50% of the critical structure volumes (D20, D30, D50), and reviewed against the initial dose-volume constraints. Lastly, a time-motion study will be conducted to calculate the efficiency gains and reduction in computational time, and human planning time.

Project Benefits

In May 2011, ATPAC and OSTC organized a 4-day training workshop in medical physics titled, "Imaging and Scientific Computing in Radiation Oncology", held at Ramathibodi Hospital, Mahidol University. The successful workshop attracted over 60 participants, including medical physicists, clinical staff, and graduate students from various radiation oncology centers throughout Thailand. Lecturers included Dr. Vorakarn Chanyavanich and Brian Harrawood from Duke University, as well as Dr. Puangpen Tangboonduangjit and several clinical radiation oncology staff from Ramathibodi Hospital at Mahidol University.

With the intent of building on the momentum of the previous workshop, we propose this multi-year study to continue the collaboration for the purpose of supporting medical physics research and graduate education in Thailand. Additionally, the proposed joint research project in H&N radiotherapy lends itself for mutual sharing of clinical domain expertise between US and Thai professionals. This research project can help to stimulate Thai research productivity in the areas of medical imaging, treatment planning and scientific computing. Furthermore, there is the potential to translate the work to address the treatment planning needs of other radiation therapy centers throughout the world. The research project will provide an opportunity to work together with Thai professionals, medical physicists and radiation oncologists, to develop a clinically relevant software tool that can potentially lead to improvements in radiation therapy treatments. The development of knowledge-based treatment planning software tools can help to address existing clinical workflow inefficiencies by substantially reducing treatment planning time. Ultimately, there is the potential that knowledge-based planning can also provide a means of rapidly designing new treatment plans of high quality, which would improve patient survival and quality of life.

Summary of expected benefits

- Increased utilization of IMRT for head & neck cancers will lead to improved overall patient survival and reduced morbidity.

- Develop a decision-support software tool to improve the quality of IMRT treatment planning.
- Knowledge-based IMRT planning can improve clinical workflow by potentially reducing the planning time and inefficiencies of trial/error efforts.
- A database of prior plans can be used as a training tool to establish a consistent benchmark of plan quality, and may lead to improvements in overall plan quality across institutions.

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Development of Eco-Routing Navigation Algorithms for Thai Vehicles

BY *KANOK BORIBOONSOMSIN* AND *PRAPRUT SONGCHITRUKSA*

Executive Summary

Roadway transportation accounts for a significant fraction of total energy use in Thailand. Traveling on a route that would consume the least amount of fuel ("eco-routing") is one of the energy conservation measures for those who use personal vehicles. Research has shown that eco-routing navigation systems could help save fuel by an average of 8%. Dr. Boriboonsomsin has been developing eco-routing navigation technology in the U.S. over the last six years. His technology can be readily transferred to Thailand as almost all of the components already exist. The last jigsaw that is needed is eco-routing navigation algorithms specifically developed for Thai vehicles.

It is proposed to develop such algorithms in cooperation with stakeholder groups in Thailand, including public agencies, research entities, non-profit organizations, as well as private companies. The project tasks consist of: 1) experimental design, 2) data collection, 3) vehicle fuel consumption model development, and 4) eco-routing navigation algorithm development. The developed eco-routing navigation algorithms will be able to integrate with existing roadway navigation systems, allowing these systems to find a travel route that would consume the least fuel for the trip. Even partial adoption of eco-routing can contribute to the reductions of petroleum consumption and emissions, which are beneficial to the drivers themselves (in terms of cost savings) as well as to the environment.

Background and Rationale

Roadway transportation accounts for a significant fraction of total energy use in Thailand. Therefore, there is a strong need to reduce energy consumption from the transportation sector through a variety of measures. Energy conservation is one such measure that can be very cost-effective and implementable in the near term. Energy conservation in the context of roadway transportation can be achieved by eliminating unnecessary trips or using public transits (e.g., buses, trains). In cases where using personal vehicles are unavoidable, ones can still conserve energy from their travel by choosing travel route and drive in a way that is more fuel-efficient.

Over the last few years, there has been a proliferation of roadway navigation tools that provide route guidance to drivers in Thailand. For instance, there are now several Internet sites (e.g., Google Maps) that provide driving directions from any origin to any destination in the roadway network. Many vehicle manufacturers and third party companies also offer on-board navigation systems and personal navigation devices that use GPS technology combined with sophisticated mapping and routing software to provide driving directions to specified destinations. These navigation systems primarily find a route corresponding to the shortest distance or shortest duration between an origin (or the current location of a vehicle) and a destination.

Studies have shown that selecting different travel routes between the same origin-destination pair can result in significant differences in the amount of fuel consumed and emissions produced [1], [2]. An exploratory study in Sweden found that 46% of the trips were not made on the most fuel-efficient route. These trips could have saved fuel by an average of 8% with the help of a fuel-optimized navigation system [3]. Recently, efforts have been made in developing eco-routing navigation systems that find an "eco-route" requiring the least amount of fuel and/or producing the least amount of emissions [4], [5]. These systems rely on eco-routing navigation algorithms that predict vehicle fuel consumption on any roadway links in real-time. It has been previously shown that these least-fuel or least-emission routes are not always the same as the shortest-distance or shortest-duration route [4], [5]. This is partly because of the nonlinear relationship between travel speed and vehicle fuel consumption [6]. It is also due to other factors affecting vehicle fuel consumption including vehicle characteristics (e.g., vehicle type, model year), roadway characteristics (e.g., road type, vertical grade), and traffic conditions (e.g., speed, congestion level) [7]-[12].

It is proposed herein to develop eco-routing navigation algorithms for vehicles in Thailand. These algorithms will be able to integrate with existing roadway navigation systems, allowing these systems to calculate eco-routes for Thai vehicles.

Objectives

The objectives of this project are to:

1. Collect real-world driving pattern and fuel consumption data from vehicles in Thailand,
2. Develop fuel consumption prediction models for vehicles in Thailand, and
3. Develop eco-routing navigation algorithms for vehicles in Thailand.

Current Status

Dr. Boriboonsomsin has been developing eco-routing navigation technology in the U.S. over the last six years. The technology consists of several components: (a) a digital map of roadway network that integrates historical and real-time traffic information from multiple data sources; (b) eco-routing navigation algorithms, which are a compilation of energy/emission factors for a variety of vehicle types under various roadway characteristics and traffic conditions; (c) a routing engine, which contains shortest-path algorithms used for optimal route calculation; and (d) user interfaces that receive origin-destination inputs from users and display route maps to the users. Figure 1 shows an example of the eco-routing navigation technology on a web-based platform.

The eco-routing navigation technology can be readily transferred to Thailand as almost all of the components already exist. Over the last few years, real-time traffic information has become increasingly available in Thailand, especially in Bangkok (see Figure 2). The traffic information as well as the underlying raw traffic data are accessible through the Intelligent Traffic Information Center Foundation (iTIC), as shown in Figure 3. At the same time, a routing engine

and user interfaces are a common part of any roadway navigation tools. Thus, the only thing that is needed is eco-routing navigation algorithms specifically developed for Thai vehicles.

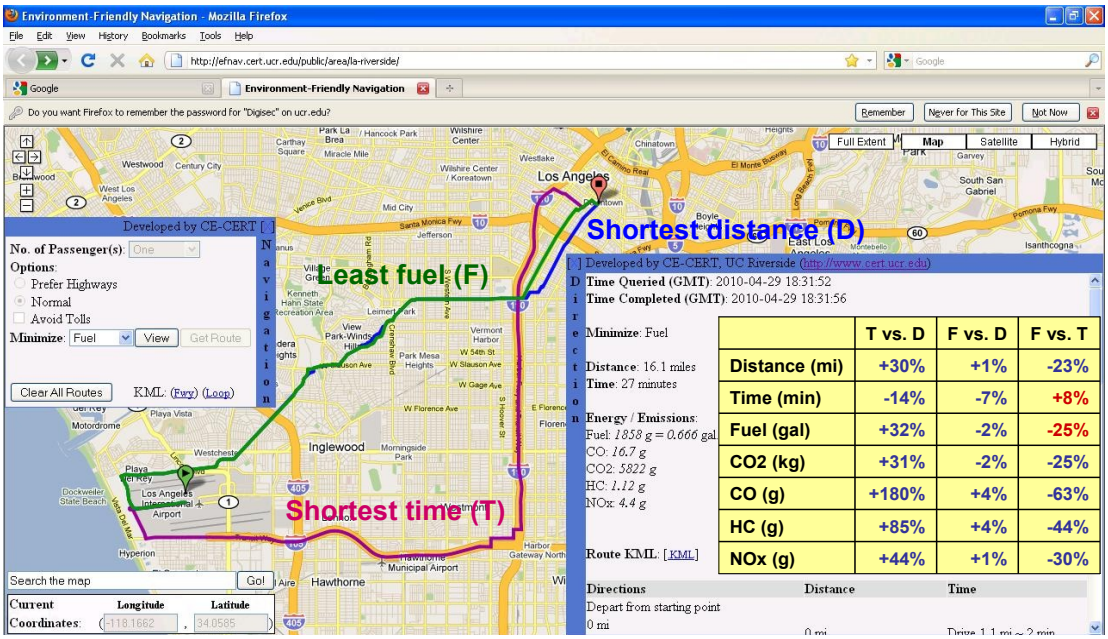

Figure 1. Web-based eco-routing navigation system

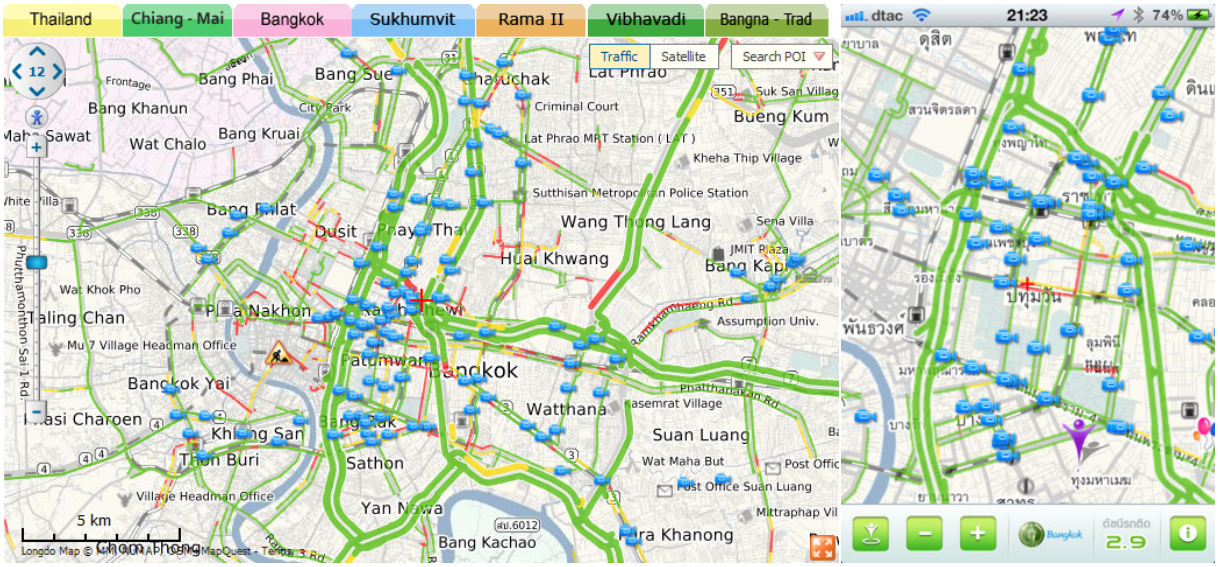

Figure 2. Real-time traffic information for Bangkok from iTIC Traffic Map website (left) and BMA[1] Live Traffic mobile app (right)

[1] Bangkok Metropolitan Administration

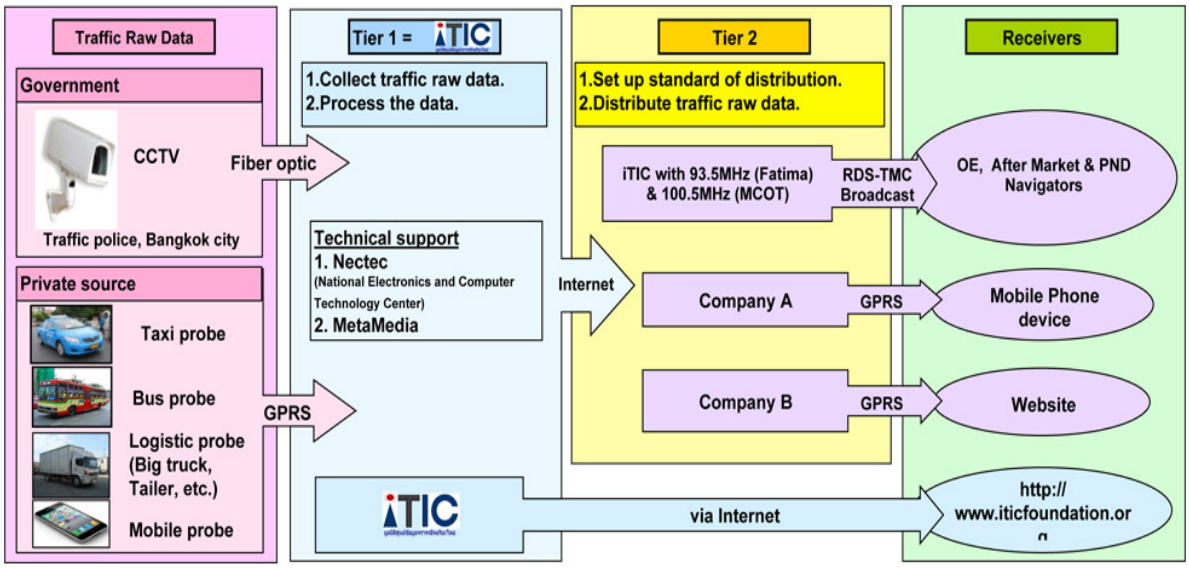

Figure 3. Architecture of iTIC's real-time traffic data collection and information dissemination

Proposed Study

To achieve the objectives of this project, the following research tasks are proposed:

Task 1: Experimental Design

In this task, major vehicle types in Thailand (e.g., gasoline cars, LPG trucks, etc.) will be identified based on literature review and consultation with stakeholder groups. Then, a vehicle recruitment plan will be prepared. Also, a data collection plan for collecting real-world fuel consumption data from the test vehicles will be developed, which includes driving targets on roadways with different characteristics (e.g., road type, speed limit, etc.).

Task 2: Data Collection

Each of the recruited test vehicles will be equipped with a GPS data logger and an OBD-II reader. The GPS data logger will record vehicle position (i.e., latitude, longitude), timestamp, and speed while the OBD-II reader will record several vehicle and engine parameters, which can be used to calculate fuel consumption. Both GPS and OBD-II data will be recorded at high resolution (e.g., second-by-second). If resources permit, the vehicles will also be equipped with a telematics system that can send the GPS and OBD-II data to a system server wirelessly in real-time, as shown in Figure 4. The test vehicles will be driven under real-world operating conditions. The data will continue to be collected until all the driving targets are reached.

Task 3: Vehicle Fuel Consumption Model Development

For each vehicle, the collected driving data stream will be cut into short snippets based on roadway links. This requires the driving data to be map matched to the digital roadway network as shown in Figure 5. In the figure, the data stream is cut into three snippets in red, blue, and green eclipses. For each snippet, the average speed and the fuel consumption per kilometer will

be calculated and plotted against each other. After data from a number of snippets are plotted, a curve will be fitted on the data resulting in a fuel consumption model for the vehicle as a function of average speed. The process can be expanded to include additional variables in the fuel consumption model.

