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3. To stimulate and support education at the university level

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Editorial Note

Since Journal of Thai Interdisciplinary Research (JTIR) has indexed in ACI (https://www.asean-cites.org) and TCI of tier 1 (https://www.tci-thaijo.org/) since 2006 to present. The journal aims to provide an interdisciplinary platform for the dissemination of current knowledge and advances in the interdisciplinary science and technology research. To further enhance its international reputation and prepare it for submitting to the international indexing journal database, the editorial board , therefore, has had the meeting resolution to change the journal title to "Interdisciplinary Research Review" or IRR, starting with the first issue in Vol.14, No.4 (July to August, 2019). IRR sets to serve as an international platform for the dissemination of current knowledge and advances in the interdisciplinary science and technology research. Areas covered include Agricultural and Biological Sciences, Biotechnology and Agro-Industry, Chemistry and Pharmaceutical Sciences, Medical Sciences, Nursing, Computer and Information Technology, Engineering and Industrial Research, Water Engineering and Sciences, Environmental and Natural Resources, and Physical Sciences, Mathematics and Statistics, Social and Humanities Sciences.

This issue contains of ten research articles in diverse fields: (1) Long-term care (LTC) system for the elderly in Japan, (2) Does predation risk affect body size and shape ontogeny in the silver barb *(Barbonymus gonionotus)*?, (3) Can migration solve income inequality problem?, (4) Defining risk thresholds: Appropriate body mass index cut-off for hypertension in Thai Cohort Study, (5) Study on physical, optical and luminescence of zinc tellurite glassese doped with bismuth oxide, (6) Spectrum allocation scheme on multi-user MIMO cognitive radio systems, (7) Social, religious, recreational and medicinal usage of cannabis in India and Thailand, (8) Norodom Sihanouk's special relationship with North Korea: A Preliminary Survey, (9) The occurrence of passive intermodulation and troubleshooting in Thailand mobile industry, and (10) Data mining model and application for stroke prediction: A combination of demographic and medical screening data approach.

The Editorial Board of the IRR encourages anyone to submit articles for evaluation and review. The processes of submission, review and publication of articles are described on the journal's website, https://www.tci-thaijo.org/index.php/jtir. The Editorial Board and Committees of the IRR sincerely thank all peer reviewers who have sacrificed their time to help us produce a better journal, and also wish to thank all teachers, researchers and other academicians for submitting their valuable research to this journal. Finally, we thank readers of our journal who help to spread the knowledge and benefits gained to others. With your feedback and suggestions, we will strive to improve the quality and relevance of the IRR.

Yongyudh Vajaradul
Editor
Interdisciplinary Research Review

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Long-term care (LTC) system for the elderly in Japan

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Abstract

This qualitative research aims to study long-term care (LTC) system for the elderly in Japan, it is using in-depth interviews to collect data from government and related private sectors, including the Health and Welfare Center (Wakaba), Shukutoku Kyoseien Institute and Shalom's Young Leaves Institution. The findings are: 1) The target group under LTC insurance is divided into 2 categories: Category 1: people aged 65 or over who request care or support services for whatever reason, Category 2: people aged 40-64 who suffer from specified 16 diseases, caused by aging. 2) Types of long-term care services included: (1) LTC requirements for levels 1-5 (2) Support requirements protection for levels 1-2 (3) Not certified; people who are still self-help, can get health promotion services for LTC preventive care in general. 3) Strong points and weak points: Strong points are (1) All forms of long-term care are similar but differ according to individual elderly situation (2) Co-payment between the government and the service users, who pays only 10-20% of their income. (3) Community-based services where people in the community participate in providing care services for the elderly to reduce hospital or institution costs, and keeping the elderly close to their family. (4) Services provision limited according to the classification of physical and mental conditions approved by the board. A Weak point is inadequate number of LTC workers to perform LTC services.

Keywords: Long-term Care System, Elderly

Article history: Received 6 March 2019, Accepted 30 August 2019

1. Introduction

According to the statistic report of UN 2017 Revision, the world's population reached nearly 7.6 billion. Globally, the population aged 60 years or over is growing faster than all younger age groups. As fertility rate declines and life expectancy rises, the phenomenon, known as population aging, is occurring throughout the world. In 2017, there were an estimated 962 million people aged 60 or over in the world, comprising 13 percent of the global population. [1] With the same cause, the Japanese population is aging rapidly with longer life expectancy and lower birth rate. By 2010, the number of Japanese people aged 65 years and over had almost doubled from 15 million to 29 million, making 23% of the population and the highest proportion in the world. Currently, 33% of Japan's population are 60 years up. [1,2] The change of national situation led to reconsideration of the policy and LTC insurance system. In 2015, Thailand has the second highest proportion of elderly people (aged 60 and over) among the 10 ASEAN member countries at 15.8 percent, or about 11 million people, followed by the Republic of Singapore at 17.0 percent. [3, 4] Japan has developed a LTC system and become one of the best LTC models at present. LTC Insurance Act was introduced in December 1997. During this time, efforts have been put for continuous development until LTC system can be established later on in 2000. The Japanese LTC insurance scheme is characterized by a clear classification of the elderly based on physical and psychological needs, benefits return, etc. Japanese LTC insurance system covers preventive services, health promotion, rehabilitation and long-term care of different levels. Thailand is in the early stages of developing the appropriate LTC system. This study aims to contribute towards LTC system for Thai elderly in the near future.

2. Objective

To study the long-term care system in Japan to use as a guideline for developing a LTC system appropriate to Thailand.

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3. Scope of the Study

3.1. Scope of Content

This study the content of LTC system in Japan as a guideline to develop a LTC system appropriate to Thailand.

3.2. Scope of Research Sites

Government and private agencies involved in LTC service, namely the Health and Welfare Center, Shukutoku Kyoseien Institute and Shalom's Young Leaves Institute which all 3 are located in Chiba Prefecture, Japan

4. Terminology and Definitions

Long–term Care Model: Public health services and social services that are held to meet the needs of elderly people who can't move, can or cannot help themselves, or people with disabilities to be able to live a normal and happy life. The service must be provided appropriately to the context of each area.

Guidelines: the good practices which are useful for developing of LTC system in Thailand.

Elderly: male and female aged 65 years and over who are in LTC insurance system.

Relevant agencies: Government and private agencies involved in LTC system in Japan, i.e. municipal health and welfare centers, special homes for elderly care.

5. Research Methodology

The qualitative research design is chosen because it is the best approach for the purposes of the study. In-depth interview is conducted to collect data from the LTC system and services providers. The target groups for this study are the representatives of agencies involved in LTC; both government and private from 3 selected agencies; Health and Welfare Center (Wakaba), Shukutoku Kyoseien Institute and Shalom's young leaves Institute.

The instrument for data collection: Semi-structured interview guideline was used during in-depth interview session to collect data in details through face to face conversation.

Data collection data analysis: Data collection and Voice Recorder together with documents and literature review are transformed into an information system to be analyzed through content analysis approach and present in the descriptive research report.

6. Findings

The result of the study can be concluded as follows:

6.1. Long-term care insurance system

The LTC Insurance Act was promulgated in December 1997. Later on, in 2000, LTC insurance system was established and continuously developed to LTC system. In Japanese national administration, the municipality is the primary agency to take care of the people who are in need, the municipality will have agencies in each county to serve them. Therefore the municipality must spread it's agencies to all county to serve them near their home. So the elderly and families who need LTC can reach them conveniently at their local site either contact the Ahshin Care Center or local Health and Welfare Center.

At the first step, people who need to assess a LTC system can consult the Anshin Care Center. (Anshin in Japanese means comfort) This Center is based on a government policy that 3,000-5,000 people justify the need to set up Anshin Care Center to help citizens who are struggling and defending their rights. Anshin Care Centers are set up nationwide under the supervision of the municipality. In Japan, the municipality is the primary agency in providing care to the people, when they are in trouble, the municipality will have agencies in each county to serve them. So if the elderly and families need long-term care, they can reach out to Anshin Care Center near their home or contact the local Health and Welfare Center.

Steps to assess LTC service

Step 1: Applicants and families must applying for LTC insurance at the Health and Welfare Center or the elderly institution (i.e. nursing home support companies, nursing institutions or Anshin Care Center) may do it for them instead. The documents required are application forms, health insurance cards and long-term care insurance cards. There are 2 categories of insured persons under the LTC Insurance System ; (1) Category 1: people aged 65 or over who request for care or support services for whatever reason (2) Category 2: people aged 40-64 who suffer from specified 16 diseases, caused by aging such as terminal cancer or rheumatoid arthritis and require care or support.

Step 2: Approval of LTC services starts with the municipal officials examining the physical and mental health of the applicant's home, contact the doctor to provide a formal document as a feedback on the patient's medical history then pass to the committee for consideration to give approval for LTC in accordance with the criteria set for each category.

Step 3: If the applicant is dissatisfied, the applicant can submit an appeal within 3 months from the date of approval. Applicants or families who have been approved a move to another location, can contact the LTC center at that new location.

Evaluation into service

Everybody who applies for LTC system has to be tested by 25 criteria of basic health checklist to appraise the elderly ability to do their daily life function, then classified into 2 main groups 1) the applicants

who do not pass the checklist can be sub-divided into 2 categories (1) people who should get LTC requirements for levels 1-5 (2) people who should get protection for levels 1-2 and 2) the applicants who pass the checklist can be sub-divided into 2 categories (1) people who stay alone and need help should get protection for long-term care services (2) people who stay alone but do not need help should get general care in order to prevent long-term care more intensive.

6.2. Types of Long-term care services

LTC Services are divided into 3 levels as follows

(1) Services requiring support for level 1-2: people who can do most of their daily routine, but require help for some activity, or getting worse in doing daily life routines, can receive life support protection either at home or at the institution, including: helper, day service, home service, short stay, facilities rent/buy, home improvement, home visit by nurses to take care of their health. Institutional Services are physical rehabilitation and life support services such as cooking, cleaning done by helpers. Some families bring the elderly to the daycare for health care, self-help training, exercise, and preventive service to delay future LTC.

(2) Elderlies requiring long-term care for level 1-5: people who got worse in doing daily life activities or memories decline. In the 1-2 stage, they receive some LTC services but not all, while in the 3-5 stage they need all LTC services because they cannot live otherwise. Most institutional services include special nursing homes, health care center for the elderly who need nursing care etc.

(3) Health Promotion Services: people who do not need LTC services. The elderly who can't live alone will get long-term preventive care activities, including rehabilitation services in institutions. (Short-term as an outpatient) and home visits in cooperation with the community, supported by the institution. In addition, elderly people who don't need help, will get long-term preventive care activities, such as elderly leadership training, exercise (fitness) and exercise in public (Taichi, for example).

6.3. Long-Term Care Services

Data from interviews with 3 organizations (government and private sector) Health and Welfare Center (Wakaba), Shukutoku Kyoseien Institute and Shalom's Young Leaves Institute. Relevant information is as follows:

Wakaba Health and Welfare Center is a subdivision of Chiba Municipality at district level. It is a government agency providing support services included:

(1) Free diapers: Elderly people with unconscious urine or stools, and those who receive services at home from their health insurance scheme, people who registered as Chiba residents, poor people without asset or bank deposits, the elderly people with incomes below 3,604,000 yen per year or families with less than 6,287,000 yen per year, can get this service. New regulations from September 2018, the person who pays tax is not entitled to receive this service because it indicates income. The service is available for the elderly classified as LTC requirement at level 1-3 only (not level 4-5). The period for free diaper service is 1-2 years. After that, the elderly have to go to the Municipal Office to check the condition for LTC and resume their insurance.

(2) Contact emergency signal: Elderly people living alone, when they press the emergency button, the system will connect a call to the center, when the center receives an emergency signal, it will automatically contact back, if no one answer, it will automatically contact the ambulance to go to that elderly place immediately.

(3) Equipment for daily living: 1) Microwave oven 2) electrical signal receiver 3) Fire extinguisher. Service Condition, elderly 65 or over and alone, if smoke is present in the room, the signal or the heat controller will cause the signal to ring and connect to the center, when the center recognizes Hazard Types, it will coordinate the relevant agencies to ensure safety. The municipality encourages the elderly to use microwave oven to minimize fire risks.

(4) Wheelchairs: Wheelchairs have many different types depending on the needs of the elderly. Service Condition, the elderly aged 65 and over, legs are not strong, can't walk normally.

(5) Community care: In each community, there will be 1-2 community representatives usually are ordinary people, retired, no minimum educational qualification, work with heart, volunteers student who informed the staff or relevant officials then go down to see the elderly. Community care is a national policy, there are regular meetings between the municipality and the community.

Shukutoku Kyoseien is the institute affiliated with Shukutoku University and work under Buddhist concept to help people in the community. This institute has 5 floors; B1,1 are patient treatment clinic and day care service. Floors 2, 3, and 4, are elderly LTC accommodation. The institution's services are aimed at ensuring satisfaction for all the three parties: the elderly, their family and the staff through their strong cooperation. The concept of the institute is "The three partners: the service user, their family, and the staff must work in collaboration to create better **Quality of life. (QOL)**" Today, the concept is changed into "The three partners: the service user, their family, and the staff must work together to achieve their **Happiness of life (HOL)**." The institution provides physical and psychological care. For physical aspect, there are clinical and nursing care for elderly, while for psychological aspect, activities are organized for the happiness of the elderly, their families and the staff focus on making the elderly feel at home. Institute services include:

(1) General Clinic: providing treatment for approx-

imately about 20 patients per day, including health check-up service for the elderly in accommodation. The clinic is prompted with physicians, pharmacologist and modern medical instruments e.g. CT scan, etc.

(2) Day Care Center: there are 2 service groups 1) Services for the unhealthy elderly, lack of strength, seldom spoken, unsteady mood 2) Services for the elderly with Alzheimer or Dementia or who can not communicate. Keeping the elderly at home all day will make the family very tired. Therefore the families take them to daycare to relieve frustration, get rest and ready to take care again during the night. The service here is well prepared to create a home-like atmosphere such as cooking, tomato planting, walking around the house, festive activities.

(3) Special elderly nursing home: a LTC nursing home. Each elderly live in one room and for group of 10 person it is referred to as a unit. This nursing home has 100 elderly people (10 units). The institute has about 70 staff comprising of caregiver, day care staff, home care staff and care managers, etc. Each elderly will have 1 caregiver to provide varying services according to their limitations and needs.

The institute arranges Buddhist festival and Dharma convention for the elderly and their family to participate. There are Buddhist monks from various denominations who volunteer to give lectures on Dharma, each of which is different in style. In general, the proportion of Buddhist discourse around 20%, while news, Japanese drama, tradition, and cultural aspects are approximately 80%. This kind of activity is held every Friday, about 40 times a year. The president of Shukutoku is a Buddhist who does not want anyone to miss the opportunity to learn about Buddhism, while other institutions don't have this activity. Everybody who has experienced the loss of relatives or loved ones can come to worship and pray to feel at ease. This is the main purpose of organizing Buddhist Dharma meeting. After listening to Dharma, the president would lecture that death is something common and read the memoirs of the deceased, his or her history, in order to mourn and honor the deceased and comfort relatives, then the families make merit for the deceased. The institute will record the names of all the dead persons who have lived here to commemorate them. At the last period of life, the institution does not focus on medical caring, but on peaceful natural departure, comfort, like life ending at home and ascend to heaven. The clinic and the doctor can provide palliative care for the elderly until the final moment of life without having to die at the hospital.

Shalom's Young Leaves (Chiba city Wakaba Ward) is a branch of Shalom Higashikurume in Tokyo, which is under the Social Welfare Corporation San Iku Live. Shalom is an institution holding concept derived from the teachings of Christianity. The concept of the institution is to choose an elderly person who wants to stay at home, be taken care at home and the institution will go to take care of the last moment of life at home. There are 4 floors in this institution: 1st floor and 2nd floor are elderly people care center, the 3 rd floor is a church area providing social care services, which is the main activity, 4th floor is a special residence for homeless people, with food donated by Shalom to these people. This institution has been established for 24 years by Christian people volunteers to help the disadvantaged people. Institute services included

(1) Nursing home care: Nursing home care for the elderly who doesn't want to stay in the institution, but prefer to stay and die at home. Other services provided here are such as self-help training, bathing, physical therapy.

(2) Day Care Service Center: the institution will go to the elderly 's home to provide daily care such as eating, sleeping, communicating with others, sometimes the elderly is brought to the day service center for rehabilitation because of better facilities than at home. An elderly can also come to the daycare service center to get help for their daily lives, such as bathing, dressing, etc.

(3) Home Renovation: is a service from the LTC insurance system, such as floor smoothing, railings fixed, home renovating etc.

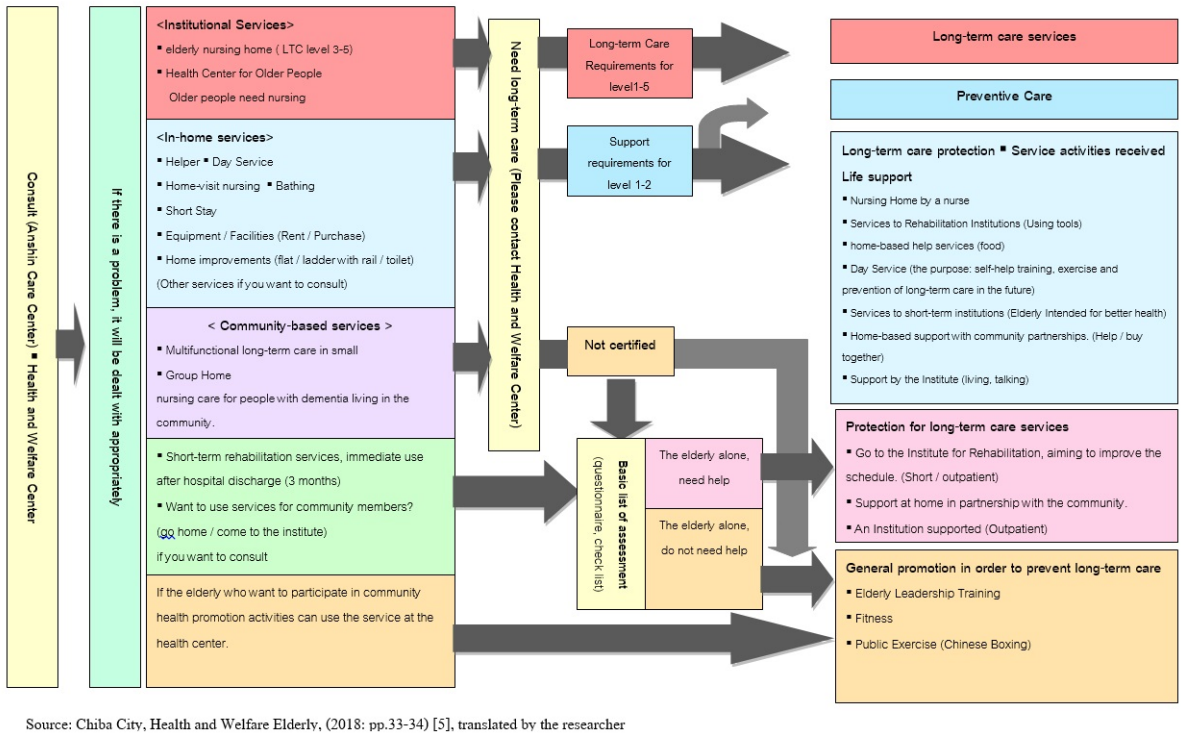
(4) Anshin Care Center is a consulting center for people in the area about LTC insurance system. At the first step, people come to this Center to consult about the insurance system, Anshin Care Center make people feel comfortable, relaxed and free from distress. This center provides information and recommend how to do it. In addition, sometimes the center offers telephone counseling by specialists such as care managers, social workers, insurance staff and nurse who specialize in solving specific problem.

(5) Group Home Rainbow House: while nursing home is a place where the government helps elderly people who can't live alone, Group Home Rainbow House is a community-based business nursing care for supporting dementia in daily life activities. The Group Home Rainbow House cherish the lifestyle in home atmosphere, all rooms are private and well protected for safety.

(6) In-home care support: the helper is sent to take care of the elderly at home.

7. Conclusion

The findings are: 1) The target groups under LTC insurance is divided into 2 categories: Category 1: people aged 65 or over who request care or support services for whatever reason, Category 2: people aged 40-64 who suffer from specified 16 diseases, caused by aging. 2) Types of long-term care services included: (1) LTC requirements for levels 1-5 (2) Support requirements protection for levels 1-2 (3) Not cer-



Source: Chiba City, Health and Welfare Elderly, (2018: pp.33-34) [5], translated by the researcher

Figure 1: Long Term Care Insurance System (Kaigo hoken).

tified; people who are still self-help, can get health promotion services from LTC preventive care in general. 3) Strong points and weak points: Strong points are (1) All forms of LTC are similar but differ according to individual elderly situation (2) Co-payment between the government and the service users, who pays only 10-20% of their income. (3) Community-based services where people in the community participate in caring services for the elderly to reduce hospital or institution costs, and keep the elderly close to their family. (4) Services provision is according to the classification of physical and psychological conditions approved by the board. A weak point is inadequate number of LTC workers to perform LTC services. Shown as figure 1-2.

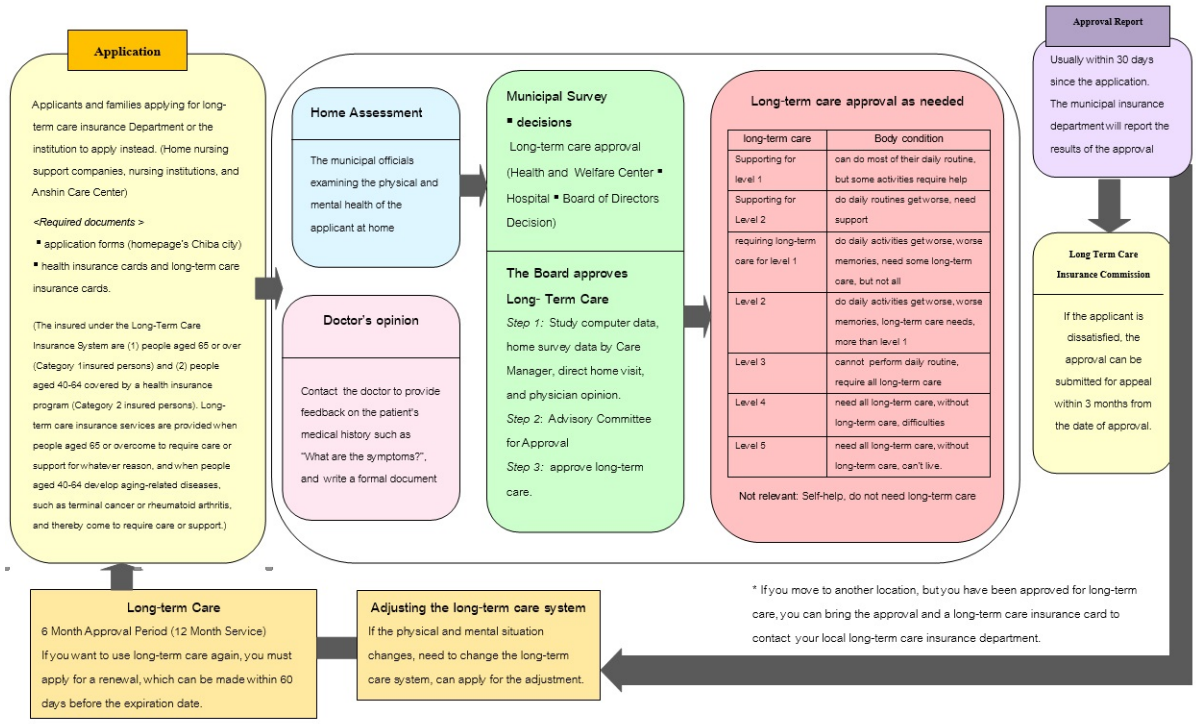
8. Discussion and Recommendations

Discussion

The 3 prominent findings that define LTC system in Japan cannot be compared with other countries since it is based on unique cultural context; the current situation, users' needs of services and service concept.

1) The current situation: The situation and problem at the national, provincial and local levels determine the format of the service. Japan's population is aging rapidly with long life expectancy and low birth rate, by 2010, the number of people aged 65 years and older had almost doubled from 15 million to 29 million, making 23% of the whole population and the highest proportion in the world. Currently, Japan's elderly (60 years up) made up 33% of total population. [1,2] This is the national situation that determines the policy and LTC insurance system. In addition, the rapid increase of people with dementia is another condition that causes higher demand in long-term care services for the elderly. According to data of the World Health Organization report, there are an estimated 36.5 million people with dementia worldwide, who need long-term care. The incidence of dementia is projected to grow from 47 million worldwide in 2015 to 75 million in 2030. [6] For instance, in the United States, nearly 40 percent of the population aged 85 years and older suffer from Alzheimer's and Dementia. An increasing rate has also been found in Japan. Asada (2012) [7] studied the prevalence of dementia among the elderly people aged 65 years and older in Japan using the data from a recent nationwide survey, the results of this survey were collected from seven sites in Japan, the prevalence rate was estimated to be 15.75% (95% CI: 12.4-22.2%) which was much higher than what had been estimated before. Alzheimer disease is the most common illness that causes dementia. Therefore, LTC services are correlated and directly proportional to dementia incidence. LTC for people with dementia such as Group Home, nursing care for people with dementia living in the community, support at home in partnership with the community, etc.

2) The needs of service user: From an exploratory study of the Patterns of Long Term Care in 29 European countries by Damiani et al. (2011) [8], the main findings are the majority of Nordic countries have high



Source: Chiba City, Health and Welfare Elderly, (2018: pp.35-36) [5], translated by the researcher

Figure 2: Steps to apply for long-term care service.

levels of formal care with strong state responsibility for providing formal care [9] including Denmark [10]. That means these countries have to shoulder a big amount of budget for LTC. According to the research of Ayumi et al. (2014) [11] study clarified combinations of community-based services and factors associated with each combination in the Japanese LTC insurance system which are 9 categories found: (1) day care; (2) daycare and assistive devices; (3) day care, home helper, and assistive devices; (4) home helper and assistive devices; (5) assistive devices; (6) home helper; (7) daycare and home helper; (8) home helper, visiting nurse, and assistive devices; and (9) others. The use of services was determined by care need level, cognitive function, living arrangements, and medical procedures rather than characteristics of care management agencies. These researches show that the important factor in providing long-term care services is the needs of the elderly. As a conclusion, in Europe, formal services and the development of nursing homes for older persons are needed to provide long-term care, rather than informal services. But In Japan, there is a combination of institutional services, home services, and community-based services to form long-term care services based on the needs of the service users.

3) The service concept is very important in defining the service system equally to government policy, current situation and needs of a service user. The concept is the identity of the institution which represents the image of the institution explicitly seen. From visiting and interviewing the 3 selected institutions; Health and Welfare Center (Wakaba), Shukutoku Kyoseien Institute and Shalom's young leaves Institute revealed that the institutions strictly recognize "Philosophy, Mission, and Ethics" in doing their work. The concept of the institution is at the heart of the services. In the past, long-term care services focused on well being or the ability to do daily activities, but nowadays, the emphasis was on honoring and respecting humanity, as defined by the World Health Organization that "the activities undertaken by others to ensure that people with or at risk of a significant ongoing loss of intrinsic capacity can maintain a level of functional ability consistent with their basic rights, fundamental freedom, and human dignity" [6]. In consideration of service, the pattern requires an understanding of the present situation, and human nature, not just the basic needs, but the internal needs; self-esteem, joy, peace, spirituality, respect in each other's differences. The accomplishment of the service business is not based only on competitive ability or profitability, but it is the result of the inner growth of the minds of service user and service providers.

Recommendations

This study should be used as a guideline for developing the LTC system in Thailand.

8.1. Recommendation for Improvements at the Policy Level

(1) The government should have a law on LTC insurance to take care of the elderly and reduce the burden of expenses which will increase in the future, as well as be able to plan and implement effective LTC service.

(2) The government should have the policy to enforce all sectors to participate and cooperate in the LTC system for the elderly by clearly defining roles and contribution for each sector.

8.2. Recommendations for Improvements at the Operational Level

(1) Local administrative organizations should work collaboration with the Provincial Public Health Office to examine the elderly, classified by physical, psychological and social conditions, in order to make a clear and convenient classification for LTC services provision.

(2) The local administrative organization should issue a certificate of evaluation for the elderly to make the family aware of the elderly physical and psychological conditions. It is useful for choosing the type of service to meet the needs of the elderly.

(3) Local administrative organizations should inspire the community to participate in caring for the elderly such as arranging a contest for the best participative community

(4) The service unit or the sub-district health promotion hospital should be fully supported to provide a variety of services, including protection services, and LTC services.

(5) The service unit or the sub-district health promotion hospital should focus on proactive services rather than routine-based services, focus on providing services at home and giving consultation to their local families.

8.3. Recommendations for Further Studies

The further study should be about problems and factors affecting the LTC system for the elderly in Thailand in other aspects, i.e., budget, a readiness of local administrative organizations, provision of other various types of services.

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Does predation risk affect body size and shape ontogeny in the silver barb *(Barbonymus gonionotus)*?

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Abstract

We studied here the effect of predation risk on size and shape during the development of the Cyprinid fish *(Barbonymus gonionotus)*. In the experiment, juvenile silver barbs (*Barbonymus gonionotus)* were developing either together or not together with the predator snakehead fish *(Channa striata)* during 25 days. Predation was limited by isolating the predator from the silver barb with a net. In replicated trays, 60 fish were randomly selected and compared before and after the experiment in presence and absence of the predator. The experiment was replicated three times. Fourteen landmarks were recorded on the fish body and a generalized Procrustes superimposition was performed. Analyses of variance and linear discriminant analyses were used to detect effects of the predator presence on body shape and growth pattern. Results show that if presents, effect of the predator on size and shape evolution in silver barbs is very subtle. A small increase of size and a decrease in relative caudal peduncle height could be reported in all cases suggesting either that the predator could exert directional selection or that developmental plasticity induced by the predator was present. In the case of shape, this developmental plasticity appears to be maladaptive in the experiment because the predator may have selected for these shape attributes in the tank showing the highest predation rate. Finally we found that shape variation decreased with development suggesting that phenotypic canalisation was acquired during the ontogeny of the fish but that size differences among individuals were accumulating with ontogeny.