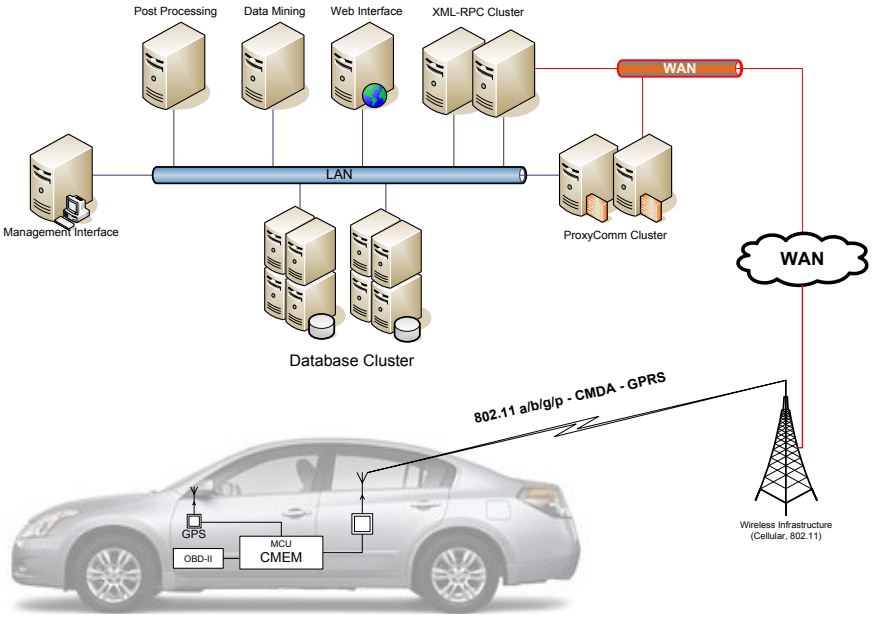

Figure 4. Vehicle telematics system

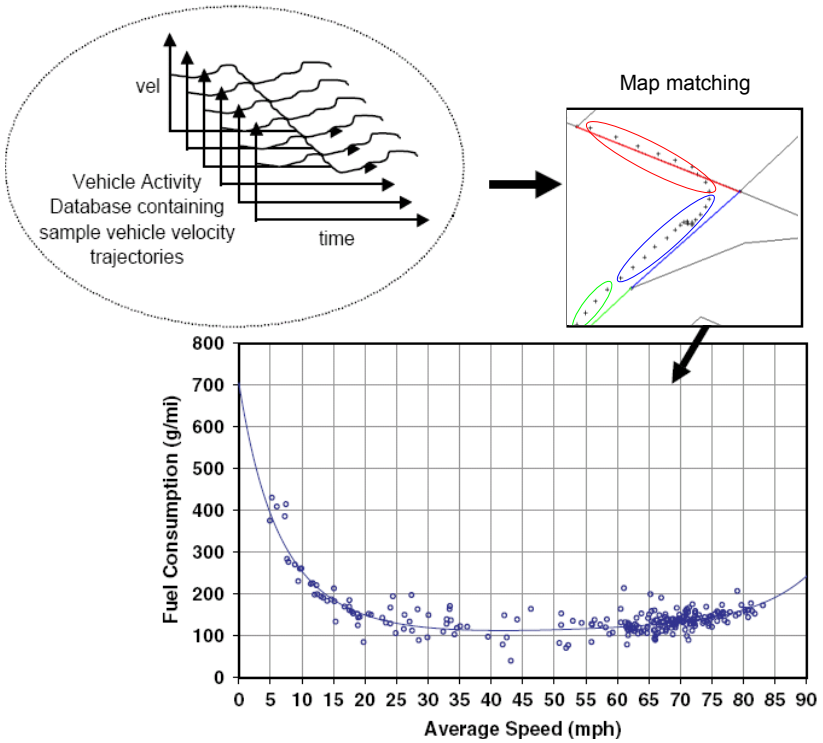

Figure 5. Methodology for developing vehicle fuel consumption model

Task 4: Eco-Routing Navigation Algorithm Development

After the fuel consumption models of all the vehicles have been developed, eco-routing navigation algorithms will be developed. This involves applying the fuel consumption models to appropriate attributes of roadway links in order to estimate the amount of fuel a vehicle will consume in order to traverse each link. The resulting fuel consumption map can then be used by shortest path algorithms in any routing engines to determine an eco-route.

Project Benefits

This project is expected to provide the following benefits:

1. The developed eco-routing navigation algorithms will be able to integrate integrated with existing roadway navigation systems, allowing these systems to find a travel route that would consume the least fuel for the trip. By providing additional route options and the corresponding travel costs to drivers, they can consider the tradeoff among the routes and make a choice with regards to which route to take based on their preferences and circumstances. Even if the drivers take eco-routes in only some of their trips, it could still contribute to the reductions of petroleum consumption and emissions, which are beneficial to the drivers themselves (in terms of cost savings) as well as to the environment.

2. The vehicle fuel consumption models in the algorithms can be used to estimate vehicle fuel consumption on any roads in Thailand. This provides a scientifically sound method for monitoring and inventorying energy use and carbon emissions from the roadway transportation sector.

3. The vehicle fuel consumption models can also be used to estimate the impact of traffic flow improvement projects on vehicle fuel consumption and carbon emissions as part of a benefit-cost analysis or a performance monitoring program.

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Water Resource and Flood-Risk Management

BY *NISAI WANAKULE*

Background

The Great Flood of 2011 has devastated several central provinces, including six major industrial estates located in the suburbs north of the Bangkok Metropolitan Area. This flood event is not only the biggest in terms of the magnitude of flow and the flooding acreage, but is also the most prolonged inundation in the modern history of Thailand. It has immensely affected more than six million residents along the path of the flood, resulting in the loss of life, diminishment of livelihood and physical and mental well-being, as well as the destruction of homes, belongings, and sentimental collections. The government, in collaboration with various international organizations and academic institutions, conducted a Post Disaster Needs Assessments (PDNA), which suggested that the value of flood damage last year could be as large as THB 1.4 trillion ($45.9 billion), or about 14% of the GDP. In the manufacturing sector alone, the damage and loss assessment was estimated at THB 1 trillion ($32.8 billion) on manufacturing equipment losses and production losses due to factory shutdowns. In addition, it is expected that several more billion baht will be lost in possible foreign investments due to the uncertainties in the governmental flood protection policy for flood prone areas of national economic significance.

Although this Great Flood of 2011 has a return period on the order of 100 years, the possibility of experiencing another flood of this magnitude does not diminish in the next few decades. As a matter of fact, the possibility of facing future floods of this magnitude will be higher or more frequent due to future climate change. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report released in 2007 (known as AR4) confirmed the effect of increasing carbon dioxide concentration on climate variability (IPCC, 2007). It also projected the possible impacts of future climate change under several scenarios, as described in the Special Report on Emissions Scenarios (SRES, 2000). The SRES report recognized the risk of more complex, frequent, intense, or unpredictable climate-related extreme events associated with global temperature increase, changing precipitation patterns, and sea-level rise, coupled with both gradual and non-linear change to ecosystems and natural resources. It suggested the need for a renewed focus on the ways that disaster risk reduction and adaptation can influence the context in which extreme events and climate change occur. AR4 identified the usefulness of taking a "risk perspective" in order to identify synergies to "promote sustainable development, reduce the risk of climate-related damages and take advantage of climate-related opportunities."

For Thailand, the global scale projection by AR4 had been confirmed by recent high-resolution climate scenario analyses conducted by the Southeast Asia START Regional Center, which were based on downscaling regional climate models. The study suggested that (Chinvanno et al., 2010):

"…the future climate in Thailand and surrounding countries will get warmer, have a longer summertime, a shorter and warmer wintertime and a rainy season with higher intensity of rainfall resulting in higher annual total precipitation. These changes are unlikely to be irreversible and would have impact on various systems and sectors."

Evidences of climate change impacts on water resources have become increasingly clear. Here are some recent examples:

- The most destructive Atlantic Hurricane Katrina was strengthened to a Category 5 over the warm Gulf of Mexico water and made the second landfall as a Category 3 hurricane on the morning of August 29, 2005 in southeast Louisiana. It was the costliest natural disaster, as well as one of the five deadliest hurricanes, in the history of the United States. At least 1,833 people lost their life due to hurricane and subsequent floods, especially in New Orleans where the levee failures causing rapid flooding. The damages were widespread along the Gulf coast from central Florida to Texas, which estimated at $108 billion.
- In April and May 2011, the Mississippi River has experienced the largest and most damaging floods of the century. The record breaking rainfall from four storm systems, which also spawned the largest tornado outbreaks in U.S. history, combined with springtime snow melt from the Upper Midwest, resulted in a 500-year flood along the Mississippi. Several historic actions were made to prevent entensive damages to downstream populated areas.
    - The blasting of the Birds Point - New Madrid levee, the operation to intentionally breach and relieve pressure on the levee at nearby Cairo, Illinois, a small town located at the confluence of the Mississippi River and the Ohio River. The flood stage near Cairo reach 61.72 feet, which past the previous recode of 59.5 feet, before the first explosion was set off on May 3. The blast allowed water from the swollen Mississippi River to flow into 130,000 acres floodway of prime agricultural lands in southeastern Missouri.
    - For the first time since 1973 flood, the Morganza Spillway was opened on May 14, deliberately flooding 4,600 square miles (2,944,000 acres) of rural Louisiana to save most of Baton Rouge and New Orleans. The operation diverted approximately 150,000 cfs (~4,200 m^3/s) of water from the Mississippi River to the Morganza and Atchafalaya floodways.
    - On May 23, 2011, 330 of the structure's 350-bay Bonnet Carré Spillway, near New Orleans, were opened to divert water from the Mississippi River to Lake Pontchartrain. The operation reduced water levels and flow that might jeopardize levees protecting around New Orleans. The last time that this many bays were opened was in 1983.

- The non-hurricane prone areas in the northeastern of US started to encounter changing in major hurricane paths and patterns. On August 27, 2011, Atlantic Hurricane Irene made the first United States landfall near Cape Lookout, on North Carolina's Outer Banks as Category 1. Its path continued along the East Coast and made the second landfall in southeastern New Jersey. While losing its strength and was degraded to a tropical storm it continued hugging the New Jersey coastline to make another landfall in the Coney Island neighborhood of New York City. Hurricane and Tropical Storm Irene caused extensive flood damage in the Coastal areas due to storm surge. In additional riverine flooding reported in many areas with measured record flood stages. Several river gages in State of New York reported 100-year to 500-year flood records. Throughout its path in the contiguous United States, Irene caused approximately $15.6 billion in damage and 47 deaths.

- In 2012, the Atlantic Super Hurricane Sandy took an offshore track parallel to Irene's path. Because of its size measure at 1,100 miles in diameter, its effects was felt several miles westward of the United States East Coast as far as Michigan and Wisconsin. It downgraded to an Extra-tropical Cyclone before making a 90 degree turn and moving ashore near Atlantic City, New Jersey. Over twenty states were affected in one way or another by Sandy with major damage was concentrated around Coastal areas of New Jersey and New York City. Sandy caused more than 19,000 flights cancellation. Flooding and other storm-related problems disrupted Cities' transportation systems and caused widespread power outages that left 4.8 million customers without power for several days. In United States alone, 113 lives were lost and the damage was assessed at $50 billon, half of which was due to business interruption.

Current Status

In November 2011, the government established a Strategic Committee on Water Resources Management (SCWRM), the members of which were comprised of high profile experts in the field of water resources development. The committee is chaired by the Prime Minister, and has been tasked to conduct a fact-finding study about the causes of this flood and weaknesses in dealing with the situation. In addition, the committee responsibilities included establishing guidelines and plans to ensure that the severe flooding situation would not reoccur during the rainy season next year, as well as developing a sustainable water resources management system. Recently, a Water and Flood Management Commission (WFMC) was established to oversee water management programs being undertaken by related organizations and ministries to ensure their effectiveness. *The committee will consider possible adaptation of water management projects in foreign countries to prevent repetition of water shortages and flooding in the near future.*

There are eight programs currently considered by the WFMC, including the effective management of reservoirs, floodways used when the reservoirs overflow, effective drainage systems, effective forecasting and warning systems, contingency plans for specific areas in time

of flooding, establishment of an organization to handle holistic water management, land use management in floodplain, and reforestation. These eight programs are estimated to cost approximately THB 350 billion ($11.5 billion) and will provide flood protection along Chao Phraya River basin and a few other basins in the Northeast. In July, WFMC issued a TOR for the proposal on "A Conceptual Plan for the Design of Infrastructure for Sustainable Water Resources Management and Flood Prevention for the Kingdom of Thailand." There were 303 local consulting firms and 37 international firms expressed their interests and received the TOR package. Interested firms have 30 days after July 24, 2012 to submit their profiles and applications for qualification screening. Qualified firms will have until Nov 23, 2012 to submit their proposed conceptual plans for consideration. The selection process, which includes ranking of a short list, interview and contract negotiation for each project, will take place during the 60-day period following the submission dateline.

Objectives

Missions given to the committee and commission are very challenging. It is next to impossible to guarantee all impacts of severe flooding impacts would not reoccur. Engineers and planners can design flood protection system to certain parameters and probabilistic criteria (e.g., 100 year or 1% annual probably) and develop strategies for reducing vulnerability or increase resiliency from climate change. There are always residue risks. There also may be areas where providing a high level of protection may be cost prohibitive or socially unacceptable. The key public policy issues may be ensuring informed decision making regarding risk reduction and residual risk. All flood protection systems are designed to ensure the impacts of severe flooding would be greatly reduced and any residue risk will be managed through a sustainable and integrated water resources management plan.

Any large scale program and projects have inherent risks and impacts. The larger the project becomes the greater the risk and impacts will be. To ensure that these programs will be implemented effectively and program massive infrastructures are constructed with minimum risk and economic impacts, workshops and roundtable meetings should be held to review the WFMC's flood protection programs by experienced US experts in the field of flood disaster risk reduction management. Topics of discussion can include the US experiences in minimizing and/or mitigating risks and impacts from mega projects on flood protection system. Experience has shown that there were always some residue risk and impacts and an opportunity for economic trade-offs between risk and impacts. These workshops and meetings will allow Thai experts to broaden their perspective and consideration on the acceptable risk and impacts as well as to gain international knowledge on integrated water resources and flood management.

The US Army Corps of Engineers (USACE) has more than a century of experience in managing Mississippi River floods and are staffed with many experienced experts in construction of flood protection infrastructure as well as flood risk reduction management. With assistance from USACE, construction management experience gained from the $14 billion Hurricane and Storm

Damage Risk Reduction System (HSDRRS) projects, which included flood protection infrastructure, will be the most valuable lessons learned experience for the WFMC.

The recent networking development among OSTC/DC, USACE (Headquarter), and ATPAC has allowed us to gain access to USACE experts. We would like to leverage on this new relationship by requesting for assistance from USACE to identify their staff that can participate in the tasks outline in this proposal. OSTC/DC staff and an ATPAC member, who is an expert in water resources management, will act as liaisons between USACE and WFMC. The OSTC-ATPAC-USACE linkage is necessary to avoid the sensitive government-to-government assistance process. Since consulting firms from several countries have expressed their interest in submitting proposals for bidding, the assistance provided must be transparent and cannot have perceived influence by US Government. Note that ATPAC is a registered business under State of Florida and a non-profit organization under IRS Code section 501(c)(3).

Recommendation

To hold workshops and roundtable meetings between US experts in flood risk reduction management and flood infrastructure construction management with Thai counterparts from WFMC and water resources management related agencies to discuss and exchange ideas and experiences in order to assist Thai agencies in the following topics

1. What was the scoring process USACE used to select consulting firms for the $14 billion Hurricane and Surge Disaster Risk Reduction System (HSDRRS) in New Orleans? What should WFMC look for in consulting firm qualifications for screening, and in consulting firm's proposed conceptual design plan to decide on the firm short list?

2. WFMC would like to implement design build (DB) or Early Contractor Involvement (ECI) contracts to expedite the construction of flood prevention infrastructure, as listed in the TOR. USACE has recently employed the methods with several construction projects under HSDRRS and is in a good position to provide assistance to WFMC in implementing DB or ECI.

3. For the list of projects in the TOR, WFMC needs US expert's opinions on the priority, as well as help on identifying the alternatives and missing components. Since the projects listed in the TOR were drawn from several departmental plans on water resources management, it will be very helpful for US experts to review Thailand's water resources management master plan. This review may include the evaluation of structural and non-structural measures for flood risk reduction, and comments and/or recommendations for a long-term flood risk reduction management plan and strategy.

4. The Gulf Intracoastal Waterway (GIWW) Western Closure Complex Project, a component of HSDRRS, has been highly successful in using the public participation process to allow the construction of flood protection structures at the boundary of the environmentally sensitive areas (the wetland of national significance, known as Bayou

Aux Carpes 404c site). With the assistance from USACE, WFMC should seriously explore how the lessons learned from the process can be adapted for successful application to projects listed in the TOR.

5. Since the projects in the TOR will require massive construction materials, this may cause future shortages and price increases on related commodities. USACE anticipated and prepared for the situation by conducting studies on the risks and economic impacts of HSDRRS projects. This foresight resulted in the improved management of construction materials. It is important that WFMC carry out similar studies and prepare for these possible scenarios. USACE can help WFMC draft the objective and scope of the study, and outline the necessary tasks that will lead to better construction management decisions.