Keywords: developmental plasticity, predation, fish

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1. Introduction

It has long been known that adaptive phenotypic plasticity might be advantageous when it allows a genotype to have a broader tolerance to environmental conditions and hence higher fitness across multiple environments including interaction with predators (see review in [1]). Several examples in plants or animals have shown that predation risk could induce phenotypic changes during development due to adaptive phenotypic plasticity or local adaptation [2 – 6]. Trinidadian guppy fish (*Poecilia reticulata*) are well studied in this regard. For instance, it was reported that male fish that lived upstream and exposed to low predation risk were more colourful or brighter and larger in size than the male fish living downstream exposed to high predation environment [7]. In this fish species, predation risk can also alter metabolic rate and growth rate [8]. It has been shown that predation risk can indeed generate change in body shapes for the Trinidadian guppy [9]. However, few studies have been addressed in the laboratory, where predation and generations can be controlled, and it is invariably difficult to attribute the relative importance of phenotypic plasticity and local adaptation for understanding the role of predation risk.

In this study, we investigated whether the presence of a predator was altering size and shape changes in the silver barb (*Barbonymus gonionotus*). *Barbonymus gonionotus* is a common native Cyprinid fish in South-East Asia [10, 11] and it is found in rivers, streams, floodplains and occasionally in reservoirs, although it is likely that this Cyprinid species prefers standing water habitats to flowing waters [12]. Furthermore, this fish is one of the most important freshwater species in commercial, aquaculture and inland fisheries [13, 14]. In Thailand, reintroduction program of this fish species has been implemented ev-

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ery year in river and natural habitat by Department of Fisheries when there are special occasions [15]. In nature, the silver barbs, especially juveniles, are exposed to several predators (both terrestrial vertebrate predators and aquatic fish predators), including the common and native snakehead fish (*Channa striata*) [16]. In the laboratory, it was shown that the snakehead fish was a predator for the juvenile silver barb [17]. If adaptive phenotypic plasticity as response to predation risk is present in the juvenile silver barb (*Barbonymus gonionotus*), we would expect changes in size and shape depending on the presence of the snakehead fish (*Channa striata*) as a predator.

2. Method

2.1. Experimental design

About 1800 juvenile silver barb fish were obtained from commercial farm (Chalong Pun Pla, Chachoengsao Province, Thailand WGS84: N 13° 34' 13.7"E 101° 7' 23.0") in October 2017. Because fertilisation is under control in the farm by using a few males and females for mating over one night, age of the fish was the same for all fish when they arrived at the laboratory, Department of Aquatic Science, Faculty of Science, Burapha University (27 days after fecundation). Furthermore, because fertilisation is external in Cyprinids and several males were used during the breeding process, the obtained population was outbred. Six pools of fish were obtained from the same stock of the farm and then placed in six circular independent tanks with 300 litres of water and with air pumps to aerate each tank. The number of fish at the beginning of the experiment was approximately the same in each tank (around 300). In three of these tanks (treatment: T1, T2 and T3), fish were exposed to a predator (the snakehead fish) whereas the other three tanks had no predators (control: C1, C2 and C3). Fish were fed ad libitum during the whole experiment twice a day in the morning and in the afternoon with commercial dried artemia. For avoiding active predation on fish, the predator was isolated from the silver barb by a net. However, the net was large enough to allow the silver barb to go in the compartment of the predator. Therefore, it was not impossible that a few fish were eaten by the predator. Sixty fish were taken at random in every tank and anaesthetized with clove oil and digitized at equal focal distance at the beginning and at the end of the experiment (25 days after). Since photographed fish were exposed to clove oil, they were removed from the original sample. At the end of the experiment, the number of remaining fish was counted to provide an estimate of mortality rates (Table 1). Fish were photographed after the experiment and timing of the photography was recorded to know whether there was potential variation within the day.

2.2. Quantitative shape analysis and statistical methods

In order to quantify shape variation among tanks and changes before and after the experiment, fourteen landmarks were digitized on the fish body (Figure 1). In total, 720 fish were digitized. In addition, 12 fish were photographed anaesthetized and photographed two times in order to have an idea of percentage measurement error due to digitization bias (anaesthesia, photography and digitization) by comparison to interindividual variation within a tank. Shape components and size were later obtained by the use of a partial generalized Procrustes analysis on digitized coordinates [18]. In this analysis, all fish configurations of landmarks were scaled to unit centroid size, translated on their centroid and rotated in order to remove information due to scaling, position and orientation. The superimposed coordinates were later projected onto the tangent shape space so that they could serve as shape variables in further analyses [18]. Procrustes superimposition and projection was done in R [19] using the functions developed by Claude [20].

Percentage measurement error for size and shape was obtained by following the ANOVA procedure [21] adapted for Procrustes data (see [20, 22]). More precisely, for size, expected variance due to error and individual variation was assessed from the ANOVA and was summed up; the ratio of expected variance due to error on the sum of expected variances provided the percentage of measurement error. Shape measurement error was obtained similarly by using a Procrustes ANOVA [23]. In that case, traces of expected variances were taken into account.

Pairwise proportion tests (Chi squared test) were used to estimate different mortality between tanks at the end of the experiment. In order to have an idea of selection, we used the mortality rate in control tanks (tanks without predators) and compared that mortality rate with the one estimated in the tanks containing a predator.

In order to estimate size and shape changes before and after the experiment, we performed mixed linear models [24]. For size, which is univariate, we tested whether differences could be reported before and after the experiment, whether size changes was greater or smaller in the group exposed to the predator by comparison to the control group, and whether these differences are replicable among groups. In the model, time was therefore considered as a fixed effect (before and after the experiment), treatment (with or without predator) as a fixed effect, the interaction between these two effects as a fixed effect, and tank as a random effect. The full model is, therefore, on the form size ~ time x treatment (fixed effects) + tank (random effect). Significance of effects was assessed by using Akaike Information Criterion (AIC). Differences at the end of the experiment were tested by AIC and LRT test using group as random effect and models were run with the

Table 1. Initial number of fish in each tank and mortality during the experiment.

	Initial number of fish	Mortality during the experiment
tank C1	298	12
tank C2	298	55
tank C3	298	12
tank T1	300	29
tank T2	291	46
tank T3	290	18

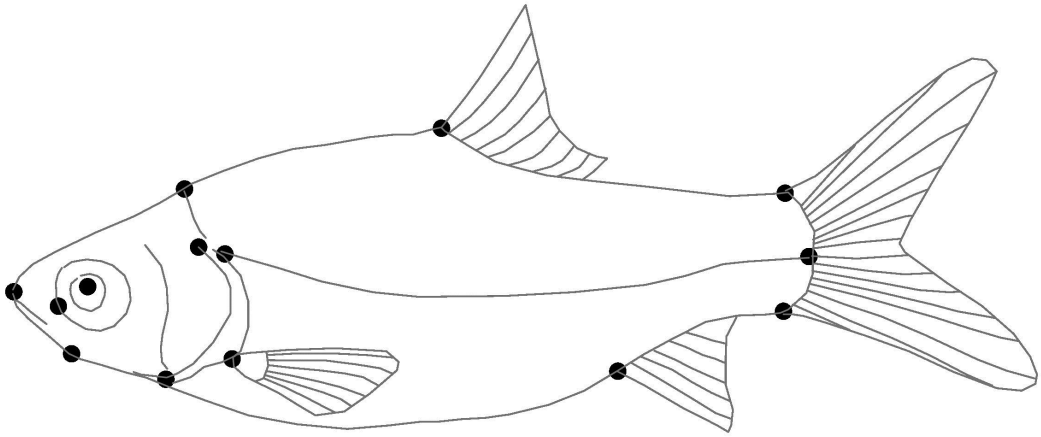

Figure 1: Location of the fourteen landmarks used to quantify shape variation.

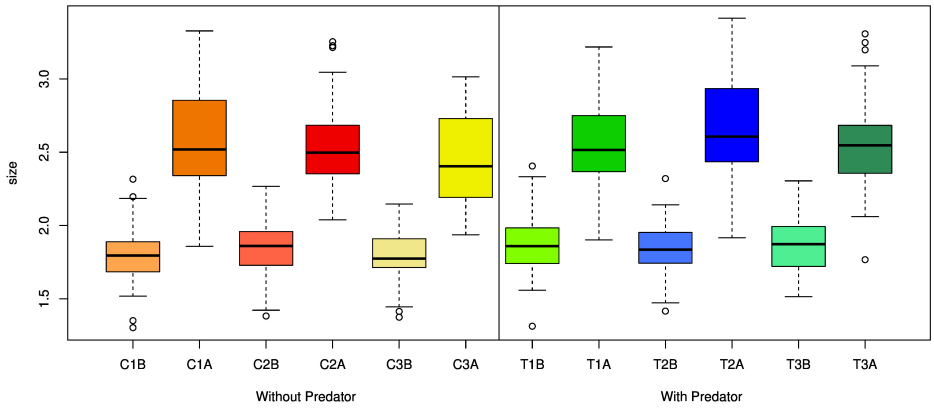

Figure 2: Box plot of size variation among tanks and with and without the predator effect. Letter C refers to tanks without a predator and letter T refers to tanks with a predator. Letter B refers to measurement before the experiment and letter A refers to measurement after the experiment. The numbers correspond to individual tanks. Size is expressed in centroid size (unit is cm.)

package lme4 in R [24]. We also checked for differences at the end of the experiment by comparing size between each tank receiving a predator at the end and control (for this we pooled size in the 3 tanks that were not receiving any predator). For shape, because there are much more variables than tanks, differences were estimated similarly by using an ADONIS based on mean shape for each tank (permutational MANOVA using euclidean distances among groups). We first computed a mean-shape for every tank and then analysed whether there was any effect of time, treatment or interaction on shape variation with the package vegan [25]. We also tested for shape differences between each tank that received a predator and pooled control tanks at the end of the experiment.

In addition to these statistical analyses, we performed canonical variate analysis on shape data and between group PCAs. In these analyses, tanks were used as group and the ordination between groups gave an idea about the importance of treatment and treatment x time interaction. We expected to find less variation among groups at the beginning of the experiment than at the end since fish were naive to presence of the predator at that time. Related shape variation was reconstructed on PC or CVA axes following procedures of Claude [20, 22]. In CVA, to obtain sketches of shape variation, linear discriminant function had to be rescaled according to intragroup variation. In addition, we pooled all the fish in the control tank from the end of the experiment to compare them to each of the tank that was receiving a predator in terms of size and shape. This last strategy allowed us to check whether the predator could have an effect on shape variation for each tank. We performed ANOVAs for size and MANOVAs for shape. For shape, since matrices were not singular, we used the non-null PCs as variable instead of Procrustes coordinates [20, 22].

We finally estimated any role of mortality rate on shape and size by applying regression (univariate for size, multivariate for shape) on tank mean size and mean shape or on tank mean size variance or tank mean shape variance (taken as the trace of variance covariance matrices for shape in every tank).

3. Results

Size and shape measurement errors were reaching 0.5% and 48.5% respectively. In both cases, interindividual variation was larger than intraindividual variation. For shape, that value means that on average difference between two individuals was about two times larger than difference between replicates on the same individual.

Mortality rates among control experiments showed no difference between tank C1 and C3 but there was an increase in tank C2 (p-value < 0.0001). Mortality in tank T2 was stronger than in tank T1 (p-value = 0.019) and T3 (p-value <0.001), whereas there was no significant difference between T1 and T3. When comparing mortality in tanks with a predator with mortality rate in all control tanks (7.8%), we found an increase only in tank T2; which showed that selection could play a role in this tank only.

When considering all fish, the treatment and time had an effect on size but the interaction were not significant (Figure 2). However, treatment was found to decrease the AIC when considering only tanks at the end (AIC=196.84 against 197.58) although the LRT test failed to be significant (p-value = 0.098). In average, sizes were increasing when fish were exposed to the predator. Significant size differences among tanks were noticed at the beginning of the experiment, showing a slight increase of size for fish that were also exposed to the predator. By analysing the timing of the pictures, we could notice that fish measured at the beginning of the experiment were just receiving food in the control group by comparison to the treatment, and that fish measured in the group exposed to the predator were measured about 12 hours after the control. Since centroid size summarizes increase of size in all directions, this result rather suggested that size variation among groups at the beginning of the experiment was more an artifact coming from the timing of fish feeding (fish just fed were larger just after their meal) and from the fact that tested fish had a bit more time to grow (the difference in size was about 15 times smaller than the averaged difference in size between the beginning of the experiment; therefore that interpretation can make sense.). Because fish were measured in the same order at the end of the experiment, a similar effect could play also at the end of the experiment, but it is more unlikely since growth was much more advanced at that time. When pooling the size of all control fish together and comparing it with fish in every tank containing a predator, we found an increase of size in all tanks but that increase was significant only in tank2 (Table 2). We did not find significant relationship between size and mortality rate (r = 0.54, p-value = 0.27) even if the relationship was positive. There was no relationship between size variance and mortality rate as well (r = 0.10, p-value = 0.85). Finally, we found a significant increase of size variance in average for every tank from the beginning to the end of experiment (Table 6, Figure 7).

We found significant shape differences between the beginning and the end of the experiment (certainly resulting from allometric growth) (Table 3). These shape changes concerned changes in head to body proportion as well as change in the position of the deeper body (more backward with age) as seen on the first axes of the between group PCA (Figure 3) or on the canonical variate analysis (Figure 4). The ADONIS performed on mean shape among tanks showed a significant effect of time, a marginal effect of treatment (probably artifact of time in the day of picture -see before-), but there was no interaction meaning that the

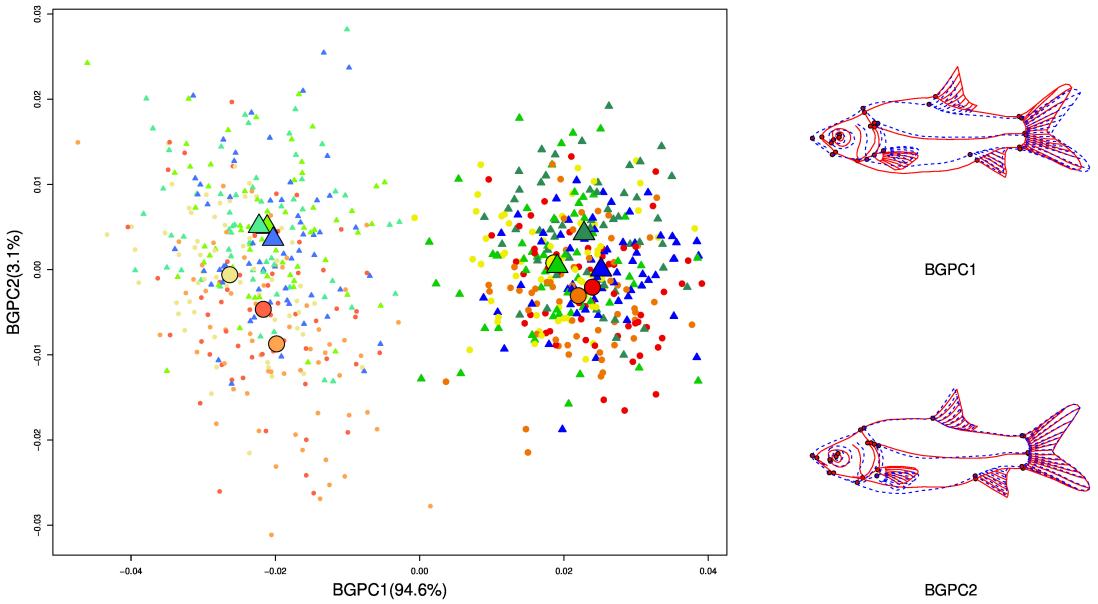

Figure 3: Between-group PCA. Colours of symbol are defined as for figure 2: upper triangles are for fish shapes in the presence of the predator, circles when the predator was absent. On the lateral side of the plot, we represented extreme shape change on each axis. The blue shape corresponds to the warped shape for the minimal value on the axis, and the red one to the maximal value on the axis

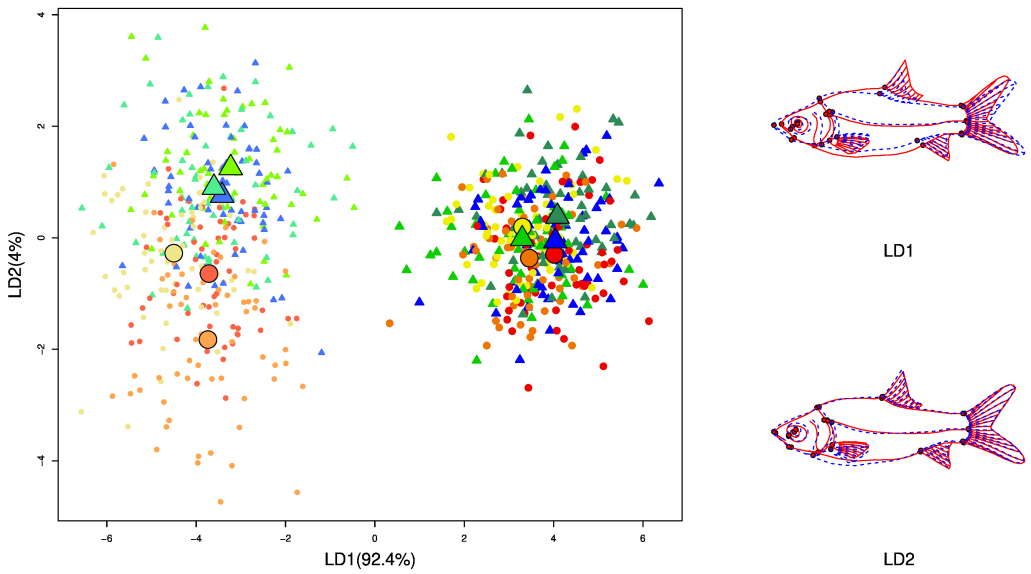

Figure 4: Canonical variate analysis among tanks before and after the analsysis: colours and symbols as for figure 3. The sketch on the lateral side of the plot shows extreme shape differences along each axis (red: maximal score; blue: minimal score).

Table 2. Relationship with size against time, presence or absence of a predator (treat), and tank as random variable. We provide parameter degrees of freedom as well as AIC (Akaike Information Criterion) for each model.

model	DF	AIC
Size ~ time × treat + (1|group)	6	94.734
Size ~ time + treat + (1|group)	5	93.08
Size ~ treat + (1|group)	4	859.2
Size ~ time + (1|group)	4	95.81
Size ~ 1 + (1|group)	3	860.26

Table 3. Pairwise differences in size between tanks that received a predator and tank without a predator (control).

Group	n	Average size after the experiment	ANOVA (control versus treated tank) F value	P-value
Control	180	2.515	-	-
Versus Tank 1	60	2.549	0.54	0.465
Versus Tank 2	60	2.643	7.11	0.008
Versus Tank 3	60	2.558	0.85	0.357

Table 4. ADONIS on fish shape against time (beginning/end of the experiment), treat (with or without the predator). In this analysis, shape was averaged for every tank to avoid pseudoreplicaiton bias.

effect	DF	SSQ	F value	P-value
Time	1	0.00577	207.61	< 0.001
Treat	1	0.00012	4.291	0.09
time:treat	1	0.00005	1.89	0.14
Residuals	8	0.00003		

Table 5. Pairwise MANOVA between control and each tank that contained a predator at the end of the experiment.

	Pillai	Approx F	P-value
Tank 1 and control	0.216	2.467	<0.001
Tank 2 and control	0.165	1.77	0.02
Tank 3 and control	0.358	4.994	<0.001

exposure to the predator had no significant effect on shape changes or that it was subtle by comparison to error variation (Table 3). The between group PCA (Figure 3) and CVA (Figure 4) showed that there was more differences among tanks in the beginning of the experiment than at the end; suggesting that the presence of the predator was not altering shape variation in the fish. Variation at the beginning of the experiment was mostly found on the second axes. Shape variation here corresponded to change in belly curvature, which was certainly related with the timing related to fish feeding. Furthermore, a PCA on all individuals was performed (not shown) and suggested that interindividual variation decreased with age, possibly as resulting from a canalisation effect. This was later confirmed by a crossed two factor ANOVA on shape variance for each tank (Figure 8, Table 6).

When applying a CVA on the 6 tanks at the end of the experiment, differences between tanks with and without the predator appeared on the first axis but there were considerable overlaps (Figure 5). Fish exposed to the predator tended to show a narrower caudal peduncle and a smaller head by comparison to body (Figure 5).

Taken individually, we looked at differences between each tank that received a predator and all the fish coming from tanks without predators (Figure 6). We found significant differences between all tanks and the control (Table 5). Interestingly, in all cases, we found some common patterns associated with the presence of the predator; this included the shape of the caudal peduncle (narrower when a predator was present), and the relative length of the head compared to the body (shorter when the predator was present). Levels of significance or percentages of good reclassification (not given here) were not related with predation or mortality rate. For instance, in tank 2 where the predator was more active, differences were more subtle than in the two other tanks with the predators. This indicates that there was a potential shape change induced by the predator but that shape phenotypic plasticity, if present was not adaptive. In other words, the predation went against phenotypic plasticity, which means that the observed phenotypic plasticity did not confer any adaptive advantage when there was some predation. Furthermore, if phenotypic plasticity was adaptive, the predation would have been against fish which were not exhibiting a strong phenotypic plasticity response. There was no relationship between final shape and mortality rate (ADONIS: F=1.022, p-value = 0.44) and no correlation between final shape variation and mortality rate (r= 0.4117, p-value = 04173).

4. Discussion

When taking tank as a random effect, size changed when the predator was present butit was not signif-

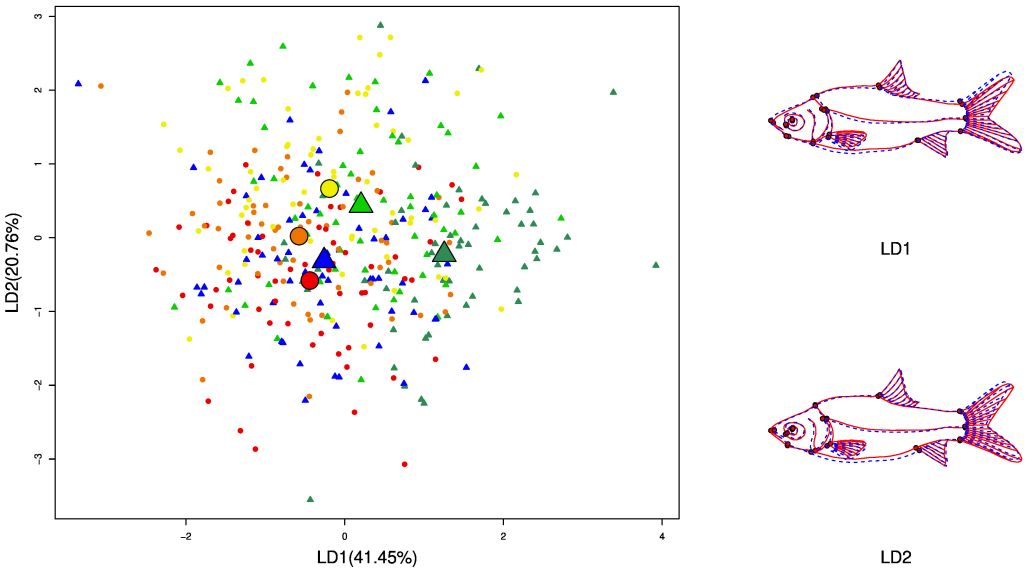

Figure 5: Canonical variate analysis among the fish sampled from the six tanks at the end of the experiment.

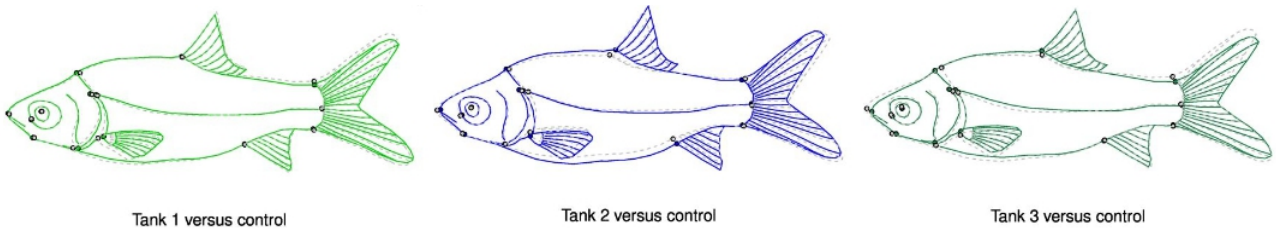

Figure 6: Warped mean shape for fish that received a predator (dotted line) against warped mean shape for fish that received a predator for tanks T1 to T3 at the end of the experiment. Colour chart follows previous figures.

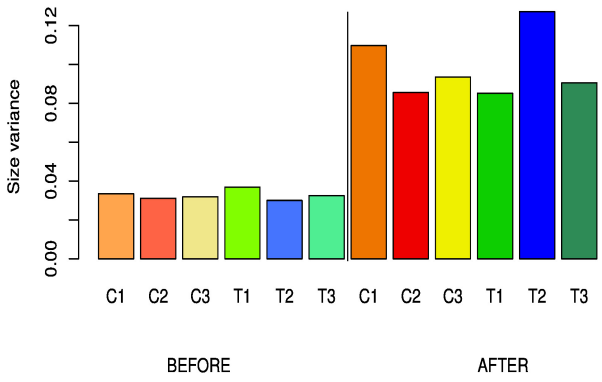

Figure 7: Barplot of size variance (in squared cm) for every tank from the beginning to the end of experiment: letters and colours as for figure 2.

Table 6. Crossed factor two way ANOVA on shape and size variance for each tank. Effects considered are the presence or absence of predator (treat), the beginning or end of the experiment (time), and the interaction (treat:time).

Size	**DF**	**SS**	**F value**	**P-value**
Treat	1	0.00002	0.13	0.72
Time	1	0.01307	76.06	< 0.001
treat:time	1	0.00001	0.06	0.81
Residuals	8	0.00017		
Shape	**DF**	**SS * 1000000**	**F value**	**P-value**
Treat	1	0.00034	0.29	0.61
Time	1	0.15234	130.03	< 0.001
treat:time	1	0.00325	2.77	0.13
Residuals	8	0.00937		

icantly different than when it was absent. Nonetheless, there was a small increase in size in all tanks exposed to the predator, but it was significant only in tank T2. In this tank, the selective pressure exerted by the predator was higher than in other tanks and size was increased. There was therefore a potential adaptive phenotypic plasticity for size [26], which involved a faster size increase when the predator was present. This effect was, however, subtle. Since the increase was not found significant in tank 1 and 3, it might also mean that predators in these tanks were also predating on the smallest fish (although it did not seem that they were involved in an increase of mortality in these tanks) and that rather to observe adaptive phenotypic plasticity, we just observed natural selection against the smallest fish. In order to know if phenotypic changes are really related to the predation risk or to the active selection made by the predator, future experiments should manage to isolate completely predator and prey.

ADONIS failed to identify a significant effect of the predator on body shape changes (no interaction) when fish body shape were averaged by tank (Table 4). This result should be eventually interpreted with caution because the number of replicates was low and the power of the analysis might be low. However, by comparing each tank containing a predator with the control, significant shape differences were discovered. These differences seemed to involve the head proportion (smaller in fish exposed to the predator) and the caudal peduncle (narrower in fish exposed to the predator). It seems therefore that during the experiment, some body parts evolved similarly. We know few results about shape phenotypic plasticity for fish and predator cues. However, there was a study that found similar patterns compared to our results [27]. In this previous study in the Trinidadian guppies, it was found that the guppies were reared with predator cues developed longer and shallower heads than fish reared without predator cues. In other words, when the guppies reared in the presence of predator cues, they developed a more fusiform head shape.

These changes could have functional grounds and improve the maneuverability [28] and show morphological adaptation for fish with steady swimming [29]. Increasing maneuverability could be an adaptive response to escape attacks from the predator. The patterns for shape were again subtle but might show that the fish display some plasticity to respond to the predator. Interestingly, the differences between control and presence of a predator were not found in the tank having displaying the more important predation rate. If developmental plasticity is indeed induced by the predator, it seems therefore maladaptive in this case. Once again, further experiments, controlling that predation is 0 in all tanks or/and controlling the shape of the predated fish could be confirmatory. We noted an interesting patterns of size and shape variation with age in all tanks. While shape variance decreased, size variance increased suggesting that shape changes were buffered while difference in size among was individuals were increasing. The decrease in shape variation would be an evidence for developmental canalisation in shape with age [30]. The introduction of the predator had no effect on these patterns, suggesting that this pattern was likely under genetic control rather than resulting from natural selection exerted by predators.

Acknowledgements

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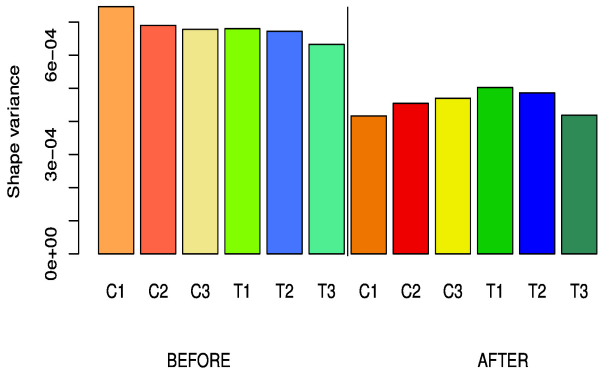

Figure 8: Barplot of shape variance for every tank from the beginning to the end of experiment: letters and colors as for figure 2.