6. USACE has been using HEC-GeoRAS (Hydrologic Engineering Center River Analysis System) extensively to help in their design and management of flood risk reduction systems. HEC, which is a unit under USACE, and the USACE Coastal and Hydraulics Laboratory (CHL), have been using the software for flood risk reduction analysis for many years. The software is free to use and has comparable capabilities to DHI's MIKE Flood that is used by the Hydro and Agro Informatics Institute (HAII). Several researchers from universities and clusters of National Science and Technology Development Agency (NSTDA) have already using HEC-RAS to develop flood routing model for their research. To expedite the model development, USACE can send modeling experts to train and help develop a Chao Phraya River model, which can later be used for flood risk reduction analysis. It is common practice to develop several models for flood prone areas of national economic significance. In the design of HSDRRS, USACE used simulation models to determine 100-year and 500-year storm surge predictions for the design of floodwalls and surge barriers. The 100-year surge was used as the design criteria while the 500-year surge was used as the factor of safety under system resiliency.

USACE assigned staff and ATPAC's expert will identify delegates of US experts who have extensive hands-on experiences in flood disaster risk reduction management. Pre-workshop teleconference calls by the US delegates will be arranged to discuss the logistics and format of the workshop. Staff from OSTC/DC, and Office of Permanent Secretary of MOST will serve as the workshop secretariat. They will be responsible for identifying at most ten Thai experts to participate in the workshop and provide logistical support for organizing the workshop. It is anticipated having two five-day workshops with the first to be held in Washington, D.C. and follow by the second in Bangkok. A report that documents the outcomes of the workshop will be prepared by the US delegates.

Project Benefits

1. A review and assessment of six proposed WFMC programs.

2. Recommendations for development of a sustainable plan on integrated water resources management for flood protection and flood disaster risk reduction.
3. Learning experience and idea for WFMC's and water related agencies' high ranking staff to develop
    a. consultant selection criteria
    b. scope of works for risk analysis and economic impacts studies for a mega water related construction project, and
    c. construction management procedures for flood protection infrastructures
4. Develop a close technical collaboration between US experts and Thai organizations for Flood Disaster Risk Reduction Management.

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Thai Airports and Carbon Credit Market

BY *METHI WECHARATANA*

Summary

This article proposes that the Thai Airport Authority and the aviation industry launch a research program to develop its emission inventory and prepare all its airports for EU ETS compliance and accreditation. As EU-ETS program kicks in this year (2013) to include airport and aviation sector in the phase III of its implementation, it is critical that Thai airlines and its airport be ready to meet the new compliance. The proposed tasks suggest that Thai airports develop their emission inventory in accordance with Standardized Registry and Guidelines, and be part of the global carbon markets and trading system. A well-planned and documented emissions inventory could pave the way for Thai airlines and aviation industry to be one of the reputable competitors in the global market, thus further strengthening our key tourism industry. Furthermore, Thai Airport Authority should promote the development of offset carbon projects such as installation of renewable energy, tree planting, etc. in all Thai airports in order to gain EUAs and RECs and be engaged in the carbon credits trading markets in order to maintain the competitiveness of Thai aviation industry in the European Union market.

Introduction

Effect of CO_2 emissions on environment and global warming are increasingly major concerns globally, leading to many policies and regulations introduced by many governments, mostly in Europe, to control the discharge of greenhouse gas. One of the outcomes is the introduction and development of Carbon Markets, where carbon credits are bought, sold, and traded as a market-based commodity in order to limit the emissions. The concept was originated from the Kyoto protocol, where various types of carbon credits from different industries were established. In Thailand, a non-profit organization called Thailand Greenhouse Gas Management (tgo.or.th) was established in 2007 to manage and promote carbon credits between Thai industry and their global counterparts. Through Thailand Greenhouse Gas Management Office, many Thai industries are presently aware of carbon credit markets and its related trading value, protocol, and policies. However, some major industries remain unfamiliar with these new trading markets, their approaches and commodities, for example, all the Thai airports and seaports, etc., a common issue that exists in many airports of both developed and developing countries, even in the United States. In 2011, the U.S. Transportation Research Board (TRB) published a report (Ref. 1), The Carbon Market: A Primer for Airports, to raise the awareness and provide the airport community with current, relevant information on carbon and other environmental credit trading markets, potential opportunities, and challenges to airport participation in these trading markets.

Globally, many airports are now exploring whether there are opportunities for revenue generation through carbon credit trading. Some airports have initiated carbon projects associated with environmental market instrument, such as geothermal, solar, wind, organic waste composting, electric ground service equipment, etc. In June 2008, the annual assembly of the

Airports Council International –Europe (ACI-Europe) adopted a resolution on climate change when its member airports committed to reduce carbon emissions from their operations, with the ultimate goal of becoming carbon neutral. In 2009, ACI-Europe launched the *Airport Carbon Accreditation*, allowing the assessment, monitoring, disclosure, and recognition of participating airports in reducing their CO_2 emissions. In recent years, several nonprofit and international organizations, such as the Climate Registry (The Registry), the Carbon Disclosure Project (CDP) have been established to keep inventory, verify, and disclose greenhouse gas emissions of many major corporations, up to 3,000 organizations globally as reported in 2008.

For Thailand, as travel industry continues to be the leading revenue generation source for the country, it is essential that the Airport Authority and all airports in most major provinces be aware of the Airport Carbon Management, inventory, disclosure, and carbon credit trading markets. This proposal suggests that all Thai airports develop their carbon footprints and be independently verified in accordance with ISO 14064. If possible, all Thai airports should be accredited by the Airport Carbon Accreditation, an independent program to enforce the accreditation criteria for airports on an annual basis. Listed in Table 1 are some of the selected airports in Europe that have been accredited by ACI-Europe.

Table 1 -ACI Europe Carbon Accredited Airports

Carbon Accredited Airports		
Paris-Charles de Gaulle Airport	Istanbul Ataturk International Airport	Stockholm-Arlanda Airport
Paris-Orly Airport	Brussels Airport	Stockholm-Bromma Airport
Amsterdam Airport Schiphol	Bologna Airport	Prague Airport
Athens International Airport	Frankfurt Airport	Milan-Malpensa Airport
Oslo Airport	Manchester Airport	Milan-Linate Airport
Trondheim Airport	Dublin Airport	London-Heathrow Airport
Kristiansand Airport, Kjevik	Cork Airport	Zurich Airport

Source: http://www.airportcarbonaccreditation.org/ April 12, 2011

Opportunity for Carbon Projects at Airport

There are two primary sources of value for airport operators to host carbon offset and renewable energy projects. The first is monetary. Project developers can sell the environmental benefits of their projects in the form of offset carbon credits or renewable energy credits. By selling these credits, the airport operators, however, gives away the right to claim their own emission reduction or renewable electricity generation. The second is the reputational value and good environmental stewardship. The weighing of these two benefits will require the airport operators to truly understand its impact and consequences. In many airports, safety and other regulatory

restriction limit the types of projects that can be implemented on airport grounds. For Thailand, it is essential to wisely weigh between reputational environmental stewardship versus monetary return from trading the accrued carbon credit as the decision could have unexpected consequences on the tourism industry of Thailand.

Overview of Greenhouse Gases (GHGs)

GHGs are gases that collect in the atmosphere, absorbing and re-emitting solar radiation through a process commonly referred to as the greenhouse gas effect, i.e. heat is trapped and contributes to an increase in global temperature. Generally, GHGs, in the context of the carbon markets, often refer to the six GHGs emitted through human activity and covered under the Kyoto protocol as follows: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Sulfur hexafluoride (SF_6), Hydrofluorocarbons (HFCs), and Perfluorocarbons (PFCs). Table 2 provides the limit of each GHG as set by the Kyoto protocol.

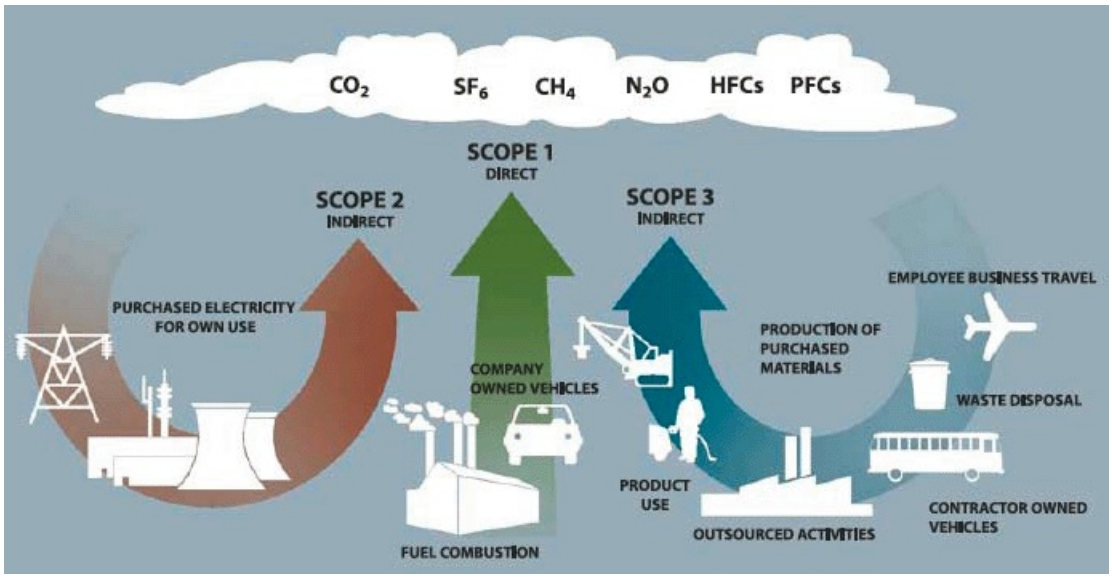

Fig. 1 The six greenhouse gases generated from daily direct and indirect human activities

Each GHG is created and emitted in a different manner and through different mediums or actions. CO_2 enters the atmosphere through the burning of fossil fuels, trees and wood products, solid waste, and as a result of chemical reactions. CH_4 is generally emitted through the production and transport of coal, oil, and natural gas. Emissions can also be the result of decay or organic waste in landfills or agricultural processes. N_2O is produced by both natural and human related sources. Trace amount of both CH_4 and N_2O are released from the combustion of fossil fuels. Soil management, animal manure, sewage treatment, and combustion of some fuels are examples of manmade sources of N_2O, HFCs, PFCs, and SF_6, known collectively as fluorinated gases, have relatively high GWP, and are emitted from a variety of different industrial processes. The effect of global warming potentials or CO2 equivalent from each of these gases is summarized in Table 2.

Table 2 Greenhouse Gas Global Warming Potentials

Greenhouse Gas	**GWP or CO_2e**
Carbon Dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous Oxide (N_2O)	310
Sulfur hexafluoride (SF_6)	23,900
Hydrofluorocarbons (HFCs)	Varies by Specific HFC (140-11,700)
Erfluorocarbons (PFCs)	Varies by Specific PFC (6,500-9,200)

Table 3 –Airport Greenhouse Gas Emission Sources

Source	GHG Emissions	Examples
Fossil Fuel Combustion	Primarily CO_2 Trace volumes of CH_4 and N_2O	Aircraft –idle, takeoff, in flight, landing, auxiliary power units Vehicles –ground support equipment, maintenance, baggage tractors, shuttle buses, private and public vehicles Stationary equipment –generators, heaters, belt movers Other miscellaneous –construction equipment, flares, fires, etc.
Refrigerants	HFCs	Fugitive refrigeration from vehicles and building HVAC systems
Waste Decomposition	CH_4	Organic matter decomposition (i.e., food, plant, wastes) Wastewater management
Electricity Consumption	Primarily CO_2 Trace volumes of CH_4 and N_2O	Purchased electricity from coal, natural gas and/or petroleum products Onsite electric production from coal, natural gas and/or petroleum products

Source: Kim, Brian. ACRP Report 11 "Guidebook on Preparing Airport Greenhouse Gas (GHG) Emission Inventories", Palm Springs, CA: UC Symposium on Aviation Noise and Air Quality, 2009.

GHG emissions from airports are primarily from basic combustion sources such as fossil fuel, refrigerants, waste decomposition, and electricity consumption. Table 3 shows links between type of GHG emissions and its sources. With a better understanding on the source and normal routine airport operation, the amount of GHG emission at the airport can be controlled and minimized. While most airports have not yet looked into GHG emissions in a serious manner, airport operators can control and influence the release of GHGs from a variety of sources and activities undertaken onsite, however, it should be noted that the majority of GHG emissions at airports are tenant –controlled. By initiating a control on GHG emissions and keeping a check on the emission inventory, airport operators may be eligible to earn offset credits by reducing GHG emissions.

Regulatory Compliance and Airport Carbon Management

Currently, in the United States under EPA's mandatory GHG Reporting Regulation, there is no federal regulatory requirement for airport operators to track, measure, and inventory their GHG emissions from stationary sources. However, a different scenario plays out in European Union. The European Union Emission Trading System (EU ETS) is the world's first and largest binding international trading system for CO_2 emissions. It covers over 11,000 energy-intensive installations across Europe and serves as an integrated emission trading system designed to reduce GHG emissions across Europe. The program requires installations to procure European Union Emission Allowances (EUAs) for every ton of CO_2e that they emitted the previous year. As the EU ETS compliance is forth coming, documenting GHG emissions in order to receive credit for reductions in the future –also known as establishing or protecting the baseline –is therefore an important concept for any industry, airport included, owners to understand. A baseline expresses what emissions would be in a business-as-usual scenario or were at a defined period of time in the past.

The EU ETS officially commenced in January 2005 with 15 member states and was designed to operate in three phases. The first phase was from 2005 to 2007 and the second began in 2008 and ended in 2012. During the first two phases, only the electric generator sector and selected large industrial sectors were covered. Phase III has just begun in 2013 and is designed to shift from emission caps set nationally and toward a more centralized system in which the majority of the allowances are auctioned by a central EU authority. A number of new industrial sectors are included under the compliance requirement in phase III with initial allocation of portion of their emission allowances. Ultimately, EU leaders have committed to reducing total EU GHG emissions 20% below the 1990 levels by the year 2020.

The aviation sector is now covered under the EU ETS compliance at the start of 2013 to be responsible for their GHG emissions. Airlines will be required to surrender one EUA or eligible off-set credits for every ton of GHG emissions released from a domestic or international flight that either originates or lands at an airport of a participating country. This means that flights originating in Thailand and landing in one of the EU-27 nations will be impacted by this regulation. As a start, the aviation sector will receive a relatively large pool of free emission

allowances initially to help mitigate the cost of compliance. In 2012, airlines have received free emission allowances that covered approximately 97% of its baseline emissions. However, these allowances will gradually decrease. To be in compliance with the EU ETS requirements, airlines must first obtain an EU ETS GHG permit to operate in the EU. Additionally, airlines will be required to develop a plan for accounting, monitoring, and verifying GHG emissions and to have implemented this to account for the calendar year 2010 emissions as an initial baseline year. The plan for tracking and reporting emissions is documented in the GHG permit. Annual emissions must be independently verified and reported to the EU by April following the close of the calendar year. Allowances to cover these emissions, which may include EUAs, CERs (up to 15% of emissions), or other approved flexibility mechanism units, must be surrendered by May 2013 and annually thereafter for the previous calendar year emissions. Finally, projected CO2 emissions covered under the EU ETS compliance must be incorporated into corporate planning and public financial information.

Following the EU ETS compliance initiative, the New Zealand Emission Trading System 9NZ ETS) was passed in 2008 and implemented in July 2010. Currently, forestry, transportation fuels, electricity producers, and industrials are covered. At present, the aviation sector is not directly covered under the NZ ETS compliance requirements. However, impacts are expected from indirect cost pass through from the transportation fuels sector.