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Can migration solve income inequality problem?

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Abstract

Income inequality is one of the serious threats to many developing countries. Income inequality causes public concern because it leads to crime, disease, and environmental degradation. The United Nations considered this issue as one of its top priorities and included income inequality as one if its strategic sustainable development goals.

When considering income disparity between regions, one common solution is migration from low-income regions to high-income regions, hoping for a better life. The governments also support this solution through the elimination of the administrative process of relocation. The effectiveness of using a migration to solve income inequality is still in doubt. Research is required to prove or disprove it.

This research aims to examine the effectiveness of migration in solving the income inequality problem. Such issue is complicated as there are many related factors and stakeholders. In addition, the impact of migration on income inequality does not happen immediately. The effect takes a significant amount of time to arise. In order to deal with this complexity, a system dynamics approach was used to create a simulated situation. This simulation was then used to analyze the impact of migration and the impact of other factors on income inequality.

The results show that migration can reduce income inequality as expected. When adjusting the level of migration, however, we found that the changes to income inequality were minor. It shows that although migration can reduce the income inequality problem, it is not an effective measure when used alone. In order to solve an income inequality problem, migration must be supported by other policies as well.

Keywords: Income inequality, migration, system dynamics, foreign investment, sustainable development goals
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1. Introduction

Economic growth is a desirable situation that every country aims to create. However, economic growth can have drawbacks, one which is income inequality.

Income inequality is a situation that the income distribution is not equal among different groups of people, which can be divided by age, gender, race, or location. Many research works have shown that income inequality is related to the speed and size of economic development. Economic development leads to wider income inequality if the country's economic level is low. On the other hand, if the economic level is high, economic development can ease an income inequality problem. This inverse-U curvilinear relationship is called the Kuznets curve, and it is used widely in many articles on income distribution and income inequality [1-3].

One of the key factors that can stimulate economic growth as well as drive up an income inequality is foreign investment. Many articles have proven that foreign investment can boost up countries' economy [4-8]. Foreign investment also benefits different group of people unequally, leading to higher income inequality [9-13].

Income inequality causes internal conflict within the country [14]. Besides, countries with a high level of income equality tend to have a higher crime rate, disease outbreak, and environmental degradation. Due to such seriousness, the United Nations included an income inequality problem into its global strategic sustainable development goal to create a sustained income growth of the bottom 40 percent of the population at a higher-than-average rate.

One phenomenon that we can expect to see when there is an income difference between the two regions is a migration from low-income regions to high-income regions. People in a low-income region move to regions with higher income, hoping that they can

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get a better paid so the quality of life of themselves and their families will be improved.

This belief is not only for an individual. Governments and international bodies also consider migration as a solution to solve income disparity. UN includes a migration issue and migration policy into its targets that should be achieved to fulfill the inequality goal. This target selection shows the UN's perception that migration is a remedy for the inequality problem.

Although it makes sense that migration can ease an inequality problem, no one has examined its effectiveness before. Based on my knowledge, there is no study on the effectiveness of encouraging migration to reduce income inequality. This lack is a missing piece that is very important in solving an inequality issue. If migration can effectively reduce an income inequality problem, migration should be a key policy for all governments facing an inequality problem. On the other hand, if a migration policy is less effective than other measures, migration policy should have lower priority. Without knowing its effectiveness, governments cannot prioritize their policies, and the overall effectiveness of their policies is low. Therefore, this paper sheds light on this important but unexplored area by analyzing the effectiveness of migration policy on reducing an income inequality problem.

It is methodologically challenging to study the effectiveness of a policy. The scientific method of analyzing the effectiveness of one thing is to alter independent variables, control other variables, and observe the change in the dependent variable. However, this approach is almost impossible when analyzing the policy because the policy is hard to change after implementation, and we cannot control other relating factors. To solve this methodological difficulty, we use a simulation method. We create a model from relationships among relating factors, simulate it, adjust the migration factors, and observe the change in income inequality.

We are surprised to find that encouraging migration is not an effective measure to solve an income inequality problem. When we reduced the migration barrier by half, an income difference between regions is reduced by about five percent. However, the impact of migration on an income difference is more significant in the long run. We can imply that a migration policy cannot be used as a fire extinguisher to fight a fire, but it is more like an interior design that can limit the fire in the long run.

2. Foreign Investment and Income Inequality

Foreign investment stimulates economic growth, and every government encourages foreign investment into their countries. However, foreign investment can have a negative side effect on income distribution [13].

Based on the Kuznets curve, a higher level of economy is related to a higher income inequality [4, 5, 15]. Foreign investment can improve host countries' economy in many aspects. First, a foreign investment will improve the employment rate because foreign firms offer jobs to local as well as an increase in employment from local firms due to technology transfer [7, 8, 16-20]. Moreover, jobs offered by foreign firms tend to pay better which pressure local firms to increase wages as well [6, 8, 21-28].

Besides the effect of economic growth on income inequality, foreign investment can also directly impact income distribution. Foreign firms tend to locate in specific areas such as capital cities or special economic zones. The investment will boost up the average income of people in those areas, making the difference of income between areas with foreign investment and other areas wider [10-12, 29-31]. Besides, foreign investment also creates income inequality within the same region. Foreign firms prefer to hire qualified and skilled workers. Therefore, there are wider income gaps between qualified and skilled workers and others in the same region [27, 28].

3. Migration and Income Inequality

Policymakers perceived migration as a remedy for the income inequality problem. A migration can reduce an income difference between regions because people from lower-income regions can have an opportunity to improve their income to match with others. Most of the time, migrants are qualified, educated, and skilled people. Therefore, people in a low-income region tend to invest more in education, which also increases their income [32-34].

However, there is a debate that the migration worsens income inequality. Migrants compete in the labor market with locals, and weak locals may lose their jobs. It results in a wider income difference [35]. For example, Singapore had around 2.5 million immigrants in 2017, but the income gap has been increasing continuously.

Even though there is both a positive and negative impact of migration on income inequality, migration is still promoted to ease an income distribution problem. Even said that there is no study examining the effectiveness of migration in reducing income disparity. The closest papers studying on this issue focused only on the effect of migration on inequality, but not its effectiveness in reducing an inequality problem (for example, see Barham and Boucher's paper [36]). This finding is important for governments in prioritizing their policies, and this is the area that this paper will answer.

4. System Dynamics

Examining the effectiveness of migration on income inequality is hard. To measure the effectiveness of

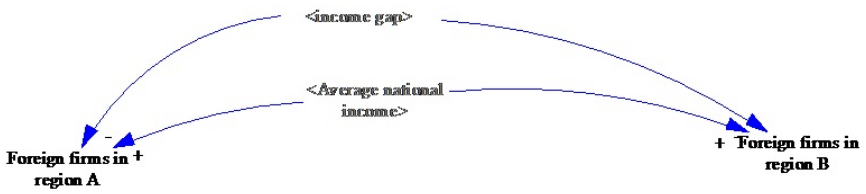

Figure 1: Foreign firm investment

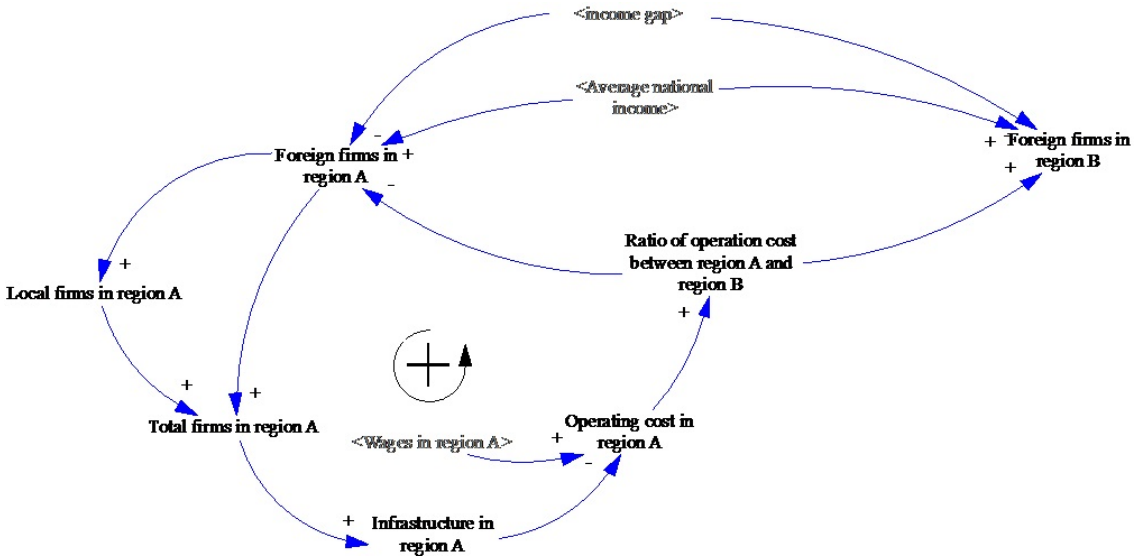

Figure 2: Firms and infrastructure development

one thing, we have to change the value of independent variables, holding others constant, and measure the changes in the dependent variable. However, it is almost impossible when measuring the effectiveness of a policy because the policy is hard to adjust after implementation, and we cannot control other factors. To overcome this difficulty, we use System dynamics method.

System dynamics is the mathematical simulation method, developed from the causal relationship of multiple factors relating to the focused issue. This method is suitable for complex situations with multiple dynamical factors [37]. Besides, it is applicable when the relationship is non-linear and recursive, which is the limitation of other approaches [38, 39].

Because of its simulation power that all factors can be adjusted, this method has been used tremendously in policy analysis and policy design in many fields such as oil and gas industry projection, electricity and carbon emission, and natural resource management [40-42].

5. Model

The model in this paper bases on the model used by Teekasap [13]. The model is shown using the Causal Loop Diagram. Due to space limitation, equations used in the model are available upon request.

We divided the model into a foreign investment module and migration module. A foreign investment module illustrates the flow of foreign investment and location selection. The migration module presents the income-based people movement.

A foreign investment module starts with foreign investment. We assume that there are two areas with different factor endowment, namely region A and region B. A foreign investment in both regions will increase when the nation's GDP is high [43]. We use the average national income as a proxy of GDP. On the other hand, an investment in both regions will drop if there is income inequality, showing with an income gap between two regions [14]. This explanation is illustrated using a diagram in Figure 1.

When foreign firms invest, they will attract local firms in the supply chain to set up their businesses in the nearby areas and become a cluster. When firms locate together, they can develop basic infrastructure which will reduce their operation cost. Besides the cost of infrastructure, wages are also a major cost for firms. If the cost is high relative to other areas, foreign firms will prefer other areas. Therefore, the relative cost will affect foreign investment, as shown in Figure 2. These relationships reinforce each other. When foreign firms invest in this region, there are more local firms, which leads to better infrastructure development. A well-developed infrastructure will reduce firms' operation cost, which will attract more foreign

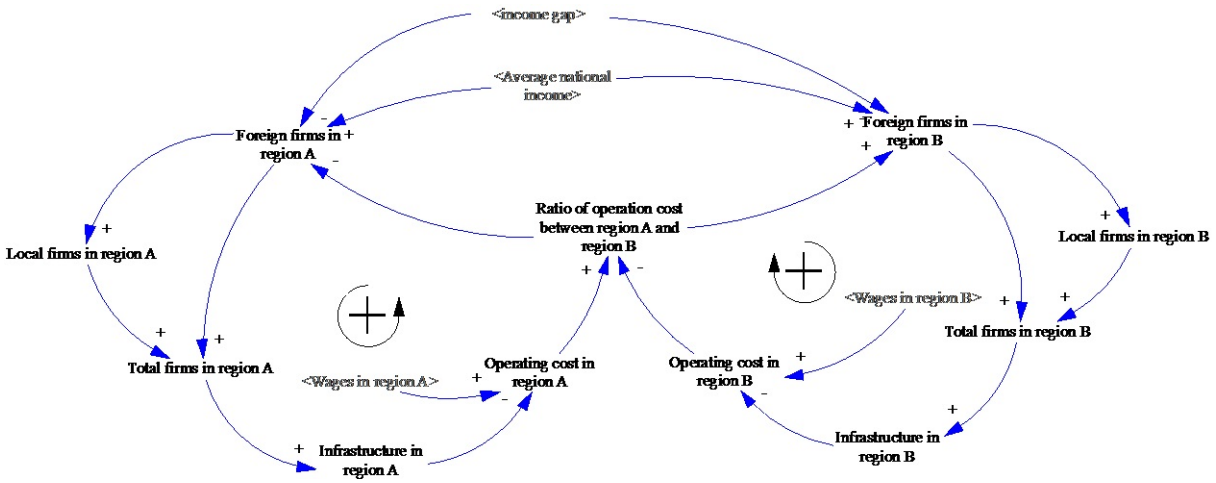

Figure 3: Foreign investment module

firms to invest.

The explained relationships are also applied to region B, as illustrated in Figure 3. An investment of foreign firms in region B will lead to more local firms in region B and become a cluster. A cluster will develop supporting infrastructure, which will reduce firms' operating cost. When cost is low comparing with another region, foreign firms will invest more.

Next is the migration module. We assume that wages drive the migration. Wages come from the balance between labor supply, presented by the number of people in region A, and labor demand, which is represented using work in region A. Number of works comes from number of firms in region A. If wages in this region is higher than another region, people will migrate from other regions into this region. This loop works to balance itself. When wages are high, people will move into this region, causing the labor supply to increase. When labor supply increase, wages will be dropped, as shown in Figure 4.

The same relationships are also applied to region B, as shown in Figure 5. Higher wages will attract people to move into region B. When labor supply increases, wages will drop.

Lastly, wages in both regions will be used to calculate the average national income and income gap, which will affect the foreign investment in the previous module. We illustrate the average national income and income gap in the diagram, as in Figure 6.

6. Dynamics of Income Inequality

To study the effect of migration on income inequality, we set a base scenario to be a control scenario. Then, the factor relating to migration will be changed. We will compare the results after changing the migration factor with the results in the base scenario.

The data used in a control scenario is simulated data. The focus of this paper is on the trend and relative changes in income inequality from adjusting the migration level. Therefore, the simulated data can appropriate. However, this is a limitation of this study that it does not represent any specific country.

In this model, all numbers, including time, are hypothetical number and do not provide any meaning. Therefore, the focus will be on a trend and pattern of graphs in the short run and a long run.

In the base scenario, we design both regions to be the same by using the same value on all factors, except an infrastructure. We assume that the region A has better infrastructure than region B. Due to better infrastructure in region A, more firms invest in region A as shown in Figure 7.

Foreign firms offer better paid than local firms. Therefore, we expect to see wages in region A to be higher than that in region B. The results shown in Figure 8 illustrate exactly as the expectation. Wages in region A increase at a higher rate than that in region B.

7. Effect of Migration on Income Inequality

We examine the effect of migration on income inequality by adjusting the value of factor relating to migration, and we measure an income gap in each scenario. In this study, we changed the migration level by adjusting a migration cost. The migration cost is one of the key factors determining the level of migration, and changing the cost of migration will directly affect the migration level. In addition to the base scenario, we create two additional scenarios. The first scenario is when we reduce the migration cost by half, and another scenario is when the cost of migration is increased by 50 percent. We name the first scenario "-50," and the second scenario is called "50."

Even though we adjust the migration cost since the start of the simulation, the differences take time to emerge, as shown in Figure 9. We can see that when we reduce the migration by 50 percent, the number of

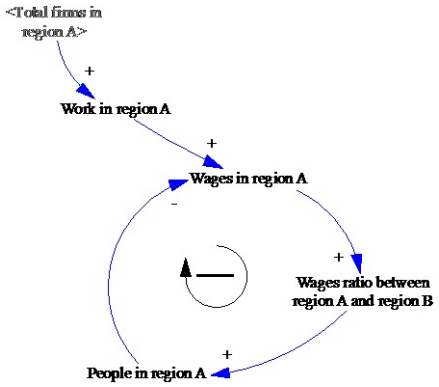

Figure 4: Wages in region A

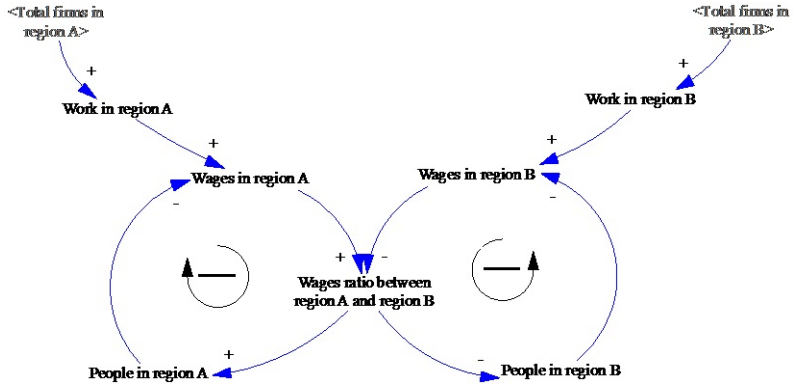

Figure 5: Wages in region B

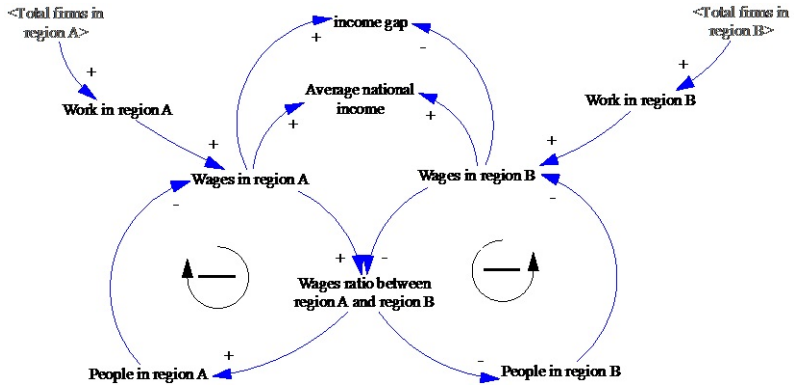

Figure 6: Migration module

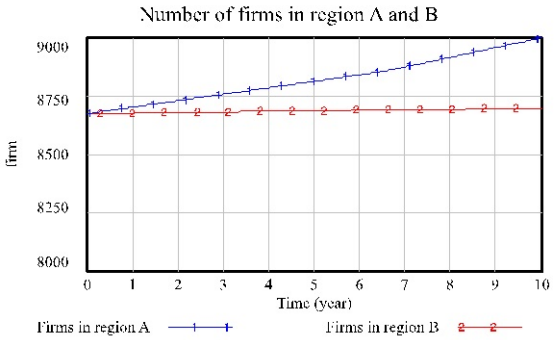

Figure 7: Firms in region A and B

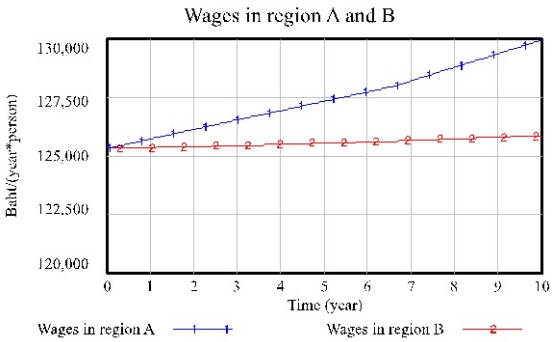

Figure 8: Wages in region A and region B

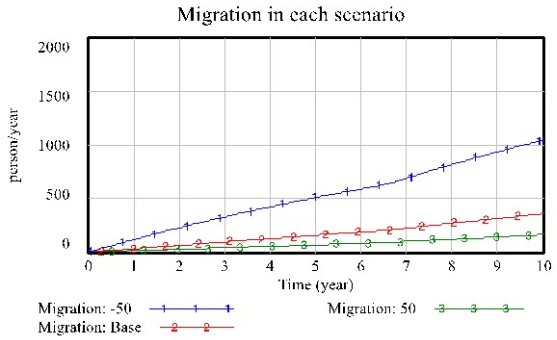

Figure 9: Migration level in each scenario

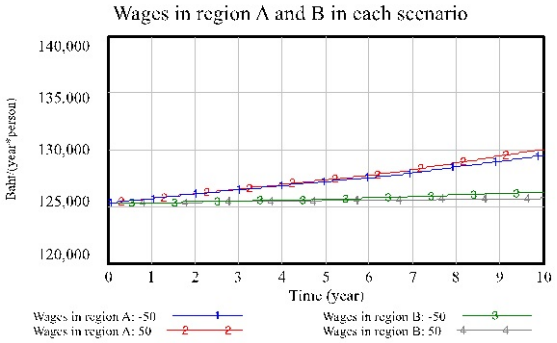

Figure 10: Comparison of wages in region A and region B in each scenario

migrants increases more than double. When we increase the cost of migration by half, the number of migrants is also reduced by half.

The cost of migration also affects the wages in both regions. As shown in Figure 10, the gap between wages in region A and region B is smaller when the cost of migration is reduced by half, and it is larger when the cost of migration is doubled.

From the graph, the changes in wages difference seem to be relatively small, comparing to the changes in migration level, which is quite large. To be more specific, we calculate the percentage change of migration level, the percentage change in wage difference between two regions, and compute the ratio between the percentage change in wage difference to the percentage change in migration. The results of scenario '-50' and scenario '50' are shown in Table 1 and Table 2 consecutively.

The results for both scenarios show that the change in migration has a small effect on the change in the wage difference between the two regions. In both scenarios, the change of wage difference is less than 5 percent of the change in migration level in a short run, showing that the migration policy can solve income inequality in a relatively small scale.

However, when we consider the change of effectiveness of the migration change on the change of wage difference, we find that its effectiveness is gradually increasing. Therefore, it shows that the migration policy takes time to adjust the differences in income between regions.

The reason why the effectiveness of using a migration to reduce income inequality is relatively small can be explained through the adjustment of firms. Wages will be increased when the demand is higher than supply. The more mismatch between the demand and supply, the higher an increase in wage. When there are more migrants from region B to region A, the labor supply in region B is reduced, so the wages in region B is increased. The labor supply in region A is also increased from a migration, causing a reduction in wages in region A. However, the change in migration also affects the number of labors. Lower wages in region A will attract more firms to invest due to a lower operating cost. In region B, firms will also invest less due to a higher wage. Because firms' investment is also adjusted according to the wage adjustment by the migration, the demand-supply balance does not significantly change, causing a small change in income distribution.

8. Conclusion and Implication

Income inequality is a chronic problem in many countries, and migration is widely perceived as a measure to ease this problem. Many research articles have proved that migration is a solution for an income inequality issue. However, no one has examined its effectiveness before. Without knowing how effective it

Table 1. Percentage of changes and wage difference comparing to migration in 'Scenario -50.'

TIME	%MIGRATION CHANGES	%OF WAGE DIFFERENCE CHANGES	% WAGE DIFFERENCE CHANGE RATIO CHANGES TO MIGRATION
0	-	-	-
1	262%	3%	1%
2	251%	6%	2%
3	241%	8%	3%
4	232%	11%	5%
5	222%	13%	6%
6	214%	16%	7%
7	207%	17%	8%
8	202%	19%	9%
9	196%	20%	10%
10	190%	22%	12%

Table 2. Percentage of changes and wage difference comparing to migration in 'Scenario 50.'.

TIME	%MIGRATION CHANGES	%OF WAGE DIFFERENCE CHANGES	% WAGE DIFFERENCE CHANGES TO MIGRATION CHANGE RATIO
0	-	-	-
1	57%	1%	1%
2	57%	1%	2%
3	56%	2%	3%
4	56%	3%	5%
5	56%	3%	6%
6	56%	4%	7%
7	55%	4%	8%
8	55%	5%	9%
9	55%	5%	9%
10	55%	6%	11%

is to reduce an income inequality problem, governments may spend too much effort on an ineffective or less important measure. This paper addresses this research gap.

Using system dynamics methodology, we confirm extant research finding that the migration can reduce an income distribution problem. When we reduce the migration barrier, we observe a lower income gap between regions. On the other hand, when the migration barrier increases, an income gap is widened. It proves that stimulating a migration can reduce an income inequality problem.

Next question that we focus on is the effectiveness of the migration policy on solving an income inequality problem. We find that migration is not an effective measure to solve an income inequality problem. The percentage change in the income gap between regions is less than ten percent of the percentage change of migration level. From this finding, we can answer our question in the research title that the migration can reduce income inequality, but it cannot solve an income inequality problem.

We also consider its effectiveness through time. We find that even though the effectiveness of using a migration to reduce an income inequality problem is low, its effectiveness increases gradually over time. It shows that the migration policy is a long-term policy.

This finding fills in the theoretical gap of the effectiveness of migration policy on solving an income inequality problem by showing that the migration policy alone is not an effective measure in the short run. It then leads to interesting further research questions on how to improve the effectiveness of the migration policy on solving income inequality.

This finding also has a policy implication. This finding shows that if countries face an income inequality problem, focusing solely on migration is not the right move. Governments should use other measures that can reduce income inequality in the short run. The migration policy is more appropriate for countries that do not have a serious income distribution right now but aim to control the income distribution in the long run.

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Defining risk thresholds: Appropriate body mass index cut-off for hypertension in Thai Cohort Study

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Abstract

Body mass index (BMI) is used to predict the risk of hypertension in some Western countries. But to date the appropriate BMI cut-off for hypertension among Thais remains unresolved. This study aims to determine the proper BMI cut-off for risk of hypertension in Thailand.

Health-risk factors and their effects on incidence of hypertension were evaluated prospectively in the national Thai Cohort Study from 2005 to 2013. All derived from 40548 initially normotensive Sukhothai Thammathirat Open University students returning mail-based questionnaire surveys in both 2005 and 2013. Adjusted relative risks of association between baseline BMI and 8-year incidence of hypertension were calculated after controlling for a wide array of confounding factors. A smooth model with a linear fit of associations between BMI and hypertension risk was compared to a non-linear model using cubic splines.

In Thailand, the 8-year incidence of hypertension was 5.1% (men 7.1%, women 3.6%). Hypertension was strongly associated with ageing and high BMI. Non-linear modelling showed the best fit with a significant upwards inflection pointing to the risk threshold occurred in the third BMI category of 20.75 (aRR = 1.89, 95% CI 1.54-2.32) compared to a reference BMI of 20.00 kg/m^2.

The health risk transition Thailand has led to a rising prevalence of hypertension which is an important risk factor for many chronic diseases. A BMI cut-off point of 21 kg/m^2, two points lower than the current 23 kg/m^2, would be appropriate for defining the threshold of hypertension risk in Thai adults. Lowering BMI cut-off for risk of hypertension will encourage people to have more awareness of their health. Our results support population level interventions design to increase exercise and decrease overweight and obesity in Thailand.

Keywords: hypertension, body mass index, cut-off point for hypertension, Thailand
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1. Introduction

Rapid economic growth in recent decades moved Thailand from a low- to a middle-income country with a concomitant steady increase in urbanization. As a result, the proportion living in cities increased from 20.9% in 1970 to 34.1% in 2011 and it is estimated that over one million Thais (1.6% of population) will be urbanized each year [1]. Urban residence tends to accompany a sedentary life-style, junk food consumption [2], higher meat and lower rice consumption and other unhealthy behaviours, especially excessive drinking and smoking [3]. There is also a higher risk of obesity [2, 4, 5]. The socio-economic and environmental transformations are changing disease patterns of Thais to resemble those in developed countries, especially emerging non-communicable diseases including hypertension [6]. Many studies concluded that overweight and obesity are major risk factors of hypertension [7-12]. Increasing BMI is associated with increased morbidity and mortality due to increasing risk of obesity related problems such as cardiovascular disease, stroke and diabetes mellitus [13, 14]. WHO

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recommends that bodyweight classifications be based on body-mass index calculated as weight in kilograms divided by height in meters squared (kg/m^2) and categorized by standard cut-offs [14]. In addition, WHO approved different BMI cut-offs for "normal", "overweight" and "obese" for Asian populations as follows: less than 18.5 kg/m^2 underweight; (18.5 ≤ BMI < 23.0) kg/m^2 normal; (23 ≤ BMI < 25) kg/m^2 overweight at risk; and 25 kg/m^2 obeseI [15]. Even these criteria may not be strict enough and we know that the lower levels of BMI still increase cardiovascular and metabolic disorder rates in some Asian populations [16-18]. The BMI cut-off values at 23 and 25 kg/m^2 respectively for overweight and obesity, recommended by WHO for Asian populations, is still too high for Singaporeans. They should be lower by 2–3 kg/m^2 (18, 19). Many studies showed that the association of BMI and percentage of body fat among different ethnic groups was not similar [20-23] so BMI cut-off point based on body fat should be defined according to ethnicity. At the same percentage of body fat, Singaporean should have a BMI lower than Caucasian people [19, 24]. Our Thai Cohort Study (TCS) is focused on the transition in health risks due to modernization. Here we study the impacts on population health, investigating demography, socioeconomy, physical activities, personal behaviour and other health risks associated with hypertension during 8 years of prospective follow-up. The normal Asian body mass index cut-offs (18.5 ≤ BMI < 23) may be too high for Thais since participants at normal body mass index still have an annual incidence of hypertension of nearly 3% [9]. Therefore, in Thailand BMI cut-offs for hypertension could need national adjustment so we performed an incidence study to determine the risk.

2. Methods

2.1. Study Population and Data

The Thai Cohort Study (TCS) began in 2005 with 87151 distance learning students enrolled at Sukhothai Thammathirat Open University (STOU) then representing 44% of the enrolled student population [6]. The STOU student body and the TCS members were similar to the Thai people for geography and socioeconomic status [25] but their age distributions are different. The student body and cohort members were younger with 56.2% and 51.5% respectively in the 21-30 year age range compared to 23.9% in the general Thai population and fewer were older than 50 years (1.2% and 2% respectively) compared with 24.7% of the Thai population. Also, in comparison with the general population, the STOU student body and TCS members had a higher education. TCS baseline data were generated from a 20-page mail-out questionnaire which included questions on demography, socio-economic status (SES), personal health and diseases (diabetes mellitus, high blood lipids, high blood pressure, stroke, chronic kidney disease, various cancers, goitre, epilepsy, asthma, arthritis, chronic bronchitis and depression). As well there are questions on hearing, vision, dental impairment, use of health services, transport, injury, social networks, personal well-being, health-related behaviour and family background. Baseline data have been published [6, 25]. The number of cohort members participating at 4-year follow up was 60569 (70%) in 2009 and there were 42785 responders (49%) in 2013 at 8-year follow up.