The GHG Inventory and Verification

GHG inventories are not carbon markets, but are nevertheless important as accounting for carbon emissions is the first stop toward defining reductions. As aviation industry comes under emission compliance in 2013, the ability to show historical reductions in GHG emissions may result in lowering compliance requirements as they serve as an established baseline emissions. An airport operator interested in measuring and reducing their carbon footprint may want to measure GHG emissions in order to quantify the reduction in emissions resulting from their initiatives. To aid in the development of GHG inventories, ACRP Report 11: Guidebook on Preparing Airport GHG Emission Inventories provides considerable guidance and methodologies. Of particular interest are two standardized registries, the Climate Registry (The Registry) and the Carbon Disclosure Project (CDP). The Registry is a nonprofit organization formed to create consistent GHG emissions standards and reporting methods for businesses, municipalities, and other organizations. Participation in the Registry is completely voluntary but the data from each of the entities must be independently verified to ensure accuracy. The Carbon Disclosure Project is an international organization based in the United Kingdom, which works with shareholders and corporations to disclose the GHG emissions of major corporations. In 2008, the CDP reported emissions data of 1,550 of the world's largest corporations, accounting for nearly 26% of global emissions and representing over 3,000 organizations in 60 different countries. The organization measure and disclose their GHG emissions and climate change strategies in order to set reduction targets and improve their environmental performance.

Proposed Research Activities

As tourism industry plays an important role in the Thai economy, it is essential that Thai aviation industry pay a close attention to prepare all its airports to be in compliance with the forth-coming EU ETS emission reduction requirements. To achieve this objective, the following actions and research are recommended:

- Identify and understand the motivation and need behind participating in carbon and environmental markets and weigh the balance between the cost-benefits and environmental reputational benefits.
- Develop a robust GHG inventory program to track GHG emissions. Inventories allow airports to measure GHG emissions, establish baseline, formulate reduction programs from various activities and offset carbon projects, and share improvements with the public. Having an existing GHG inventory, particularly if it is developed with reference to one of the leading GHG inventory organizations, can help expedite the offset carbon project registration process in the future.
- Participate in the standardized registry of GHG emission reduction of all the airports through established international and/or nonprofit organizations such as the Climate Registry or the Carbon Disclosure Project.
- Secure accreditation through Airport Carbon Accreditation program. This would enhance international reputation of Thai airports and promote Thai tourism.
- Develop and implement offset carbon projects at Thai airports to gain EUAs and CERs to help strengthen Thai airlines.
- Consider installing renewable power systems at all Thai airports. These projects could provide additional revenue to the Airport Authority of Thailand in the form of salable carbon credits.

Benefits to Thailand

The proposed research and activities was meant to raise the preparedness of the Thai aviation industry and airports to be ready for the forth-coming regulation on limiting greenhouse gas emissions. Even though only the 27-member European Union is presently imposing the emission trading system (ETS), EU represents the largest aviation market for Thailand and thus it only makes sense for Thailand and her aviation industry to be well prepared for these new compliances. Secondly, tourism is still the major source of revenue for Thailand, to have all the Thai airports be accredited for carbon emission compliance by respected international and nonprofit organizations such as the Airport Carbon Accreditation, the Climate Registry, and/or the Carbon Disclosure Project is undoubtedly a smart way to stay competitive in the global aviation industry. To develop emission inventory for the operation of any organization, businesses, and/or facility often takes time as historical records have to be kept to set up baseline in order to show reduction and improvement, it is therefore essential that the Thai aviation start

this research and activities without delay. Examples and guidelines for these processes can be obtained through the listed references.

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Development of Pervious Concrete for Thailand – An Option for Stormwater Management

BY *METHI WECHARATANA*

Summary

This article proposes that pervious concrete technology be explored and researched in Thailand as new construction products that could help mitigate flooding problems in most major cities, Bangkok in particular. At present, all stormwater are drained as surface runoff directly through small catch basins along city streets, leaving insufficient time for stormwater to flow through the drainage system and commonly lead to flooding. Pervious concrete, with proper mix proportions, could allow stormwater to seep into subbase and subgrade and percolate into groundwater, an alternative pathway that can help mitigate short-term flooding after a heavy storm. Pervious concrete pavement can also turn parking lots into temporary retention ponds, thus help slow the rate of surface runoff through catch basins and drainage along the roadways. While the technology is not new, there are needs to research and develop appropriate mix proportions and products that are suitable for Thailand's tropical environment. Development of new pervious concrete products, understanding its behaviors and performance characteristics are critical as pervious concrete is not a replacement to normal conventional concrete. Guidelines and best practice need to be formulated so the products can be used safely and effectively.

Introduction

In recent years, Thailand has increasingly experienced flooding during the rainy season. The floods normally began from several major rivers upstream in the North and Northeastern part of the country, and slowly moved down to the central plain. Flash floods are rather common among rural provinces in the North and Northeast after major storms as there are no retention ponds, lakes, or sufficient reservoirs for flood control. The flood that happened last year (in 2011) was considered to be the worst in the past100 years, which flooded more than 60% of the country, not to mention a large portion of the Bangkok metropolitan causing the loss of hundreds of life and billions of dollars of damages to businesses, factories, and residential housing. It is generally believed that deforestation was the cause, coupled with global climate change and irregularity of the weather pattern during the past few years.

For the capital city of Bangkok, formerly known as Venice of the East (but no longer today), flooding is rather common these days as most canals were filled during the last three decades to make way for more roads and cars, leaving in place small drainage pipes on each roadway to handle stormwater. Most roadways, sidewalks, parking lots, and driveways are all made of either concrete or asphaltic concrete, materials with low permeability, leaving no pathway and time for stormwater to percolate into ground, subbase, and subgrade under the pavement. All stormwater turns into surface runoff and with small catch basins flooding is therefore imminent. To solve the flooding problems of the city, reduce surface runoff by increasing stormwater

retention somewhere and/or increase the size of drainage pipes are the only known viable solutions thus far. This article introduces the use of pervious concrete as pavement for most major cities in Thailand, Bangkok in particular, to assist in stormwater management. Furthermore, pervious concrete can also be used as cover for dangerous open (uncovered) storm drains, cover for crucial waterways that are critical to water supply system of the city such as Klong Prapa, and walkways for vegetation and trees in most crowded cities. Pervious concrete can also be used for pavement of open parking lots, preventing nuisance water puddles or ponding.

Fig. 1 Water flows through pervious concrete

What is Pervious Concrete?

Pervious concrete is a high porosity concrete used for outdoor flatwork that allows water to pass through (see Fig. 1), thereby reducing the runoff from a site and recharging groundwater levels. The high porosity is attained by a highly interconnected void content. Typically pervious concrete has little to no fine aggregate and has just enough cementitious paste to coat the coarse aggregate particles while preserving the interconnectivity of the voids. Pervious concrete is traditionally used in parking areas, areas with light traffic, pedestrian walkways, and greenhouses. It is an important application for sustainable construction. In some cases, pervious concrete is used to impound the needed amount of rainfall in heavy storms to help solve flooding problems. Parking lots are being designed to store water not only in voids of the pavement or base materials, but also on top of the pavement. These parking lots temporarily store an additional 6 in. (15 cm) of rainfall up to the curb line on a completely flat lot. Their entrance aprons must be humped up enough to retain the design storm water amount and not allow it to run out into the adjacent road or gutter.

Mix Proportions and Basic Mechanical Properties

Pervious concrete is a special type of concrete with low water/cement ratio, low-slump mix consisting of cement, narrowly graded coarse aggregate with little or no fine aggregate, water and admixtures. The actual mix proportions for pervious concrete varies depending on the application, mechanical properties required and materials used. Concrete producers should develop the mix proportions based on the project specifications. Table 1 provides the ranges of material used to make pervious concrete as well as mix for the typical use.

Table 1 –Range of Mix Proportion and a Typical Mix

	Proportion Range kg/m^3 (lbs/yd^3)	**Typical Proportions kg/m^3 (lbs/yd^3)**
Cementitious Material	270 to 415 (450 to 700)	325 to 400 (450 to 700)
Water/cementitious Ratio	0.20 to 0.45	0.27 to 0.30
Coarse Aggregate	1,190 to 1,600 (2,000 to 2,700)	1,400 to 1,550 (2,400 to 2,600)
Void Content	15% to 35%	20% to 30%

The amount of cementitious material used per volume of pervious concrete varies, however a good starting point is about 355 kg/m^3 (600 lbs/yd^3). Percolation rates or permeability or water drainage rate ranges from 100 to 900 L/min/m^2 (or 2 to 18 gal/min/ft^2) of surface. As the void content increases, the water drainage rate through the concrete also increases. If more strength is needed, a small amount of fine aggregate could be added to the mix, but this will reduce the void content and its permeability. Typical compressive strength ranges between 3.5 to 28 MPa (500 to 4,000 psi), although 17 MPa (2,500 psi) is common. Slump is usually less than 20 mm (3/4 in.). Chemical admixtures are used to control water/cementitious ration, influence workability and setting times, and enhance mechanical properties and durability.

Standard methods for concrete mix proportioning and testing are employed for pervious concrete. However air content tests are not applicable and slump testing provides limited information. Often, rather than air content test, a typical standard test method to measure the unit weight (fresh density) of concrete (ASTM C29) is widely accepted, a test that also measures the void content. A more applicable test for consistency often used in the field is the hand-squeeze test (Fig. 2).

Fig. 2 Practical Hand-Squeeze Consistency Test for Pervious Concrete

A typical pervious concrete pavement has a 15-25% void structure and allows 3-8 gallons of water per minute to pass through each square foot. A well-mixed pervious concrete can result in a very high permeability concrete that drains quickly. With its high void content, pervious concrete is also lightweight, about 118 to 128 lb/ft^3. After placement, pervious concrete resembles popcorn. Its low paste content and low fine aggregate content make the mixture coarse, with a very low slump. Fig. 3 compares the surface texture of pervious concrete with conventional concrete. The compressive strength of pervious concrete is limited since the void content is so high. Most commonly used pervious concrete is in the form of unreinforced pavement. However, it is possible to develop a lightly reinforced environmental-friendly pervious concrete using coarse aggregate from recycle concrete.

Water Content

Like other concrete, the amount of water used in the mix is critical. Too much water and the concrete mix will segregate, while too little water will lead to balling in the mixer and slow unloading times. The correct amount of water will impart a wet metallic appearance or sheen. Squeezing and releasing a handful of the mix should result in a mix that neither crumbles (too dry) nor loses its structure as paste flows away from the aggregates (too wet). Too little water can also hinder curing of the concrete and could lead to premature raveling of the surface.

To provide some additional examples of the mix proportions of pervious concrete used in practice, Table 2 compares the mix proportion of pervious concrete used in Florida, Massachusetts, Colorado, and Arizona.

Table 2 –Pervious concrete mix proportion examples used in various states

Parking Lot	Florida	Massachusetts	Colorado	Arizona
Cementitious Material	355 kg/m^3 (600 lbs/yd^3)	370 kg/m^3 (620 lbs/yd^3)	360 kg/m^3 (611 lbs/yd^3)	410 kg/m^3 (691 lbs/yd^3)
Water	75 to 90 kg/m^3 (125 to 150 lbs/yd^3)	105 kg/m^3 (174 lbs/yd^3)	80 kg/m^3 (135 lbs/yd^3)	125 kg/m^3 (210 lbs/yd^3)
Water/Cementitious	0.21 to 0.25	0.28	0.22	
Coarse Aggregate	1,540 kg/m^3 (9.5 to 1.18 mm) stone 2,600 lbs/yd^3 (3/8 to 3/32 in.)	1,600 kg/m^3 2,700 lbs/yd^3	1,365 kg/m^3 (10 mm) 2,030 lbs/yd^3 (3/8 in.)	1,540 kg/m^3 (10 mm) 2600 lbs/yd^3 (1/2 in.)
Void Content	22% to 25%	18%	35%	15%
Admixture	260 to 400 mL/100kg (4 to 6 oz/cwt)	425 mL/100kg (6.5 oz/cwt)	195 mL/100kg (3 oz/cwt)	250 mL/100kg (3.8 oz/cwt)

Fig. 3 Texture Comparison between Normal and Pervious Concrete

Curing

Curing procedures shall begin immediately but no later than 20 minutes from the time the pervious concrete is discharged from the truck. Placing, finishing, and tooled jointing must be completed within the 20-minute window after discharge. The pavement surface shall be covered with a minimum of 6 mil thick polyethylene sheet or other approved covering material. The cover shall overlap and be sealed at all edges and shall be secured (without using dirt or stone) to prevent uncovering due to winds and adjacent traffic conditions.

Due to the low water to cementitious ratio and large areas of exposed surface, pervious concrete is especially susceptible to drying out. The surface shall be kept moist and evaporation prevented using some of the following methods: fogging, spray applied curing compound, application of water under the plastic covering. Special care must be ensured that the cover polyethylene sheet is well secured. The curing cover shall remain securely in place, uninterrupted, until the concrete has reached a maturity equivalent to 14 days of curing at 70oF (21oC) at 95% relative humidity. No vehicular traffic shall be permitted on the pavement until curing is complete.

Fig. 4 Water flows through pervious concrete pavement quickly

Pervious Concrete –An Environmental-Friendly Product

Under the National Pollutant Discharge Elimination System (NPDES) Act, EPA considers pervious concrete a beneficial green concrete product that helps support sustainable development. LEED provides pervious concrete up to 3 LEED credit points as it reduces stormwater runoff, use recycled and regional materials, and reduce urban heat islands. Environmentally, pervious concrete provides vertical drainage, a more effective alternative than conventional horizontal run-off. EPA's best management practice includes eliminating drain invert filtration systems; provide first flush pollution mitigation –remove up to 90% of pollutants that typically are in the runoff from the first half inch of rainfall; eliminate the need to acquire additional detention ponds; provide air and water to tree roots and other vegetation; and parking lots made of pervious concrete serve 3 purposes: as parking lots, temporary detention pond, and water filtration. Fig. 4 illustrates water flows through pervious concrete pavement quickly without leaving puddles or ponding on the pavement.

Benefit from Pervious Concrete

Pervious concrete can be used in place of traditional stormwater management measures given the proper site conditions. The primary advantages include:

- Quantity and Flood Control
- Water Quality Treatment
- Recharges Groundwater
- Reduction in Stormwater Infrastructure (piping, catch-basins, ponds, curbing, etc.)
- Suitable for Cold-Climate Applications, Maintains Recharge Capacity when Frozen
- No Standing Water or Black Ice Development during Winter Weather Conditions
- Maintain Traction While Wet

- Reduced Surface Temperature; Minimizes the Urban Heat Island Effect
- Extended Pavement Life Due to Well Drained Base and Reduced Freeze-Thaw
- Less Lighting Needed Due to Highly Reflective Pavement Surface

Proposed Research

Pervious concrete technology provides an opportunity for Thailand to explore developing alternative concrete products that could help mitigate flash flood problems in most major cities. Highly permeable concrete allows stormwater to seep into subgrade rather than heading to small catch basins on roadside, thus reducing the amount of surface runoff and help alleviate flooding. Being in the tropical zone with high humidity and temperature, the concrete community in Thailand will have to carry out research to develop appropriate mix proportions and formulations with the required strength and durability that are suitable for Thailand. Furthermore, there are opportunities to develop many new construction products such as cover for open drainage, sidewalk in the parks, new design for athletic fields with no water puddle or ponding, and residential driveways, etc. for Thailand's domestic consumption. In addition, these products are considered environmental friendly and are green products for a sustainable development of Thailand.

Final Remarks

Pervious concrete pavement is a unique and effective means to address important environmental issues and support green, sustainable growth. By capturing stormwater and allowing it to seep into the ground, porous concrete is instrumental in recharging groundwater, reducing stormwater runoff, and meeting U.S. Environmental Protection Agency (EPA) stormwater regulations. In fact, the use of pervious concrete is among the Best Management Practices (BMPs) recommended by the EPA—and by other agencies and geotechnical engineers across the country—for the management of stormwater runoff on a regional and local basis. This pavement technology creates more efficient land use by eliminating the need for retention ponds, swales, and other stormwater management devices. With increasing flooding problems in Thailand, pervious concrete, coupled with other stormwater management plan, may be an interesting technology that could help alleviate the flooding problems in Thailand.

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Use of Recycled Plastic as Structural Members in Construction

BY *METHI WECHARATANA*

Summary

Plastic waste has been recycled into structural members in recent years. These products exhibit adequate strength for load bearing capacity for normal service condition, and, in addition, they are water-proof and show exceptional durability against weathering and corrosion. Furthermore, these products are 100% recycled and can be reused indefinitely. With abundant amount of plastic waste in Thailand, reclaim and recycle these plastic wastes into usable value-added construction materials make the most logical sense and worth the effort and investment. Thai research community also has the needed scientists and know-how in polymer science and construction to carry out research and development in this area. This proposed research program, if successful, can introduce many useful green construction products to our building and construction industry, leading us into a sustainable future.