2.2. Incident hypertension

Incident hypertension was defined as self-report of doctor diagnosed hypertension in 2013 after being normotensive in 2005. Hypertension incidence was the binary dependent variable for analyses and the person-time denominator included all individuals at risk—those 40548 (94.8%) of the 42785 participants with 8-year longitudinal data (2005 to 2013) who were negative for hypertension at the start (2005).

2.3. Independent variables

The independent variables that were available for analysis included age, sex, marital status, socioeconomic status (SES - income, household assets, and education), urbanization, body mass index (BMI), and underlying diseases (diabetes mellitus, high lipids and kidney disease). Other variables assessed included sedentariness (screen time, sitting time and housework or gardening), other lifestyle features (physical exercise, tobacco smoking, alcohol consumption, soy bean consumption, fruit and vegetable intake and soft drinks) and food preferences (Western, roast, smoked, instant, deep fried).

BMI calculation was based on self-report weight and height which were considered to be accurate due to the report of validation study [26]. Asian cut-offs following guidelines of the International Obesity Task Force [13]: underweight (BMI < 18.5), normal (18.5 ≤ BMI < 23.0), overweight (23 ≤ BMI < 25.00), or obese (BMI ≥ 25) were used to calculate and categorize BMI. In addition, we also created 8 categories (< 18.5BMI, 18.5 ≥ BMI < 20.75, 20.75 ≥ BMI < 23, 23 ≥ BMI < 25, 25 ≥ BMI < 27.5, 27.5 ≥ BMI < 30,30 ≥ BMI < 32.5, and BMI ≥ 32.5) which divided normal into two categories and more categories for obese.

Age was divided into three categories (≤ 30. 31-40, > 40). Marital status was defined as married/living with a partner or single. Urbanization status was classified in childhood (aged 12 years) and at baseline (2005) producing 4 lifelong categories: ruralites (RR), urbanizers (RU), de-urbanizers (UR) and urbanites (UU). Education level was grouped into three categories (High school, Diploma, University). Personal monthly income was divided into four categories in baht. In 2005, one US dollar was equivalent to 42 baht.

Household assets were classified into three categories (low, medium, high in baht).

Screen time and sitting time (hours/day) were proxies for sedentariness. Incidental exercise (frequency of housework or gardening), was categorised into 4 groups: ≤3 times per month; 1-2 times per week; 3-4 times per week; most days. Various forms of physical activity (at least 20 minutes of mild, moderate or strenuous exercise, 10 minutes or more walking sessions) were also included and recorded using 4-item ordinal categories.

An overall measure of planned physical activity was calculated separately at both the baseline and the 8-year mark. This was based on the cohort members reporting the number of sessions per week of strenuous and moderate exercise for at least 20 minutes, and of walking for at least 10 minutes. We weighted the measure as follows: (2×strenuous+1× moderate+1×walking) sessions per week, weighting based on the recommendation of the International Physical Activity Questionnaire and the Active Australia Survey as used in other analyses of cohort data [27, 28]. Finally, for each individual, the 'overall measures' of weekly exercise for 2005 and 2013 were added and then averaged by dividing by 2, creating a longitudinal measure of planned physical activity (LPPA).

Smoking was self-reported and grouped into never, ex-smoker or current smoker. Alcohol consumption had four categories: never, ex-drinker, occasional drinker or current-drinker. Foods that may influence hypertension (deep fried, instant, roast or smoked, soybean products and soft drinks) and Western-style fast foods were assessed for consumption frequency. Fruit and vegetable consumption were recorded as standard serves eaten per day.

2.4. Statistical Analyses

We performed all analyses using SPSS software. Hypertension incidence and 95% CI were calculated for each value of each categorical variable. For statistical inference, all p values were two tailed and significance was set at 5%.

In a large study of an uncommon disease (incidence less than 10%) relative risks (RRs) can be accurately estimated as odds ratios (ORs) [29]. Accordingly, for each risk variable, the RR and 95% CI were estimated using logistic regression to calculate the bivariate OR for hypertension. Adjusted RRs (aRRs) were estimated by multivariate logistic regression ORs controlled for confounding by age, sex, marital status, socioeconomic status (SES), BMI, underlying diseases and personal behaviours (cigarette smoking and alcohol drinking). A co-variable was included in the multivariable model if bivariate analysis had indicated a statistically significant association with incidence of hypertension. Some variables were included because earlier analyses reported elsewhere had shown a significant or substantial association with hypertension.

3. Results

3.1. Baseline characteristics

Overall, 42785 of the original cohort participated in the 8-year follow up. Of these cohort members 40548 had self-reported as normotension in 2005 are shown in Table1. The mean age at baseline of these longitudinal participants was 32 years and there were more females than males (56% vs 44%). The highest proportion of participants resided in the Central and North-eastern regions and the lowest proportion lived in the East. Sixty three percent of the participants lived in urban areas. More than half of participants had a higher education attainment than high school and their monthly incomes were lower than 10000 baht. The distribution of household assets of participants was quite similar with a slightly higher proportion of participants in the low category. Fifty-four percent of participants had a'normal' BMI and the 'overweight' and 'obese' were about 16%, followed by 'underweight' for 13%. Participants with diabetes and high lipids were 0.8% and 9.8% respectively while those with kidney disease were 2.5%. The ex- smoker participants were 16.8% while current smokers were 8%. The occasional drinkers were 58.3% while regular-drinkers and ex-drinkers were 4.6 and 8.3 respectively.

3.2. BMI and incidence and risks of hypertension

The age and multivariable adjusted association between baseline BMI and hypertension incidence by 2013 are shown in Table2 and Fig.1. Overall, the risk of hypertension increased with an increased BMI. The risk of hypertension (aRR=1.89, 95% CI 1.54-2.32) rose above a value of 1 starting with the third ordinal category of BMI (20.75 ≤ BMI < 23) when compared to those with normal BMI (second ordinal category18.5 ≥ BMI < 20.75) or those underweight. An exponential increase in hypertension risk followed in all the subsequent (increasing) categories of BMI. Also noteworthy, comparing to participants with normal BMI (18.5 ≥ BMI<20.75), those with BMI (23.0 ≤ BMI < 25.0) had a risk of incidence of hypertension about three times (aRR = 2.95, 95% CI 2.4-3.62).

4. Discussion

This is the first large nationwide cohort study to investigate the incidence of hypertension associated with overweight and obesity in Thai adults. The 8-year follow up from 2005 to 2013 of participants initially normotensive revealed a cumulative incidence of hypertension over this period of 5.1% with 7.1% in men and 3.6% in women. Ageing and obesity were

Table 1. Characteristics of 40548 normotensive participants at the 2005 Thai Cohort Study baseline

Factor	Participants			
	n	%	HT(n)	I[a]%(95% CI)
Demographic data				
Participants	40548	100	1958	5.1 (4.9-5.3)
Age (y) mean	32.10			
(SD)	(8.2)			
Age group				
≤30 y	6852	40.8	208	3.2 (2.6-3.4)
31-40 y	6360	37.9	444	7.0 (6.4-7.6)
>40 y	3590	21.4	537	15.0 (13.8-16.1)
Sex				
Male	17769	43.8	1189	7.1 (6.7-7.5)
Female	22779	56.2	769	3.6 (3.3-3.8)
Married/partnered				
No	20586	52.1	517	7.1 (6.7-7.4)
Yes	18946	47.9	1371	2.9 (2.6-3.1)
Regions				
Bangkok	6522	16.2	378	6.1 (5.5-6.7)
Central	9630	23.9	476	5.2 (4.8-5.7)
North	8125	20.0	422	5.5 (5.0-6.0
North-east	8580	21.3	389	4.8 (4.4-5.3)
East	2348	5.8	112	5.0 (4.1-5.9)
South	5122	12.6	167	3.5 (2.9-4.0)
Urbanization status[a]				
Rural–rural (RR)	2508	19.1	127	5.5 (4.5-6.4)
Rural–urban (RU)	3782	28.9	152	4.3 (3.6-5.0)
Urban–rural (UR)	2346	17.9	147	6.7 (5.6-7.7)
Urban–urban (UU)	4461	34.1	271	6.4 (5.7-7.1)
Socioeconomic status				
Education level				
High school	17837	44.1	923	5.6 (5.2-5.9)
Diploma	10862	26.9	445	4.3 (3.9-4.7)
University	11753	29.1	580	5.1 (4.7-5.5)
Personal monthly income (baht) [c]				
≤7000	14663	36.9	417	3.0 (2.6-3.3)
7001–10000	9214	23.2	364	4.2 (3.6-4.6)
10001–20000	11107	27.9	675	6.4 (5.9-6.8)
>20000	4785	12.0	476	10.3 (9.5-11.2)
Household assetse (baht)[d]				
Low	15133	37.5	509	3.6 (3.3-3.9)
Medium	12865	31.9	604	4.9 (4.6-5.3)
High	12387	30.7	836	7.1 (6.6-7.5)

[a]Incidence of Hypertension

[b]Location of residence (rural, R, or urban, U) before and in 2005. The values showed only participants who moved their residences within 5 years.

[c]At the time of the survey in 2005, US1 = 31 Thai baht

[d]Replacement value in Thai baht, categorized into three groups: low ≤ 30, 000, medium 30,001-60,000 and high >60,000

Table 1. (continued...)

Factor	Participants			
	n	%kg/m^2	HT(n)	I[a](95%CI)
BMI classification[b]				
Underweight (BMI < 18.5)	5252	13.0	53	1.1 (0.8-1.3)
Normal (18.5 ≤ BMI < 23)	21915	54.0	571	2.8 (2.5-3.0)
Overweight (23 ≤ BMI < 25)	6561	16.4	457	7.4 (6.7-8.0)
Obese (BMI ≥ 25)	6314	15.6	849	14.2 (13.3-15.1)
Underlying diseases				
Diabetes mellitus (type 1&2)				
No	40209	99.2	1889	5.0 (4.8-5.18)
Yes	339	0.8	69	22.0 (17.4-26.7)
High lipids				
No	36592	90.2	1484	4.3 (4.07-4.5)
Yes	3956	9.8	474	12.7 (11.6-13.8)
Kidney disease				
No	39540	97.5	1875	5.0 (4.8-5.2)
Yes	1008	2.5	83	8.9 (7.1-10.7)
Personal behaviours				
Smoking status				
Never	29467	72.7	1127	4.0 (3.8-4.3)
Ex-smoker	6824	16.8	510	7.9 (7.3-8.6)
Cur-smoker[c]	3226	8.0	254	8.5 (7.5-9.5)
Drinking status				
Never	11204	27.6	419	3.9 (3.6-4.3)
Ex-drinker	3365	8.3	192	6.1 (5.3-7.0)
Occ- drinker[d]	23638	58.3	1125	5.0 (4.7-5.3)
Reg- drinker[e]	1868	4.6	198	11.3 (9.8-12.8)
Food consumption habit				
Instant food				
<1 time/m	8470	20.9	502	6.3 (5.7-6.8)
1-3 times/m	16247	40.1	793	5.2 (4.8-5.5)
1-2 times/wk	9883	24.4	400	4.3 (3.8-4.7)
3-6 times/wk	4803	11.8	209	4.6 (4.0-5.2)
≥ 1 times/d	864	2.1	40	4.9 (3.4-6.4)
Soft drink				
<1 time/m	10970	27.1	521	5.0 (4.6-5.5)
1-3 times/m	11831	29.2	547	4.9 (4.5-5.3)
1-2 times/wk	8883	21.9	433	5.1 (4.7-5.6)
3-6 times/wk	6118	15.1	317	5.5 (4.9-6.1)
≥ 1 times/d	2401	5.9	123	5.4 (4.4-6.3)

[a]Incidence of Hypertension
[b]Asian standard BMI classification
[c]Current-smoker
[d]Occasional drinker
[e]Regular drinker

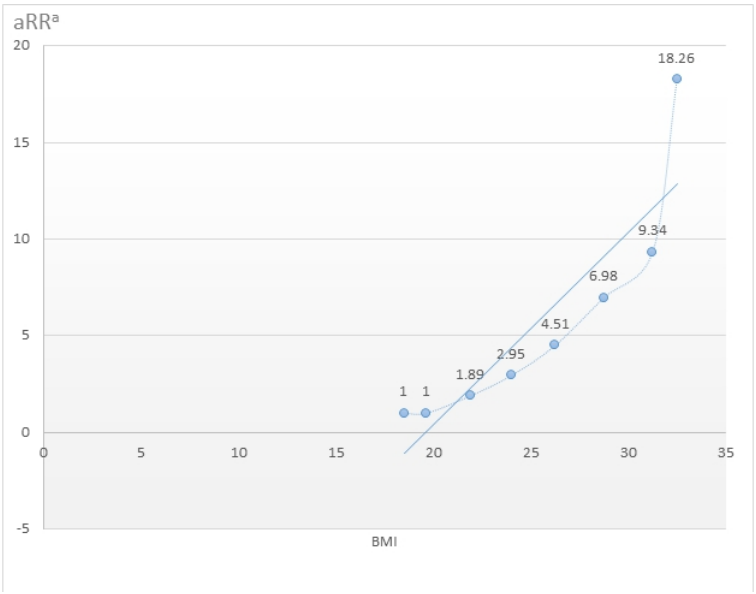

Figure 1: Adjusted relative risks of hypertensionby body mass index (Use data from table 2 model 2aRRb plot graph) aRR[a] is adjusted relative risks were calculated from multi-variable logistic regression models of hypertension adjusted for age, sex, marital status, socioeconomic status (exclude type of house), BMI classification, sedentary habits, physical activities, underlying diseases and personal behaviours.

Table 2. Association between baseline body mass index and eight-year incidence of hypertension.

Body Mass Index (kg/m^2) at baseline in 2005	HT(n)	Incident case by 2013[a] I[a] %(95% CI)	Adjusted RR estimates relating BMI and HT	
			Model 1[b] aRR[d] (95% CI)	Model 2[c] aRR[d] (95% CI)
BMI[a]				
BMI <18.5	81	1.5 (1.1-1.8)	1.01 (078-1.33)	1.0 (0.74-1.35)
18.5 ≤ BMI < 20.75	174	1.6 (1.4-1.9)	1	1
20.75≤ BMI < 23.0	397	4.0 (3.6-4.4)	2.03 (1.69-2.43)	1.89 (1.54-2.32)
23.0≤ BMI < 25.0	462	7.4 (6.8-8.1)	3.26 (2.72-3.91)	2.95 (2.4-3.62)
25.0≤ BMI < 27.5	431	11.8 (10.7-12.8)	5.27 (4.38-6.34)	4.51 (3.65-5.56)
27.5≤ BMI < 30.0	223	15.7 (13.8-17.6)	7.39 (5.98-9.14)	6.98 (5.51-8.84)
30.0≤ BMI < 32.5	111	19.5 (16.2-22.7)	10.48 (8.06-13.63)	9.34 (6.98-12.51)
BMI ≥32.5	79	26.8 (21.7-31.9)	18.79 (13.81-25.57)	18.26 (12.93-25.78)

[a]Incidence of Hypertension
[b]Model1 is adjusted relative risks were calculated from multi-variable logistic regression models of hypertension adjusted for age.
[c]Model2 is adjusted relative risks were calculated from multi-variable logistic regression models of hypertension adjusted for age, sex, marital status, socioeconomic status (exclude type of house), BMI classification, sedentary habits, physical activities, underlying diseases and personal behaviours.
[d]Adjusted relative risk

strongly associated with a higher incidence of hypertension. Our study revealed that compared to the participants with normal BMI ($18.5 \leq$ BMI < 20.75), those who have marginally higher BMI ($20.75 \leq$ BMI < 23.0) and ($23.0 \leq$ BMI < 25.0) significantly increased their risk of incidence of hypertension to approximately two and three times respectively. This study found that BMI ($18.5 \leq$ BMI < 23 kg/m^2), the normal range announced by WHO for Asian population; significantly increased risk of incidence of hypertension by two times compared to those with BMI below 20.75 kg/m^2. In addition, the BMI ($18.5 \leq$ BMI < 25.0) at the healthy range for Caucasian population strongly increases risk of incidence of hypertension in Thai people.

Our study confirmed that BMI was directly associated with the incidence of hypertension which is consistent with many studies in Asian such as in Korea [30], China [31] and India [32]. We reported that risk of incidence hypertension increased at BMI that considered to be in the normal range for Caucasian people (< 25 kg/m^2). It is consistent with previous studies which suggested that for Asian population, a BMI cut-off for cardiovascular risk should be less than 23 kg/m^{2}for overweight and 25 kg/m^2 for obesity [16, 33-35]. This result is comparable to the study in the US which reported that in Chinese Americans the corresponding BMI values were 20.9 kg/m^2 (CI, 19.7% to 22.1%) for the equivalent of the prevalence of metabolic abnormality in American whites at the BMI of 25 kg/m^2 [36].

The risk of hypertension may result from the effect of the amount of body fat. A study in African women in the US showed that body adiposity especially central adiposity was directly and significantly associated with an increased incidence of hypertension [32]. Further, a longitudinal study in Spain reported that body adiposity index was directly associated with an incidence of hypertension so it can be an alternative predictor of hypertension [37]. In addition, the studies showed that the relationship of BMI and body fat may differ between ethnic population [22]. At a similar BMI, Asians tend to have a higher body fat than Europeans [38, 39] especially for abdominal and visceral fat compared to that of Caucasians [40]. At the same amount of body fat percentage, BMI of Indonesians tended to have a two points lower than that of Dutch Caucasians [22]. Moreover, the Singaporean BMI cut-off points for overweight should be lower by 2 – 3 points than WHO recommendation for Asian population [18, 19].

This study has many strengths. To our knowledge, it is the first 8-year longitudinal study of risks of hypertension with a large number of Thai participants. Moreover, most risk factors for hypertension were analysed as well. TCS participants live all over Thailand so the study represents the Thai population well in social geography and socio-economy [25]. Therefore, the results of this 8-year study will be quite accurate despite losing some statistical power due to cohort attrition. Worldwide many studies report on BMI cut-off point for risk for hypertension however socio-economic, lifestyle and behaviour risks and ethnicity of each country are not similar. The results from our cohort will prevent incidence of hypertension in Thailand.

However, there are many limitation for our study. All data are self-reported so there may be some recalled error. Validation of self-reported weight, height and body mass index revealed that accuracy was acceptable [26]. Also we performed a validation study of self-reported hypertension using a random age-sex matched sample of the cohort reporting hypertension (n=240) or no hypertension (n=240) [41]. The study found that self-report of hypertension yes/no status was high for accuracy at 82% (yes) and 86% (no) respectively. We also investigated the impact of the non-responses to the 2009 follow-up and found small effects with under-representation of young urban men; this missing group would have a minor influence on our results and would not be expected to have a high rate of incident hypertension [42]. In addition, the attrition over 8-year followed up was 50%.

5. Conclusion

Our study concludes that lowering BMI cut-off point by two points for the risk threshold of hypertension is very important for the Thai population since we found that the incidence and risk of hypertension at the BMI ($20.75 \leq$ BMI < 23.0) was already too high. Therefore, people need to be aware that preventing hypertension, needs BMI to be at a lower point (< 21 kg/m^2) than the level used at present (< 23.0 kg/m^2). In Thailand, obesity, an important risk factor for many chronic diseases, is already high in prevalence so long term policies for preventing obesity from childhood should be developed by Ministry of Public health. Further study for BMI cut-off point for risk of hypertension should be performed in other Asian countries as well.

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Ethical Considerations

Ethical approval was obtained from Sukhothai Thammathirat Open University Research and Development Institute (protocol 0522/10) and the Australian National University Human Research Ethics Committee (protocol 2004344 and 2009570). Informed, written consent was obtained from all participants.

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Study on physical, optical and luminescence of zinc tellurite glasses doped with bismuth oxide

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Abstract

A series of zinc tellurite glasses of the composition (90-x) TeO_2 – 10ZnO – xBi_2O_3 by (where x = 10, 15, 20, 25 mol%) were synthesized using the conventional melt quenching technique at 1,150 °C for 1 hours 30 minutes. This research the physical, optical and luminescence properties of the glasses by the process just described produced. In order to understand the role of Bi_2O_3 in zinc tellurite glasses systems, the physical, optical and luminescence properties of the glasses were investigated. The result showed that density increased and molar volume increased with increasing Bi_2O_3 concentration. The optical absorption spectra of glasses were measured in the wavelength range of 200 – 1,100 nm for Bi^{3+}. The intensity of absorption also increased with increasing of Bi_2O_3 concentration. The intensity of emission bands at 602 nm increased with increasing Bi_2O_3 concentration. In addition. The luminescence properties of Bi^{3+} -dope TeO_2 – ZnO – Bi_2O_3 glass system were carried out using excitation wavelengths of 302 nm for Bi_2O_3. It was found that the luminescence peaks around 602 nm.

Keywords: Zinc tellurite glass, bismuth oxide, physical property, optical property, luminescence property
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1. Introduction

Glass based on tellurium dioxide possess good thermal and light stability, high refractive index, stable at room temperature, high dielectric constant and low phonon energy. These favorable properties make tellurite glasses as promising materials in the field of optical equipment, laser equipment, signals and telecommunication systems due to Its ability to transmit in broad wavelength region (6 μm). [1] Zinc oxide possess high thermal stability and chemical durability, high refractive index and molten point at low temperature [2-3]. Furthermore, zinc oxide can be used to develop electronic devices and make a laser device. [4] Bismuth oxide has gained a lot of attention in the glass industry because it has nonlinear properties, high refractive index and high density. It is a good choice for optical and laser codecs. [5] The development of technology producing optical materials requires suitable compositions for the manufacture of vitreous products. Concerning, the purpose of this paper was to establish the glassforming in the TeO_2 – ZnO – Bi_2O_3 system and study in physical, optical and luminescence.

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2. Experiment

A series of zinc tellurite glasses of the composition (90-x) TeO_2 – 10ZnO – xBi_2O_3 by (where x = 10, 15, 20, 25 mol%) have been synthesized from high purity powder of TeO_2, ZnO and Bi2O3 total weight of 15 g by conventional melt quenching technique at 1,150 °C for 1 hours 30 minutes and annealing at 350 °C for 3 hours. Analysis of physical properties by density and molar volume via Archimedes melted using densitometer HR-200 weighing valance was carried out. The optical measurement sample of 0.3 mm thickness were cut and polished to optical quality. The transmission spectra of the samples prepared were measured using a UV-Visible Spectrophotometer Cary 50 Scan (VARIAN) in the 200-1,100 nm range and the excitation emission spectra were collected by using a Cary Eclipse Fluorescence Spectrophotometer (Agilent Technologies).

3. Results and Discussion

3.1. Physical properties

The result showed that density increased and molar volume increased with increasing Bi_2O_3 concentration by density range of 4.3936 ± 0.0294 to 7296.4

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Table 1. Density and molar volume of the bismuth-doped glasses

Physical Properties	Density (g/cm^3)	Molar Volume (cm^3/mol)
10 mol%	4.3936 ± 0.0294	41.5175
15 mol%	4.6177 ± 0.0047	42.8199
20 mol%	4.7123 ± 0.0124	45.2111
25 mol%	4.7296 ± 0.0083	48.2851

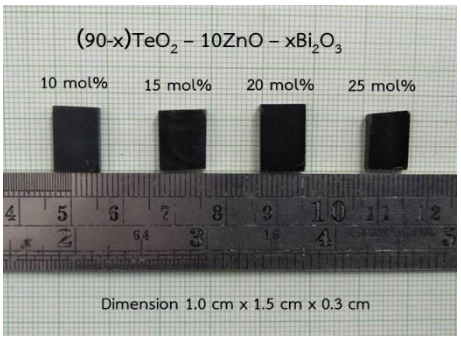

Figure 1: Glass sample of the bismuth-doped zinc tellurite glasses.

± 0.0083 g/cm^3 and molar volume range of 41.5175 to 48.2851 cm3/mol. It is clear that with increasing concentration of Bi_2O_3, the overall molecular weight of the glasses has increased due to its high MW (465.96 g/mol), as a result, the density of bismuth-doped glasses was increased and has shown maximum value 5.732 g/cm^3. That can be explained by high refractive index of individual Bi_2O_3 (≈2.4), and indicates the increase of non-bridging oxygens to bridging oxygens ratio [6].

3.2. Optical properties

The result showed that optical absorption spectra of glasses were measured in the wavelength range of 200 – 1,100 nm for Bi^{3+} the intensity of all absorption bands increased with increasing Bi_2O_3 content by absorption edge of 532, 555, 581 and 646 nm. In fact, measuring cut-off wavelength is a useful factor in order to clearly understand optical transitions and electronic band structure in amorphous solids. From the absorption spectra, within the wavelength range 400–800 nm, absorption coefficient $\alpha(\lambda)$ was calculated for all the glasses with thickness of 'd' using the optical absorbance A, based on the following formula that reported in [7] :

$$\alpha(\lambda) = 2.303\left(\frac{A}{d}\right) \quad (1)$$

The polished glasses thickness was≈ 3.0 mm. In our glasses due to the≈ (3 mm) thickness, we choose absorption coefficient $\alpha(\lambda)$ at ≈ 12 cm^{-1} as a reference similarly as in absorbance A, based on the following formula that reported in [8].

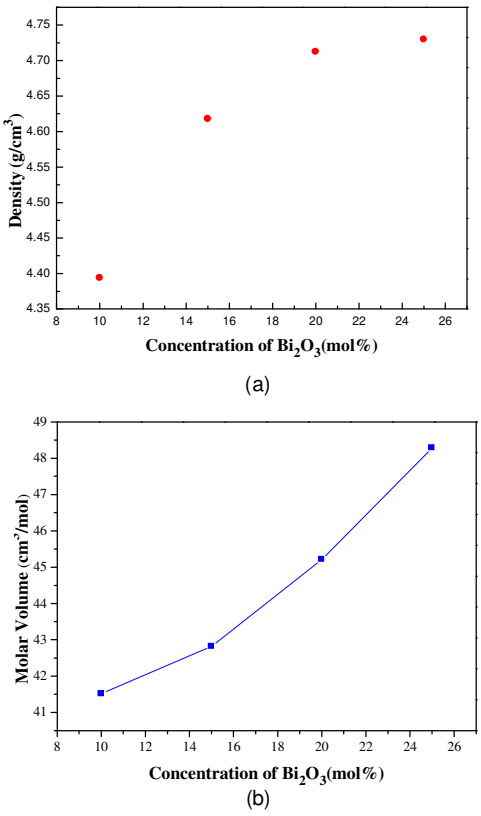

Figure 2: (a) Density of the bismuth-doped glasses (b) Molar volume of the bismuth-doped glasses

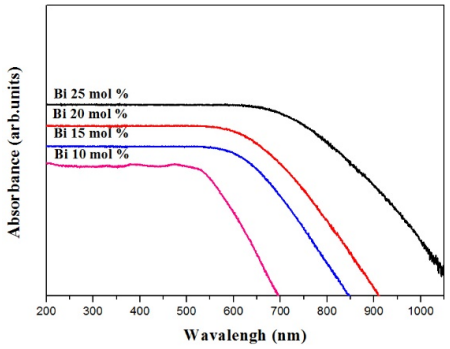

Figure 3: Absorption spectra of the bismuth-doped glasses.

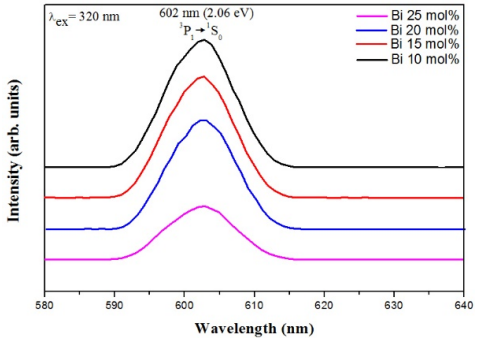

Figure 4: Emission spectra of the bismuth-doped glasses.

3.3. Luminescent

The result showed that Emission spectra of glasses were carried out using excitation wavelengths of 302 nm for Bi_2O_3 the luminescence peaks around 602 nm.

4. Conclusions

The result showed that density increased and molar volume increased with increasing Bi_2O_3 concentration. The optical absorption spectra of glasses were measured in the wavelength range of 200 – 1,100 nm for Bi^{3+} the intensity of all absorption bands increased with increasing Bi_2O_3 content. The intensity of all emission bands increased with increasing Bi_2O_3 contents. In addition, the luminescence properties of Bi^{3+} -dope TeO_2 – ZnO – Bi_2O_3 glass system were carried out using excitation wavelengths of 302 nm for Bi_2O_3 the luminescence peaks around 602 nm.

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Spectrum allocation scheme on multi-user MIMO cognitive radio systems

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Abstract

In this paper, the spectrum allocation scheme has been proposed to enable complete spectrum sharing in multi-user MIMO cognitive radio (CR) systems. Performance analysis has been developed to evaluate bit error rate (BER) of each secondary user (SU) because of the effect of node member positions in multi-user CR network. In order to achieve this SUs which are ready to receive data and can communicate by ignoring any damage caused to the primary user (PU)'s communication at the same time. The authors have successfully used this method to process each frequency channel and to allocate channel to the appropriate SUs. The advantages of this system are as follows: 1) the performance analysis is able to support multi-user CR systems, 2) this research can clearly indicate the effect of the positions of node members in the CR network on their service quality, 3) the impact on both downlink and uplink operations are combined in order to make the final decision for communication, and 4) the spectrum allocation scheme which is able to allocate frequency channels for all users in CR systems is presented. The simulation results that are provided, show the performance of SU in term of BER inside their coverage areas along with the effect of GPS error. The results present the complete allocation of spectrum sharing for multi-user CR systems. The outcome of this research is very useful in further development of CR systems. In addition to this, it can be easily implemented in practice at the stage of spectrum sharing. Each SU can decide for themselves whether their position is adequate for good quality communication or not.

Keywords: Cognitive radio, MIMO, spectrum sharing

Article history: Received 14 January 2019, Accepted 30 August 2019

1. Introduction

Currently, CR concept put emphasis on opening new ways of communication. Many researchers have proposed spectrum sensing as the basic function to operate CR systems, the work in [1] has presented the spectrum sensing enhancement methods in terms of theory and the work in [2] has presented the optimization techniques for spectrum sensing using node member cooperation in CR network. The work in [3] has developed a cooperative decision technique to support the imperfect feedback channel in which the work can reduce the wrong identifying on the channel statuses. The work in [4] has proposed the privacy-preserving protocols enabling SUs to operate with the reliable performance and efficient spectrum sensing. The work in [5] has proposed the control channel on media access control (MAC) protocol employed by SUs to share the spectrum sensing results. Then, SUs can create the self-schedule to achieve the better throughput. Furthermore, the work in [6] has presented the CR broker concept in which PUs open the opportunity for SUs to access idle channel by exchanging the formal payment. When the spectrum sensing process has been developed to be reliable enough, SUs can access the available channel by ignoring harm to primary link or access the occupied channel under the acceptable level of interference. Thus, there have been various works that introduce the ways to reduce interference for spectrum sharing [7, 8]. The works in [9, 10] have proposed the performance analysis for spectrum sharing in MIMO CR systems employing transmit antenna selection (TAS) at the secondary transmitter (ST) and maximum ratio combining (MRC) at secondary receiver (SR). It can be seen that the interference level is up to transmitted power of each node member in CR network. Furthermore, energy management is an important issue for current technology [11]. Hence, many works have focused on power control scheme. Such as in [12-15], the works have introduced power allocation schemes to support CR systems. Because the existing performance analysis does not support multi-user systems, the work in [16] has developed the performance analysis to support multi-

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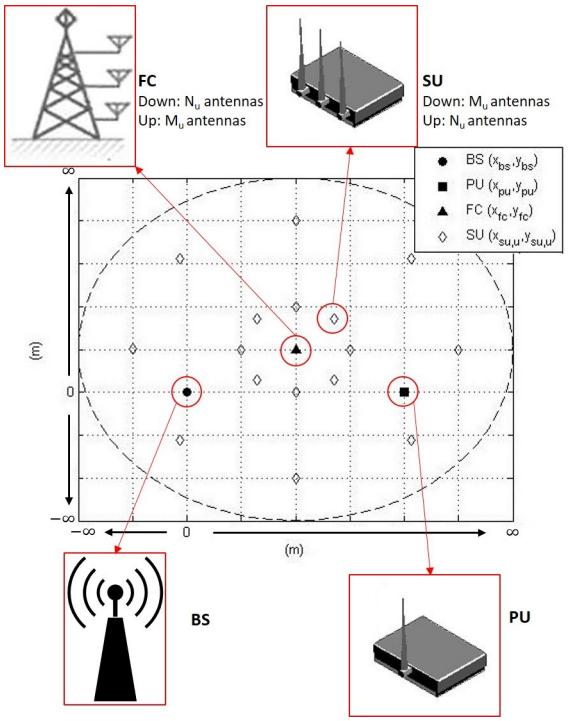

Figure 1: System model for multi-user one-cell spectrum sharing in MIMO CR system.

user MIMO CR systems and displayed the BER based on the position of each SU on both downlink and uplink. The results can guide SUs to evaluate themselves at a certain frequency channel.

For the concept of multi-user CR systems, the first proper group from all SUs can access the first frequency channel. Hence, the rest SUs can pass the BER condition for the next channels due to the reduced interference factors. In this paper, the authors proposed the spectrum allocation scheme for multi-user MIMO CR systems. The simulation results describe the performance of each SU in term of BER based position on both downlink and uplink. The intersection result is brought to perform the spectrum allocation in order to thoroughly allocate the frequency channels to all users in CR system.

2. System Model

In this CR system as seen in Figure 1, there is only one primary link per one frequency channel that is composed of one antenna for both primary transmitter (PT) and primary receiver (PR). Nevertheless, there are U SUs inside the coverage area of a fusion center (FC) for $u = 1, 2, ..., U$. In this CR system as seen in Figure 1, there is only one primary link per one frequency channel that is composed of one antenna for both primary transmitter (PT) and primary receiver (PR). Nevertheless, there are U SUs inside the coverage area of a fusion center (FC). Each secondary link is composed of N_u and M_u antennas for secondary transmitter (ST) and secondary receiver (SR), respectively. For supporting the MIMO systems, the number of antenna elements of each secondary node has to be not less than 2 antennas.

For downlink, the base station (BS) is PT, FC is ST, PU is PR, and SUs are SRs. The channel between the selected antenna of FC and the k^{th} antenna of the u^{th} SU has a channel coefficient $h_{sk,u}$. The channel between the selected antenna of FC and an antenna of PU has a channel coefficient h_{sp}. The channel between an antenna of BS and the k^{th} antenna of the u^{th} SU has a channel coefficient

For uplink, BS is PR, FC is SR, PU is PT, and SUs are STs. BS is defined as PR while FC is defined as SR, and PU is defined as PT while SUs are defined as STs. The channel between the selected antenna of the u^{th} SU and the j^{th} antenna of FC has a channel coefficient $h_{sj,u}$. The channel between the selected antenna of the u^{th} SU and an antenna of BS has a channel coefficient $h_{sp,u}$. The channel between an antenna of PU and the j^{th} antenna of FC has a channel coefficient h_{pj}. The channel between the selected antennas of other SUs in the same coverage area and the j^{th} antenna of FC has an average channel coefficient $\bar{h}_{ij,u}$. From Figure1, the received power on both downlink and uplink of primary links are given as

$$P_p = P_{max}\left(\frac{\lambda}{4\pi R_p}\right)^2 G_t G_r, \tag{1}$$

where R_p is distance between PT and PR, λ is wavelength, P_{max} is maximum primary transmitted power, and G_t and G_r are transmitter gain and receiver gain, respectively.

For both downlink and uplink, the distance from PT to SR is $D_{ps,u}$, and the distance from ST to SR is $D_{ss,u}$

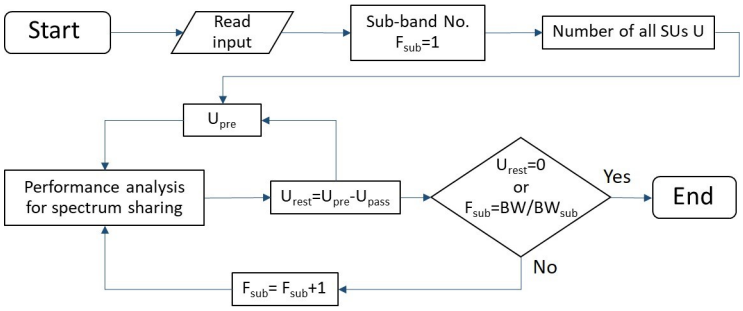

Figure 2: Block diagram of spectrum allocation scheme for overlapping spectrum sharing.

. Hence, their received powers from both distances are given as

$$P_{ps,u} = P_{max}\left(\frac{\lambda}{4\pi D_{ps,u}}\right)^2 G_t G_r, \tag{2}$$

$$P_{ss,u} = P_{smax}\left(\frac{\lambda}{4\pi D_{ss,u}}\right)^2 G_t G_r, \tag{3}$$

in which P_{smax} is a maximum secondary output power. But only for uplink, it has the interference power vector due to other SUs in the same coverage area, which can be defined as

$$\mathbf{P'}_{ssI\_u} = \mathbf{P'}_{ss\_u} - [0 \ \ldots \ P_{ss,u\_u} \ 0 \ L \ 0], \tag{4}$$

where $P_{ss,u\_u} \in \mathbf{P}_{ss\_u}$. In order to avoid any confusion, we have added subscript $\_u$ into the power variables and power matrices representing for the uplink, and $\_d$ for downlink.

3. Performance Analysis

To evaluate BER, the $m-$QAM modulation is employed, where m is constellation size. Then the received power from ST to PR is given by

$$P_{sp} = \left(\frac{-1.5P_pG_c}{(m-1)\ln\left(5BER_p\right)} - N_o\right)\frac{1}{\bar{g}_{sp}}, \tag{5}$$

where $\bar{g}_{sp} = avg\left(\left|\mathbf{h}_{sp}\right|^2\right)$ is an average channel gain from ST-PR., G_c is the coding gain [17, Eq. 9.38], and N_o is the power spectral density of noise assumed to be constant and the same for all states. Next, by considering the power P_{sp} from (5), the BER region of primary network due to interference from ST in the same location can be found by

$$D_{sp} = \frac{\lambda}{4\pi}\left(\frac{P_{smax}G_tG_r}{P_{sp}}\right)^{\frac{1}{2}}. \tag{6}$$

By using PR as a reference position, the distance from ST to PR D_{sp} from (6) will show the possible position of ST that can be available to communicate with FC around PR. Thus, the positions of ST that affect PR satisfaction can be predicted.

Next, SNR from ST-SR link for both downlink and uplink are defined as

$$\gamma_{ss,u} = g_{ss,u}\frac{P_{ss,u}}{N_0}. \tag{7}$$

where $g_{ss,d} = \sum_{k=1}^{M_u}\left|h_{sk,u}\right|^2$ for downlink and $g_{ss,u} = \sum_{j=1}^{M_u}\left|h_{sj,u}\right|^2$ for uplink. When interference from PT-SR is considered, SNR from PT-SR on downlink is defined by

$$\gamma_{is,u\_d} = g_{ps,u}\frac{P_{ps,u\_d}}{N_0}, \tag{8}$$

where $g_{ps,u} = \frac{\left|\sum_{k=1}^{M_u} h^*_{sk}h_{pk,u}\right|^2}{g_{ss,u}}$ is the channel gain from PT-SR for downlink. For uplink, SNR is defined by

$$\gamma_{is,u\_u} = g_{ps}\frac{P_{ps,u\_u}}{N_0} + \bar{g}_{is,u}\sum_{u=1}^{U}\frac{P_{ssI,u\_u}}{N_0}, \tag{9}$$

where $g_{ps,u} = \frac{\left|\sum_{j=1}^{M_u} h^*_{sj,u}h_{pj}\right|^2}{g_{ss,u}}$ and $\bar{g}_{is,u} = \sum_{j=1}^{M_u}\left|\bar{h}_{ij,u}\right|^2$ for uplink. Then, the BER for both downlink and uplink is

$$BER_{Int,u}(a,b) = \frac{a}{2}\sqrt{\frac{b}{2\pi}}\frac{1}{\Gamma(M_u+1)}[I_{1,u} + I_{2,u} + I_{3,u} + I_{4,u}], \tag{10}$$

where

$$I_{1,u} = \frac{(-1)^{M_u(N_u-1)+1}}{(M_u(N_u-1)-1)!}e^{\frac{1}{\gamma_{is,u}}}\left(\frac{\gamma_{is,u}}{\gamma_{ss,u}}\right)^{M_uN_u} \frac{\Gamma\left(M_uN_u+1,\frac{1}{\gamma_{is,u}}\right)}{\left(M_uN_u+\frac{1}{2}\right)}\frac{\Gamma\left(M_uN_u+\frac{1}{2}\right)}{\left(\frac{1}{\gamma_{ss,u}}+\frac{b}{2}\right)^{M_uN_u+\frac{1}{2}}} {}_2F_1\left(1, M_uN_u+\frac{1}{2}; M_uN_u+\frac{3}{2}; \frac{b\gamma_{ss,u}}{2+b\gamma_{ss,u}}\right), \tag{11}$$

$$I_{2,u} = (-1)^{M_u(N_u-1)}(M_uN_u)!\Gamma\left(M_uN_u+\frac{1}{2}\right) e^{\frac{b\gamma_{ss,u}+2}{4\gamma_{is,u}}}\sum_{k=1}^{M_uN_u}\frac{(k-1)!}{k!}\sum_{m=0}^{k-1}\frac{\left(\frac{1}{\gamma_{is,u}}\right)^m}{m!} \left(\frac{1}{\gamma_{ss,u}}+\frac{b}{2}\right)^{-\frac{1}{2}\left(M_uN_u+m-k+\frac{3}{2}\right)}\left(\frac{\gamma_{ss,u}}{\gamma_{is,u}}\right)^{\frac{1}{4}(2k+2m-2M_uN_u-1)} \mathrm{W}_{\frac{1}{2}\left(m-k-M_uN_u-\frac{1}{2}\right),-\frac{1}{2}\left(M_uN_u+m-k+\frac{1}{2}\right)}\left(\frac{b\gamma_{ss,u}+2}{2\gamma_{is,u}}\right), \tag{12}$$

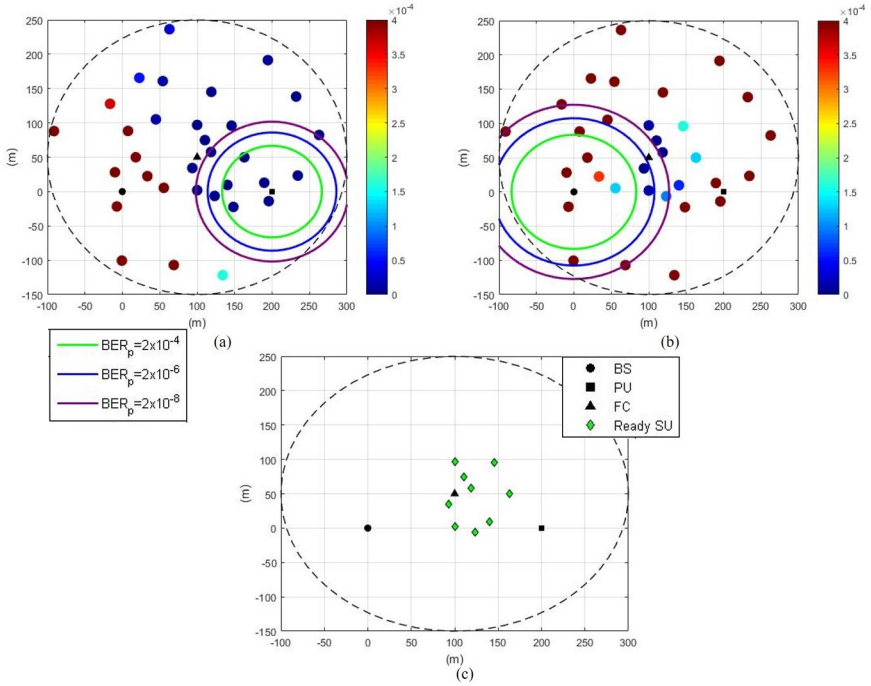

Figure 3: Spectrum sharing in multi-user MIMO CR systems, (a) downlink, (b) uplink, and (c) their intersection.

$$I_{3,u} = \left(\frac{1}{\gamma_{is,u}}\right) e^{\frac{b\gamma_{ss,u}+2}{4\gamma_{is,u}}} \sum_{k=0}^{M_u(N_u-1)-2} (-1)^{M_u(N_u-1)+k} k!\,(M_uN_u-k-1)!\Gamma\left(M_uN_u-k-\frac{1}{2}\right)\times \sum_{m=0}^{M_uN_u-k-1} \frac{\gamma_{ss,u}}{m!}^{1-m}\left(\frac{1}{\gamma_{ss,u}}+\frac{b}{2}\right)^{-\frac{1}{2}\left(m+\frac{1}{2}\right)}\left(\frac{\gamma_{ss,u}}{\gamma_{is,u}}\right)^{\frac{1}{2}\left(m-\frac{3}{2}\right)} \mathrm{W}_{\frac{1}{2}\left(2k-2M_uN_u+m+\frac{3}{2}\right),\frac{1}{2}\left(-m+\frac{1}{2}\right)}\left(\frac{b\gamma_{ss,u}+2}{2\gamma_{is,u}}\right), \tag{13}$$

and

$$I_{4,u} = M_u!\left[\sqrt{\frac{2\pi}{b}} - \left(\frac{1}{\gamma_{is,u}}\right) e^{\frac{b\gamma_{ss,u}+2}{4\gamma_{is,u}}} \sum_{k=0}^{M_u} \Gamma\left(k+\frac{1}{2}\right) \sum_{m=0}^{k} \frac{\gamma_{ss,u}}{m!}^{-m+1}\left(\frac{1}{\gamma_{ss,u}}+\frac{b}{2}\right)^{-\frac{1}{2}\left(m+\frac{1}{2}\right)}\left(\frac{\gamma_{ss,u}}{\gamma_{is,u}}\right)^{\frac{1}{2}\left(m-\frac{3}{2}\right)} \mathrm{W}_{\frac{1}{2}\left(m-2k-\frac{1}{2}\right),\frac{1}{2}\left(-m+\frac{1}{2}\right)}\left(\frac{b\gamma_{ss,u}+2}{2\gamma_{is,u}}\right)\right], \tag{14}$$

where a and b are the modulation-specific constants, such as (a,b) =(1,2) for BPSK, $(a,b) = (1,1)$ for BFSK, and $\left(2\left(m-1\right)/m, 6\log_2\left(m\right)/\left(m^2-1\right)\right)$for $m-$PAM. $\Gamma(.)$ is the gamma function, $\Gamma(.,.)$ and $\gamma(.,.)$ are the upper incomplete gamma function and the lower incomplete gamma function, respectively. ${}_2F_1\left(.,.;.;.\right)$ is the hypergeometric function, and $W_{\varepsilon,\mu}\left(.\right)$ is the Whittaker W-function [16].

4. GPS Error

Although the current GPS devices have the high accuracy, there are still some errors that cannot be ignored in practical spectrum sharing process. The GPS error can be inserted into the performance analysis using

$$\hat{\mathbf{x}}_{su} = \mathbf{x}_{su} \pm \mathbf{rand}[0, error_{GPS}]_{U\times Q} \cos\left(\tan^{-1}\left(\frac{\mathbf{y}_{su}}{\mathbf{x}_{su}}\right)\right), \tag{15}$$

$$\hat{\mathbf{y}}_{su} = \mathbf{y}_{su} \pm \mathbf{rand}[0, error_{GPS}]_{U\times Q} \sin\left(\tan^{-1}\left(\frac{\mathbf{y}_{su}}{\mathbf{x}_{su}}\right)\right), \tag{16}$$

to replace in the distance equations of the above sections. The GPS error is in meters which has the value between 0 and $error_{GPS}$, where $error_{GPS}$ is the highest GPS error according to the accuracy of each GPS device.

5. Spectrum Allocation Scheme

The last process of CR system is spectrum decision in which appropriate frequency channel is chosen by the demand of users. This spectrum allocation scheme manages the appropriate frequency channel for each SU in the entire system. By the way, a diagram of this scheme is demonstrated in Figure 2 along with the steps as follows.

Step 1: Starting next to spectrum sensing process, there is the important information including the number of SUs and their positions, and the number of considered frequency channels defining from bandwidth value divided by sub-bandwidth value. Thus, the considered frequency channel $F_{sub} = 1, 2, ..., BW/BW_{sub}$, in which BW and BW_{sub} values are defined based on each communication standard. Incidentally, F_{sub} is called the sub-band number. Then, the first frequency channel is analyzed.

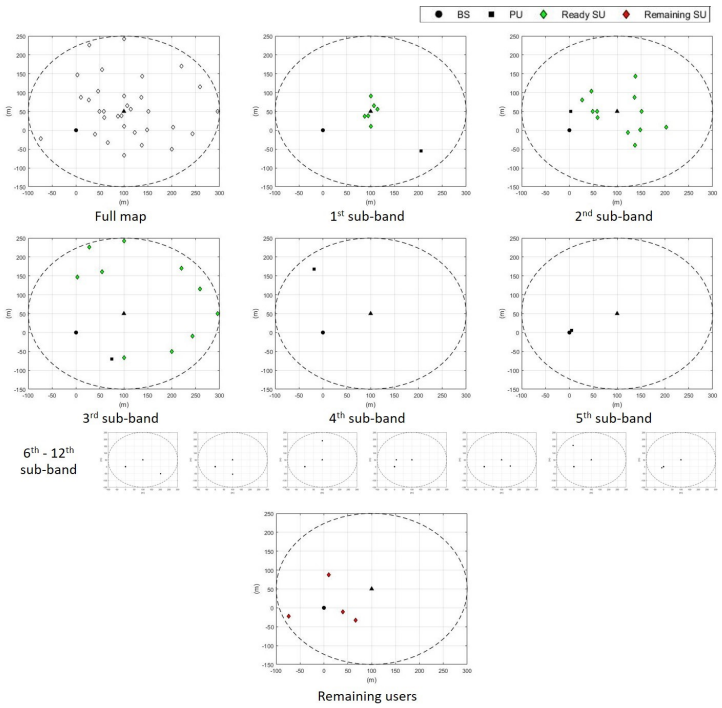

Figure 4: Full-system spectrum sharing with 32 secondary users inside the coverage area of fusion center.

Step 2: The number of all SUs and their positions are brought into the performance analysis process. The appropriate SU is SU that passes the BER condition on both downlink and uplink in the considered round. Therefore, the result of this step is the number of SUs that are ready for communication.

Step 3: The rest number of SUs U_{rest} is calculated by (17) in which these SUs still are not passing a BER condition on both downlink and uplink in the considered round.

$$U_{rest} = U_{pre} - U_{pass}, \tag{17}$$

where U_{pre} is the rest number of SUs from a previous round, and U_{pass} is the number of SUs that pass the BER condition on both downlink and uplink in the considered round and are ready to perform the communication. Note that U_{pre} is equal to a number of all SUs in the first round. Incidentally, U_{pre} and U_{rest} are the same but are in different rounds.

Then, the steps 2 and 3 will be repeated until the overall SUs is ready to perform the communication. If the process comes to the last round that $F_{sub} = BW/BW_{sub}$ but $U_{rest} \neq 0$, the rest SUs cannot operate the communication at this time

Step 4: The new term of spectrum sharing has to wait for the next observation time of spectrum sensing process.

6. Simulation Results and Discussion

The channel model under simulation is referred to LTE standard [18], which defines the system parameters including 1920 MHz – 1980 MHz for uplink operating band, 2110 MHz – 2170 MHz for downlink operating band, 23 dBm for maximum transmitted power, -103.535 dBm for minimum received power, and the tolerated BER = 2×10^{-4}. For this work, the authors have defined the number of antennas of SUs are random from 2 up to 4, $(a, b) = (1, 2)$, $G_t = 0$ dB, $G_r = 6$ dB, $G_c = 6$ dB, the transmitted power of BS is 10 dBW, $m = 16$, and the GPS error around 0−3 m. There is a PU per one frequency channel that randomly appears inside the macrocell, and there are 32 SUs inside the coverage area of FC.

Figure 3 displays the BER of SUs. For downlink in Figure 3(a), there are some SUs that do not pass the BER condition due to the interference from BS. Especially, there are the circles around PU that indicate $BER_p = 2 \times 10^{-4}$, 2×10^{-6}, and 2×10^{-8}. If PU walks into FC too closely in which FC stays inside the circle $BER_p = 2 \times 10^{-4}$, the FC has to access other frequency channels in order to avoid the undesirable interference to primary link. For uplink in Figure 3(b), if any SU appears inside the circle $BER_p = 2 \times 10^{-4}$, SU cannot perform the communication at this frequency channel. And there are some SUs that do not pass the BER condition due to the interferences from PU and other SUs. Apart from these SUs, the others in different positions are available to operate MIMO CR communications. Finally, the intersection result of available SUs between Figure 3(a) and Figure 3(b) is shown in Figure 3(c). It is observed that some SUs can perform spectrum sharing under successful operation on both downlink and uplink. This is based on each SU position under the condition that BER of both PU and SU have to be less than 2×10^{-4}.

To achieve the goal of spectrum sharing operation, all processes in Figure 3 are performed in which the results are shown in Figure 4. Additionally, $BW_{sub=5}$ MHz. Thus, the number of sub-bandwidths is 12 referring to the bandwidth in LTE standard. Starting with the top left figure, it shows the full map of CR system which represents all of node member positions except PU that appears in a different position for each frequency channel. Then, PU appears in the next figure. As in Figure 3, after the performance analysis process of 1st sub-bandwidth, the result is shown in the top center figure. The appropriate SUs achieves the permission first reducing the interference factor at the next sub-bandwidth. At the 4th-12th sub-bandwidths, there are no any SUs that can perform the communication in this spectrum. Because the spectrum allocation comes to the last round, the rest SUs cannot operate and have to wait for the new observation time of spectrum sensing process. As seen in the last bottom figure, the remaining SUs are shown. If analyzed by the location of those SUs, then it can be explained that it is the effect of powerful interference from the BS on downlink. If those SUs change their positions before the next observation time of the spectrum sensing process, they may have the occasion to pass the BER condition and can perform the communication. Note that the effect of GPS error of this result existed but not displayed and not focused due to the fact that the system does not know how much impact it has in reality. This effect of GPS error depends on the quality of each GPS device which is inexact.

7. Conclusions

The performance analysis based on the positions of node members for spectrum sharing techniques has been presented in this paper. The relationship between BER and positions of users is shown in the mathematical solution in which the users at the same frequency channel affect each other depending on their positions. The simulation results can describe the interference impact of each user in CR system related to a thorough performance analysis in terms of BER that supports both downlink and uplink operations. In addition, the system can allocate the frequency channels to all users as thoroughly as possible employing the spectrum allocation scheme. Because the primary link is the main priority in the system, this work is suitable for data transferring applications which can wait for the proper position of SU in communication. Hence, the proposed CR concept is very useful for multi-user MIMO CR implementation. It can decide for SUs in the appropriate positions offering them good quality communication. Moreover, the rest SUs can access the next channels due to the reduced interference factors.

Acknowledgements

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Social, religious, recreational and medicinal usage of cannabis in India and Thailand

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Abstract

Cannabis usage is controversial both in India and Thailand. Cannabis has a history of social, religious, recreational and medicinal usage dating back centuries. This article, based on literature review, focuses on the history of cannabis usage in India and Thailand in order to highlight the importance of more research regarding the medicinal use of cannabis in oncology in different countries as India and Thailand. As more countries approve cannabis use for therapeutic uses, physicians need to research more information regarding the risks and benefits of use. Hence the present article reviews the history, the importance of cannabis usage in different societies from the past to the present. There is difference in the form of cannabis usage between India and Thailand in the past as it was used for social, religious and medicinal purpose in traditional India. On the other hand, in Thailand, it was used mostly for recreational culture and industrial purpose. One similarity of the two countries at present is in the medicinal usage. Both countries are trying to legalize the use of cannabis for medical research and medicinal purposes. On the whole, more research should be done with the legalization of cannabis usage for therapeutic purposes and research in medical science.

Keywords: cannabis usage, (social, religious, recreational and medicinal), India, Thailand
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1. Introduction and Historical Background

In recent decades, people have been affected by various kinds of incurable common diseases, such as cancer, diabetes, arthritis, heart disease, insomnia and so on. This made medical scientists, oncologists and doctors to turn their attention on a herb called "*cannabis*", also known as *marijuana* for therapeutic use. *Cannabis/marijuana* plant is unique in the world as it produces chemical cannabinoids or psychoactive drug called THC. THC stands short for tetra-hydro-cannabinol, which is a chemical compound found in the cannabis plant. It produces chemical effects in the brain via cannabinoid receptors when it is taken through ingestion or inhalation. The cannabinoid compound when used in low dosage helps to reduce pain, aggression, nausea etc. and at the same time stimulates appetite. When consumed in higher dosage, it may cause intoxicating effects also called the "high" commonly associated with marijuana, the effect of it causes change in one's perception of time and space, and feelings of happiness or fatigue.

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However, till date, there is limited investigation on this herb due to its Schedule I classification and therefore, it is hard to make effective use of this herb legally due to the imposition of strict laws. This article aims to fill available knowledge gap through reviewing literatures, highlighting the significance of this herb and the need to make effective use of this herb, by pushing the respective governments to lift ban on cannabis for medical research or further studies. This article aims at:

– reviewing the historical background of cannabis usage in different societies, particularly in India and Thailand from past to present

– reviewing the social, religious, recreational and medicinal usage of cannabis in India and Thailand

– highlighting similarities and differences for cannabis usage in India and Thailand

The findings from this review may help to bring awareness or knowledge about the variation of its usage and the status of legalization of cannabis usage in between India and Thailand. The authors have obtained secondary data through an extensive literature review, such as textbooks, journal articles and from internet sources relating to history of cannabis usage,

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social, recreational, religious and medicinal purposes in India and Thailand. The article is organized as: Introduction and Historical Background, Objectives and Methods, Cannabis Usage in India, Cannabis Usage in Thailand, Summary and Conclusions, and Recommendation.