Introduction

Plastic, the most common product that plays an important role in our daily life today, from water bottle to grocery bags, cell phones, computers, auto parts, shipping and packaging materials, etc., nearly everything around us is made from some type of plastics. Every year, hundred millions tons of used plastics end up in our landfills worldwide, causing enormous environmental burdens and problems as plastics are hard to breakdown and/or decay under normal weathering and natural environment. Most plastics today are of the thermoplastic group that can be recycled, and attempts to reuse waste plastic have begun as far back as thirty years ago. Today, the European Union is taking the lead in launching the "end-of-waste" program for all waste plastic (Ref. 1) where all used plastics will be reused or recycled.

General Description and Characteristics of Plastics

Plastic is an organic solid material, essentially a polymer or combination of polymers of high molecular mass. A polymer is a chain of several thousand of repeating molecular units of monomers. The monomers of plastic are either natural or synthetic organic compounds. The term *resin* is sometimes used as synonym of a commercial polymer.

Plastics can be classified by chemical structure, i.e. by the main monomer of the polymer's backbone and side chains. Some important groups in these classifications are the acrylics, polyesters, silicones, polyurethanes, and halogenated plastics. Plastics can also be classified by the chemical process used in their synthesis, such as condensation, and cross-linking. Other classifications are based on properties that are relevant for manufacturing or product design, e.g. thermoplasticity, biodegradability, electrical conductivity, density, or resistance to various chemical products.

The vast majority of plastics are composed of polymers of carbon and hydrogen alone or with oxygen, nitrogen, chlorine or sulfur in the backbone. More often than not, plastics contain a main polymer, and a bespoke load of additives to improve specific properties, e.g. hardness, softness,

UV resistance, flame formation resistance, or their behavior during manufacture (lubricants, catalysts, stabilizers, solvents, polymerization, and recycling). The content of additives in plastics varies widely, from less than 1% in PET bottles and up to 50-60% in hard PVC, striking often a balance between technical properties and economics, as some additives are considerably more expensive than the main polymers, while others are very inexpensive (inorganic fillers such as limestone or talc). A non-exhaustive list of additive types is provided in the Table below:

Additives enhancing properties of plastic products	**Additives enhancing properties of the processing of plastics:**
Stabilizers (acids, oxidation, biodegradation, heat, UV)	Lubricants
Flame retardants	Nucleating Agents
Plasticizers	Polymer Processing Aids
Colorants	Blowing agents
Antifogging and antistatic agents	Additives for Recycling of Plastics
Optical brighteners, fluorescent whitening agents	
Fillers and Reinforcements/Coupling Agents	
Impact modifiers	

Waste Plastic Reclamation and Recycling

Plastic conversion is understood as the transformation of waste plastic materials by application of processes involving pressure, heat and/or chemistry, into finished or semi-finished plastic products for the industry and end-users. The process normally involves size reduction operations, (reduce to shreds, flakes) or regrind, agglomerates, and finally granular (pellet) or powder form. The total yearly consumption of plastic conversion just in the EU-27 in 2009 was approximately 46.4 million tons. There are many polymers in the EU market, but five categories of plastic polymers dominate the EU plastic market and account for around 75% of the production demand. In 2010 these proportions were:

- Polyethylene (29%, including low density-LDPE, linear low density-LLDPE, and high density-HDPE)
- Polypropylene (PP, 19%)
- Polyvinylchloride (PVC, 12%)
- Polystyrene (solid-PS and expandable-EPS, 8%)
- Polyethylene terephthalate (PET, 6%)

Plastic materials are used in a variety of end-use applications. Figure 1 shows the amount of plastic consumption in different industry in the EU-27 market. Packaging is clearly the main

application for plastics (39%), followed by building and construction (20.6%), automotive (7.5%) and electric and electronic applications (5.6%).

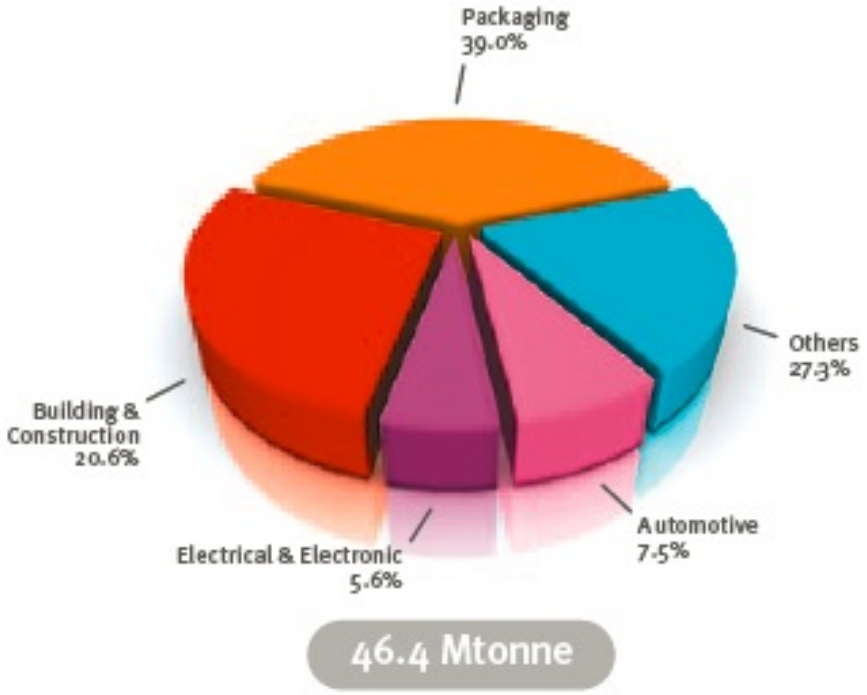


Figure 1 -Demand by industry of different plastics in the EU27 in 2010 (Source: PlasticsEurope et al. 2011)

Waste Plastic Classification

With the variety of plastics applications and uses, there are many grades of waste plastic. Some grades are homogeneous, while some others are a heterogeneous and/or complex mixes of polymers and other impurities. Regional and country differences in waste collection systems offer different qualities of waste plastic grades. Several classifications for waste plastic are possible, based on e.g. the polymer type, the physical shape and use in recycling, or the origin.

Classification by recycling stage and shape

Waste inputs to recycling are bulk or baled materials that have normally received no other processing than sorting. Some illustrations of these materials are presented below:

Once processed by a reprocessor, the following categories of material are handled:

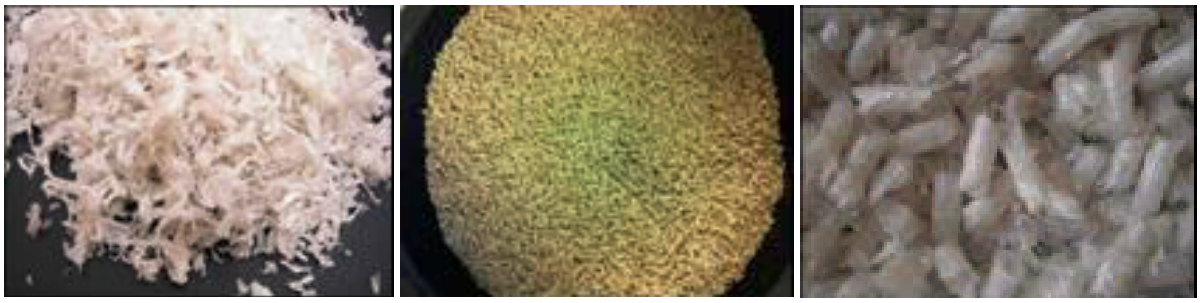
Regrind or Flake

Waste plastic is shredded and/or granulated recovered plastics material in the form of free-flowing material. Examples are depicted below:

The term *flake* is especially used in the PET business, referring to shredded bottle material. The typical particle size of regrind/flake is below 2.5cm, but this size can vary. In the case of PVC, micronization is an extra step which further reduces the size of the recyclates to produce a powder, which is easier to blend and dose in new PVC production.

Agglomerate

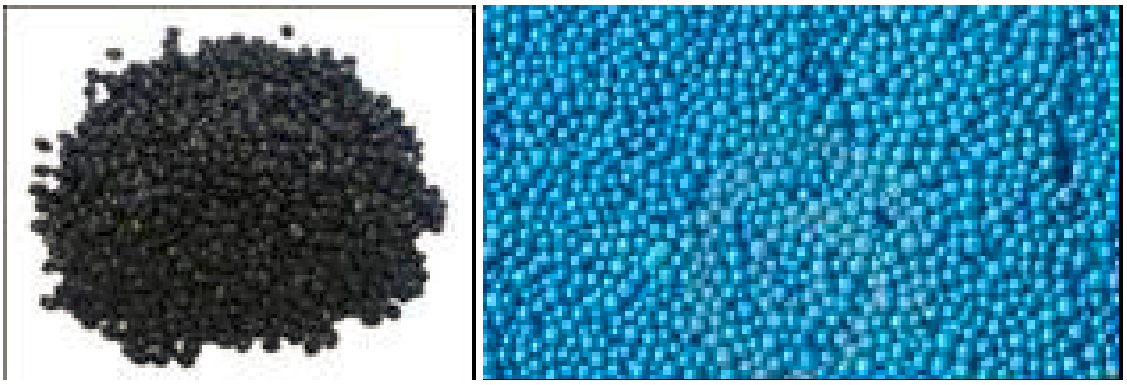
Agglomerate is the process of shredded and/or granulated film material in the form of particles which cling together after an agglomeration process (pressing or thermal) with the aim of increasing the products bulk density. Examples of agglomerates are shown below:



The typical size of agglomerate is 3cm x 2cm x 3cm.

Pallet

A pellet is the product resulting from the recycling process using an extruder. Commonly pallet is a standard raw material used in plastics manufacturing and conversion. Examples are illustrated below:



The typical size of a pellet is around 0.2cm x 0.2cm x 0.2cm.

Classification by Polymer

Most post-consumer waste contains a wide range of plastic polymer types, reflecting the variety of plastic polymers consumed in daily life. The *SPI* resin identification coding system is a set of symbols placed on plastics to identify the polymer type. It was developed by the Society of the Plastics Industry (SPI) in 1988, and is used internationally (Table 2). The primary purpose of the codes is to allow efficient separation of different polymer types for recycling.

Table 2 Plastic Code and Main Used Polymers

Code	Name of Polymer
1	Polyethylene terephthalate (PETE, PET)
2	High-density Polyethylene (HDPE)
3	Polyvinyl chloride (PVC or V)
4	Low-density Polyethylene (LDPE) includes Linear Low Density Polyethylene (LLDPE)
5	Polypropylene (PP)

6	Polystyrene (PS)
7	Other plastics, including acrylic, fiberglass, nylon, polycarbonate, and polylactic acid, and multilayer combinations of different plastics

Plastic Structural Members

Attempts to reuse waste plastic as construction materials have been investigated for the past twenty years. Initially, the first product came out in the form of recycled plastic plank, often used for benches in the public park. Constituents of recycled materials were clearly visible in the final products with traces of shredded plastics, aluminum cans, etc. As the plastic recycle technology advanced, the quality of these planks improved, to the point that one cannot tell that it is made from recycled plastic or other recycled materials. Furthermore, the strength and durability of these recycled structural members are also improved. Figures shown below illustrate samples of the plastic structural members made from recycled plastic waste: double-T box girders, pilings, boards, and I-beams. Others show two bridges that were built completely with recycled-plastic structural members. These bridges can carry the load of an M1-A1 tank (as shown) or other construction equipment and vehicles.

Mechanical Properties of Recycled Structural Members

The following are some reported mechanical properties of structural members made from recycled plastics:

Property	**Reported Values**
Specific Gravity	0.85-0.90
Density	50-55 lb/ft^3
Coefficient of Thermal Expansion	0.00004 $in/in/^oF$
Compressive Strength (parallel to grain)	3,000 psi
Compressive Strength (perpendicular to grain)	1,250 psi
Modulus of Elasticity (Compression)	175,000 psi
Modulus of Elasticity (Flexure)	315,000 psi
Modulus of Rupture	4,000 psi
Shear Strength	1,500 psi

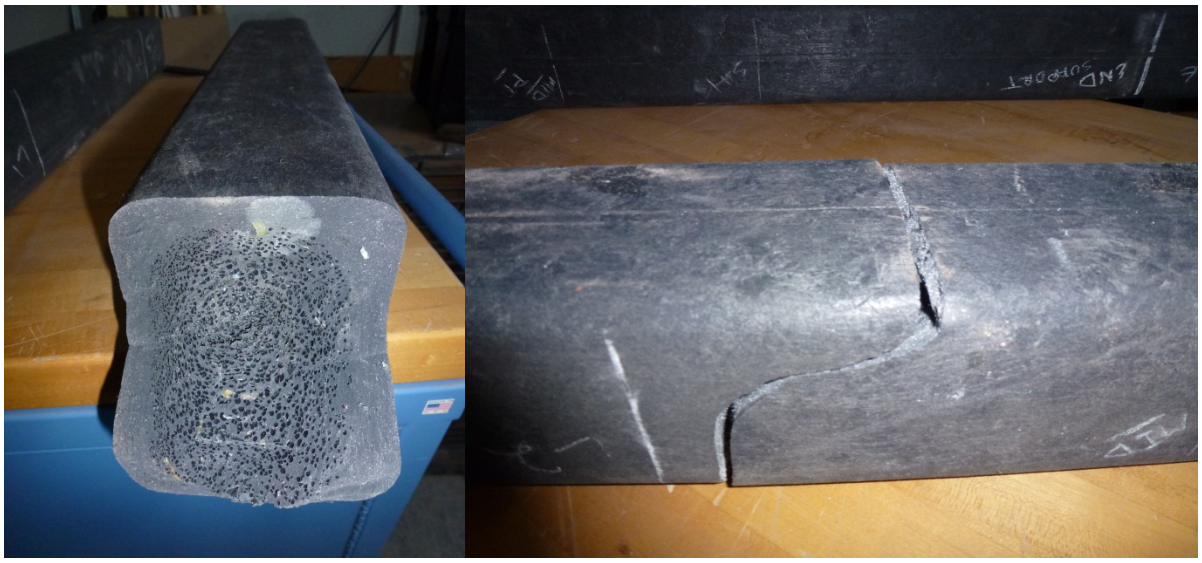
In general, recycled-plastic structural members are not as strong as conventional construction materials like steel and concrete. However, these members are much more durable than steel and concrete as it can better withstand weathering and thus does not corrode or gets rusted. It

generally has a higher tensile strength than conventional concrete so there is less cracking in these members. One of the main problems remained is the effect of high temperature on its properties. As temperature increases, plastic materials, virgin or recycled alike, loose its properties and get soften. In addition, under high temperature, as in a building fire, these materials may release toxic fume as chemical composition of polymers breaks down.

In light of these shortfalls, recycled-plastic structural members possess many advantages particularly for tropical environment like in Thailand. Among them are 1) water resistance makes these products suitable for subsurface structures, such as sheet piles, pilings, off-shore structures, boat piers, underground tunnel, basement walls, underground parking structures; 2) outdoor structures such as benches, swing sets, decks, etc.; 3) these materials are 100% recycle and therefore can be reused indefinitely, making it an ideal materials for a sustainable future. It is an ideal green construction product that deserves close attention on future research and product development; 4) it is a material that does not post any electro-magnetic interference, thus making it the ideal construction materials for structures of the electronic and telecommunication industry.

The following figures show several recycled-plastic beams of a 4 in. x 4 in. x 4 ft. dimension, which were tested at our NJIT's Structural and Concrete Laboratory.

These members were tested under a four-point-bend beam test. The beams could withstand excessive deflection far beyond conventional concrete and timber members of similar cross section. A closer investigation of the fractured surface found that the density of the section is not uniform, denser around the boundary and more porous in the middle. It is unclear at this report whether this sectional characteristic is a result of the manufacturing process, intentionally or unintentionally. Nonetheless, the observed mechanical properties are in line with what reported by the manufacturers. The tests confirm that these materials have the potential to be used in actual construction projects if design guidelines and specifications are available.



Recommended Research

With reference to the information provided above on recycled-plastic structural members, it is recommended that Thai research community launch a national research program aims at developing recycled plastic construction products. There are enormous amount of used and reclaimed plastics from many landfills in Thailand today, and it is logical to research and develop these plastic wastes into value-added materials for the construction industry. There are significant number of Thai scientists who are specialized in chemistry, polymer science, and civil and construction engineering in Thailand, both in the public and private section. Keeping in mind that plastic-recycled products are 100% recycled, do not corrode, and water-proof, these recycled-plastic structural members can be reused indefinitely without wasting any new natural resources. Successful implementation of this program will also reduce the size of our landfills, thus lesser our environmental burdens in the long run. These materials are ideal green construction products for a sustainable future.