Cannabis is one of the oldest plant known to mankind, with records of its cultivation dating back thousands of years. The first evidence of the use of cannabis was found in China, where archeological and historical findings indicate that cannabis plant was cultivated there for fibers since 4.000 B.C. [1, 2]. The use of cannabis as a medicine by ancient Chinese was reported since the remote past and it continues until today, which cannabis seeds continue to be used as a laxative by Chinese physicians [3]. In India, cannabis was used both as a medicine and as a recreational drug on socio-religious occasions as the sacred virtue of cannabis plant has an association with ancient religion of India. It has been mentioned in the *Atharva Veda* (a collection of sacred texts of unknown author) that cannabis was a sacred plant, providing mankind a source of happiness and freedom. Hence, cannabis use became part of numerous social and religious rituals in India [3]. The use of cannabis in America is assumed to begin in South America, introduced to Brazil by the African slaves in the 16th century. While in Europe, during this period, cannabis was cultivated exclusively for fibers [4]. Along with this, in course of time, cannabis was introduced in the western medicine in the middle of the 19th century with the usage of cannabis extracts to treat epilepsy, tetanus, rheumatism, migraine, asthma, trigeminal neuralgia, fatigue and insomnia The western medicinal usage of cannabis declined significantly in the first decades of the 20th century due to difficulties in obtaining consistent results from various batches of plants having different compounds. This causes interests to the medical scientists and practitioners to identify the chemical structure of cannabis components and the possibility of obtaining its pure constituents through renewed research and investigation of cannabinoid receptors and the identification of an endogenous cannabinoid system in the brain in the 1990's. Along with this, a new and more consistent cycle of the use of cannabis derivatives as medication begins, since treatment effectiveness and safety started to be scientifically proven [1]. Cannabis has a long history of medicinal use in the Middle East, Asia and South East Asia, with references as far back as the 6th century BC [5].

1.1. Types of Cannabis Plants

There are two major types of cannabis plants, namely, *Cannabis Indica* and *Cannabis Sativa* as shown in Figure 1 and 2. *Cannabis Indica* plants are short, bushy plants with wide leaves, grow faster and have a higher yield than the sativa variety. Medicine produced from Cannabis Indica have higher CBD and lower THC counts. The major qualities of Indica medicinal strains include: increased mental relaxation, muscle relaxation, decreases nausea, decreases acute pain, increases appetite, increases dopamine for night time use [6]. Cannabis Indica is assumed to be originated from Pakistan, Afghanistan, Morrocco or the Asian subcontinent near Tibet, where the climatic condition is suitable for its growth. European botanist Jean-Baptiste Lamark first published a description of *Cannabis Indica* which he discovered in India back in 1785. Hence the prefix "*Indi-*" is put [7]. *Cannabis sativa*, on the other hand, is a species of the Cannabaceae family (hemp) that grows tall to around 4.5 meters with spaced branches and narrow leaves, originated in the equatorial countries of Colombia, Mexico, Thailand, and South East Asia and thrive in warmer weather and is one of the oldest and biggest psychoactive plant used for food, fiber, medicine, oil etc. It has been used by innumerable ethnic societies in Asia [8.]. Now, it is one of the most widespread species in nature. It is found in various habitats ranging from sea level to the temperate and alpine foothills of the Himalayas, from where it was probably spread over the last 10,000 years [5]. Sativa plants are also generally a lighter shade of green than the Indica strain. Sativa strains take longer to grow, takes ten to sixteen weeks to be fully grown and require more light. Medicine produced from *Cannabis Sativa* plants have lower CBD and higher THC counts. The major qualities of Sativa medicinal strains include: anti-anxiety, anti-depressant, treats chronic pain, increases focus and creativity, increases serotonin (a neurotransmitter involved in the regulation of learning, mood, sleep, anxiety and appetite) for day time use [7].

2. Cannabis Usage in India

Cannabis usage is rooted in the ancient history of India. It has been used for many purposes by many ethnic societies such as Uttaranchal, an ethnic region in the Northern part of India, where the plant is a part of the local culture. Shah [8] in his study of cannabis described the indigenous uses and ethno botany of its seed, seed oil, stems, fiber, leaves, inflorescences and resin along with various recipes of seeds. His study concluded that its cultivation should be promoted in the Himalayan regions of India, which grows naturally as the climate there is favorable and also embedded with the way of life for the rural people living in the region. Similarly, Godlaski [9] stated that cannabis has been used in India for thousands of years since the time of myths, mythology and folklores. The practice of consuming cannabis can be traced from legends such as the *Vedas* (the ancient sacred books of Hinduism) about the origin of cannabis and its relationship to Shiva dating about 1400 BC. It is mentioned in his work that many worshippers of Lord Shiva, the

Figure 1: Cannabis Sativa

Figure 2: Indica

Sources:
1. [www//res.cloudinary.com/woahstorklearn/image/upload/v1496420060/Sativa_vs_Indica_Comparison_ur82a1.png]
2. [www.hcillinois.com/images/lists/189/indica%20v%20sativa.jpg]

Hindu God, consumed cannabis orally in the form of *bhang* on *Shivaratri* (auspicious holy day dedicated to Shiva) and other festival days that worship Lord Shiva. Lord Shiva is considered as the destroyer of evil, lived the life of an ascetic on Mount Kailash [10] as shown in Figure 3, Figure 4, and Figure 5.

According to an ancient Hindu legend, when the Gods stirred the heavenly ocean with the peak of Mount Mandara, a drop of *amrita (sacred nectar)* fell from the sky. Where it landed, the first cannabis plant sprouted. Lord Shiva brought the plant down from the Mount for the benefit of mankind [11]. Since that time, the use of cannabis has been closely associated with the devotion to Shiva. The Vedas call cannabis a source of happiness, joy-giver, liberator that was compassionately given to humans to help human beings attain delight and lose fear [12, 13]. According to another legend, Shiva wandered off into the fields after an argument with his family. Upset by this family conflict and fatigued by the hot sun, he fell asleep under a leafy plant. When he woke up, he noticed the beautiful plant under which he found shade and decided to try the leaves of the plant. He was immediately rejuvenated. Shiva made the plant his favorite food and he became known as the *Lord of Bhang* [14]. Thus, *Bhang* is the most commonly consumed preparations of cannabis in India, made from the leaves of Hemp by grinding it, also known as ganja, weed or pot and is generally consumed on the day of *Shivratri* (the day of worshipping Shiva), also offered it to images and statues of Lord Shiva. According to another belief in traditional India, Bhang is used to destroy the evil eyes of demons, because it is believed in ancient India religion that the cannabis plant contains spirit which can counter the activity of demons [15]. The *Sathus* (Holymen of India) who are devoted to Lord Shiva, and having an ascetic life, consume cannabis quite often but not in the form of bhang, by smoking the highly resinous buds of the female plant or the resin itself which is called, *hashish*, in small clay pipes. These pipes are called *chillum* and sadhus use them in rituals of worship, meditation, and yogic practice [16]. Chillum smoking is usually done in religious social occasion, smoking in rotation by passing it in a clockwise circular form. The first person fills the bowl and passes it to the second and the second person raises the bowl to his forehead and utters a short formula, chanting "Bum Shankar!" dedicated to the act to Shiva. He then lights it with two matches, representing the male and female poles of the universe. When all the hashish has been consumed, the last person taps the ashes into his hand and puts them on his tongue to swallow. These ashes are believed to have powerful medicinal properties [17]. Ratsch [17] comments that chillum smoking is a relatively elaborate process that demonstrates the profound respect the consumer has for the plant as well as shows the religious rituals and tradition which is closely associated with hemp smoking. Touw [3] comments that such behavior would seem to indicate that the use of cannabis is as sacred, significant, and highly respected as is the use of wine in Holy Communion by Christians according to his experience on and sadhus use them in rituals of worship, meditation, and yogic practice [16]. Chillum smoking is usually done in religious social occasion, smoking in rotation by passing it in a clockwise circular form. The first person fills the bowl and passes it to the second and the second person raises the bowl to his forehead and utters a short formula, chanting "Bum Shankar!" dedicated to the act to Shiva. He then lights it with two matches, representing the male and female poles of the universe. When all the hashish has been consumed, the last person taps the ashes into his hand and puts them on his tongue to swallow. These ashes are believed to have powerful medicinal properties [17]. Ratsch [17] comments that chillum smoking is a relatively elaborate process that demonstrates the profound respect the consumer has for the plant as well as shows the religious rituals and tradition which is closely associated with hemp smoking. Touw [3]

Figure 3: Lord Shiva holding Bhang syrup

Figure 4: Lord Shiva meditating on Mt. Kailash

Figure 5: A sadhu smoking cannabis on Shivratri

Sources:
3. [https://www.festivalsofindia.in/img/shiva-aum.jpg]
4. [https://i.pinimg.com/736x/c2/73/6b/c2736bd186b3ab79500a122a35aebf6c–hindu-deities-hinduism.jpg]
5. [https://www.iciclesadventuretreks.com/wp-content/uploads/2015/02/1119.jpg]

comments that such behavior would seem to indicate that the use of cannabis is as sacred, significant, and highly respected as is the use of wine in Holy Communion by Christians according to his experience on *Shivaratri,* an auspicious holy day dedicated to Shiva. It should be noted that the use of cannabis in India, both for religious and for medicinal purposes, is not something that happened only in the distant past, but it continues till the present. Given the very negative view of some developed nations concerning the use of cannabis, it might seem reasonable to expect that the Indian government might also adopt such a view, however due to the common use of cannabis and its very strong association with religious worship, it cannot be forbidden. Toward the end of the colonial domination of India by Great Britain, a large-scale study of cannabis usage in Indian society was conducted by a specially appointed commission [18]. The Commission conducted a very large number of interviews with cannabis users throughout India and concluded that the use of cannabis was highly beneficial to Indian society both as a substance used in religious observance and as a medicine [9].

As a result, it can be said that cannabis usage is closely related to traditional culture and their rituals. Researching relevant historical background and examining associations would give insight into how these substances were viewed in various cultures and the place that they had in those cultures and its functions in history. This has been supported by Gumbiner [14] who stated that cannabis usage has a long history in India, associated closely in Indian legends and religion such as in the *Vedas* (Sacred book of Hindus) [12]. He, too, mentioned the close connection of Lord Shiva and *cannabis/ bhang* in India. In course of time, Cannabis usage is confined not only in the legends or myths but continues in different ages such as soldiers drinking bhang before entering battle in order to make themselves bold, fearless and brave in the battlefield while fighting the enemy during the middle ages.

There are different ways of consuming cannabis in India at that time, as a drink, or boiling it with milk and mixing it with nuts, spices like almonds, pistachios, poppy seeds, pepper, ginger and sugar. Yogurt can also be used instead of milk. But generally, it is rolled and eaten in small balls. Other preparations of cannabis in India are called *ganja* and *charas*. Stronger than bhang, *ganja* is made from the flowers and upper leaves of the female plant. *Charas* is the strongest preparation and is made from blooming flowers. Similar in strength to hashish, *charas* contains a lot of resin. Both are smoked in an earthenware pipe called a *chillum.* The pipe is usually shared among 2 to 5 people, making smoking a communal activity especially for religious occasions.

The British found the use of cannabis so extensive in colonial India, that they commissioned a large scale study in the late 1890s [19] since they were concerned that the abuse of cannabis was endangering the health of the native people and driving them insane. This made the British government who ruled India at that time to ask the government of India to appoint a commission to look into the cultivation of hemp plant, preparation of drugs from it, trade in those drugs, the social and moral impact of its consumption and possible prohibition. Along with commission, over 1,000 standardized interviews were conducted throughout India by eminent British and Indian medical experts by sampling a large and diverse group of people in a range of situations, from farmers to hospital psychiatrists. After years of detailed work, the Indian Hemp Drugs Commission Report produced six volumes of data and concluded that suppressing the use of herbal cannabis (bhang) would be totally unjustifiable since its usage had religious sanction among Hindus since ancient time, and is harmless if used in moderation. Furthermore, prohibition would be difficult to enforce, with many outcries by religious clerics, and possibly may lead to the use of more dangerous narcotics. These findings, conducted over 100 years ago,

are surprisingly relevant today [18, 20].

The Hindu beliefs about cannabis usage shows the capacity of cultural systems to order and direct the course of complex phenomenal events as the effect of its use shows diverse and contradictory effects which depend not only on dose, frequency and way of administration, but also on subjective and cultural contexts. Cannabis effect is considered to be two dimensional:*provide motivation to work and improve motivation.* While cannabis appears to interfere with execution of highly complex tasks and the long-range planning that accompanies them, it may facilitate concentrated focus on repetitive endeavors. As a result, the Hindu belief system accommodates the usage of low potency cannabis preparations as *bhang/thandai* in such a way that prescribing its use becomes beneficial as the drug is also taken in a ritualized context, facilitating concentration and relaxation. It is taken at times, such as in the evening or on holidays, in which focus on the immediate moment is a welcome change [21]. Cannabis, as a psychotropic drug, is rooted in India, used both as a narcotic and medicine in association with the social and religious functions of India and mentioned as a sacred herb in the religious holy books of India [13]. During certain social and religious rites of India, hemp boughs were thrown into fire to destroy evils and overcome enemies. In each region of India, cannabis is offered in different ways according to the locally most favored form of God. To worship Goddess Durga, it is customary to drink bowls of a cannabis preparation and to offer them to others. Similarly, in Madras, *Kama* (god of love), as well as *Shiva* and *Kali*, are worshiped with cannabis offerings [18]. Cannabis has different names in ancient India [4] as cannabis is held to bestow supernatural influence and powers on the user [18]. This practice of using cannabis in the socio-religious functions or rituals continue even to this day. Due to its close association with Hindu religion, countless Indian households in the ancient times grow a cannabis plant or two so as to be able to offer cannabis to a passing sadhu (holy person), or smoked by everyone present during an evening worship of Lord Shiva [22]. Beside the socio-religious uses of cannabis, it has long been used as a medicine for various kinds of diseases and ailments [18, 23]. Particular mention can be made for the use of cannabis as medicine for neurologic conditions [24], as antispasmodic in epilepsy, convulsions and tetanus, for treating paralysis, against hemorrhoids [25] and as a remedy for delirium during fever [24].

From the above review, many ancient texts of India quoted that cannabis plants were used for ailments besides the social and religious aspects. The following are some of the ailments that Indian medicine men have used cannabis to treat for thousands of years:

– Headaches and migraines
– Gastrointestinal disorders
– Generalized and localized pain
– Easing childbirth
– Clearing phlegm
– Sharpening the appetite
– Aiding & quickening digestion
– Refreshing the mind and intellect
– Curing insomnia
– Relieving dysentery
– Anemia and weight loss
– Cough [26].

This shows that cannabis has been used in India not just for social and religious aspects but for medicinal purposes for many centuries. The push to legalize cannabis for therapeutic use is not confined just to the United States but also to India. Doctors in India are pushing for further studies on the efficacy of cannabinoids in cancer patients. However, it is hard to make effective use of this herb legally due to strict laws imposed on the Indian people [26].

Rao [27] said that doctors in India are pushing for further studies on the efficacy of cannabinoids in cancer patients. An article in the Times of India (TOI) Newspaper on Jan 2, 2015 reported that the doctors proposed the government to lift ban on cannabis for medical research. According to the oncologists of India, ganja or marijuana may be frowned upon as a banned recreational drug, but it is high time that the Indian Medical Council make proper use of this herb, as it can be an effective cure for cancer. Their interest in cannabis research was raised up during the recent debates against tobacco farming. The oncologists of India campaigns against tobacco cultivation, as it is the main cause of cancer production, while encouraging cultivation of cannabis, as it can be used for curing many kinds of diseases. The oncologists of India cannot pursue research on cannabis as procurement of the plant is illegal in India. Dr. Vishal Rao, a surgical oncologists on Jan 2, 2015 in TOI compared the situation of cannabis usage in the US and India for medicinal purposes. According to him, 21 states in the US are prescribing derivatives of cannabis for cancer treatment, quite contrary to India, which is lagging behind other countries in cannabis research. According to Dr. Rao [27] cannabis derivatives prevent blood supply to cancer tumour. As cancer cells are hungry cells, once there is discontinuity in the blood supply, they shrink due to lack of glucose. In addition, it is helpful in reducing nausea and vomiting sensation for cancer patients who undergo chemotherapy. This made the oncologists of India approached the government with a proposal to legalize medicinal use of cannabis, to enable the researchers to pursue research on the medicinal benefits of cannabis derivatives and to make available cannabis plants for research purposes. They made it clear that they do not encourage to use the herbs for recreational purposes. However, in the current situation of India, speaking about marijuana is a taboo even among the medical fraternity, leaving aside the medicinal properties of cannabis compounds. Mention can

be made of some drugs from cannabis derivatives such as dronabinol, which is used to treat loss of appetite among HIV positive and AIDS patients who have suffered drastic weight loss, and nabilone, used for treating cancer patients, who have nausea and vomiting sensation induced by chemotherapy and can also be used for chronic pain management. At last the efforts of these doctors bear fruits when India lifted its ban on cannabis research in 2015, and hosted its first-ever medical cannabis conferences to spread awareness of the therapeutic uses of the cannabis plant [26].

3. Cannabis usage in Thailand

Cannabis also called *"ganja"* in Thailand is a popular plant in the history of Thailand. The name cannabis has many considerations to different groups of people in Thailand. The police and government consider it to be a dangerous substance and users are charged as criminals, the common Thai people consider it as a recreational substance abused by youngsters for pleasure, while the medical fraternities and oncologists consider it as a miracle plant with a variety of medicinal and industrial uses. Blair [28] analyzes the history of cannabis usage in Thailand and the cultural and political factor affecting its cultivation and usage.

Traditionally cannabis has been used extensively in daily life in Thailand for many purposes, particularly as a cooking condiment in *kway teeow rua* or boat-noodle soup, and for recreational purposes [29]. Thai cannabis were introduced to the US by American troops, when they were in Thailand during the Vietnam War (1955-1975) [30]. However, the use of cannabis as a spice in Thailand is currently outlawed, but is still found in provincial markets in the neighboring countries of Laos and Cambodia.

Thailand's association with the recreational use of Cannabis first sprang into international public spotlight during late 60s. Wars at that time, have led an ideal vehicle for the cross-pollination of cultural ideas and activities and the United States soldiers based in Southeast Asia during the Vietnam era was no exception to this process. As Thailand was the main station for US soldiers serving in Vietnam, there were more US soldiers in Thailand than in Vietnam. A number of US soldiers were introduced to the recreational use of cannabis during Vietnam War, when they patrolled through fields of wild growing cannabis in Thailand. Reports at that time indicate that US troops began smoking marijuana soon and the arrests for marijuana possession reached a peak of up to 1,000 a week [28]. The use of marijuana or cannabis can be indirectly traced to the negative cultural impact of Vietnam War, when the soldiers were based in Thailand. The Drug Enforcement Administration's Intelligence Division in a 2001 report, revealed that Thailand was Southeast Asia's major cultivator of cannabis and producer of marijuana in the 1970s and 1980s.

Thai weed is 100% sativa, and therefore is prone to be more effective in bringing happiness, lethargy and relaxation to the recreational users due to its high THC content. Thai youth have a pro cannabis culture in their social life. This pro cannabis culture can be seen primarily in their selection of music and fashion. Mention can be made of the "Hippy Movement" in Thailand as the *"Peua Cheewit"* or "for life" social movement in the 1970s. The movement was for restoration of the democracy in Thailand at that time. In addition, Thai Folk Songs sung by Carabao and Maleewana, well known bands at that time, were related to marijuana or *"gancha"* as is commonly known in Thailand. Among the Thai youths, Reggae music is also very popular and many Reggae fans follow Reggae culture related to cannabis plant to show their support by enjoying music and wearing T – Shirt symbolizing support of cannabis plant, as wearing cannabis leaf logo t-shirts all over Thailand[30].

In addition to social, recreational and kitchen uses, Thai cannabis plant were used for manufacturing of clothing and other textile product, particularly by the Hmong Hill tribes, a minority ethnic group originally from China, who dwelled in the mountainous area in the Northern part of Thailand [31]. The fibers from the cannabis plant, as well as hemp plants, were woven together, making it some of the most popular and common materials used in Thailand's manufacturing of fashionable garments, ropes, clothing, accessories and other textile products. These textile made from cannabis or hemp fibers were the indigenous products of Northern Thai people. With the passing of Thailand's Narcotic Act in 1979 [30], Thailand prohibits cannabis cultivation, with the exception of Hemp plant, used till today for clothing and other accessories production. As a result, hemp plant is currently used to make clothing in Thailand and is currently one of the world's leading suppliers. The Thai government, being aware of the economic productivity of these fibers, approved the official proposal of industrialization and cultivation of cannabis hemp in the region in 2009, and since then hemp fiber industry is a popular export item and has been developing gradually. Beside this, it was also used in early *Muay Thai* martial arts. Muay Thai Fighters would protect their hands during the games with hemp hand wraps that ended in seashell-shaped knobs even though this method of hand-protection is being replaced by Western-style boxing gloves in the 1920's [29].

Beside the above usage of Thai cannabis plant for social, recreational and textile industry, Thai cannabis is also applicable for medicinal usage even though the CBD content of Thai seeds is quite low. Traditional Thai medicine and massage practitioners used cannabis to treat a variety of health conditions such as, analgesic, sedative, massage oils and astringent. It is also used for treatment of depression, stress, pain

and fatigue. This made the Thai Institute of Healing Arts to consider cannabis as an analgesic and sedative to control pain [29].

In the past, Thailand had no laws prohibiting cannabis use or possession. However, with the formation of the League of Nations International Opium Convention of 1912, Thailand, also called Siam, enacted anti-drug legislation, followed by introduction of the first anti-drug laws, the Narcotics Act B.E. 2465, in 1922 and Marijuana Act B.E. 2477 in 1937. According to Marijuana Act, anyone who plants or possesses marijuana seeds, or who imports or exports marijuana, would be subjected to imprisonment for up to one year, or to a fine not exceeding 500 Baht. Sections 7, 8 and 10 of the Act imposed a jail sentence of not more than six months or a fine for those who were caught possessing, buying, selling or using marijuana. Those who had already planted marijuana before the Act was passed were given one year in which to harvest and dispose of their crop.

In 1979 Thailand passed the Narcotics Act, which prohibited cannabis use in all forms. Under the Act, anyone caught producing, exporting or importing Thai weed are liable for imprisonment of between 2 and 15 years and/or a fine of up to 1.5 million Thai baht (up to $40,000 USD). After this act, production and cultivation of Thai cannabis receded and moved to the neighboring countries of Laos and Cambodia.

Recently, Thailand's medical fraternities came to recognize the importance of the medicinal properties of cannabis even though cannabis/marijuana was used in Thailand as a traditional medicine, until it was banned in the 1930s. The medical fraternities aim to bring awareness to the Narcotics Control Board of Thailand, pressuring them with a rewritten draft of the country's drug laws to legalize the use of cannabis for medicinal purposes. According to this proposed draft, medicinal cannabis would be available over-the-counter for patients with a valid prescription from their doctor [32]. According to a recent news published on December 25, 2018, Thailand's parliament has voted to amend the Narcotic Act of 1979 to approve cannabis for medical use, with a key lawmaker calling it a "New Year's gift" to the Thai people. Recreational use will remain illegal. However, complete legalization of cannabis is still an ongoing debate. There are various opinions, both pros and cons, even from the medical fraternities. Some fear that legalization will be harmful to children as they may use it for recreation and this will affect their brain development. According to the latest media, Anutin Charnvirakul, a contestant and leader of *Bhum Jai Thai* (Proud to be Thai) party, for the March 24 General Election in Thailand, after almost five years of military rule, campaigned for legalization of household cannabis plant. The party supports the legalization of recreational cannabis after Thailand last year became the first Southeast Asian nation to allow medical cannabis. In an interview, he said that his Bhum Jai Thai party would allow each Thai household to grow up to six cannabis plants, and this is expected to help Thai people to supplement their incomes by earning as much as $2,200 per kilogram of the crop [33].

It is not the first time that Thailand is making attempt to address cannabis laws. At the moment, farmers are allowed to grow hemp but not marijuana, a kind of cannabis with high effect. South East Asia has some of the world's toughest penalties for drug usage or possession, and Thailand is the first in the region to allow medicinal marijuana/cannabis with strict prescription for consumers from a recognized physician or certified doctor according to the Bangkok Post Newspaper. Licenses for production and sale of the product will be strictly controlled.

4. Summary and Conclusions

From the review of literatures, we can compare and contrast cannabis usage in both countries. Cannabis usage has a long history in India, associated closely with Indian legends, religion and religious rituals such as the close connection of Lord Shiva and cannabis, commonly called *bhang, charas* or *ganja.* On the other hand, there is scarcity of literature dealing with cannabis usage in the remote past in Thailand. However, some literature can be traced here and there which deals with cannabis usage by the American soldiers during the Vietnam war, when the soldiers were based in Thailand and their introduction of Hippy culture after they returned to USA, by smoking and inhaling cannabis which they had brought from Thailand. Due to acculturation and assimilation of cultural process, many Thai youths, imitated the hippy lifestyle of American people, and became a patron of cannabis plant, cannabis logo etc. Thai youth used cannabis mostly for social and recreational purposes and many have a pro cannabis culture in their social life. This pro cannabis culture can be seen primarily in their selection of music and fashion. Thai youths usage of cannabis is culture related along with recreation as can be been with the popularity of Reggae Music in Thailand. This shows their support of Thai culture related to the preservation and tradition of cannabis plant by enjoying music and wearing fashion T – Shirt having cannabis leaf logo. Beside the recreational use, Thailand's cannabis textile products is very popular in international markets. Thai hemp plant is currently used to make clothing and is currently one of the world's leading suppliers. This highlights the important difference between India and Thailand cannabis usage, where religious culture is an important part in India, unlike in Thailand, which is more for recreation and textile production.

However, there is an important similarity in both countries with regard to the ongoing debates regarding the legalization of cannabis usage in medical re-

search and therapy. After debating the pros and cons of cannabis usage from various sources as mentioned in the review, it is concluded that a beneficial consensus will be brought about soon to legalize the cannabis usage for medicinal purposes in both countries. Thus, the push to legalize cannabis for therapeutic use is not confined just to the United States but also happens to India and Thailand. Doctors in India and Thailand are pushing for further studies on the efficacy of cannabinoids in cancer patients and the day will not be far off when the incurable diseases like cancer can be prevented or cured with cannabis therapy.

5. Recommendation

The current article was framed by reviewing available literatures from various sources. It can be recommended that a research should be conducted further to find out the scientific study of cannabis in both India and Thailand, with a special focus on the medicinal properties of cannabis and the legalization process of medicinal cannabis usage in the two countries as well the outcomes of the attempts.

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Norodom Sihanouk's special relationship with North Korea: A Preliminary Survey

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Abstract

The article explores Norodom Sihanouk's ties with North Korea since his first meeting with Kim Il Sung in 1965 until his demise in 2012, by arguing that there were at least two factors for the solidification of relationship. The first factor was Sihanouk and Kim Il Sung, in their quest for national autonomy, shared a mentality of small state surrounded by dominant neighboring countries. The second was that, by the end of the 1970s, Cambodia had been devastated by years of wars and political turbulences, like North Korea after the Korean War (1950-1953). Sihanouk therefore saw North Korea's successes in postwar reconstruction as an example for the Cambodian people to rebuild their ravaged country.

Keywords: Cambodia, Kim Il Sung, Norodom Sihanouk, North Korea, Special Relationship
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1. Introduction

The late King-Father Norodom Sihanouk of Cambodia was one of the prominent figures on the world stage during the Cold War. His relationships with foreign leaders played an important part in shaping post-independence Cambodia. His friendship with Chinese Premier Zhou Enlai, for example, which began in the 1955 Afro-Asian Summit in the Indonesian city of Bandung laid the foundation of Sino-Cambodian collaborations against the pro-American Lon Nol regime in the first half of the 1970s and the pro-Vietnamese Heng Samrin regime throughout the 1980s. However, one of the puzzling relationships Sihanouk maintained over decades was that he had with North Korean leader Kim Il Sung, whom he described as the best friend and the honor of Asia [1]. Milton Osbourne, a biographer of Sihanouk, called it "bizarre relationship" for reasons that have never been clear [2].

2. Research Objective and Methods

In contrast to the hypothetico-deductive approach, this article aims to find out the preliminary reasons behind Norodom Sihanouk's intimate ties with Kim Il Sung by using grounded theory method, beginning with a question without formulating a hypothesis and followed by the collection of qualitative data. The author utilizes primary sources including Sihanouk's written work and memoirs, along with scholarly studies and news reports. The collected data were then analyzed to find out influential elements (i.e., Sihanouk's subjective experiences and interpretations of events regarding Cambodia – North Korea relations) before reaching the conceptualization stage.

3. Sihanouk's Intimate Ties with Kim Il Sung

According to Sihanouk's memoirs entitled *Shadow over Angkor*, cordial and special relationship with Kim Il Sung was formed in 1964 when Sihanouk, claiming that the Democratic People's Republic of Korea (DPRK or North Korea) was the only legal state for the country and the entire nation of Korea, decided to break off consular relations with the government in Seoul and established diplomatic relations with Pyongyang. Sihanouk's decision greatly impressed Kim Il Sung whose country was then ignored by the majority of non-aligned countries [3]. The two leaders held their first meeting in April 1965 at the Indonesian capital city of Jakarta, on the occasion of the 10th anniversary of the Afro-Asian Summit. Shortly afterwards, the North Korea - Cambodia Friendship Association was formed in September [4] and Sihanouk made the first state visit to Pyongyang in October of the same year.

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The relationship between the two leaders solidified in March 1970 when Sihanouk was toppled through the U.S.-supported military coup led by General Lon Nol. In May 1970, Kim Il Sung recognized Sihanouk's government in exile based in Beijing. During his visit to Pyongyang in June 1970, Sihanouk was treated as a visiting head of state, being entertained in state banquets and welcomed in special mass rallies [5]. In addition, Kim Il Sung gave him the assurance of North Korean support, as described in his memoirs:

President Kim Il Sung gave me, in conclusion, the assurance that whatever might happen to me in the future, he, his party, his people, his state would never abandon me, would always support me in whatever I might undertake for my country especially for its national independence and its territorial integrity, and would always offer me the most generous and caring hospitality [3].