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Education

Ph.D.	Transportation Engineering	University of Mississippi, Oxford (2004)
M.Eng.	Infrastructure Engineering	Asian Institute of Technology, Thailand (2001)
B.Eng.	Civil Engineering	Chulalongkorn University, Thailand (1999)

Professional Experience

2012 – Present	Associate Research Engineer, Center for Environmental Research and Technology, University of California, Riverside, CA
2012 – 2013	Assistant Adjunct Professor, Department of Chemical and Environmental Engineering, University of California, Riverside, CA
2007 – 2012	Assistant Research Engineer, Center for Environmental Research and Technology, University of California, Riverside, CA
2005 – 2007	Postdoctoral Scholar, Center for Environmental Research and Technology, University of California, Riverside, CA
2004 – 2005	Visiting Assistant Professor, Department of Civil Engineering, Ohio Northern University, Ada, OH

Licensures

2008 – Present	Professional Traffic Engineer, State of California
2008 – Present	Professional Civil Engineer, State of Michigan
1999 – Present	Civil Engineer, Thailand

Major Areas of Research Interest

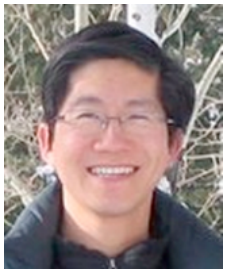
- Sustainable transportation
- Intelligent transportation systems
- Traffic simulation
- Traffic operations
- Vehicle energy and emissions modeling
- Vehicle activity analysis
- GIS applications in transportation
- Transportation modeling

Synergistic Activities

Associate Editor	The IEEE Intelligent Transportation Systems Magazine
Editorial Board	The Open Transportation Journal
Member	Intelligent Transportation Society of America (ITSA)
Member	Transportation Research Board (TRB) • ADC20: Transportation and Air Quality Committee • Planning & Environment Group's Young Member Council
Member	American Society of Civil Engineers (ASCE)
Member	Institute of Transportation Engineers (ITE)
Member	International Society for Maintenance and Rehabilitation of Transportation Infrastructures (iSMARTi) • SC010: Infrastructure Asset Management Committee • SC020: Environment and Sustainable Development Committee

Selected Scientific Articles

- **Boriboonsomsin, K.**, Barth, M., Zhu, W., and Vu. A. (2012). "ECO-routing navigation system based on multi-source historical and real-time traffic information." *IEEE Transactions on Intelligent Transportation Systems*, 99, 1-11.
- Xia, H., **Boriboonsomsin, K.**, and Barth, M. (2012). "Dynamic ECO-driving for signalized arterial corridors and its indirect network-wide energy/emissions benefits." *Journal of Intelligent Transportation Systems*, in press, DOI: 10.1080/15472450.2012.712494.
- **Boriboonsomsin, K.**, Sheckler, R., and Barth, M. (2012). "Generating heavy-duty truck activity data inputs for MOVES based on large-scale truck telematics data." *Transportation Research Record*, 2270, 49-58.
- **Boriboonsomsin, K.**, Zhu, W., and Barth, M. (2011). "A statistical approach to estimating truck traffic speed and its application to emission inventory modeling." *Transportation Research Record*, 2233, 110-119.
- **Boriboonsomsin, K.**, Scora, G., and Barth, M. (2010). "Analysis of heavy-duty diesel truck activity and fuel economy based on electronic control module data." *Transportation Research Record*, 2191, 23-33.
- Wu, G., **Boriboonsomsin, K.**, Zhang, W.-B., Li, M., and Barth, M. (2010). "Energy and emission benefit comparison between stationary and in-vehicle advanced driving alert systems." *Transportation Research Record*, 2189, 98-106.
- Zhu, W., **Boriboonsomsin, K.**, and Barth, M. (2010). "Defining a freeway mobility index for roadway navigation." *Journal of Intelligent Transportation Systems*, 14(1), 37-50.
- **Boriboonsomsin, K.**, Barth, M., and Xu, H. (2009). "Improvements to on-road mobile emissions modeling of freeways with high-occupancy vehicle facilities." *Transportation Research Record*, 2123, 109-118.
- **Boriboonsomsin, K.** and Barth, M. (2009). "Impacts of road grade on fuel consumption and carbon dioxide emissions evidenced by use of advanced navigation systems." *Transportation Research Record*, 2139, 21-30.
- Barth, M. and **Boriboonsomsin, K.** (2009). "Energy and emissions impacts of a freeway-based dynamic eco-driving system." *Transportation Research Part D*, 14, 400-410.
- Li, M., **Boriboonsomsin, K.**, Wu, G., Zhang, W.-B., and Barth, M. (2009). "Traffic energy and emission reductions at signalized intersections: a study of the benefits of advanced driver information." *International Journal of Intelligent Transportation Systems Research*, 7(1), 49-58.
- Barth, M. and **Boriboonsomsin, K.** (2008). "Real-world carbon dioxide impacts of traffic congestion." *Transportation Research Record*, 2058, 163-171.
- **Boriboonsomsin, K.** and Barth, M. (2008). "Impacts of freeway high-occupancy vehicle lane configuration on vehicle emissions." *Transportation Research Part D*, 13(2), 112-125.
- **Boriboonsomsin, K**. and Barth, M. (2007). "Evaluating air quality benefits of freeway high occupancy vehicle lanes in Southern California." *Transportation Research Record*, 2011, 137-147.
- **Boriboonsomsin, K**. and Reza, F. (2007). "Mix design and benefit evaluation of high solar reflectance concrete for pavements." *Transportation Research Record*, 2011, 11-20.



Vorakarn Chanyavanich, Ph.D.

Medical Physicist, Department of Radiation Oncology
Emory University, Atlanta, GA

Education

Ph.D.	Medical Physics	Duke University, Durham, NC (2011)
M.S.	Medical Physics	Univ. of Colorado Health Sciences, Denver, CO (1999)
A.M.	Education	Stanford University, Palo Alto, CA (1993)
B.A.	Physics/Math	Macalester College, St. Paul, MN (1992)

Professional Experience

2011 – Present	Medical Physicist, Dept. of Radiation Oncology, Emory University, Atlanta, GA
2007 – 2011	Research Assistant, Medical Physics, Duke University, Durham, NC
2001 – 2006	Physics Teacher, San Marcos High School, Santa Barbara, CA
2002 – 2003	Visiting Researcher, Physics, Univ. of California at Santa Barbara, Santa Barbara, CA
1999 – 2001	Medical Physicist, Argus Software, Redwood City, CA
1997 – 1999	Medical Physics Assistant, Radiation Oncology, Porter Hospital, Denver, CO
1996 – 1997	Research Assistant, Radiology, U of Colorado Health Sciences Center, Denver, CO

Honors and Recognitions

- Carey E. Floyd, Jr., Graduate Fellowship, Duke University
- Director's Exemplary Service Award, Medical Physics, Duke University
- Graduate Fellowship, Univ. of Colorado Health Sciences Center
- Graduate Fellowship, Stanford University

Professional Membership

- Member, American Association of Physicists in Medicine (AAAPM)
- Member, Radiological Society of North America
- Member, American College of Radiation Oncology
- Member, Association of Thai Professionals in Americas and Canada (ATPAC)

Selected Scientific Articles and Presentations

- Chanyavanich V, Freeman M, Lo JY, Das SK, "A Plan Quality Metric for Knowledge-Based IMRT Treatment Planning", SU-E-T-572, Med. Phys. 39, 3837, (2012).
- Chanyavanich V, Siddiqi A, Elder E, Dhabaan A, "Evaluation of the effect of the dose buildup region for flattening filter free beams in IMRT plans of lung and sinuses," SU-E-T-415, Med. Phys 39, 3800 (2012)
- Chanyavanich V, Das SK, Lee WR, Lo JY, "Knowledge-based IMRT Treatment Planning for Prostate Cancer", Med.Phys. 38(5), pp. 2515-2522, (2011).
- Chanyavanich V, Das SK, Lo JY, "An inter-institutional comparison of knowledge-based IMRT treatment planning for prostate cancer," SU-E-T-851, Med. Phys. 38, 3687 (2011).

- Freeman M, Chanyavanich V, Das SK, Lo JY, "A Linear Metric of Knowledge-Based IMRT Treatment Plan Quality for Prostate Cancer," SU-GG-T-131, Med. Phys. 37, 3214 (2010).
- Chanyavanich V, Freeman M, Das SK, Lo JY, "Knowledge-Based IMRT Treatment Planning for Prostate Cancer," SU-GG-T-134, Med. Phys. 37, 3215 (2010).
- Chanyavanich V, "Knowledge-based Prostate IMRT Treatment Planning", Medical Physics Seminar, Georgia Tech University, September 2011.
- Chanyavanich V, "Using Mutual Information for Similarity Assessment of IMRT Treatment Plan Quality", Medical Physics Seminar, Mahidol University, Ramathibodi Hospital Dept. of Radiation Oncology, Thailand, May 2011.
- Chanyavanich V, "Development of a Knowledge-base of Prostate IMRT Treatment Plans," Medical Physics Seminar, Duke University, August 2009.
- Chanyavanich V, "Features Extraction and Visualization of Prostate IMRT Treatment Plans," Visualization Friday Forum Seminar, Department of Computer Science, Duke University, April 2009.

Research Funding Support

- A Visualization Tool for Knowledge-Based Treatment Planning for Prostate Cancer, Renaissance Computing Institute of North Carolina (RENCI)- Applied Scientific and Information Visualization Program, 2010-2011 ($12,000)
- Knowledge-based Optimization of IMRT Treatment Planning for Prostate Cancer, Wallace H. Coulter Translational Partnership Award renewal, 2009-2010 ($60,000)
- Knowledge-based Optimization of IMRT Treatment Planning for Prostate Cancer, Wallace H. Coulter Translational Partnership Award, 2008-2009 ($120,000)

Wanpracha Art Chaovalitwongse, Ph.D.

Associate Professor, Departments of Industrial & Systems Engineering and Radiology, University of Washington, Seattle

Education

Ph.D.	Industrial & Systems Eng.	University of Florida (2003)
M.S.	Industrial & Systems Eng.	University of Florida (2000)
B.Eng.	Telecommunication Eng.	King Mongkut Institute of Technology Ladkrabang (1999)

Professional Experience

2011 – Present	Associate Professor, Departments of Industrial & Systems Engineering and Radiology (UW School of Medicine), University of Washington, Seattle
01 – 07/2011	Visiting Associate Professor, Department of Operations Research and Financial Engineering, Princeton University, Princeton
2010 – 2011	Associate Professor, Department of Industrial and Systems Engineering, Rutgers, the State University of New Jersey, New Brunswick
2010 – 2011	Affiliate Associate Professor, Rutgers Center for Operations Research (RUTCOR), Rutgers, the State University of New Jersey, New Brunswick
2005 – 2010	Assistant Professor, Department of Industrial and Systems Engineering, Rutgers, the State University of New Jersey, New Brunswick
2004 – 2005	Post-Doctoral Fellow, Corporate Strategic Research, ExxonMobil Research & Engineering, Annandale, NJ
2003 – 2004	Post-Doctoral Associate, Brain Institute, University of Florida, Gainesville

Honors and Recognitions

- Institute of Electrical and Electronics Engineers (IEEE) Senior Member, 2011
- Rutgers University Presidential Fellowship for Teaching Excellence, 2010
- Early promotion to Associate Professor (with tenure), Rutgers University, 2010
- Outstanding Service Award, The Association of Thai Professionals in America and Canada (ATPAC), 2009
- Rutgers FASIP Award for Research, Teaching and Service, 2006, 2007, 2008, 2009
- Pierskalla best paper award for research excellence in health care management science, Institute for Operations Research and the Management Sciences (INFORMS), 2008
- Nominated for the National Security Science and Engineering Faculty Fellowship (NSSEFF) Program by Rutgers' President McCormick
- Notable Alumni, King Mongkut Institute of Technology at Ladkrabang, 2006
- National Science Foundation (NSF) CAREER Award, 2006
- Omega Rho International Honor Society (Operations Research and Management Science), 2005
- Pierskalla best paper award for research excellence in health care management science, Institute for Operations Research and the Management Sciences (INFORMS), 2004
- Annual Award for Excellence in Research, Industrial & Systems Engineering, University of Florida, 2003
- Several best paper awards with my students: Finalist of the 2012 INFORMS Data Mining Student Paper Competition; Finalist of the 2011 INFORMS Data Mining Student Paper

Competition; Winner of the 2010 Annual NJ Chapter of INFORMS Student Research Contest; Finalist of the 2009 Annual NJ Chapter of INFORMS Student Research Contest

Patents

- "Multi-Dimensional Multi-Parameter Time Series Processing for Seizure Warning and Prediction", United States Patent: US 7,263,467 B2, awarded Aug 2007
- "Optimization of Multi-Dimensional Time Series Processing for Seizure Warning and Prediction", International Patent: 7,373,199, awarded May 2008
- "Optimization of Spatio-Temporal Patterns Processing for Seizure Warning and Prediction", United States Patent: US 7,461,045, awarded December 2008
- "Multi-Dimensional Dynamical Analysis", filed on Jan. 27th, 2006 (U.S. Patent Application, Attorney Docket No. 1028724-000154)

Book and Book Chapters: 3 books, 1 edited volume and 27 book chapters

Refereed Scientific Articles: A total of 117 peer-reviewed publications

Invited Professional Presentations: > 200 presentations - including invited talks at renowned universities such as Massachusetts Institute of Technology (MIT), Princeton University, University of Michigan, University of Illinois, Lehigh University, SUNY-Buffalo, North Carolina State University, Arizona State University, Oklahoma State University, University of Houston, U de Montreal, University of Warwick, University of London, Seoul National University, Korea Advanced Institute of Science and Technology

Synergistic Activities

- *Executive Vice President*, The Association of Thai Professionals in America and Canada, 2007-present
- *Director of Northeast Region*, Omega Rho International Honor Society, 2006-2011
- *Associate Editor/Editorial Board Member:* (a) Journal of Global Optimization; (b) Journal of Combinatorial Optimization; (c) Optimization Letters; (d) Annals of Operations Research; (e) International Journal of Engineering and Management; (f) International Journal of Electronic Transport; (g) IEEE Transactions on Human-Machine System
- *National Science Foundation (NSF) Panelist*: (a) CISE - Mar 2005; (b) CISE - Jun 2005; (c) CISE - Sep 2005; (d) BIO - Nov 2008; (e) CDI - Mar 2009; (f) CRCNS - Feb 2010; (g) CRCNS – Mar 2011; (h) SI2 – Nov 2011
- *External Grant Reviewer:* NSF: Chemical, Bioengineering, Environmental, and Transport Systems (CBET), 2009, NSF: CAREER, Information & Intelligent Systems (IIS), 2009, NSF: CAREER, Computing & Communication Foundation (CCF), 2009, Alzheimer's Association: International Research Grant Program, 2010, The Center for Multimodal Solutions for Congestion Mitigation (CMS), University of Florida, 2010, The Grants to Enhance and Advance Research (GEAR), University of Houston, 2007, Wiener Wissenschafts-, Forschungs- und Technologiefonds (WWTF), Vienna Science and Technology Fund, 2007, The National Medical Research Council, Singapore, 2010
- *Conference Program Committee (selected from >30 conferences)*: Brain Informatics 2012; CIMSA 2012; Pacific-Asia Conference on Knowledge Discovery and Data Mining 2012; ICQR 2011*;* IEEM 2010; CIMSA 2010; Conference on Biomedical Data & Knowledge Mining: Towards Biomarker Discovery (2010); IEEM 2009; COCOA 2009; WCGO 2009; ICDM 2008; IEEM 2008; GrC 2008; ICCS 2008; GrC 2007; ICDM 2007; ICCS 2007

Eakalak Khan, Ph.D.

Professor and Chair, Department of Civil Engineering
North Dakota State University, Fargo, ND

Education

Ph.D.	Civil Engineering	University of California, Los Angeles (UCLA), 1997
M.S.	Civil Engineering	University of California, Los Angeles (UCLA), 1994
M.S.	Agricultural Engineering	University of Hawaii, 1993
B.Eng.	Environmental Engineering	Chiang Mai University, Thailand, 1990

Professional Experience

1/10 – Present	Chair, Dept. of Civil Engineering, North Dakota State University (NDSU), Fargo, ND
7/02 – Present	Assistant Professor, Associate Professor, and Professor, Dept. of Civil Engineering, NDSU, Fargo, ND
1/99 – 5/02	Assistant Professor, Dept. of Civil Engineering, Polytechnic University, Brooklyn, NY
1/98 – 11/98	Postdoctoral Research Associate, UCLA, Los Angeles, CA
7/94 – 12/97	Graduate Research Assistant, UCLA, Los Angeles, CA
1/93 – 9/93	Junior Specialist and Pilot Operator, University of Hawaii, Honolulu, HI
1/91 – 12/92	Graduate Research Assistant, University of Hawaii, Honolulu, HI

Honors and Recognitions

- Odney Award for Excellence in Teaching, North Dakota State University, 2008 (university-wide teaching award given to one instructor per year)
- Researcher of the Year, 2005, College of Engineering and Architecture, North Dakota State University
- CAREER Award, National Science Foundation, 2005
- First Prize Poster Competition at the Surface Water Treatment Workshop, Moorhead, MN, 2004 (co-author with M.S. student, Trent Museus)
- Third Prize Student Research Paper Competition at the 76th Annual New York Water Environment Association Conference, New York City, NY, 2004 (co-author with Ph.D. student, Rungrod Jittawattanarat)
- *Journal of Environmental Engineering* (American Society of Civil Engineers) Editor's Award for outstanding reviews, 2002

Synergistic Activities

Reviewer: *Applied Biochemistry and Biotechnology*; *Bioresource Technology*; *Chemosphere*; *Environmental Science and Technology*; *Journal of Environmental Engineering*; *Journal of Hazardous Materials*; *Water Environment Research*; *Water Research*; and National Science Foundation.

Others: Advisor, NDSU Engineers Without Borders Student Chapter; Co-Advisor, NDSU Water Environment Federation Student Chapter; and visiting professor (2 weeks/year), Chulalongkorn University, Thailand.

Selected Scientific Articles

- Kasi, M., Wadhawan, T., McEvoy, J., Padmanabhan, G., and Khan, E. (2012) Effect of Carbon Source during Enrichment on BTEX Degradation by Anaerobic Mixed Bacterial Cultures. *Accepted for Publication in Biodegradation.*
- Simsek, H., Kasi, M., Wadhawan, T., Bye, C., Blonigen, M., and Khan, E. (2012) Fate of Dissolved Organic Nitrogen in Two Stage Trickling Filter Process. *Water Research*, **46**(16), pp. 5115-5126.
- Bezbaruah, A., Shanbhogue, S., Simsek, S., Khan, E. (2011) Encapsulation of Iron Nanoparticles in Alginate Biopolymer for Trichloroethylene Remediation. *Journal of Nanoparticle Research*, **13**(12), pp. 6673-6681.
- Schuh, M., Casey, F., Hakk, H., DeSutter, T., Richards, K., Khan, E., and Odour, P. (2011) Effects of Field-Manure Applications on Stratified 17 β-Estradiol Concentrations. *Journal of Hazardous Materials*, **192**(2), pp. 748-752.
- Fan, Z., Casey, F., Hakk, H., Larsen, G., and Khan E. (2011) Sorption, Fate, and Mobility of Sulfonamides in Soils. *Water, Air, and Soil Pollution*, **218**(1), pp. 49-61.
- Pramanik, S., Khanna, R., Katti, K., McEvoy, J., and Khan, E. (2011) Effects of Entrapment on Nucleic Acid Content, Cell Morphology, Cell Surface Property and Stress of Pure Cultures Commonly Found in Biological Wastewater Treatment. *Applied Microbiology and Biotechnology*, **92**(2), pp. 407-418.
- Kasi, M., McEvoy, J., Padmanabhan, G., and Khan, E. (2011) Groundwater Remediation Using Enricher Reactor - Permeable Reactive Biobarrier for Periodically Absent Contaminants. *Water Environment Research*, **83**(7), pp. 603-612.
- Zitnick, K., Shappell, N., Hakk, H., DeSutter, T., Khan, E., and Casey, F. (2011) Effects of Liquid Swine Manure on Dissipation of 17β-Estradiol in Soil. *Journal of Hazardous Materials*, **186**(2-3), pp. 1111-1117.
- Schuh, M., Casey, F., Hakk, H., DeSutter, T., Richards, K., Khan, E., and Odour, P. (2011) An On-Farm Survey of Spatial and Temporal Stratifications of 17β-Estradiol Concentrations. *Chemosphere*, **82**(11), pp. 1683-1689.
- Pramanik, S., McEvoy, J., Siripattanakul, S., and Khan, E. (2011) Effects of Cell Entrapment on Nucleic Acid Content and Microbial Diversity of Mixed Cultures in Biological Wastewater Treatment. *Bioresource Technology*, **102**(3), pp. 3176-3183.
- Wadhawan, T., Maruska, Z., Siripattanakul, S., Hill, C., Gupta, A., Prüβ, B., McEvoy, J., and Khan, E. (2011) A New Method to Determine Initial Viability of Entrapped Cells Using Fluorescent Nucleic Acid Staining. *Bioresource Technology*, **102**(2), pp.1622-1627.
- Ratpukdi, T., Casey, F., DeSutter, T., and Khan, E. (2011) Bromate Formation by Ozone-VUV in Comparison with Ozone and Ozone-UV: Effects of pH, Ozone Dose, and VUV Power. *Journal of Environmental Engineering-ASCE*, **137**(3), 187-195..

Collaborators and other affiliations

- **Collaborators during the past 48 months:** Achintya Bezbaruah, NDSU; Frank Casey, NDSU; Kimberly Jones, Howard University; Konstantinos Kostarelos, University of Cyprus; Tawan Limpiyakorn, Chulalongkorn University; John McEvoy, NDSU; G. Padmanabhan, NDSU; Alisa Vangnai, Chulalongkorn University; and Kyung-Duk Zoh, Seoul National University.

Gaviphat Lekutai, Ph.D.

Lead Member Technical Staff (Director level), Radio Technology
AT&T Labs, Redmond, WA

Education

Ph.D.	Electrical Engineering	Virginia Tech, Blacksburg, VA, 1997
M.S.	Electrical Engineering	Virginia Tech, Blacksburg, VA, 1993
B.S.	Electrical Engineering	West Virginia Tech, Montgomery, WV, 1991

Professional Experience

2009 – Present	Lead Member Technical Staff, Radio Technology R&D, AT&T (formerly Cingular, formerly AT&T Wireless), Redmond, WA
2004 – 2009	Principal Member Technical Staff (Manager), Radio Technology R&D, AT&T
2002 – 2004	Senior Member Technical Staff, Network Technology Labs, AT&T
2000 – 2002	Member Technical Staff, Radio Access Development, AT&T
1996 – 2000	RF Engineer, Network Operations, AT&T (formerly Cingular, formerly SBC dba Cellular One, Wash/Balt), Hanover, MD

Honors and Recognitions

- Recognized by Who's Who among Students in American Universities & Colleges, 1991

Summary

- Accomplished R&D Lead with over 16 years of experience in wireless technologies
- Small cells technology subject matter expert
- Vice-chair of Backhaul Special Interest Group in the Small Cell Forum (www.smallcellforum.org)
- Seven US Patents Granted (US patents)
- Family and community focus:
- President of Atammayatarama Buddhist Monastery, Woodinville WA, 2010-2011 (atamma.org)
- Board of Directors of Thai Association of Washington, 2009-2011 (thaiwashington.org)
- 2011 Person of the Year presented by Thai Association of Washington (personoftheyear2011)

Selected Career Highlights

- Three key positions in Small Cell Forum: Radio/Physical Layer, Backhaul Special Interest and Operator Working Groups, 2012
- Instrumental in the development of multi-standard small cells and strategy for AT&T and the industry, 2012
- Initiated NLOS wireless backhaul development program and witnessed a successful first live NLOS wireless transport transmission in 2.3 GHz licensed spectrum in US operator, 2010-11
- Validated AT&T nationwide speed claim of HSUPA and HSPA 7.2Mbps technologies, 2008-9
- Pioneered and witnessed the first 3G UMTS voice and data calls (384 kbps) in North America, 2002

Selected Scientific Articles

- Gaviphat Lekutai and Hugh F. VanLandingham, "Self-Tuning Control of Nonlinear Systems Using Neural Network Adaptive Frame Wavelets," IEEE International Conference on Systems, Man, and Cybernetics, Orlando, FL, October 1997
- Gaviphat Lekutai and Richard L. Moose, "Design of a Jump Matrix State Estimator for Noisy Nonlinear Systems," Proceedings IEEE Southeastcon '93, Charlotte, NC, April 1993

Witoon Prinyawiwatkul, Ph.D.

Professor, Department of Food Science
Louisiana State University and LSU Agricultural Center

Education

Ph.D.	Food Science and Technology	University of Georgia, Athens, GA (1996)
M.S.	Food Science and Technology	University of Georgia, Athens, GA (1993)
B.Sc.	Agro-Industrial Product Development with a minor in Marketing	Kasetsart University, Thailand (1989)

Professional Experience

2010 – Present	Horace J. Davis Endowed Professor, Louisiana State University
7/2005 – Present	Professor, Louisiana State University and LSU AgCenter
7/2001 – 6/2005	Associate Professor, Louisiana State University and LSU AgCenter
12/1996 – 6/2001	Assistant Professor, Louisiana State University and LSU AgCenter

Major Areas of Research Interest

- Value-added new food product research and development from Louisiana agricultural, seafood and aquacultural byproducts and wastes from processing plants;
- Sensory science and evaluation methods as a driving force and tool for the development of new products;
- Consumer-oriented product optimization and acceptance as a primary tool for the success of new products in the market;
- Use of statistical methods and analyses as a tool for assisting the interpretation of complex sensory and consumer results;
- Functional properties of raw materials as affected by product formulation and process conditions which influence overall sensory properties of end products.

International Instructional Contributions and Activities

International seminars, short courses and workshops related to sensory sciences and product development (**>60** in Thailand, Ukraine, Venezuela, Mexico, Honduras).

Honors and Recognitions

2010 Gamma Sigma Delta (the Honor Society of Agriculture) Distinguished Achievement to Agriculture Award, Louisiana State University Chapter.
2008 LSU Alumni Association Faculty Excellence Award
2007 College of Agriculture Alumni Award for Excellence in Teaching
2007 Gamma Sigma Delta (the Honor Society of Agriculture) Research Award of Merit, Louisiana State University Chapter
2006 LSU Distinguished Faculty Award
2005 National Association of Colleges and Teachers of Agriculture (NACTA) Teaching Award
2005 Gamma Sigma Delta (the Honor Society of Agriculture) Teaching Award of Merit, Louisiana State University Chapter
2005 LSU Tiger Athletic Foundation President's Award
2004 LSU Advisor of the Year awarded by the University College
2004 LSU College of Agriculture Sedberry Undergraduate Teaching Award

2011 - 1998 (14 consecutive years) The Gamma Sigma Delta Award of Merit Teacher Honor Roll, LSU College of Agriculture

1999 The Tiger Athletic Foundation Award for Outstanding Teacher (Assistant Professor), LSU College of Agriculture

Adjunct Professor/Graduate Faculty/Mentors

- University of Maryland Eastern Shore (UMES). 2005-2008
- Mae Fah Luang University, Chiang Rai, Thailand. 2005-2009
- Kasetsart University, Bangkok, Thailand 2005-now
- A Special Lecturer for the Ph.D. Program in Agro-Industry Product Development, Division of Product Development Technology, Faculty of Agro-Industry, Chiang Mai University (2011-now)
- Major/Minor Professor: 22 M.S. students
- Major/Minor Professor: 15 Ph.D. students
- Co-Major Professor for other and Foreign Universities: 2 M.S. students
- Committee Member: 35 M.S. students
- Committee Member: 22 Ph.D. students

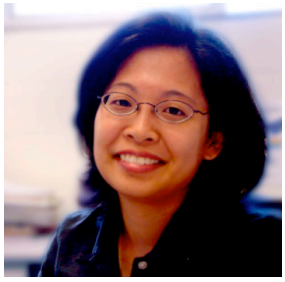
Book and Book Chapters: 1 book and 5 book chapters

Refereed Scientific Articles: A total of 116 papers

Domestic and International Professional Presentations: > 230 presentations

Editorial Board for Refereed Scientific Journals

- *Associate Editor and Editorial Board,* Journal of Food Science, Sensory and Food Quality Section (2008-present)
- *Associate Editor and Editorial Board,* Journal of Food Science, Sensory and Nutritive Quality Section (2006-2007)
- *Associate Editor and Editorial Board,* International Journal of Food Science and Technology (2004-present)
- *Editorial Board,* Journal of Food Quality (2005-present)
- *Editorial Board*, Journal of Sensory Studies (2003-present)



Malisa Sarntinoranont, Ph.D.

Associate Professor, Department of Mechanical & Aerospace Engineering, University of Florida

Education

Ph.D.	Mechanical Engineering	University of California at Berkeley (1999)
M.S.	Mechanical Engineering	University of California at Berkeley (1996)
B.M.E.	Mechanical Engineering [Highest Honor]	Georgia Institute of Technology (1994)

Professional Experience

8/2009 – Present — Associate Professor, Mechanical & Aerospace Engineering, University of Florida

8/2003 – 8/2009 — Assistant Professor, Mechanical & Aerospace Engineering, University of Florida

3/2004 – Present — Affiliate Faculty, Biomedical Engineering, University of Florida

- Computational modeling of transport within soft tissues. Developing imaging-based models of tissue transport and physiological fluid flow that incorporate anisotropic properties and anatomically correct geometry.
- Soft tissue mechanics. Experimental microindentation of soft hydrated materials including contact lenses and tissue slices. Biphasic models of indentation and tissue infusion.
- Physiological fluid flows. Porous media transport and extracellular fluid flows in nervous and tumor tissues.

8/1999 – 7/2003 — Research Fellow, Bioengineering and Physical Science, National Institutes of Health

- Created computational models of drug infusion into the spinal cord.
- Supervised research involving FEM models of microdialysis and gel-tissue substitute infusion experiments.

1/1995 – 5/1999 — Graduate Research Assistant, University of California at Berkeley

- Mathematical modeling of biological soft tissue mechanics. Created a mechanical model of a growing solid tumor using poroelastic theory. Analyzed the effects of tissue growth and interstitial fluid pressure on blood vessel collapse and macromolecular drug transport.

6/1998 – 5/1999 — Engineering Intern, Nitinol Devices and Components (Cordis Corp.)

- Provided mechanical testing data for determining the effect of pulsatile flow on the total life of NiTi stents. Designed and conducted fatigue experiments on superelastic NiTi to determine the effect of mean strain on cycles to failure.

Honors and Recognitions

- Graduate Opportunity Fellowship, 1995, U.C. Berkeley
- George W. Woodruff School of Mechanical Engineering Director's Award, 1994
- Research Fellow, DBEPS, NIH, 1999

Professional Service & Memberships

Memberships

- American Society of Mechanical Engineers

- Biomedical Engineering Society
- Association of Thai Professionals in America and Canada

Societal Activities

- ASME Summer Bioengineering Conference, Local Arrangements Chair (2013)
- ASME Summer Bioengineering Conference, Session Chair (2007, 2008, 2011)
- ASME Summer Bioengineering Conference, Session Co-chair (2006, 2008, 2009)
- ASME Summer Heat Transfer Conference, Track Co-Organizer and Session Organizer (2008)

Grant Review

- Veterans Administration, CAMM (2011)
- NIH Study Section Member, Tissue Engineering (2003, 2008, 2009, 2011)
- NSF Review Panel, Nano and Bio Mechanics (2008)

Associate Editor & Advisory Board

- ASME Nanotechnology in Engineering and Medicine (8/2011 to present)

Journal Review

- Journal of Neurosurgery, Physical Biology, Biomechanics and Modelling in Mechanobiology, IEEE Transactions on Biomedical Engineering, Journal of Biomechanics, ASME Journal of Medical Devices, Molecular Cancer Therapeutics, Journal of Membrane Science, Biomedical Microdevices, Medical Engineering & Physics, Annals of Biomedical Engineering, Journal of Biomechanical Engineering, Journal of Heat Transfer, Cancer Research, American Journal of Physiology

Sirivatch Shimpalee, Ph.D.