During Sihanouk's first period of exile (1970-1975), Kim Il Sung virtually made Pyongyang Sihanouk's second home by dispatching a construction crew to build a 60-room luxurious mansion at the foot of Mount Taesong, overlooking the Changsuwon Lake, north of the capital city. Sihanouk and his wife Monique had a movie theatre, a Buddhist shrine, a gymnasium and their own personal bodyguards. Eyewitnesses described a building which has its overall shape looked somewhat like Angkor Wat [6]. Reciprocally, Sihanouk spent these years composing political or revolutionary-style songs praising Kim Il Sung and the people of North Korea, as the following examples, translated by the author from Sihanouk's own French translations [7]:

Long live the Marshall
Great leader of the Korean people
Illustrious hero of Asia
Flag bearer of the revolution
Glory to President Kim Il Sung
Light of new Asia
Architect of the real paradise
For the greater happiness of the people
(From *Cambodian Tribute to Marshall Kim Il Sung*)

Oh dear Korean friends
We Cambodians never forget
Your continuous support for our people
This support encourages us powerfully
In the fight that we lead
Against our enemy, imperialism
(From *Cambodia-Korea Amity*)

After the Sihanouk - Red Khmers coalition supported by China had gained victory over the Lon Nol regime in 1975, Sihanouk returned to Phnom Penh to be the titular head of state before being deposed by the Red Khmers leader Pol Pot in the following year and put under house arrest. His son, the future King Norodom Sihamoni, continued to study filmmaking in North Korea until he was called to join the family in Phnom Penh in 1977. His second exile period began on December 1978 when Vietnam invaded Cambodia, expelled the pro-Chinese Red Khmers, and established the pro-Vietnamese Heng Samrin regime. Sihanouk flew to Beijing and soon afterwards, according to his memoirs, found that although China opposed Vietnam's occupation of Cambodia, it preferred the Red Khmers to Sihanouk to become the leading faction in the anti-Vietnamese coalition. Therefore, he decided to go to Pyongyang for consolation [3].

During his second exile period (1979-1991), Sihanouk spent several months a year in Pyongyang, claiming that the environment there is quieter and more conducive to writing his memoirs than in Beijing [8]. However, the real reason might be his frustration with China and his gratitude for Kim Il Sung's support to put him as a leading figure in the anti-Vietnamese coalition, as revealed in his interview in North Korea to Western journalists in 1979:

Since my arrival, President Kim Il Sung has never asked me to cooperate with the Red Khmers. President Kim Il Sung told me: "I support only you ... Prince Sihanouk... only you, not the Red Khmers... only you". The embassy of the Red Khmers is still here, but its name is never mentioned. President Kim Il Sung said only one sentence: "I support only Prince Sihanouk!". In contrast, China never supports Prince Sihanouk. Never. China said: "Prince Sihanouk must support Pol Pot" [9].

After the endorsement of peace settlement by the International Conference on Cambodia in Paris in October 1991, Sihanouk returned to his country in the following month with 35 North Korean bodyguards, commanded by a general from Kim Il Sung's presidential bodyguards [10], and was reinstalled as king in 1993. To express his gratitude for the assistance Kim Il Sung gave to him during the two exile periods, Sihanouk decided to give Teaksin Phirom, his mother's house where he lived during his childhood, rent-free to be used as the North Korean Embassy in Phnom Penh [11].

4. Reasons Behind the Relationship: the Quest for National Autonomy and Postwar Reconstruction

How could blue-blooded Sihanouk and Kim Il Sung, the lowly-born man from the peasant village in Pyongyang, maintain special relationship for decades? The question has never been answered clearly. Although both of them were prominent figures during the Cold War, they were not influential enough to concretely help each other in world politics, especially in relations with major powers like the United States, the Soviet Union, and China. The author argues that, firstly, a shared mentality of "small state" played a role in forging relationship between the two leaders and,

secondly, Sihanouk eyed North Korea as a model of postwar national reconstruction.

Cambodia and North Korea are small countries surrounded by influential and dominant countries which have always tried to encroach upon smaller neighbors. Cambodia in the mid-19th century was a battlefield between the two traditional hegemons, i.e. Siam/Thailand and Vietnam, whereas the Korean peninsula since the late-19th century has been a contested area between China, Japan, Russia/the Soviet Union, and the United states. As Thai political scientist Surachai Sirikrai argues:

One of the problems that small states have faced throughout history is the issue of survival. i.e. how to maintain territorial integrity, culture, and freedom to determine their own political order and conduct of foreign relations [12].

Sihanouk came to the throne after the death of his maternal grandfather King Sisowath Monivong in 1941 and assumed the office of prime minister in 1952. He was successful in wresting national independence from the French in 1953, although it could not be denied that he played the nationalist card to suppress republican and social-revolutionary groupings. However, Cambodia's independence came during the height of the Cold War when the United States tried to contain the spread of Communism in South-East Asia with the establishment of South-East Asian Treaty Organization (SEATO), with Thailand and the Philippines as South-East Asian members, and establishing the pro-American South Vietnamese Government in 1954 and 1955 respectively. The United States was anxious for Cambodia to place itself under SEATO's protection but Sihanouk refused, partly because of Thai and American supports for his political opponent Son Ngoc Thanh [2]. Furthermore, his participation in the 1955 Afro-Asian Summit in Bandung served to convince him that non-alignment was the best guarantee for Cambodia's security against hostile neighbors like Thailand and South Vietnam, both of whom allied with the United States [13].

Similarly, Kim Il Sung had led guerilla warfare against Japanese imperialism more than a decade. Although the Soviet forces brought him to power after Japan's defeat in 1945 and his regime survived the Korean War (1950-1953) with massive assistance from China, Kim Il Sung harbored bitter memories of the interference by external powers, which became one of the factors leading to his idea of juche (self-reliance). Therefore, he thought that his expansion into the Third World would be the most convenient way to escape servitude to the Soviet Union and China [14] and thus throughout the 1960s and 1970s became busy in advocating the cause of non-aligned countries. In other words, Sihanouk and Kim Il Sung found common ground on their quest for national autonomy in international arena.

Besides, by the late 1970s, realizing that his country had been devastated by wars and political turbulences, Sihanouk eyed North Korea as a model of national reconstruction. As shown in table 1, North Korea was quite successful in post-Korean War economic recovery. Although the growth was at a slower rate than South Korea, it was still regarded by countries outside the U.S. camp as a success, at least until the late 1970s, with its Gross National Product (GNP) rising steadily from 1960 to 1978 [15].

Table 1. GNP of North Korea from 1960 to 1978

Year	GNP (USD Billion)
1960	1.52
1966	2.41
1970	3.98
1971	4.09
1972	4.62
1973	6.27
1974	7.29
1975	9.35
1976	9.68
1977	10.64
1978	13.32

During his stay in Pyongyang in 1979, Sihanouk wrote a book entitled *The DPR Korea Seen by Norodom Sihanouk*, praising the developmental success of North Korea as an example for his own country. As he stated admirably in the introduction:

The DPRK which was devastated by the 1950-1953 destructive war recovered its war wounds only in a few years and has made an amazing, all-round progress ... The Cambodian people who will have to rebuild their ravaged country, though in great misfortune at present will, when time comes, learn from the splendid example of our great Korean friends with the same will to regenerate as the Koreans' though with less manpower and material resources [2].

5. Declining Ties after the Death of Kim Il Sung

As the special relationship between Phnom Penh and Pyongyang relied on a personal bond between Sihanouk and Kim Il Sung, the latter's demise in 1994 shook the foundation of such relationship. Meanwhile, with the rise of Prime Minister Hun Sen in the mid-1990s, Sihanouk's political influence gradually declined. He had to accept the decision made by the Ranariddh - Hun Sen coalition government in 1996 to establish diplomatic relations with North Korea's arch-rival, South Korea, although it was reported that he strongly condemned any change in Cambodia's position that there was only one Korea, i.e. the DPRK [16].

Personally, Sihanouk and his family in the late 1990s still showed their gratitude to North Korea by setting up a privately-owned shipping registry to be the

flag of convenience for North Korea. It was named the Cambodia Shipping Corporation (CSC) which became a scandal in 2002 when the ship was stopped at the western coast of Africa carrying a massive haul of cocaine [10]. Besides, on the occasion of the 92nd birthday of the late Kim Il Sung in 2004, Sihanouk stayed in Pyongyang from April 10 to August 3. When North Korea's second generation leader Kim Jong Il died in December 2011, Sihanouk issued a private message of condolence. Shortly before his death in October 2012, North Korea awarded him the International Kim Il Sung Prize. Sihanouk's passing marked the end of the special relationship between Phnom Penh and Pyongyang

6. Conclusion

Norodom Sihanouk's relationship with foreign leaders played an important part in shaping Cambodia's post-World War II history. One of the puzzling relationships was that he had with North Korean leader Kim Il Sung, making Cambodia one of the few Southeast Asian nations with close ties to Pyongyang, apart from Hanoi during the Vietnam War [17]. The article shows that the relationship between them was founded on a shared mentality of small state surrounded by dominant neighbouring countries, in quest of national autonomy. In addition, by the end of the 1970s, as Cambodia had been devastated by wars and political turbulences, North Korea was perceived by Sihanouk as a model of postwar reconstruction. Unfortunately, as the relationship relied on a personal bond, it did not outlive them. Nowadays, without the two leaders' linking arms, the two countries' destinies rarely link to each other.

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The occurrence of passive intermodulation and troubleshooting in Thailand mobile industry

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Abstract

This paper describes the problem of the passive intermodulation (PIM) in mobile communications. We focus on the problem occured between the transmitter and antennas. The paper starts from the theory of intermodulation,mathematics concept and effect in mobile channels. The problem occured when two or more signals frequencies are transmitted at the same time in the same passive device. The non-linear behavior produced spurious signals where the frequencies were linear combinations of the frequencies of the original signals. When PIM level occurred,we measured such level and find out the methods to reduce PIM level. Finally,we got some methods in reducing PIM level to meet IEC 62037 standard.

Keywords: Passive Intermodulation (PIM), impedance, linearity
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1. Introduction

1.1. What is passive intermodulation (PIM)

The Passive Intermodulation (PIM) is a growing issue for cellular network operators. PIM issues occur as existing equipment generation when co-locating new carriers or when installing new equipment. PIM is a particular issue when overlaying (diplexing) new carriers into old antenna runs. PIM can create interference that will reduce a cell's receive sensitivity or even block calls. This interference can affect both the cell that creates it as well as other nearby receivers. PIM is created by high transmitter power so on-site PIM testing needs to be done at or above the original transmitter power levels to make sure that the test reveals any PIM issues. PIM is a serious issue for cellular operators wanting to maximize their network's reliability, data rate, capacity, and return on investment. It is worth noting that PIM testing does not replace impedance-based line sweeps but it completes line sweeping which is now more important than ever. High-speed digital data communications make PIM testing critical. As cell usage and throughput grows, the peak power produced by the new digital modulations increases dramatically which contribute heavily to PIM problems. On-site experiments have shown significant decrease in download speed. Drive tests have revealed an approximate 18% drop in download speed while residual PIM level was increased from –125 dBm to –105 dBm. [1]

1.2. Impedance versus linearity

The PIM test is a measure of system linearity while a Return Loss measurement is concerned with impedance changes. It is important to remember that they are two independent tests, consisting of mostly unrelated parameters that are testing opposite performance conditions within a cellular system. It is possible that a PIM test passes while Return Loss fails, or that PIM test fails while Return Loss passes. Essentially, PIM test will not find high Insertion Loss and Return Loss will not find high PIM. Line sweeping and PIM testing are both important. Some cable faults show up best with a PIM test. For example, if an antenna feed line has a connector with metal chips floating around inside, it is highly likely that a connecter test will fail PIM test while the line sweep passes. The antenna run most certainly passess nearly ideal impedance characteristics, but the presence of metal flakes bouncing around will cause the failling PIM test. It is also an indication that the connector was not fitted correctly. Another possible cause of PIM test failure is braided RF cables. These cables will test perfectly in a Return Loss or VSWR test, but

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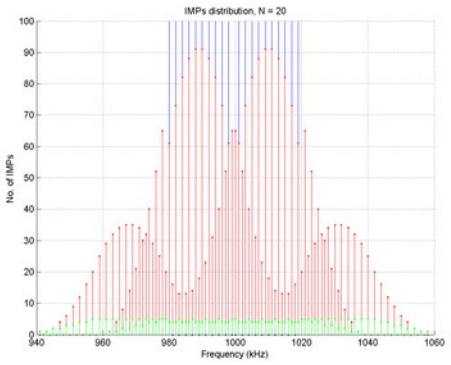

Figure 1: PIM in many orders.

generally possess only average PIM performance. The braided outer conductor can act like hundreds of loose connections that behave poorly when tested for PIM, particularly as they age. For permanent installations, braided cables are not recommended. Low PIM precision test cables are available commercially and they perform well, although they are very expensive. Some cable faults show up best in a Return Loss or VSWR test. A good example is a denoted or pinched main feeder cable, which will have an impedance mismatch at the point of damage, but may still be linear. Return loss testing will quickly spot this sort of damage, while PIM testing cannot. With the rollout of spread-spectrum modulation techniques, such as W-CDMA, and OFDM technologies like LTE and WiMAX, it has become essential to test both PIM and impedance parameters accurately.

2. Mathematical Background

2.1. Mathematics equations related to PIM

When two or more modulated signals are transmited into the same non-linearity media such as transmission cable,the signals will interference called Passive Inter Modulation (PIM). The results are interference signals in many orders. Figure 1. shows PIM in many orders. In this figure, two modulated signals are transmited at frequencies 150 MHz and 151 MHz with the same power. PIM creates interference at 3 , 5 ,7 , 9 orders on both sides of the spectrum. The most significant order that interferes a system is 3rd order because it has the highest power.

We assume the non-linear transfer function is characterized by a third order polynomial

$$y = a_1 x + a_2 x^2 + a_3 x^3 \tag{1}$$

where x and y represent instantaneous input and output respectively.

In PIM testing procedure, IEC 62037 standard, we use two tests input signals with unit amplitude at closely spaced frequencies which cause PIM. The input x is composed of two signal or carriers $\cos\omega_1$ and $\cos\omega_2$ in the equation (2). [2]

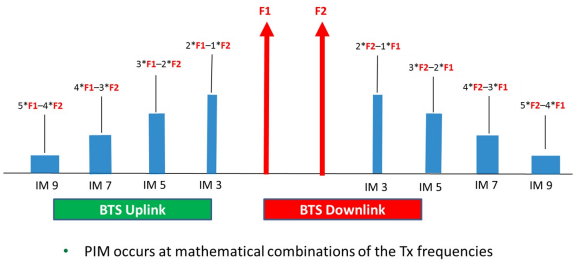

Figure 2: PIM in many orders and their calculated frequencies.

$$x(t) = \cos\omega_1 t + \cos\omega_2 t \tag{2}$$

Where ω_1 and ω_2 are angular frequencies of carriers . Then we substitute equation (2) in equation (1). We get .

$$\begin{aligned} y(t) &= a1(\cos\omega_1 t + cos\omega_2 t) \\ &+ a2[1 + (1/2)\cos 2\omega_1 t \\ &+ (1/2)\cos 2\omega_2 t + (1/2)\cos(\omega_1 + \omega_2)t \\ &+ (1/2)\cos(\omega_1 - \omega_2)t] \\ &+ a3[(5/4)\cos\omega_1 t + (5/4)\cos\omega_2 t \\ &+ (1/4)\cos 3\omega_1 t + (1/4)\cos 3\omega_2 t \\ &+ (1/2)\cos(2\omega_1 + \omega_2)t \\ &+ (1/2)\cos(2\omega_1 - \omega_2)t \\ &+ (1/2)\cos(2\omega_2 + \omega_1)t \\ &+ (1/2)\cos(2\omega_2 - \omega_1)t] \end{aligned} \tag{3}$$

The output y is consisted of many harmonics such as ω_1 , ω_2 , $2\omega_2$ - ω_1 , $2\omega_2 + \omega_1$, $\omega_1 - \omega_2$, etc. For PIM interference of mobile industry, we are interested in the third order $2\omega_1 - \omega_2$ on the lower spectrum and $2\omega_2 - \omega_1$ on the upper band because they have the highest power. In the deep research of next generation mobile system likes 5G when the bandwidth and transmission speed become greater, we will calculate PIM more than third order. In this paper, we focus on third order of PIM of which their frequencies are shown in equation (4).

$$\begin{aligned} &\text{3rd order PIM (Hz) = 2F1–F2 at lower spectrum} \\ &\text{and 3rd order PIM(Hz) = 2F2–F1 at higher spectrum} \end{aligned} \tag{4}$$

Figure 2 illustrates IM3 , IM5 , IM7 , IM9 (3^{rd} order , 5^{th} order , 7^{th} order and 9^{th} order) and their calculated frequencies on both side of the spectrum.

The basic problem of PIM is nonlinearity of transmission media. The nonlinearity can happen from many phenomena at the junction such as poor connector termination, metal flakes, metal folded, loose copper, etc. This will cause the nonlinearity in the contact surface in transmission line [3].

The other effect beyond PIM that can degrade the signal is impedance. We must matching the

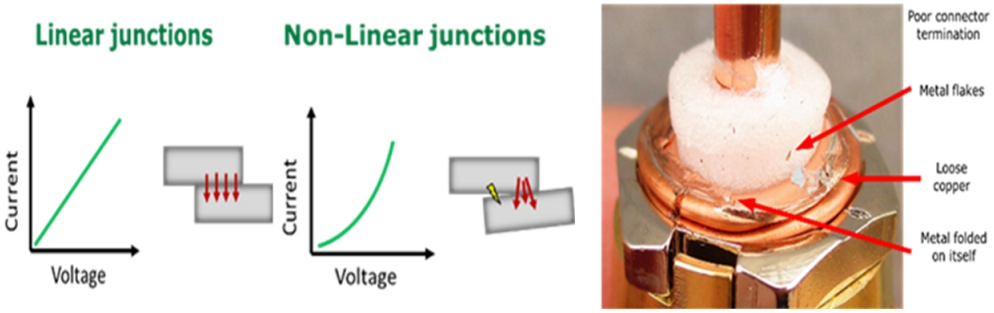

Figure 3: Nonlinearity phenomena in metallic contact.

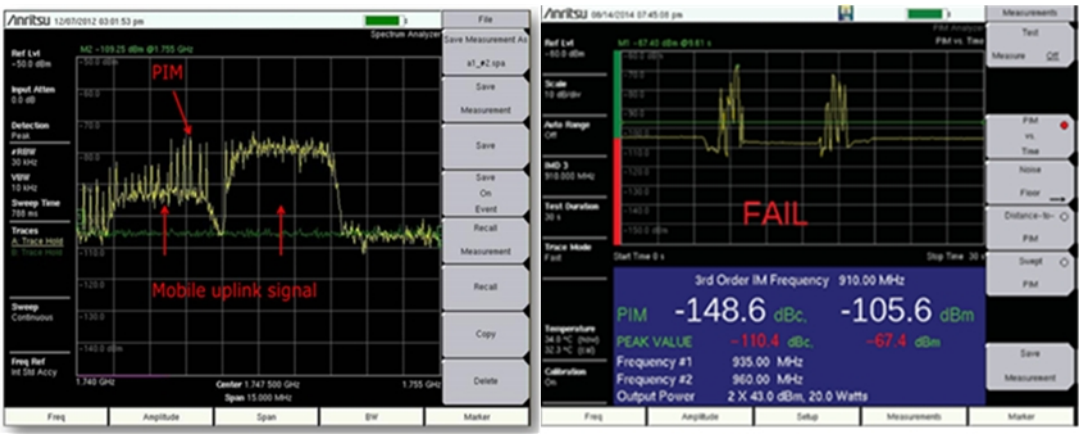

Figure 4: PIM spectrum display.

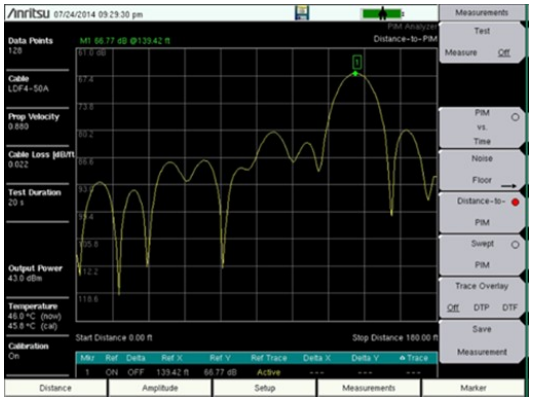

Figure 5: Distance to PIM (DTP) Measurement.

impedance between any junctions in the transmission lines or networks.

2.2. *Mathematics of power measurement in decibel unit*

A Decibel is a subunit of a larger unit called the bel. As originally used, the bel represented the power ratio of 10 to 1 between the strength or intensity ,i.e., power, of two sounds, and it was named after Alexander Graham Bell. Thus a power ratio of 10:1 = 1 bel, 100:1 = 0.01 bels. It is readily seen that the concept of bels represents a logarithmic relationship since the logarithm of 100 to the base 10 is 2 (corresponding to 2 bels), the logarithm of 1000 to the base 10 is 3 (corresponding to 3 bels), etc. The exact relationship is given by the formula

$$\text{Bels} = \log(\text{P2}/\text{P1}) \tag{5}$$

where $P2/P1$ represents the power ratio. Since the bel is a rather large unit, its use may prove inconvenient. So, a smaller unit, the Decibel or dB, is used. 10 decibels make one bel. A 10:1 power ratio, 1 bel, is 10 dB; a 100:1 ratio, 2 bels, is 20 dB. Thus the formula becomes

$$\text{Decibels (dB)} = 10\log(\text{P2}/\text{P1}). \tag{6}$$

It should be clearly understood that the term decibel does not in itself indicate power, but rather is a ratio or comparison between two power values. It is often desirable to express power levels in decibels by using a fixed power as a reference. The most common references in the world of electronics are the milliwatt (mW) and the watt. The abbreviation dBm indicates dB referenced to 1.0 milliwatt. One milliwatt is then 1.0 dBm. Thus P1 in equations (5) or (6) becomes1.0 mW. Similarly, the abbreviation dBW indicates dB referenced to 1.0 watt where P2 being 1.0 watt. Thus one watt in dBW is one dBW or 30 dBm or 60 dBμW. For antenna gain, the reference is the linearly polarized isotropic radiator, dBLI. Usually the "L" and/or "I" is understood and left out. **dBc** is the power of one signal referenced to a carrier signal, i.e.

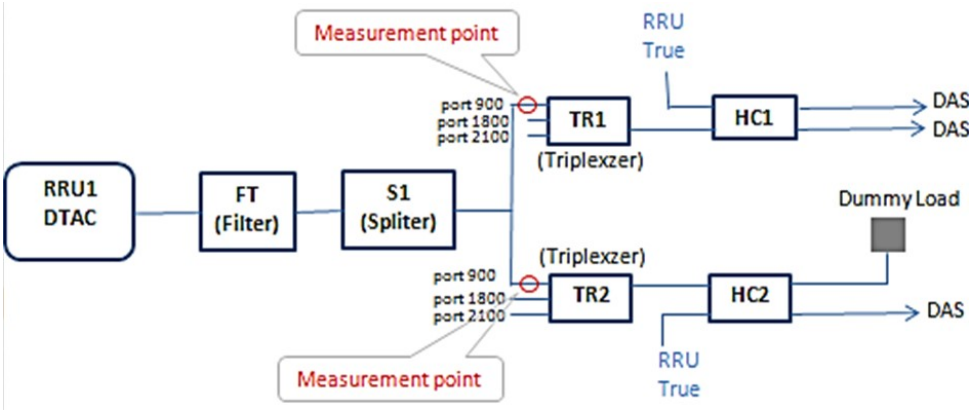

Figure 6: Diagram of DTAC mobile network at a simple site.

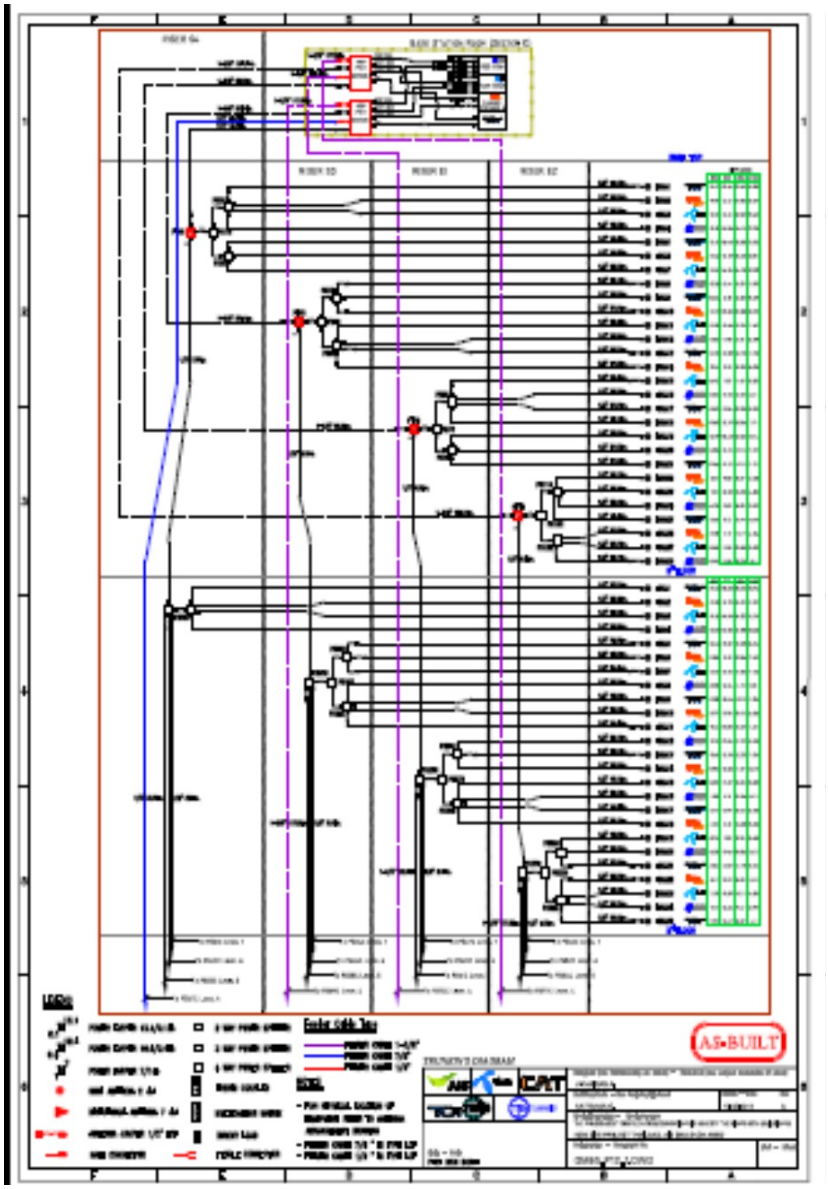

Figure 7: Trunking diagram of network.

Figure 8: Antenna install to the ceiling and too long of inner conductor, one of high PIM value problems.

Table 1. PIM report form

Output	To	Cores	Floor	Coverage	PIM	
					dBc	DTP Meter
1	PT2C	3	4	4,3,2,1	-114	45.1
2	PT1C	4	9	9,8,7,6,5	-96.7	46.4
3	PS69C	3	9	9,8,7,6,5	-118	32.2
4	PS67C	4	4	4,3,2,1	-125.1	48.4
1	PT3C	1	9	9,8,7,6,5	-134.0	24
2	PT4C	2	9	9,8,7,6,5	-126.5	20
3	PS73C	1	4	4,3,2,1	-142.0	37.2
4	PS77C	2	4	4,3,2,1	-119.5	27.6
1	PT3C	1	9	9,8,7,6,5	-134.0	24

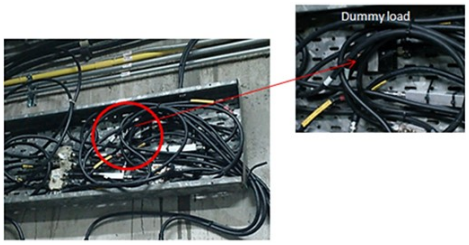

Figure 9: Dummy load can cause PIM.

Figure 10: Loose or too tight connection.

if a second harmonic signal at 10 GHz is 3 dB lower than a fundamental signal at 5 GHz. Then , the signal at 10 GHz is -3 dBc.

3. PIM Measurement Methods

In the measurement fields such as the base station of each mobile operator nowadays , we use the PIM Analyzer as the test & measure equipment. We measure many parameter to clarify the PIM problems.

3.1. PIM versus time

This measurement tracks instantaneous PIM and also records Peak PIM levels throughout a fixed frequency PIM test. It is useful for dynamic PIM tests and provides a visual indication of the stability of the system under test. We measure in dBm and dBc unit. The test frequencies Tx1 and Tx2 power according from IEC 62037 are 20 watt or 43 dBm. If 3rd order PIM is -105.6 dBm then PIM in dBc unit is 148.6 according to equation (7)

$$\text{PIM (dBm)} - \text{Transmit Power(43 dBm)} = \text{PIM (dBc)} \quad (7)$$

Figure 4 on the left shows the PIM interference in the bandwidth of mobile uplink cell phone to base station. Figure 4 on the right shows PIM level that exceed the standard at -140 dBc.

3.2. Noise floor

Before measuring PIM level , we must test line sweep and impedance matching of the transmission lines or networks. The networks should have low VSWR or high return loss for good matching as table 1 below. The PIM power level in this section must be ≤ - 100 dBm , VSWR must be ≤ 1.3:1 and return ross ≥ 18

3.3. Distance to PIM (DTP)

When the PIM occure in our system we solve the problems by repair , tighten , replace or cleaning at the junctions that PIM occurred . This function let us know the distance from the test equipment to PIM and the problem is there. Figure 5 show DTP measurement function.

4. PIM Measurement and Troubleshooting

Thailand mobile industry has PIM problems more than in the past. The 4G networks use higher bandwidth , higher bit rate and so on. This mean PIM is a very sensitive parameter when new 4G equipments are installed in the base station or when the new 4G system is replacing the old 3G networks. Every operator in Thailand such as AIS , DTAC and TRUE measures and solves PIM problems in their networks.