Research Associate Professor, Department of Chemical Engineering
University of South Carolina

Education

Ph.D.	Mechanical Engineering	University of South Carolina (2001)
M.S.	Mechanical Engineering	Bradley University (1998)
B.M.E.	Mechanical Engineering	Chiang Mai University, Thailand (1992)

Professional Experience

2005– Present	Co-founder & Vice President of Engineering Services, Palmetto Fuel Cell Analysis & Design, LLC
2008 – Present	Research Associate Professor, Department of Chemical Engineering, University of South Carolina
2002 – 2008	Research Assistant Professor, Department of Chemical Engineering, University of South Carolina
2001 – 1002	Research Associate, Department of Chemical Engineering, University of South Carolina
1992 – 1995	Technical Service Engineer, Siam-Hitachi Construction Machinery Co., Ltd., Bangkok, Thailand

Honors and Recognitions

- Crystal Flame Innovation Award in Entrepreneurship, The FuelCellSouth 2004, March 16, 2004, Columbia, SC

Major Areas of Research Interest

- Fuel Cells, Transport Phenomena
- Flow Field Design
- Computational Fluid Dynamics
- Modeling Electrochemical Systems

Professional Service & Memberships

Memberships

- Electrochemical Society (ECS)
- Association of Thai Professionals in America and Canada

Synergistic Activities

- Co-founder, Palmetto Fuel Cell Analysis and Design, LLC (2005) (Fuel Cell Software & Services).
- Consultant, CD-adapco, Inc. March 2003 to present (CFD software and Fuel Cell subroutines).
- Consultant, Mechanical Engineering, Chiang Mai University, Thailand, January 2005 to present (Fuel Cell operation).
- 2 USC software disclosures licensed.

Selected Scientific Articles

- J. Farmer, M. Martinez, **S. Shimpalee**, B. Duong, S. Seraphin, J.W. Van Zee, "Assessing porosity of PEM fuel cell gas diffusion layers by SEM image analysis," In press J. of Power Sources (2011).

- C. Andres Lozano, M. Ohashi, **S. Shimpalee**, P. Aungkavattana, J.W. Van Zee, "Comparison of hydrogen and methane as fuel in micro-tubular SOFC using electrochemical analysis," J. of Electrochem. Soc., 158 (10), B1235-1245, 2011.
- **S. Shimpalee**, V. Lilavivat, H. McCrabb, A. Lozano-Morales, J. Van Zee, "Understanding the effect of channel tolerances on performance of PEMFCs," In press Intl. J. of Hydrogen Energy (2011).
- T. Gu, **S. Shimpalee**. C-Y. Chen, C-W. Lin, J. W. Van Zee, "A study of water adsorption and desorption by a PBI-H3PO4 membrane electrode assembly," J. of Power Sources, 195/24, 8194-8197, 2010.
- M. Venkatraman, **S. Shimpalee**, J. W. Van Zee, "Effect of Net Geometry on the Nusselt Number Distribution for Channel Flow" Numerical Heat transfer Part A: Applications, 55, 309-336, 2009.
- M. Venkatraman, **S. Shimpalee**, C. Extrand, S. Moon, J.W. Van Zee, "Estimates of pressure gradients in PEMFC gas channels due to blockage by static liquid drops," Intl. J. of Hydrogen Energy, 34, 5522-5528, 2009.
- **S. Shimpalee**, M. Ohashi, C. Ziegler, C. Stoeckmann, C. Sadeler, C. Hebling, and J. W. Van Zee, "Experimental and numerical studies of portable PEMFC stack,,"Electrochemica Acta, 54, 2899-2911, 2009.
- M. Martinez, **S. Shimpalee**, and J. W. Van Zee, "Comparison predictions of PEM fuel Cell behavior using Maxwell-Stefan and CFD approximation equations" Computer and Chemical Engineering, 32, 2958-2965, 2008.
- D-h. Jeon, S. Greenway, **S. Shimpalee**, and J. W. Van Zee, "The effect of serpentine flow-field designs on PEM fuel cells performance," Intl. J. of Hydrogen Energy, 33, 1052-1066, 2008.
- **S. Shimpalee**, D. Spuckler, J. W. Van Zee, "Prediction of transient response for a 25-cm2 PEM fuel cell," J. of Power Sources, 167/1, 130-138, 2007.
- **S. Shimpalee**, U. Beuscher, J. W. Van Zee, "Analysis of GDL flooding effects on PEMFC performance," Electrochimica Acta, 52/24, 6748-6754, 2007.
- **S. Shimpalee**, U. Beuscher, and J. W. Van Zee, "Investigation of Gas Diffusion Media inside PEMFC Using CFD Modeling," J. of Power Sources, 163, 480-489, 2006.
- **S. Shimpalee** and J. W. Van Zee, "Numerical study on rib/channel dimension of flow-field on PEMFC performance," Int. J. of Hydrogen Energy, 32/7, 842-856, 2007.
- **S. Shimpalee**, S. Greenway, and J. W., Van Zee, "The impact of channel path length on PEMFC flow-field design," J. of Power Sources, 160, 398-406, 2006.
- S-h. Kim, **S. Shimpalee**, and J. W. Van Zee, "Effect of Channel Length and Voltage Change Rate and Range on Second Order Dynamic Behavior." J. of Electrochem. Soc. 152(6), A1265-A1271, 2005.
- **S. Shimpalee**, S. Greenway, D. Spuckler, and J. W. Van Zee, "Predicting Water and Current Distributions of a Commercial Size PEMFC." J. of Power Source, 135, 79 – 87, 2004.
- W-k. Lee**, S. Shimpalee**, and J. W. Van Zee. "Verifying Prediction of Water and Current Distribution in a Serpentine Flow Field PEMFC," J. of Electrochemical Society, 150(3), pp. A341-A348, 2003.

Refereed Scientific Articles: A total of 57 papers (30 refereed; 27 non-refereed)

Domestic and International Professional Presentations: 60 presentations

Nisai Wanakule, Ph.D., P.E.

OROP & Modeling Program Supervisor
Tampa Bay Water

Education

Ph.D.	Water Resources System Engineering	University of Texas at Austin (1984)
M.Eng.	Agricultural Soil & Land Resources Eng.	Asian Institute of Technology (1975)
B.Eng.	Civil Engineering, Honors	Kasetsart University, Thailand (1973)

Professional Experience

2004 – Present	Modeling Program Supervisor & Project Manager, Tampa Bay Water, A Regional Water Supply Authority, Clearwater, FL
1997 – 2003	Water Resources Engineer & Project Manager, Tampa Bay Water
1986 – 1997	Hydrogeologist & Assistant Director, Edwards Aquifer Research and Data Center, Southwest Texas State University San Marcos, TX
1987 – 1989	Adjunct Professor, Department of Computer Science and Department of Biology, School of Science, Southwest Texas State University San Marcos, TX
1987 – 1995	Consulting Engineer, Southwest Texas State University San Marcos, TX
1985 – 1986	Research Associate, Center for Research in Water Resources, University of Texas at Austin, TX
1982 – 1984	Graduate Research Assistant, Center for Research in Water Resources, University of Texas at Austin, TX
1980 – 1981	Research Core Team, Mekong Secretariat, The Economics and Social Committee for Asian and Pacific (ESCAP), United Nations Bangkok, Thailand
1979 – 1980	Visiting Scholar, College of Engineering, University of Texas at Austin, TX
1980 – 1981	Technical Specialist, Office of the National Environment Board, Bangkok, Thailand
1975	Student Research Assistant, The Geotechnical Engineering Division, AIT, Bangkok, Thailand
1973	Engineer I, The Royal Irrigation Department, Bangkok, Thailand

Licensures

- Professional Engineer, State of Florida, No. 53230

Major Areas of Research Interest

- Water Resources System Planning and Management
- Contaminant Transport and Water Quality Modeling
- Environmental Impact Assessment for Water Resource Related Projects
- Surface Water Hydrological and Hydraulic Models
- Operations Research (Linear, Nonlinear, Integer, Dynamic, and Network Programming)

Selected Scientific Articles

- Mok C.M., Armen Der Kiureghian, and Nisai Wanakule, A Reliability-Based Optimization Model for Integrated Water Supply Operation Management, Asian-Pacific Symposium on Structural Reliability and Its Applications, Hong Kong, June 2008
- Mok C.M., Nisai Wanakule, Jeff Geurink, and Miao Zhang, Impact of Uncertainty on Water Resources Management, EWRI 2008 World Environmental & Water Resources Congress, American Society of Civil Engineers, Honolulu, HI, May 2008.
- Mok C.M., Nisai Wanakule, Jeff Geurink, and Miao Zhang, Effect of Various Hard and Soft Data on Parameter Uncertainty of An Integrated Hydrologic Model, EWRI 2008 World Environmental & Water Resources Congress, American Society of Civil Engineers, Honolulu, HI, May 2008.
- Asefa, T., Nisai Wanakule, and Alison Adams, Field-Scale Application of Three Types of Neural Networks to Predict Ground-Water Levels, *J. Am. Water Res. Ass*. 43(5), 2008
- Tampa Bay Water, Optimized Regional Operations Plan Annual Report, submitted to the *Southwest Florida Water Management District*, Brooksville, Florida, 1998 to 2008.
- Wanakule, N., and Chin Man Mok, Reliability Based Water Supply Management Model, Water Resources Management Conference, International Association of Science and Technology for Development, Honolulu, HI, 2007.
- Mok C.M., Nisai Wanakule, and Jeff Geurink, Effectiveness of Various Hard and Soft Data in Reducing Uncertainty of Parameters in An Integrated Hydrologic Model." C.M. Mok, N. Wanakule, J. Geurink. Presented at International Conference on Model Calibration and Reliability", Copenhagen, Denmark, September 2007
- Mok, C.M, Nisai Wanakule, Armen Der Kiureghian, Steven Gorelick, and Zhang, M., Coping with Predictive Uncertainties in Optimization of Sustainable of Water Resources, IAHS Redbook, IUGG, XXIV 2007, Perugia, Italy, July 2007.
- Wanakule, N., and Chin Man Mok, A Stochastic Optimization Model for Managing Water Supply Operations, EWRI 2007 World Environmental & Water Resources Congress, American Society of Civil Engineers, Tampa, FL, 2007.
- Wanakule, N., and Marsh Lavenue, Optimizing a Groundwater Level Monitoring Network for Wellfield Management, EWRI 2007 World Environmental & Water Resources Congress, American Society of Civil Engineers, Tampa, FL, 2007.
- Wanakule, N., Optimizing Groundwater Level Monitoring Network Using Environmental Suitability Analysis, The 26th Annual ESRI International Users Conference, San Diego, CA, August 2006.
- Mok, C.M, Armen Der Kiureghian, Nisai Wanakule, Steven Gorelick, Anthony Daus, Adaptive and Integrated Management of Water Resources Through Reliability Optimization, Summer Specialty Conference: Adaptive Management of Water Resources, American Water Resources Association, Missoula, MT. June 2006.
- Mok, C.M., Armen Der Kiureghian, Nisai Wanakule, Steven Gorelick, Anthony Daus, Protecting Wetland Ecology by Integrated Management of Water Resources, HydroEco Conference, Czech Republic, 2006.
- Mok, C.M., Armen Der Kiureghian, Nisai Wanakule, Steven Gorelick, Anthony Daus,
- Reliability-Optimization Water Resources Management Model, Proceedings of the Modflow 2006 and other Modeling Odysseys, International Ground Water Modeling Center, Colorado School of Mines, Golden, CO. May 2006.

Methi Wecharatana, Ph.D.

Professor, Department of Civil and Environmental Engineering
New Jersey Institute of Technology

Education

Ph.D.	Materials Engineering	University of Illinois – 1982
M.S.	Structural Mechanics	Asian Institute of Technology –1978
B.M.E.	Civil Engineering	Chulalongkorn University –1976

Professional Experience

1991 – Present	Professor, Civil and Environmental Engineering, New Jersey Institute of Technology (NJIT)
1986 – 1991	Associate Professor, Civil and Environmental Engineering, NJIT
1982 – 1986	Assistant Professor, Civil and Environmental Engineering, NJIT
1984 – 1986	Director of Concrete Lab, NJIT
1981 – 1982	Post-doctorate and Research Engineer, Department of Civil Engineering, Northwestern University
1979 – 1981	Research Assistant/Associate in Fracture Mechanics of Cementitious Materials, University of Illinois at Chicago Circle

Honors and Recognitions

- Recipient of the Chi Epsilon's James Robin award, 1984
- Recipient of the Dow Outstanding Young Faculty Award, 1985
- Recipient of an Honorary Doctoral Degree in Environmental Engineering from Khon Kaen University, Thailand, December 2001
- Recipient of the First Technologist of the Year Award from the Foundation for the Promotion of Science and Technology, Ministry of Science and Technology, Thailand, October 2002
- Recipient of NJIT Excellence in Teaching Award: Upper Division for 2005-06
  - "Compressive Strength of Concrete and Mortar Containing Fly Ash", U.S. Patent No. 5,853,475
  - "Sulfate and Acid Resistant Concrete and Mortar", U.S. Patent No. 5,772,752
  - "Method for Increasing the Rate of Compressive Strength Gain in Hardenable Mixtures Containing Fly Ash", U.S. Patent No. 5,681,384
  - "Compressive Strength of Concrete and Mortar Containing Fly Ash", U.S. Patent No. 5,624,491
- Recipient of NJIT Master Teacher Designation Award, 2008
- Recipient of the Robert W. Van Houten Teaching Excellence Award from NJIT Alumni Association, 2010
- Recipient of the Benjamadirekkunaporn Royal Decoration from the King's of Thailand for the lifelong contribution to the Advancement of Science and Technology, and Higher Education of Thailand, 2010

Consulting Services

- Consulting in tall building design, development of advanced cement-based materials, improvement of higher education system, environmental reporting and indicators, and establishment of government-university-industry cooperative research center

Licensures

- Professional Engineer, Thailand, PE 3540

Professional Service & Memberships

Memberships: American Society of Civil Engineers, American Concrete Institute, Materials Research Society, Society of Experimental Mechanics

Professional Service

- Greening of the Industry Network – Member of the Board of Directors
- American Concrete Institute - Member of Technical Committee - 446 Fracture Mechanics - 544 Fiber Reinforced Concrete
- Association of Thai Professionals in America and Canada - President (1995-1999) and Member of the Board of Directors, 1991-present, Chairman, Board of Directors, 2009-present

Peer Review Service: National Science Foundation, Thailand Research Fund, American Concrete Institute, International Journal, Science Asia, Serve as external reviewer for promotion and tenure of several US universities

Institute Service: Institute Committee on Graduate Council, Institute Committee on Teaching Excellence Award, Institute Committee on Master Teachers, Department P&T Committee

Principal publications of last five years (selected) [Published more than 140 publications in books, refereed journals and conferences]

- Wecharatana, M., "Education and Learning for the 21st Century", Invited lecture, Mae Fah Luang University, Thailand, July 9, 2012
- Wecharatana, M., "21st Century's Learning", Keynote lecture, given at Chiang Mai University, July 2, 2012, and
- Wecharatana, M., "Establishment of a Thailand-U.S. Cooperative (TUSCO) Foundation", presented to the Federation of Thai Industry, September 26, 2012, and to the Ministry of Science and Technology, Thailand, July 4, 2012
- Wecharatana, M., "Recycled Concrete as Aggregate in Concrete", invited paper, Science and Technology Report, Office of Science and Technology Counselor, Royal Embassy of Thailand, Washington, D.C., February 2012.
- Wecharatana, M., "Proposal to Establish a Thailand-U.S. Science and Technology Cooperative Foundation", published in "Strategic Research Plan for Thailand 2011", Association of Thai Professionals in America and Canada (ATPAC), December 2011.
- Wecharatana, M., "Twenty Years of ATPAC, Lessons Learned", published in the Proceedings of the Association of Thai Professionals in America and Canada, July 2009.
- Wecharatana, M., "Forward Looking University", Invited lecture, presented to the University Administration, Chulalongkorn University, August 25, 2010
- Wecharatana, M., "Outcome-based Education, Assessment, and Accreditation", Invited seminar given to faculty members of School of Engineering, Chulalongkorn University, August 13, 2010
- Wecharatana, M., "Thailand Sustainable Development –Technology Information Towards Sustainability", Invited lecture, Thailand Sustainable Development Conference, organized by Siam Cement Group, Thailand, October 14, 2010
- Wecharatana, M., "Body of Knowledge, Education and Accreditation for the 21st Century", Invited presentation given to Thai Higher Education, Office of Higher Education (OHEC), Ministry of Education, Thailand, August 6, 2009