We measured PIM by the methods in topic 3 then all the report forms as tabled. The forms consist of data such as PIM level in dBm or dBc, distance from the test instrument to PIM, junction names , floor and signal floor coverage. Before measuring, we study a networks diagram to see the junctions, the splitters, triplexers, etc. and their whereabouts.

Figure 6 shows a simple netwok diagram of DTAC at the site. DTAC used three groups of carriers as we see in the diagram below. The carriers are 900 MHz, 1800 MHz and 2100 MHz and TRUE share this simple network with DTAC via hybrid coupling circuit HC.

Table 2 shows PIM report form. It contains important data that use to improve PIM to acceptable level . From this table we found that PIM at output 3, core E1 , floor 4 is higher than the acceptable level(-140dBc). It appears at 37.2 meters from the PIM analyzer. We had checked the conjunction at that point. Figure 7 shows network trunking diagram. We adjusted PIM points by several methods based on the problems at those points. Figure 8,9 and10 show some PIM problems found in the networks. After resolving them, we remeasured PIM until they get to be at the acceptable level.

5. Conclusion

Signals send in nonlinear networks can degrade the receive sensitivity of a mobile system. This limits the reliability, data rate, capacity and coverage of the networks. PIM tests can troubleshoot these problems. PIM occur from two or more modulated signals mixing in a non-linear device. These non-linear devices, or junctions, occur in improperly tightened, damaged, corroded connectors or in damaged antenna. Rusty components, such as mounts and bolts, are also suspected when finding the sources of PIM. Troubleshooting PIM starts with quality transmission networks. The growing in capacity, new services, speed rate are all conducive towards this problem. PIM testing is becoming more important especially in the era of 5G mobile system .

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Data mining model and application for stroke prediction: A combination of demographic and medical screening data approach

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Abstract

This paper presents the data mining process that was used for building a stroke prediction model based on demographic information and medical screening data. The data that was gathered from a physical therapy center in Thailand comprised of outpatients' medical records, medical screening forms, and a target variable. A group of 147 stroke patients and 294 non-stroke individuals with six demographic predictors were selected for the study. Three classification algorithms were used in the study. These were; Naïve Bayes, Decision Tree, and Artificial Neural Network (ANN). They were used to analyze the data collected and the results were compared. They were evaluated by use of a 10-fold cross-validation method. The selection criteria were primarily measured by accuracy and the area under ROC curve (AUC). The secondary selection criteria were indicated by False-Positive Rate (FPR) and False-Negative Rate (FNR). The results showed that the best performing algorithm that was studied was ANN combined with integrated data. This approach have an overall accuracy of 0.84, an AUC of 0.90, a FPR of 0.12 and an FNR of 0.25. The results of the study demonstrated that ANN with the integration of demographic and medical screening data produced the best predictive performance compared to the other models. This result was found according to both the primary and secondary model selection criteria.

Keywords: Stroke prediction, data mining, medical screening data
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1. Introduction

Stroke is a disease that affects the arteries leading to the brain [1]. It would cause the abnormalities of vascular in a brain and affecting of the nerves such as muscle weakness, numbness and can be fatal. It can be separated into two types: Ischemic stroke and Hemorrhagic stroke. Ischemic stroke occurs as a result of an obstacle within a blood vessel transferring blood to the brain. The underlying condition for this type of obstacle is the development of fatty deposits lining the vessel walls. The common consequence includes aphasia, physical disability, losing of cognition, communication skills, depression and other mental health problems. Moreover, stroke is a major public healthcare concern and has a significant impact on individuals, families and wider society. Recently, the World Health Organization [2] reported that stroke is the third leading cause of mortality overall life periods.

Stroke identification is tedious and time-consuming for medical diagnosis which is initially driven by experts' experience. Therefore, it would be beneficial if there is an automated system to predict the risk of stroke in patients. There are various types of data involved in the analysis depending on availability and level of abstraction. Therefore, those methods are to identify the independent risk factors based on the certain data source, some of them employed several input data such as medical history, symptoms, and the theoretical proven to be accurate risk factors. However, those secondary data may be difficult to collect and need special medical equipment. The high level of abstraction is required to discover related risk factors and build the complex identification model. Furthermore, some data analytics technology are required for creating the model. One analytical technology, data mining, is known for the knowledge discovery from the database [3]. It is an interdisciplinary field to discover patterns or model in high-volume data involving methods from several areas, such as artificial intelligence, machine learning, statistics, and database systems [4].

Some prior studies related to the finding of the stroke risk factors are reviewed. Preliminary, study was made to discover stroke risk factors, specifically

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for Thai citizen [5]. This study found that the factors are Hypertension, Diabetes, Obesity, Dyslipidemia, Smoking, Cardiovascular disease (CAD) and Drug use, in descending order of severity. Hanchaiphiboolkul *et al*. [6] proposed another stroke risk factors study. They applied cross-sectional analysis by using baseline health survey data which are age, gender and region to discover stroke prevalence in Thailand. By using multiple logistic regression as a tool based on 19,997 subjects, the study found that stroke prevalence in Thailand has few continuously increasing but lower than other developed countries. In geographic variation, stroke prevalence mostly discovered in Bangkok, Central, and Southern regions. Moreover, the age over 65 years old, male gender, and occupation class are found to be slightly significant. This study motivates us in model building aspect by using the demographic data as the primary source.

The most recent work proposes Arslan *et al*. [7 aimed to develop the medical data mining processes for extracting patterns approaching to predict ischemic stroke from collected dataset belonging to Inonu University, Turkey. The experiments were compared among three classifiers: Support Vector Machine (SVM), Stochastic Gradient Boosting (SGB), and Penalized Logistic Regression (PLG) which worked on 80 stroke patients and 112 healthy individuals consisting of demographic data and blood test results. The experiment showed that the SVM was the best classifier indicated by 0.9789 accuracies and 0.9783 AUC. This finding supports our hypothesis that the stroke risk prediction model is possible to create. Moreover, the important variables were also explored that the top three essential factors were age, Creatinine (CR), and Chlorine (CL), consecutively. Interestingly, the gender and marital status were slightly relevant in the eighth and thirteenth from overall seventeen variables. This work proved that the demographic data could be useful in model building.

Amini *et al*. [8] studied the stroke prediction based on data mining model with the data collected from Iran's hospital. The 50 risk factors of 807 patients dataset was experimented by two prediction algorithms: k-Nearest Neighbors and C4.5 Decision Tree. The results showed that the C4.5 decision tree performed best accuracy and precision. However, those risk factors were excessive and impossible to gather by end users who do not own a medical equipment and may cause difficulties in data collection. Sudha *et al*. [9] also proposed an alternative stroke prediction model based on medical history and symptoms including physical exam results, blood test results and diagnoses. The test data were collected from medical institute. Therefore, the data preprocessing was performed by removing duplicate records, missing data, noisy and inconsistency. They compared the model by four indicators which are accuracies, false-positive, false-negative, and AUC, combined with three classification methods: C4.5 Decision Tree, Naïve Bayes, and Artificial Neural Network (ANN). The result showed that the C4.5 decision tree is the best classification algorithm proven by 0.98 accuracies. In the real application, plenty of inputs may confuse the non-medic users. Thus, use of more concise input data is challenging for developing the prediction model. Nevertheless, their work has motivated us towards selecting understandable data as an input set and setting up of the experiment is interesting and may be applied in our work. Other prior related works on stroke prediction model were also reviewed.

Other related studies on the application of data mining in stroke disease are widely developed. Easton *et al*. [10] examined the risk factors of short-term and short/intermediate-term for post-stroke mortality using Naïve Bayes, Logistic Regression, and Decision Tree. Panzarasa *et al*. [11] used the classification tree for analyzing the stroke care process which aimed to identify the specific key indicators and was able to monitor the quality of medical process for stroke care.

From abovementioned research, the data mining have been widely proposed in various aspects for the stroke including data source, data schema, types of prediction models and applications. However, most of them are based on the factors that are inconvenient for end users to obtain. In this paper, we develop the stroke prediction model based on two kinds of outpatients' information, which are demographic data and medical screening data. Both data types are collected from a physical therapy center in Thailand during 2012 to 2015. The demographic data has been electronically stored in the relational database while the medical screening data has been in a paper-based format, called medical screening form. The medical screening form has been designed for preliminary self-screening outpatients in the center before transferring them to the proper clinic. By using the medical screening form, the information gathered from patients is more concise and easily understood. Then, the smashing prediction model is selected from three classification data mining algorithms, namely Naïve Bayes, C4.5 Decision Tree and Artificial Neural Network (ANN). They are experimented with both information sources and their integration. Finally, an application based on the best model will be extensively demonstrated for ease of use. The expected benefit of this research is the stroke risk prediction model based on high-level of abstraction data which are demographic and medical screening data evaluated in both technical and medical aspects.

The remainder of the paper is organized as follows: the coming section introduces the research methodology including some technical issues and setting up of the experiments. The next section presents the experimental results and discussion on technical issues, some insights into the medical domain and demonstration of the system application. Finally, we conclude

Parameter setting of modeling algorithms:

Naïve Bayes: *None*

C4.5 Decision Tree:

Minimum number of instances per leaf: 2

ANN Parameters:

Activation function: Unipolar Sigmoid Function

Number of hidden layers: 1

Initial number of hidden nodes: (attributes + classes)/2

Minimum Mean Squared Error: 0.05

Learning rate range: 0.05 to 0.5

Momentum range: 0.1 to 0.4

Evaluation method: *10-fold cross-validation*

Model Selection Criteria:

Primary: accuracy and AUC
Secondary: FPR and FNR

Figure 1: The setting up of the experiments.

the paper and suggest some directions for future research.

2. Methodology

2.1. Data source

The required information for this study is data of all outpatients during 2012 to 2015. In our study, there are two data types in this study: demographic data and medical screening data which will then be separately described for their characteristics, collection procedures and preprocessing method in the next subsections.

2.2. Demographic data collection and preprocessing

The demographic data refers to the general information of clients such as H/N number, name, gender, occupation, etc. This kind of information is already stored in the accessible relational database and can be gathered by database querying. An original demographic data source consists of 8 tables with total 112 attributes and more than 100,000 transactions. This high volume of data is needed for selection and filtering procedure. A general exclusion criterion is an age [5]. It was reported that age under 20 years old should be excluded in stroke determination for meaningful analysis. Moreover, since the medical diagnosis has been encoded in ICD-11 code [12] standard format, the inclusion criteria will filter the range of I60 (non-traumatic subarachnoid hemorrhage) to I69 (sequelae of cerebrovascular disease) as stroke patients and the rest is non-stroke falling in other attributes. Some demographic characteristics were eliminated due to their rare occurence. Thus, the remaining gathered factors

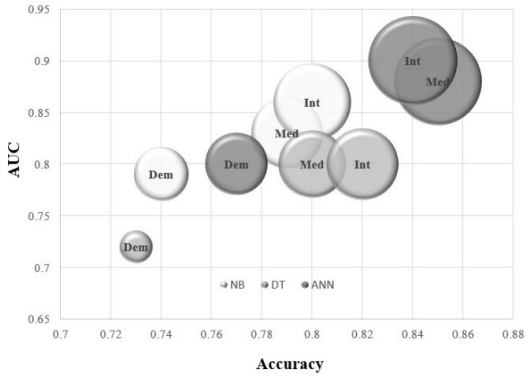

Figure 2: Comparison of accuracy and AUC of all datasets and algorithms.

are sex, age, province, marital status, education, and occupation.

Once the demographic data had been prepared already, it was found that the proportion of healthy and stroke patients revealed a vast imbalance (67,010:147) and should be resampled. Theoretically, the data resampling method can be chosen between under-sampling and over-sampling. The under-sampling is to remove majority class randomly. On the other hands, over-sampling helps to achieve a more balanced class distribution by replication minority class sample or combining it together [13]. In this research, the non-stroke patients should be down-sampled to reduce the proportion instead of using the up-sampling method because the quantity of majority class is remarkably higher than another group. After the down-sampling procedure, the final ratio between those two groups is 294:147. The characteristic, quantity and distribution of the final demographic data are shown in Table 1.

2.3. Medical Screening data collection and preprocessing

In the selected physical therapy center, a medical screening form is a self-input document which is designed to pre-filter unregistered outpatients and transfer them to the most suitable clinic possible. The medical screening form which consists of 29 simple questions with three answer choices (Yes/No/Unknown) in a paper-based format. The resampled patient records with HN number from the demographic data collection step were retrieved manually from archival storage by an assistant using spreadsheet application. During the collection process, the researcher found that the screening form was continuously improved and updated which caused four screening form versions between 2012 and 2015. Thus, some items of those forms needed to be merged into a single format as summarized in Table 2.

When the collection process of both data types was completed, we obtained three dataset for the experiment: demographic data, medical screening data and

Table 1. Preprocessed demographic data characteristics

Attributes	Values	Quantity (N=441)	Stroke	Non-Stroke
Stroke	Stroke	147		
	Non-Stroke	294		
Sex	Male	174	83	91
	Female	266	64	202
Age in Years	(Numerical)	-	67.3 (Mean)	53.90 (Mean)
Province	Capital City	302	95	207
	Fringe	109	44	65
	Countryside	25	6	19
Marital Status	Single	161	36	125
	Cohabit	246	97	149
Education	Primary	57	39	18
	High School	44	19	25
	Vocational	30	14	16
	Diploma	18	4	14
	Bachelor	156	35	121
	Master	51	8	43
	Doctoral	3	1	2
Occupation	Public servants	99	26	73
	Merchant	42	13	29
	Farmers	44	11	33
	Steward	79	33	46

their integration. The integrated dataset is the merging of both data sources using HN number as a joining key. Therefore, the experiment was conducted by datasets of 441 patients combined with three modeling algorithms described in the next step.

2.4. Modeling

In this paper, the predictive modeling is experimental compared between three classification algorithms: Naïve Bayes, Decision Tree, and Artificial Neural Network (ANN). Theoretically, each method has a unique advantage in simplification, interpretability and powerful computation. Their details including principle, strength and limitation are as following:

2.4.1. Naïve Bayes

The Naïve Bayes [14] depends on Bayes' theorem which works on the probabilistic statistical classifier. The major advantage of this method includes rapidity of use and simple for handling the dataset containing several attributes. Firstly, the dataset would be transformed into a frequency table consisting of each attributes value of all attributes. Then, the likelihood of each value is calculated by using probabilities respect to each class. When it is applied for a new case, the Naïve Bayes equation [15] is used to determine the posterior probability for each class. The class with the highest posterior probability is the outcome of prediction. The main advantage of this method is its fast training due to the single round of database scanning. Nevertheless, its limitation is that all attributes are considered to be independent.

2.4.2. Decision tree

Another classification algorithm used in this research, which is interpretable and provides a step-by-step determination, is the decision tree. One of the well-known decision tree algorithms is C4.5 [16] and its sibling. A robust interpretable computational method of this extension of the ID3 algorithm used to generate a decision tree whose construction is based on the concept of information entropy (Quinlan 1993). Firstly, the algorithm finds an effective split of the data based on the highest normalized information gain [17] for each attribute. It then creates a decision node using the selected node and the expected value of splitting. The algorithm recurs on the split data on the selected attribute and adds these nodes as child nodes. A distinct advantage of this method is its interpretable result. However, a small variation in data can lead to different decision trees, especially in small training size.

2.4.3. Artificial neural network (ANN)

Apart from a simple tabular model like the Naïve Bayes or interpretable method like the decision tree, a meta-heuristic approach such as an ANN could be an effective classifier, particularly when the interested domain is high volume and complicated. Theoretically, the ANN is a computational model that is inspired by the structure and function of the biological neural system. It consists of an interconnection of artificial neu-

Table 2. Preprocessed demographic data characteristics

Attributes	Stroke	Quantity (N=441)		
		Attribute Values		
		Yes	No	Unknown
Hypertension	Stroke	111 (76%)	27 (18%)	9 (6%)
	Non-stroke	65 (22%)	179 (61%)	50 (17%)
Diabetes	Stroke	53 (36%)	76 (52%)	18 (12%)
	Non-stroke	18 (6%)	223 (76%)	53 (18%)
Heart disease	Stroke	29 (20%)	95 (65%)	23 (16%)
	Non-stroke	28 (10%)	248 (84%)	18 (6%)
Asthma Bronchitis Allergy	Stroke	15 (10%)	111 (76%)	21 (14%)
	Non-stroke	54 (18%)	225 (77%)	15 (5%)
Hyperlipidemia	Stroke	57 (39%)	20 (14%)	71 (48%)
	Non-stroke	34 (12%)	68 (23%)	191 (65%)
Accident	Stroke	25 (17%)	86 (59%)	36 (24%)
	Non-stroke	56 (19%)	180 (61%)	58 (20%)
Fracture	Stroke	22 (15%)	90 (61%)	35 (24%)
	Non-stroke	29 (10%)	202 (69%)	63 (21%)
Cancer	Stroke	6 (4%)	107 (73%)	34 (23%)
	Non-stroke	5 (2%)	229 (78%)	60 (20%)
Rheumatoid Gout	Stroke	21 (14%)	93 (63%)	33 (22%)
	Non-stroke	50(17%)	185(63%)	59(20%)
Tuberculosis	Stroke	2(1%)	109(74%)	36(24%)
	Non-stroke	3(1%)	228(78%)	63(21%)
Osteoporosis	Stroke	10(7%)	94(64%)	43(29%)
	Non-stroke	14(5%)	206(70%)	74(25%)
Weight Change	Stroke	7(5%)	99(67%)	41(28%)
	Non-stroke	13(4%)	215(73%)	66(22%)
Urinary Incontinence	Stroke	28(19%)	89(61%)	30(20%)
	Non-stroke	32(11%)	59(20%)	203(69%)
Vertigo	Stroke	20(14%)	49(33%)	78(53%)
	Non-stroke	19(6%)	87(30%)	188(64%)
HIV	Stroke	0(0%)	74(50%)	73(50%)
	Non-stroke	0(0%)	102(35%)	192(65%)
Liver disease	Stroke	2(1%)	68(46%)	77(52%)
	Non-stroke	6(2%)	94(32%)	194(66%)
Herpes zoster or Psoriasis	Stroke	1(1%)	71(48%)	75(51%)
	Non-stroke	5(2%)	98(33%)	191(65%)
SLE	Stroke	0(0%)	72(49%)	75(51%)
	Non-stroke	0(0%)	101(34%)	193(66%)
Depressive	Stroke	13(9%)	56(38%)	78(53%)
	Non-stroke	9(3%)	94(32%)	191(65%)
Pregnant	Stroke	0(0%)	69(47%)	78(53%)
	Non-stroke	0(0%)	102(35%)	192(65%)
Kidney	Stroke	7(5%)	105(71%)	35(24%)
	Non-stroke	3(1%)	227(77%)	64(22%)
Family Cancer	Stroke	21(14%)	81(55%)	45(31%)
	Non-stroke	62(21%)	163(55%)	69(23%)
Family Heart Disease	Stroke	27(18%)	70(48%)	50(34%)
	Non-stroke	65(22%)	154(52%)	75(26%)
Family Diabetes	Stroke	57(39%)	49(33%)	41(28%)
	Non-stroke	110(37%)	114(39%)	70(24%)
Family	Stroke Stroke	67(46%)	41(28%)	39(27%)
	Non-stroke	23(8%)	188(64%)	83(28%)
Family Heredity	Stroke	3(2%)	75(51%)	69(47%)
	Non-stroke	13(4%)	175(60%)	106(36%)

Table 2. Preprocessed demographic data characteristics (Cont.)

Attributes	Stroke	Quantity (N=441)		
		Attribute Values		
		Yes	No	Unknown
Bleed	Stroke	4(3%)	36(24%)	107(73%)
	Non-stroke	2(1%)	129(44%)	163(55%)
Muscle	Stroke	22(16%)	99(73%)	15(11%)
	Non-stroke	199(65%)	89(29%)	17(6%)
Loss Balance	Stroke	108(55%)	89(45%)	1(1%)
	Non-stroke	111(46%)	117(48%)	15(6%)

rons, and it processes information using a connectionist approach. There are several types of ANN. In this research, an ANN with a feedforward and backpropagation architecture [18] is chosen. The backpropagation algorithm learns the weights for a multi-layer network with a specified number of nodes and their connections. It aims to minimize the mean-squared error that quantifies the difference between network output values and the target values for these outputs. The ANN iteratively computes the error of the production and the gradient with respect to the error in order to update all weights in the network. The training will be eliminated when the threshold criteria such as a mean square error are reached.

There are several parameters for the training process of ANN: (1) A number of hidden layers and hidden nodes: The optimal number of units in the hidden layer of any network is difficult to determine. Specifically, in back propagation learning, there have been many reports recommending numbers of hidden layers and hidden nodes due to the generalization, complexity, and overfitting [19]. However, the study by Eberhart *et al*. [20] reported that a single hidden layer is sufficient to transform any non-linear functional relationship. Therefore, only a single hidden layer is used in this research.

(2) Learning Rate: A learning rate (theoretically a fraction between 0.0 and 1.0) will affect how quickly and efficiently the network is trained. A lower learning rate means a slower learning tempo which causes a longer training time. If this parameter is specified too high, the network may move to local optimum quickly, but it may also jump over the global optimal point which causes divergence or an oscillational effect.

(3) Momentum: This parameter (theoretically a fraction between 0.0 and 1.0) can accelerate or decelerate the learning process. The learning pace will be increased when all weight changes are going to the same direction to speed up the convergence, otherwise slower to find ways to escape from the stagnation. Too high momentum causes the learning process to slow down.

(4) Stopping criteria: This parameter specifies threshold parameter to stop the training process which is a level of residual error. The mean square error

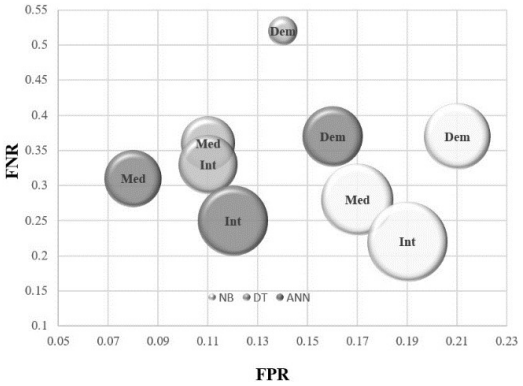

Figure 3: Comparison of FPR and FNR of all datasets and algorithms.

(MSE) is measured in every iteration of training to quantify the difference between the target and the calculated output. The training process is halted once the MSE is less than or equal to the set value. This stopping criterion is to stop the training in case the solution is divergent or oscillated.

2.5. Evaluation

In this research, the K-fold cross-validation [21] is selected to evaluate the model. In K-fold cross-validation, the original samples are randomly partitioned into K subsamples. A single subsample is held for validating. Then the cross-validation procedure repeats K times (the number of folds), with each of the K subsamples used exactly once as the validation data. Then the K results from the folds are averaged as a single outcome. The benefit of this method is that all data are used for both training and validation, and each observation is used for validation exactly once. In general, 10-folds cross validation is commonly used.

2.6. Performance measurements

In the current study, accuracy, area under the Receiver Operating Characteristic curve (AUC), false-positive rate (FPR), and false-negative rate (FNR) were utilized as model evaluation metrics [3]. These measurements are defined below in equation (1) to (3).

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (1)$$

Table 3. Comparative experimental results.

Method	Dataset	Accuracy	AUC	FPR	FNR
NB	Dem	0.74	0.79	0.21	0.37
	Med	0.79	0.83	0.17	0.28
	Int	0.80	0.86	0.19	0.22
DT	Dem	0.73	0.72	0.14	0.52
	Med	0.80	0.80	0.11	0.36
	Int	0.82	0.80	0.11	0.33
ANN	Dem ($i = 6, h = 2, o = 2, l = 0.3, m = 0.1$)	0.77	0.80	0.16	0.37
	Med ($i = 29, h = 2, o = 2, l = 0.1, m = 0.2$)	0.85	0.88	0.08	0.31
	Int ($i = 35, h = 37, o = 2, l = 0.3, m = 0.2$)	0.84	0.90	0.12	0.25

$$FPR = \frac{FP}{FP + TN} \tag{2}$$

$$FNR = \frac{FN}{TP + FN} \tag{3}$$

where TP is the number of true-positives (correctly classified stroke patients), TN is the number of true-negatives (correctly classified non-stroke patients), FP is the number of false-positives (misclassified non-stroke patients), and FN is the number of false-negatives (misclassified stroke patients). Additionally, the area under the ROC curve (AUC) is a measurement of how well parameters can distinguish between two diagnostic groups. The AUC quantifies the accuracy regarding overall ability of the test to discriminate those patients.

2.7. Setup of the experiments

The setting up of the experimental parameters according to the information of dataset and algorithms discussed in previous subsections are shown in Figure 1.

2.8. Model deployment

A sample application is developed and deployed based on the selected model to approach the practicality. The result is demonstrated in the next section.

3. Result

3.1. Model performance

Experimental results are shown in Table 3. As introduced, the results are compared between three classification algorithms (the Naïve Bayes (NB), the C4.5 decision tree (DT), and Artificial Neural Network (ANN)) and three datasets (demographic data (Dem), medical screening data (Med), and integrated data (Int)). The measurements are accuracy, AUC, FPR, and FNR. Additionally, since the ANN consists of some adjustable parameters, the optimum parameters set, which are the number of input nodes (i), the number of hidden nodes (h), the number of output nodes (o), learning rate (l), and momentum (m), are also reported.

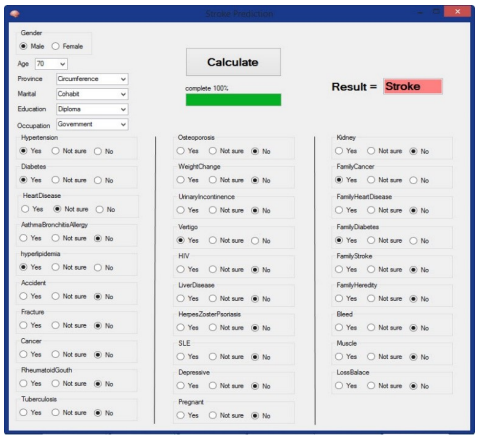

Figure 4: A sample data input for stroke prediction application.

The primary model selection criteria have been set to the measurement of accuracy and AUC because this study emphasizes on the measurement of correctly predicted results. The results in Table 3 are illustrated in a bubble chart shown in Figure 2 which aims to visualize both indicators in a single diagram. Since the ideal model have to satisfy for the high value of both accuracy and AUC, the expected bubble should be near to the top-right corner of the chart while the size of each bubble varies directly with the value of accuracy and AUC. It is shown that there are two best models which can be candidates. The result of the ANN with the integrated data (0.84 accuracies and 0.90 AUC) is very close to the ANN with medical screening data (0.85 accuracies and 0.88 AUC). Although the medical screening dataset provides a slightly higher discrimination power than the integrated data, it is less accurate, based on the whole test set. However, they are much closed. Thus, the secondary criteria are considered.

In the same visualizing fashion, both values are also comparatively illustrated as a bubble chart in Figure 3. The secondary criteria focus on the two types of wrong prediction, the FPR, and the FNR. Ideally, the

FPR can be high for the prevention advantage. On the other hands, the ideal FNR have to be minimized due to the false-diagnostic prevention which should be pessimistic, specifically in the medical domain. Thus, the expected bubble of this comparison should be near to the bottom-right corner of the chart while the size of each bubble varies directly with the FPR but varies inversely with the FNR.

As shown in Figure 3, although the primary measurement of ANN applied with integrated data is close to the medical data, the secondary criteria of these rivals indicate that the ANN with integrated data is superior to another one because of its significant less false negative rate (0.31 and 0.25). This result affirms that the ANN with integrated data set should be awarded as the best stroke prediction model for demographic and medical screening input data due to its capabilities for complication, Therefore, to illustrate the deployment phase, the best ANN model is selected and exemplified with a sample case in the next section.

3.2. Model deployment

Approaching to the practicality, we combine the best features to create a tool and illustrate some input which is simulated as a new patient information shown in Figure 4. For example, the tool can predict that a male patient with age equal seventy years old, living in a suburb, cohabit marital status, hypertension, diabetes, hyperlipidemia, vertigo, and family members appear to have cancer and diabetes, would be predicted as stroke. However, the proposed tool is intended to be applied in ANN model needed for input of all factors. To facilitate end-users, a number of input factors might be reduced if some feature selection methods are applied before model building phase.

4. Conclusions

This research proposed the stroke risk prediction model using three datasets: demographic data, medical screening data and their integration applied by three classification algorithms which are Naïve Bayes, Decision Tree, and Artificial Neural Network (ANN). This research was approved by IRB and data owner to gather and collect outpatients' information from the physical therapy center in Thailand between 2012 and 2015. The demographic data was queried from existing relational database with some filtering criteria while the medical screening data was collected from the paper-based document using a data collecting application. Several versions of medical screening form were integrated into a single data format. The benefit of employing the medical screening data in this research is its user-friendly checklist data form to the patient. After gathering, the imbalance between stroke and non-stroke patients have been found and was solved by the under-sampling method. Then, the data were used in model building by three algorithms and evaluated by the ten-fold cross-validation method. The accuracy and AUC are the primary criteria for model selection while the FP rate and FN rate are the validating criteria in medical field research. The best model from the experiment is the ANN with integrated data by accuracy 0.84, FP rate 0.12, FN rate 0.25 and AUC 0.90. Finally, the deployment is proposed by applied the best model to the simple data input application.

However, since this research developed a stroke risk prediction model based on the data collected from the physical therapy center during 2012 – 2015 which locates near to the capital city, the bias in the data source may be hidden due to the behavior of patients. Additionally, since to medical screening data has been directly input by the patients, the linguistic bias may be attached to the research because some patients may not clearly understand the definition of the medical terms stated in the medical screening form.

To extend and enhance the research to be more realistic and practical, the researcher offers the future works. The first one is to expand the data source to discover a model that representable for the whole population of the country. Another possible future research is that of deeper data exploration and analysis for the benefit of the best resampling method selection. Finally, the feature selection or extraction process may be applied to enhance the model performance.

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